

# 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 investment projects and asymmetric information about the quality of securitized assets. I show that when retaining part of the risk, the issuer of securitized assets can credibly signal its quality. However, in the boom stage of the business cycle this practice is inefficient: information on asset quality remains private, and lower-quality assets accumulate on balance sheets of financial intermediaries. This prolongs and deepens a subsequent recession with an intensity proportional to the length of the preceding boom. I present empirical evidence from securitization deal-level data consistent with this result.

***JEL Classification: E32, E44, G01, G20.***

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# 1 Introduction

Securitization as well as the whole market-based system of financial intermediation grew significantly in importance in the decades preceding the financial crisis of the late 2000s (Adrian and Shin, 2009). However, due to its role in the financial crisis (e.g., Bernanke, 2010), securitization has recently attracted a great deal of criticism. New research focuses on the problematic aspects of securitization. Consider Shleifer and Vishny (2010), who argue that it creates systemic risks and inefficiencies in financial intermediation. Currently, the regulation of the financial sector is being redrafted and strengthened in many developed countries. The new regulation also addresses securitization practices.<sup>1</sup>

Most of the criticism points to various agency problems related to securitization that stem from the asymmetry of information about the quality of securitized assets between their issuers and buyers. However, these problems are not new, and various tools, mainly explicit or implicit guarantees by issuers (in other words, risk retention by issuers), are used in the securitization process precisely to limit these problems. The question that is addressed in this paper is whether risk retention worked efficiently in the period prior to the late-2000s financial crisis.

This paper suggests that risk retention contributes to reduction in the asymmetry of information. However, in boom stages of the business cycle, including the period prior to the late-2000s financial crisis, this practice is inefficient, information about quality of securitized assets remains private and low-quality assets accumulate on balance sheets of financial intermediaries. In the empirical section of the paper, I provide evidence from securitization deal-level data consistent with this result. The paper shows that this mechanism implies deeper and longer recessions proportionally to the length of the preceding boom period. Those results are relevant for the newly proposed regulations of securitization. Since self-regulation by risk retention is not sufficient, more standardization and transparency is necessary, especially in boom stages of the business cycle, to address the problem of asymmetry of information.

To study the efficiency of risk retention tools in alleviating the problems related to asymmetric information, I develop a dynamic stochastic general equilibrium model of financial intermediation through securitization. The model features heterogeneous investment opportunities and an asymmetry of information about the distribution of those investment opportunities, from which stem most problem related to securitiza-

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<sup>1</sup>Pozsar et al. (2012) describe the role of securitization in shadow banking; Adrian and Ashcraft (2012) review the proposals for new regulation.

tion. Moreover, I reflect the varying return from investment opportunities of different quality over the business cycle. In particular, following 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, the relative cross-sectional difference in the productivity (productivity dispersion) of investment projects in this model is also countercyclical. As a result, I show that, in periods of high productivity dispersion (recessions), the economy is in a separating equilibrium, where only high-quality projects are being financed. However, in periods of low productivity dispersion (boom stage), due to the asymmetry of information, the economy is in a pooling equilibrium, where both high- and low-quality projects are being financed and information about their qualities remains private. This results in inefficient allocation of resources among investment opportunities.

Having developed a model of securitization, I investigate whether the introduction of the aforementioned risk-retention tools can change the above result. In particular, I focus on the provision of the implicit guarantees by issuers. The reason why implicit guarantees were frequently preferred to higher explicit guarantees (such as tranche retention schemes) was mainly regulatory arbitrage. An implicit guarantee (or recourse) is a non-contractual support provided by issuers of securitized products to holders of these assets.<sup>2</sup> This support is enforced in a reputation equilibrium, where failing to provide implicit support may be followed by punishment in the form of an inability to sell on the primary market for securitized assets in the future. I show that reputation concerns can allow originators of securitized products to credibly signal the quality of loans by providing implicit recourse, and thus limit the problem of asymmetric information and improve the efficiency of financial intermediation. However, there are limits to the size of a credible implicit guarantee based on reputation. In the boom stage of the business cycle, where the difference in the productivities of projects is sufficiently small, the separating equilibrium would require levels of implicit recourse so high that they cannot be enforced through reputation.

Therefore, even though the provision of implicit guarantees increases the occurrence of separating equilibria, in the boom stage of the business cycle there are still only pooling equilibria, in which the information about the quality of loans remains private and the allocation of investment is inefficient. This has only very moderate effects as long as the economy stays in a boom, characterized by low productivity dispersion. However,

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<sup>2</sup>For a review of empirical evidence on implicit recourse, a description of its types, and a discussion of its role in the securitization process, I refer the reader to section 2.

the effect of an accumulated stock of low-quality assets becomes more pronounced in the subsequent downturn of the economy, which is thus deeper and longer. Also, the longer the boom, the larger the share of lower-quality assets on balance sheets and the deeper and longer will be the subsequent downturn.<sup>3</sup>

In the empirical section of the paper, I test hypotheses related to the theoretical model on the level of securitization deals using data for residential mortgage backed securities issued in the three largest European countries by securitization activity. I study the relationship between credit enhancements, which represent guarantees provided to holders of securitized assets, and the delinquency rate of the collateral as a measure of the inverse of the quality of securitized assets. I find that higher lagged credit enhancement is negatively correlated with the delinquency rate in the United Kingdom (UK). This supports the signaling hypothesis of credit enhancement.<sup>4</sup> However, in the cases when signaling relationship is found,<sup>5</sup> it disappears for the subset of deals that are issued in the boom stage of the business cycle. Those results are in line with the predictions of the theoretical model, i.e., credit enhancement can signal the quality of securitized assets, but not in the case of loans issued in the boom stage of the business cycle, when the information about quality of securitized assets remains private and as a consequence both high- and low- quality assets are issued.

The mechanism presented in this paper can contribute to the understanding of the recent financial crisis, since it replicates some of the securitization market outcomes observed prior to and during the crisis. In the period preceding the crisis, many inefficient investments of unknown quality were undertaken. While this was not a problem as long as the economy was performing well, the large amount of low-quality loans in the economy contributed to the depth of the financial crisis. To my knowledge existing models of securitization fail to produce those results in a rational-expectations framework.<sup>6</sup>

The paper is organized as follows. Section 2 reviews the related literature. Section 3 introduces the effects of the considered financial frictions in combination with

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<sup>3</sup>The model in this paper can be extended to study the adverse selection on the resale markets or effects of selected macroprudential regulation. These extensions are available in the working paper version (Kuncl, 2014b), but are omitted here for the sake of brevity.

<sup>4</sup>There is a large theoretical literature on signaling in financial intermediation under asymmetric information, e.g. Leland and Pyle (1977) or DeMarzo and Duffie (1999), among many others.

<sup>5</sup>In some countries support for signaling relationship is missing. For instance in Spain this can be explained by differences in regulation, due to which securitization was used only for liquidity purposes but not to transfer risk. Therefore, benefits of signaling were lower and it is not surprising that signaling relationship is missing.

<sup>6</sup>Detailed comparison to existing literature is in Section 2.

the provision of implicit recourse. For analytical tractability, this section focuses on the steady state with only idiosyncratic risk and in which the aggregate variables are deterministic. Section 4 reports the results of the full-fledged model with aggregate risk solved using global numerical methods and focuses on the switching between the separating and pooling equilibrium over the business cycle. Section 5 describes the empirical testing of hypotheses derived in the theoretical model.

## 2 Literature review

This paper is related to several strands of literature. In this section, I focus on research related to securitization with implicit recourse and to financial intermediation imperfections, information frictions and business cycles.

### 2.1 Securitization and implicit recourse

Securitization is the process of selling cash flows of loans issued by the originator (often called the sponsor). The sale of loans is effectuated in a legally separate entity called a special purpose vehicle (SPV) or special purpose entity (SPE). The entity purchases the right to the cash flows with resources obtained by issuing securities in the capital market.<sup>7</sup> Before the recent financial crisis, securitization was perceived mainly as a means of dispersing credit risk and allocating it to less risk-averse investors who would be compensated by higher returns, while highly risk-averse investors could invest into the most senior tranches<sup>8</sup> with high ratings. Due to the role securitization played in the late-2000s financial crisis (e.g., Bernanke, 2010), it attracted a lot of criticism, and the attention of researchers turned more to the set of agency problems present at different stages of the securitization process (Shin, 2009).<sup>9</sup> Most of these problems stem from asymmetry of information about quality of securitized assets between their originators and first buyers, therefore a main ingredient of my model is heterogeneity of investment opportunities and an asymmetry of information about their quality.

Gorton and Pennacchi (1995) were among the first to point to moral hazard problems related to securitization and to argue that securitization became popular in the 1980s

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<sup>7</sup>The sponsor and the SPV are “bankruptcy remote,” and the sale of loans is officially considered to be complete; i.e., the sponsor should transfer all risks to the holders of the newly emitted securities.

<sup>8</sup>Loans are pooled in a portfolio that is then usually divided into several tranches ordered by seniority, i.e., with different exposure to risk.

<sup>9</sup>A detailed review of those agency problems can be found in Paligorova (2009).

due to the introduction of binding capital requirements for commercial banks.<sup>10</sup> The view that an important reason for securitization is regulatory arbitrage is shared by many economists (e.g., Gorton and Metrick, 2010; Gertler and Kiyotaki, 2010; and Acharya et al., 2013). The moral hazard and agency problems in general were supposed to be alleviated by explicit and implicit risk retention by the originators of securitized assets, which should have signaled the quality of those assets.<sup>11</sup> Since explicit risk retention<sup>12</sup> is costly due to higher related capital requirements, in this paper, I focus on implicit risk retention.

Implicit risk retention or implicit recourse is a support provided by the issuers of securitized products to the holders of these assets, which is deliberately non-contractual (i.e., not explicit), to avoid higher capital requirements for the originator. This support materializes ex post (i.e., after the sale of securitized assets), typically in periods of lower asset performance, when the originator intervenes to increase the asset return. Much evidence suggests that implicit recourse was frequently used during the securitization process (“As the saying goes, the only securitization without recourse is the last” [Mason and Rosner, 2007, p. 38]). Gorton and Souleles (2006) show in a theoretical model that implicit recourse can be an equilibrium result in a repeated game due to the reputation concerns of originators, who want to pursue securitization in the future at favorable conditions. Several empirical studies documented concrete cases of implicit recourse or showed indirect evidence of its presence. Higgins and Mason (2004) study recourse events that were directed to an increase in the quality of receivables sponsored by credit card banks.<sup>13</sup> Brunnermeier (2009) describes implicit liquidity recourse. When SPVs were subject to liquidity problems, their sponsor would grant credit lines to SPVs without any contractual obligation to do so, i.e., in order to maintain their reputation.<sup>14</sup> Higgins and Mason (2004) argue that implicit recourse may help to signal to investors

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<sup>10</sup>“In 1981 regulators announced explicit capital requirements for the first time in U.S. banking history: all banks and bank holding companies were required to hold primary capital of at least 5.5 percent of assets by June 1985” (Gorton and Metrick, 2010, p. 274).

<sup>11</sup>There is a large theoretical literature on signaling in financial intermediation under asymmetric information, e.g. Leland and Pyle (1977) or DeMarzo and Duffie (1999), among many others.

<sup>12</sup>Explicit risk retention has typically a form of tranche retention. See Fender and Mitchell (2009) for a study of different tranche retention design effect on incentives.

<sup>13</sup>The forms of the support provided were, for instance, adding higher-quality accounts to the pool of receivables, removing lower-quality accounts, increasing the discount on new receivables, increasing credit enhancement, and waiving servicing fees.

<sup>14</sup>Acharya et al. (2013) study explicit liquidity guarantees and argue that their large popularity was due to lower capital requirements compared to similar credit guarantees, strengthening the argument of the regulatory arbitrage motivation of originators.

that shocks making recourse necessary are only transitory. Similarly in this model implicit recourse is used as a signaling tool. However, the efficiency of signaling varies over the business cycle.

## 2.2 Financial intermediation imperfections, information frictions, and business cycles

This paper is related to the literature on financial frictions in macroeconomic models and the role of asymmetric information and reputation in financial intermediation.

The classic papers that endogenize financial frictions on the side of borrowers and show the related “financial accelerator” effect include Bernanke and Gertler (1989), Bernanke et al. (1999), and Kiyotaki and Moore (1997).<sup>15</sup>

In this paper, I refer often to the Kiyotaki and Moore (2012) model of a monetary economy with differences in liquidity among different asset classes. I simplify this model, and in order to study the financial intermediation similar to securitization, I introduce heterogeneous quality of investment opportunities, asymmetric information and I model signaling by the provision of reputation-based implicit recourse.

There is much literature on the adverse selection in lender-borrower relationships based on asymmetric information, expanding the original contribution of Akerlof (1970). In Parlour and Plantin (2008), the intensity of adverse selection on the markets for securitized assets (sold loans) depends on the proportion of liquidity sellers and informed sellers who want to sell low-quality loans. Kurlat (2013) models a similar adverse selection problem in an extension of Kiyotaki and Moore (2012) and shows that the proportion of sellers of high-quality assets is lower in a recession, which can lead to market shutdowns.<sup>16</sup>

One of the major assumptions in the model is the existence of a productivity dispersion shock, which is inspired by the empirical evidence in Bloom (2009) and Bloom et al. (2012). Bigio (2013) uses a similar assumption and shows that a dispersion shock due

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<sup>15</sup>Some of the recent macroeconomic models with financial frictions directly incorporate securitization. For example, Brunnermeier and Sannikov (2014) find that securitization enables the sharing of idiosyncratic risks, but may amplify systemic risk.

<sup>16</sup>Recent papers study the role of asymmetric information on the interbank market. Heider et al. (2009) show that asymmetric information about counterparty risk can produce market breakdowns. Boissay et al. (2013) show that interbank market freezes are more likely after a credit boom. In an extension of this securitization model (available in the working paper version (Kuncl, 2014b)), I find similar results: the liquidity problems on the resale markets for securitization products are more severe in recessions especially after a prolonged boom period.

to the existence of asymmetric information will worsen the adverse selection problem and lead to a recession. Compared to Bigio (2013), my model features reputation-based signaling, which is more effective when the dispersion is larger.

In this paper, the quality of investment allocation decreases during the boom stage of the business cycle. There are various papers that deal with the evolution of bank lending standards over the business cycle. In an empirical paper, Lown and Morgan (2006) document deterioration of bank lending standards in the United States during the boom stage of the business cycle. Theoretical models with asymmetric information about the quality of borrowers and a costly screening by banks, Dell’Ariccia and Marquez (2006) and Ruckes (2004) suggest the reasons for the countercyclical bank lending standards. The results of lower bank lending standards during booms is similar to the outcome of this paper. However, in my model, the asymmetric information exists among financial firms trading securitized loans, and the adverse selection can be alleviated by reputation-based signaling. Also unlike the mentioned models, my model is fully dynamic and better suited to study the time dimension of asymmetric information-related effects.

There are also several papers that study the importance of reputation in lender-borrower relationships. Nikolov (2012) introduces reputation to the model of Kiyotaki and Moore (1997) and shows that reputation represents intangible capital, which is more valuable in the boom stage of the business cycle, and therefore it further strengthens the collateral amplification mechanism. Ordoñez (2014) argues that unregulated banking disciplined only by reputation forces may be efficient due to the saving on regulatory and bankruptcy costs, but is more fragile. Chari et al. (2014) present a model where originators can differentiate themselves from others by keeping a larger fraction of their loan portfolio on the balance sheet.<sup>17</sup> Pooling equilibria with adverse selection in which it is too costly for high-quality banks to separate are persistent and characterized by higher trade volumes.

### 3 Model

To allow for maximum tractability, the set-up of the model is rather simple. The economy contains a continuum of financial firms that have stochastic heterogeneous

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<sup>17</sup>Similar mechanism is in Martin (2009) where in states with low entrepreneurial wealth, screening of borrowers using collateral requirements may be too costly, and therefore the economy is in a pooling equilibrium, in which good borrowers cross-subsidize bad borrowers



investment opportunities. As a result, there is a need for financial intermediation in the model. Optimally, firms would want to transfer resources from firms without investment opportunities or with low-quality investment opportunities to firms with high-quality investment opportunities. The transfer of funds is possible through securitization, which is modelled as a sale of cash flows from the funded projects.<sup>18</sup> Financial intermediation is subject to frictions such as asymmetric information about distribution of investment opportunities, which makes it less efficient in the boom stage of the business cycle.

### 3.1 Model set-up

In this section I first describe the physical environment and specify the frictions in the model. Then I define the optimization problem of financial firms. Finally, I close the model by clearing both goods and asset markets.

#### 3.1.1 Investment projects

There are three types of projects available to financial firms, and the allocation of firms to projects is stochastic through an i.i.d. shock:

- $(1 - \pi)$  share of firms (subset  $\mathcal{Z}_t$ ) do not have access to new investment projects;
- $\pi\mu$  share of firms (subset  $\mathcal{H}_t$ ) have access to high-quality projects with high gross profit per unit of capital  $r_t^h = A_t^h K_t^{\alpha-1}$ ; and
- $\pi(1 - \mu)$  share of firms (subset  $\mathcal{L}_t$ ) have access to low-quality projects with low gross profit per unit of capital  $r_t^l = A_t^l K_t^{\alpha-1}$ .

The realization of this shock cannot be insured by ex ante contracts.

**Assumption 1:** I assume that the relative difference in gross profits from high- and low-quality projects is countercyclical:

$$\frac{\partial}{\partial A_t} \frac{A_t^h - A_t^l}{A_t^l} < 0, \quad (3.1)$$

where  $A_t$  is the aggregate component of TFP. In other words, I assume that there is a dispersion shock perfectly negatively correlated with the productivity shock.

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<sup>18</sup>To keep the model simple, I do not model any alternative means of transferring funds such as debt. Elsewhere, I present an extension of this model, where different types of debt, such as deposits or interbank loans, are considered and replicate the main qualitative results of this paper (Kuncl, 2013).

This assumption is inspired by the empirical evidence on countercyclical cross-sectional variance in the TFP of U.S. firms in Bloom (2009) and Bloom et al. (2012).<sup>19</sup> In this model, the TFP of the projects has an aggregate component,  $A_t$ , and a type-specific component,  $\Delta_t^h$  and  $\Delta_t^l$ , respectively:  $A_t^h = A_t\Delta_t^h$  and  $A_t^l = A_t\Delta_t^l$ . To satisfy the assumption in (3.1), the ratio of type-specific TFP components has to be countercyclical,  $\partial(\Delta_t^h/\Delta_t^l)/\partial A_t < 0$ .

Some of the basic features of the model are inspired by Kiyotaki and Moore (2012). Similar to Kiyotaki and Moore (2012), financial firms are subject to an i.i.d. investment shock and face constant returns to scale, i.e., they take  $r_t^h$  and  $r_t^l$  as given; however, on the aggregate level there are decreasing returns to scale:

$$Y_t = r_t^h H_t + r_t^l L_t = \left( A_t^h \frac{H_t}{K_t} + A_t^l \frac{L_t}{K_t} \right) K_t^\alpha,$$

where  $K_t = H_t + L_t$  and  $H_t$  ( $L_t$ ) are aggregate holdings of high(low)-quality capital.<sup>20</sup>

### 3.1.2 Frictions

Two **core frictions** are present in the model:

- Investing firms, which sell securitized loans, have to satisfy the “*skin in the game*” constraint (hereafter SGC), i.e., they have to keep at least a  $(1 - \theta)$ -fraction of the investment on their balance sheet. This means they can sell at most a fraction  $\theta$  of the current investment and the rest has to be financed from their own resources. For simplicity,  $\theta$  is taken throughout most of the paper as a parameter. However, in Appendix A.11 this friction is endogenized by the existence of a moral hazard problem and the results remain qualitatively unchanged.
- There is an *asymmetry of information* about the above-described allocation of investment opportunities among firms. Each firm knows the type of project it is assigned to in the current period, but it is not aware of the allocation of projects among other firms.

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<sup>19</sup>Motivated 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.

<sup>20</sup>Kiyotaki and Moore (2012) obtain this result by including labor in the production function and requiring a competitive wage to be paid to workers in order to run a project. Here, for simplicity, I omit the workers from the model, but I use the results of constant returns to scale on the individual level and decreasing returns to scale on the aggregate level by assumption.

The second friction is motivated by a certain opacity of securitized assets and by the aforementioned criticism of securitization, which takes the asymmetric information as the source of most of the related agency problems (for details see the literature review). The first friction can also be observed in reality. But the main reason for having it in this otherwise simple model is that despite the competition among financial firms, a binding SGC increases equilibrium prices above the costs of investment and, therefore, makes the securitization process profitable. Only when securitization is profitable does a reputation equilibrium with implicit recourse exist. As I explain later, when a firm defaults on the implicit recourse, it suffers a punishment by other firms, which will stop buying securitized assets from it.<sup>21</sup> And this represents a loss for the firm only when securitization is profitable.

### 3.1.3 Firms' problem

Each financial firm (indexed by  $i$ ) chooses the control variables  $\{c_{i,t+s}, x_{i,t+s}, \{a_{i,j,t+s+1}\}_j, h_{i,t+s+1}^S, l_{i,t+s+1}^S, r_{i,t+s+1}^G, \chi_{i,t+s}\}_{s=0}^\infty$  to maximize the expected discounted utility from its future consumption stream:

$$\sum_{s=0}^{\infty} \beta^s u(c_{i,t+s}),$$

where  $u(c_{i,t+s}) = \log(c_{i,t+s})$ . The budget constraint for all firms is

$$\begin{aligned} c_{i,t} + x_{i,t} (1 - q_{i,t}^G) + \sum_{j \in \mathcal{I}_t} a_{i,j,t+1} q_{j,t}^G + h_{i,t+1}^S q_t^h + l_{i,t+1}^S q_t^l + \chi_{i,t} c i r_{i,t} \\ = \sum_{j \in \mathcal{I}_{t-1}} a_{i,j,t} (r_{j,t}^{\hat{G}} + \lambda q_{j,t}) + h_{i,t}^S (r_t^h + \lambda q_t^h) + l_{i,t}^S (r_t^l + \lambda q_t^l) \quad \forall i, \forall t. \end{aligned}$$

All firms face the SGC and information asymmetry constraint and firms with no investment opportunity face an additional constraint  $x_{i,t} = 0 \quad \forall i \in \mathcal{Z}_t$ .

This constrained maximization problem describes the following options of firms. The resources of firms consist of stochastic gross profits from projects financed in the past and the market value of a non-depreciated part  $\lambda$  of those projects. They consume the  $c_{i,t}$  part of those resources. If they have an investment opportunity, they can originate

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<sup>21</sup> I assume that it is possible to commit to not buy securitized assets from a particular firm and show that such a commitment can be credible; i.e., even ex post it would be optimal to stick to the punishment rule. In other words, the punishment is renegotiation-proof under certain conditions. However, I assume that it is not possible to prevent a particular firm from buying securitized assets from others; i.e., a threat of complete autarky is not possible. I believe that also, in reality, it is easier to commit not to buy assets from particular issuers rather than forbid them to buy securitized assets.

new projects at unitary costs  $x_{i,t}$ .<sup>22</sup> I denote the subset of firms that decide to invest, i.e., originate new projects (issue new loans), as  $\mathcal{I}_t$ . Firms can also buy securitized cash flows from projects, newly originated by other firms, on the primary market  $\{a_{i,j,t+1}\}_j$  for prices  $\{q_{j,t}\}_j$ , or buy securitized cash flows from older projects of known high(low) quality on the secondary (resale) market  $h_{i,t+1}^S$  ( $l_{i,t+1}^S$ ) for price  $q_t^h$  ( $q_t^l$ ). The  $j \in \mathcal{I}_t$  subscript denotes originating firms, and superscripts  $h, l$  denote the known quality of the traded asset. Originating firms can securitize and sell cash flows from the new projects. If they sell a part of their investment,<sup>23</sup> they can provide implicit recourse to buyers of these newly securitized assets in the form of a promise for minimum gross profit per unit of capital next-period  $r_{i,t+1}^G$ . An asset with implicit recourse is traded for a market price  $q_{i,t}^G$ , which depends on the information structure in the equilibrium, i.e., on the beliefs of buyers about the type of sold asset. The following period, after the realization of the aggregate shock, each firm can decide whether to default on the implicit recourse from the previous period, which is represented by  $\chi_{t+1}$ .<sup>24</sup> If a firm honors the implicit recourse, it has to spend part of its resources covering related costs  $cir_{i,t}$ . Details on the cost of implicit recourse and the choice of default are discussed in section 3.2.4. The timing of shocks and the choice of controls by firms within each period are shown in Figure 3.1.

Note that since profits (cash flows) are observed and  $\Delta^h, \Delta^l$ , and  $A_t$  are public information, the uncertainty about the quality of financed projects is resolved at the latest in the period following investment in the project. Therefore, depending on the particular equilibrium, the quality of assets traded on the primary market may be either public or private information, and when these assets are traded in the next period on the resale market their quality is already public information. Therefore, we can collapse all assets issued in past periods into two categories of high- and low-quality assets:  $h^S, l^S$ .<sup>25</sup> Laws of motion for high- and low-quality assets traded on resale markets are

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<sup>22</sup>Gertler and Kiyotaki (2010), in their study of the interbank market, based on the same modelling approach as Kiyotaki and Moore (2012), refer to investments in projects as loans to entrepreneurs who run those projects. Entrepreneurs are able to offer perfectly state-contingent debt, and since financial firms (banks) have all the bargaining power, they can extract the entire profit from entrepreneurs. Following this approach, I will sometimes refer to the investment in projects as loans, too, and later calibrate this model using the performance of mortgage-backed securities.

<sup>23</sup>The amount of new loans kept on the balance sheet is the difference between investment  $x_t$  and the next-period holdings of assets of firm  $i$  issued by firm  $i$ :  $a_{i,i,t+1}$ , while  $x_t - a_{i,i,t+1} \geq 0$ .

<sup>24</sup> $\chi_{t+1}$  takes the value of 1 in the case of no default and 0 in the case of default.

<sup>25</sup>Later, in an extension of this model, I relax this assumption and introduce asymmetric information on resale markets.

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

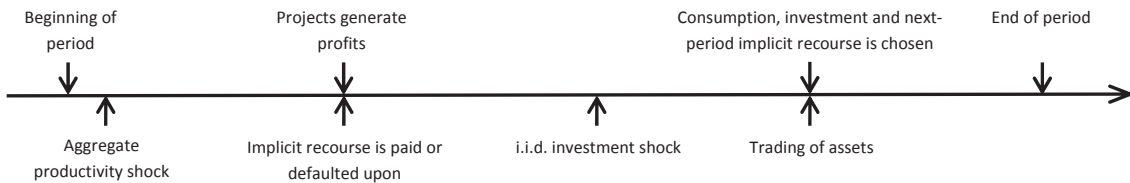
Since the uncertainty about qualities of projects lasts only for one period, for simplicity and tractability I also restrict the guarantee on the loan performance to one period after the issuance.<sup>26</sup>

Since utility is logarithmic and budget constraints are linear in individual holdings of assets, the policy functions will also be linear in the individual holdings of wealth. Due to logarithmic utility, all firms will always consume a constant fraction of their current wealth (for derivations see Appendix B):

$$c_{i,t} = (1 - \beta) \left( \sum_{j \in \mathcal{I}_{t-1}} a_{i,j,t} (r_{j,t}^G + \lambda q_{j,t}) + h_{i,t}^S (r_t^h + \lambda q_t^h) + l_{i,t}^S (r_t^l + \lambda q_t^l) \right) \forall i, \forall t.$$

Linear policy functions and i.i.d. investment opportunities enable a straightforward aggregation. An application of the law of large numbers implies that the aggregate quantities and prices do not depend on the distribution of wealth across individual firms ( $\Sigma$ ); therefore, we do not have to keep track of it.

Figure 3.1. Timing of shocks and the choice of a firm's controls within each period



### 3.1.4 Goods and asset markets

The model features a market for consumption goods and for capital goods (securitized cash flows from projects). In every period all projects generate gross profits in the form

<sup>26</sup>In a related paper, Kuncl (2014a) allows for infinite-horizon implicit guarantees, with the result that public information about the quality of assets traded on the secondary market is persistently unavailable. As a result, Kuncl (2014a) presents a richer dynamics of adverse selection on resale markets, though the model is also more complex.

of consumption goods. Consumption goods must be either consumed or converted into capital goods by investing in new projects. The goods market clears when all current output  $Y_t$  is consumed or invested:  $Y_t = C_t + X_t$ .

Capital goods are traded on asset markets. There is a secondary market on which assets of known quality are traded, and a primary market for newly issued assets whose quality is either known or does not depend on the type of equilibrium. As derived in Appendix B, the conditions for the clearing of asset markets come from the first-order conditions (FOC) of firms, which buy on asset markets (subset  $\mathcal{S}_t$ ), and which I call saving firms  $i \in \mathcal{S}_t$ . These conditions imply that the discounted return of all assets traded on markets have to be equal to 1, and that, in equilibrium, saving firms will be indifferent between holding different assets.

Asset markets clear when prices satisfy the FOC of the saving firms with respect to portfolio allocation:

$$\begin{aligned} E_t \left[ \beta \frac{c_{i,t}}{c_{i,t+1}} \frac{r_{t+1}^{\hat{G}} + \lambda q_{j,t+1}}{q_{j,t}^{\hat{G}}} \right] &= 1 \quad \forall i \in \mathcal{S}_t, \forall j \in \mathcal{I}_t, \\ E_t \left[ \beta \frac{c_{i,t}}{c_{i,t+1}} \frac{r_{t+1}^h + \lambda q_{t+1}^h}{q_t^h} \right] &= 1 \quad \forall i \in \mathcal{S}_t, \\ E_t \left[ \beta \frac{c_{i,t}}{c_{i,t+1}} \frac{r_{t+1}^l + \lambda q_{t+1}^l}{q_t^l} \right] &= 1 \quad \forall i \in \mathcal{S}_t. \end{aligned}$$

Recall that all assets depreciate over time, so the law of motion for capital (stock of projects) is  $K_{t+1} = \lambda K_t + X_t$ .<sup>27</sup>

### 3.2 Model solution in special cases

To provide intuition for the results of this paper, this section explicitly derives a solution of the model analytically in the steady state, i.e., when aggregate productivity is fixed ( $A_t = A$ ), while idiosyncratic shocks still take place. In section 4, I report numerical results from the fully stochastic case.

To demonstrate the effect of the core frictions in the model, I first briefly show the behavior and solution of the model without frictions, and then I successively introduce a binding “skin in the game” constraint and the asymmetric information. I show that

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<sup>27</sup> Similar laws hold for both types of capital (low quality and high 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:  $\beta > \lambda$ .

when the SGC is binding, a reputation equilibrium exists, where implicit recourse can be provided. Consequently, I show the solution of the model in the case of interest, i.e., where both frictions hold and the provided implicit recourse can signal the quality of securitized assets.

### 3.2.1 Case with no financial frictions: first-best

If neither of the two frictions is present—i.e., project allocation is public information and the SGC is not binding—in equilibrium only firms with high-quality investment opportunities will invest, securitize loans, and sell them to firms with low or unproductive investment opportunities (see Figure 3.2). Since there is no asymmetric information and only high-quality projects are being financed, there is only one type of asset traded in the economy. When I omit the variables that turn out to be zero in equilibrium, the budget constraints of individual firms with different investment opportunities are

$$\begin{aligned} c_{i,t} + x_{i,t} + (h_{i,t+1} - x_{i,t})q_t^h &= h_{i,t}(r_t^h + \lambda q_t^h) \quad \forall i \in \mathcal{H}_t, \\ c_{i,t} + h_{i,t+1}q_t^h &= h_{i,t}(r_t^h + \lambda q_t^h) \quad \forall i \in \mathcal{L}_t, \\ c_{i,t} + h_{i,t+1}q_t^h &= h_{i,t}(r_t^h + \lambda q_t^h) \quad \forall i \in \mathcal{Z}_t. \end{aligned}$$

Because of competition among firms with high-quality investment opportunities, the price of loans is equal to the unit costs of financing the project (issuing the loan),  $q^h = 1$ .

Combining the aggregate consumption function, the goods market clearing condition, and the law of motion for capital, we obtain<sup>28</sup>:

$$r^h + \lambda = \frac{1}{\beta}. \tag{3.2}$$

The current period gross profit per unit of invested capital plus the value of non-depreciated assets is equal to the time preference rate; therefore, the amount of investment is indeed first-best.

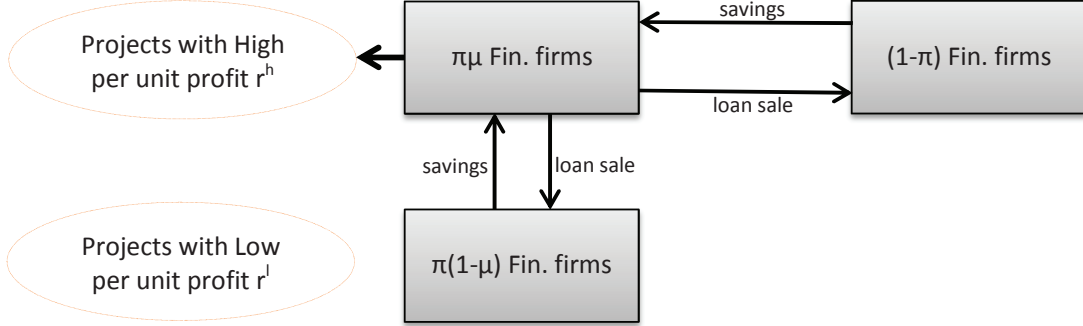
### 3.2.2 Introducing the “skin in the game” constraint (SGC)

In this section, I show that a binding SGC ( $\theta$  fraction of new loans at most can be sold) increases the equilibrium prices above the replacement rate, which makes securitization

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<sup>28</sup>For details see Appendix A.1.

Figure 3.2. Case without frictions: First-best case



Note: In the first-best case, only firms with access to projects with high profit per unit of capital invest, and they sell some of these projects to the remaining firms.

profitable. As noted above, only when securitization is profitable, can a reputation equilibrium exist. The SGC is also a common practice observed in securitization contracts in the form of tranche retention schemes.<sup>29</sup> This constraint can be motivated and endogenized by a moral hazard problem, which is derived in Appendix A.11. In this section, I assume for simplicity a constant  $\theta$ .

By lowering  $\theta$ , we limit the capacity of firms with access to high-quality projects to issue new investments. When this capacity is lower than the demand for new investments at the zero-profit price  $q^h = 1$ , the SGC becomes binding, and the price has to increase above the unit costs of investment to clear the market. Securitization becomes profitable.

If the SGC is binding for firms with access to high-quality projects, i.e., their holdings of newly issued assets represent a  $(1 - \theta)$  share of their investment  $h_{i,t+1} = a_{i,i,t+1} = (1 - \theta) x_{i,t} \forall i \in \mathcal{H}_t$ <sup>30</sup>, we can rewrite their budget constraint as

$$c_{i,t} + \frac{(1 - \theta q_t^h)}{(1 - \theta)} h_{i,t+1} = h_{i,t}(r_t^h + \lambda q_t^h) + l_{i,t}(r_t^l + \lambda q_t^l) \forall i \in \mathcal{H}_t. \quad (3.3)$$

Combining these two equations and the consumption function, we can find the level of

<sup>29</sup>For simplicity, I do not model the existence of different tranches. The “skin in the game” constraint is analogous to keeping a “vertical slice” of all tranches.

<sup>30</sup>I show below that for a subset of parameters, firms with access to low-quality projects will also optimally choose to invest and securitize loans in equilibrium. They may also face the binding “skin in the game” constraint, i.e.,  $l_{i,t+1}^l = a_{i,i,t+1} = (1 - \theta) x_{i,t}^l \forall i \in \mathcal{L}_t$ .



investment of the constrained firm with access to high-quality projects:

$$x_{i,t}^h = \frac{\beta (h_{i,t}(r_t^h + \lambda q_t^h) + l_{i,t}(r_t^l + \lambda q_t^l))}{(1 - \theta q_t^h)} \quad \forall i \in \mathcal{H}_t. \quad (3.4)$$

All policy functions are again linear, and therefore can be easily aggregated and, as Appendix A.2 shows, we can obtain the following proposition.

**Proposition 1.** *If “skin in the game” is sufficiently large to be binding, i.e.,  $\theta$  is sufficiently low to satisfy*

$$1 - \theta > \frac{\pi\mu}{1 - \lambda},$$

*then in the deterministic steady state:*

- (i) *the price of high-quality assets  $q^h$  exceeds 1;*
- (ii) *the steady-state level of output and capital is lower than in the first-best case.*

The above proposition is analogous to Claim 1 in Kiyotaki and Moore (2012), but for a complete characterization of the model’s steady state, we also need the following proposition.

**Proposition 2.** *Suppose the condition from Proposition 1 holds, then depending on parameter values, the deterministic steady state is characterized by one of the following cases:*

*Case H: Only firms with access to high-quality projects issue credit and securitize ( $q^l < 1$ );*

*Case M: Firms with access to low-quality loans use a mixed strategy and issue credit with probability  $\phi$ , ( $q^l = 1$ );*

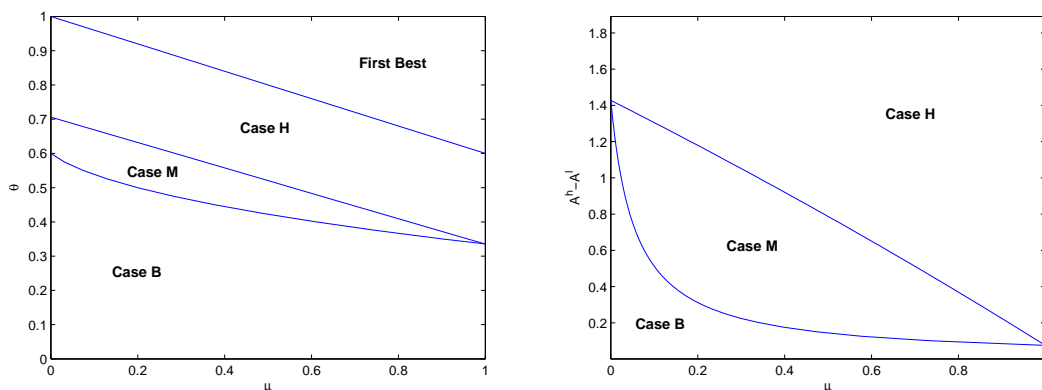
*Case B: All firms with access to high- and low-quality projects issue credit and securitize ( $q^l > 1$ ).*

The above cases are ranked from the least restricted ( $q^l < 1$ ), where output and capital levels are relatively the closest to the first-best case, to the most restricted ( $q^l > 1$ ), where output and capital are the lowest:

$$\begin{aligned} Y_{FB} &> Y_H > Y_M > Y_B, \\ K_{FB} &> K_H > K_M > K_B. \end{aligned}$$

Here subscript FB denotes the first-best case, and subscript H, M and B denote the above described cases.

Figure 3.3. Type of deterministic steady state depending on selected parameter values



Proofs of the above propositions are in the appendices (A.2 and A.3).

Figure 3.3 shows the effect of selected parameter values on the type of steady state. In the left panel we can see that lowering  $\theta$  or  $\mu$  moves the steady state from an unrestricted first-best case to more restricted cases. The right panel shows that lowering the difference in the productivity of the two types makes it more likely that low-quality projects are financed in the steady state.

### 3.2.3 Introducing asymmetric information

In this section, I describe the consequences of introducing asymmetric information about the allocation of investment opportunities among firms on the model solution. I focus on the effect of asymmetric information between issuers of securitized assets and their first buyers.<sup>31</sup>

Unless the difference in qualities is large enough, firms with access to low-quality projects mimic firms with access to high-quality projects. Since it is not possible to distinguish between the projects, saving firms, which want to diversify their portfolio, buy both high- and low-quality securitized assets at the rate corresponding to the probabilities of their arrival. This means that, in equilibrium, a  $\mu$  fraction of investment is allocated to high-quality and a  $1 - \mu$  fraction to low-quality projects.

<sup>31</sup> In this benchmark version of the model I assume that past projects are not anonymous; therefore, the quality of all existing projects becomes public information in the period following their securitization. Therefore, there is no adverse selection on resale markets. In an extension of this model (Kuncl, 2014a), I relax this assumption and show that asymmetric information on resale markets can lead to market shutdowns similar to Kurlat (2013). Kuncl (2014a) indeed focuses mainly on the interaction of adverse selection on the resale markets and the provision and default on infinite horizon implicit recourse.

**Proposition 3.** *Compared to the public information case, the allocation of capital is generally less efficient (more in favor of low-quality projects); therefore, capital is less productive and the steady-state amount of capital and output is lower.*

For a proof see Appendix A.4.

The public information case will be equal to the private information case only if the difference in quality is large enough. The firm with low-quality investment opportunities will avoid mimicking firms with high-quality investment opportunities as long as the return from buying high-quality assets exceeds the return from mimicking:

$$R \mid \text{buying high loans} > R \mid \text{mimicking}.$$

As shown in Appendix A.5, in the steady state this condition implies

$$\frac{A^h}{A^l} > \frac{(1 - \theta) q^h}{1 - \theta q^h} = \frac{(1 - \pi\mu)(1 - \lambda)(1 - \theta)}{\pi\mu\lambda + (1 - \lambda)\theta\pi\mu}. \quad (3.5)$$

If the ratio of high and low productivity does not satisfy (3.5), the resulting pooling equilibrium will be less efficient than the public information case. The separation condition can be rewritten as

$$q^l < \frac{1 - \theta q^h}{1 - \theta}. \quad (3.6)$$

Since, by Proposition 1,  $q^h > 1$ , (3.6) implies that a necessary condition for the existence of a separating equilibrium is that the equilibrium price of low-quality assets is lower than the costs of investing  $q^l < 1$ .

Note also that tightening the SGC, i.e., lowering  $\theta$ , will only increase the lower bound for the ratio of productivities in condition 3.5 and, therefore, make mimicking more likely. This result is driven by the general-equilibrium effect. A lower  $\theta$  increases the prices in the economy and, therefore, makes mimicking more profitable.

**Proposition 4.** *Under private information, increasing the “skin in the game,” i.e., lowering  $\theta$ , makes a pooling equilibrium in which firms with low-quality investment opportunities mimic firms with high-quality investment opportunities more likely.*

### 3.2.4 Introducing implicit recourse and the reputation equilibrium case

Proposition 3 implies that the outcome of the private information case is generally inefficient compared to the public information case. Firms with high-quality investment

opportunities have incentives to distinguish themselves from low-quality investment firms. However, under Proposition 4, we can see that retaining higher “skin in the game” does not lead to a separating equilibrium.

Signalling would be more efficient if originators could keep more risk from the investment on their balance sheets without restricting their investment capacity.<sup>32</sup> This could be achieved either by tranching and first-loss tranche retention by the originator (explicit risk retention) or by the provision of implicit recourse by the originator (implicit risk retention). In the real world, explicit risk retention would typically lead to higher capital requirements and would thus restrict the investment potential of originators, while implicit risk retention was popular precisely for the potential to arbitrage regulation. While in this simple model I do not model capital requirements regulation or the reasons for it, I focus my analysis on the efficiency of implicit recourse.<sup>33</sup>

It turns out that by providing **implicit recourse**, a firm with high-quality investment opportunities can distinguish itself without restricting its investment potential. Under this strategy, the issuing firm promises a minimum gross profit per unit of invested capital  $r_t^G$  to the buyers of securitized loans. Should the actual gross profits in the following period fall below this minimum, the issuing firm would reimburse the difference. This promise is not enforced by any explicit contract; rather, it is the result of collusion between issuers of loans and their buyers. Implicit recourse can be credible in a reputation equilibrium, where securitizing firms aim to keep their reputation of sticking to the promise, and firms buying securitized projects enforce this promise by punishing the issuing firms in case of default on the implicit recourse. I assume a trigger punishment strategy that prevents a firm without a reputation of honoring implicit recourse from selling securitized assets on the market. The punishment has to be credible; therefore, in this reputation equilibrium, buyers of securitized products with implicit support aim to keep the reputation of being “tough investors,” i.e., a reputation of always punishing firms that did not fulfill their promise.

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<sup>32</sup>I show this in Appendix A.8.

<sup>33</sup>In Appendix A.8 I show that higher costs of explicit risk retention may prevent it from being used in equilibrium.

At this point, it is convenient to write the problem recursively:

$$V^{ND}(\bar{s}, w - cir; \bar{S}) = \pi \left( \mu V^{ND,h}(\bar{s}, w - cir; \bar{S}) + (1 - \mu) V^{ND,l}(\bar{s}, w - cir; \bar{S}) \right) + (1 - \pi) V^{ND,z}(\bar{s}, w - cir; \bar{S}), \quad (3.7)$$

$$V^D(\bar{s}, w; \bar{S}) = \pi \left( \mu V^{D,h}(\bar{s}, w; \bar{S}) + (1 - \mu) V^{D,l}(\bar{s}, w; \bar{S}) \right) + (1 - \pi) V^{D,z}(\bar{s}, w; \bar{S}), \quad (3.8)$$

$$V^{ND,k}(\bar{s}, w; \bar{S}) = \max_{c,x,\{a'_j\}_j,h^{S'},l^{S'},r^{G'}} [\log(c) + \beta E \left[ \max \left( V^{ND}(\bar{s}', w' - cir'; \bar{S}'), V^D(\bar{s}', w'; \bar{S}') \right) \right]], \quad (3.9)$$

$$V^{D,k}(\bar{s}, w; \bar{S}) = \max_{c,x,\{a'_j\}_j,h^{S'},l^{S'}} [\log(c) + \beta E V^D(\bar{s}', w'; \bar{S}')], \quad (3.10)$$

where  $V^{ND}$  ( $V^D$ ) are the value functions for the firm that never defaulted (has already defaulted) on implicit recourse.  $w$  is individual wealth before deducting the costs of implicit recourse  $cir$ ,  $\bar{s} = \left\{ \{a_j\}_j, h^S, l^S \right\}$  is a vector of individual state variables,  $\bar{S} = \{K, \omega, A\}$  is a vector of aggregate state variables, and superscript  $k$ , which can take values  $\{h, l, z\}$ , represents the type of investment opportunity that the firm faces in the current period.

Equations (3.7) and (3.8) show the investment shock that takes place after the realization of the aggregate productivity shock and the decision on (non-)default on implicit recourse from the previous period. After the investment shock, firms optimally choose the level of consumption, the quantity of securitized loans they buy on the primary and secondary market, and, if they have an investment opportunity, they choose the optimal level of investment in new projects, the securitization of their cash flows, the fraction of the new investment that is sold, and the implicit recourse they provide.<sup>34</sup> This problem is described by equations (3.9) and (3.10) for firms with a reputation for having never defaulted on implicit recourse and for firms without this reputation, respectively.

The above problem is constrained by budget constraints that take the following form for investing firms for which the “skin in the game” constraint is binding (e.g., in the case where firms have high-quality investment opportunities):

$$c_{i,t} + \frac{(1 - \theta q_{i,t}^G)}{(1 - \theta)} h_{i,t+1} + cir_{i,t} = \sum_{j \in \mathcal{I}_{t-1}} a_{i,j,t} \left( r_{j,t}^{\hat{G}} + \lambda q_{j,t} \right) + h_{i,t}^S (r_t^h + \lambda q_t^h) + l_{i,t}^S (r_t^l + \lambda q_t^l) \quad \forall i \in \mathcal{H}_t,$$

where the price of securitized loans issued by firm  $j$ ,  $q_{j,t}^G$ , depends on the information

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<sup>34</sup>Recall that the timing of shocks and the choice of controls by firms within each period are shown in Figure 3.1.

structure, i.e., on the beliefs of buyers about the type of sold asset  $\varphi_{j,t} \mid r_{j,t}^G$ . When the “skin in the game” is binding, the costs of implicit recourse are given by

$$cir_{i,t+1} = \theta x_{i,t} (r_{i,t}^G - r_t^k) \quad \forall i \notin \mathcal{S}_t, k \in \{h, l\}.$$

The incentive-compatible constraints (ICCs), which have to be satisfied in equilibrium for the existence of reputation-based implicit recourse, are

$$V^{ND}(\bar{s}', w' - cir'; \bar{S}') \geq V^D(\bar{s}', w'; \bar{S}'), \quad (3.11)$$

for the current originators of securitized assets (subset  $\mathcal{I}_t$ ), and

$$V^P(\bar{s}'; \bar{S}') \geq V^{NP}(\bar{s}'; \bar{S}'), \quad (3.12)$$

for the current buyers of securitized assets (subset  $\mathcal{S}_t$ ).  $V^P, V^{NP}$  are the value functions for the firm that has always punished for default on implicit recourse, and for the firm that failed to punish for default and suffers the negative consequences, respectively.

Condition 3.11 determines the level of implicit recourse that can be credibly provided; i.e., it is not defaulted upon, given the trigger strategy punishment rule. The trigger punishment strategy has to be credible. Therefore, the saving firm that observes default on implicit recourse has to be ex post better off punishing the investing firm that defaulted rather than not punishing it. This corresponds to condition 3.12.<sup>35</sup>

**Definition 1.** A recursive competitive equilibrium consists of prices  $\{q^h(\bar{S}), q^l(\bar{S}), \{q_j^G(\bar{S})\}_j\}$  and gross profits per unit of capital  $\{r^h(\bar{S}), r^l(\bar{S})\}$ , individual decision rules  $\{c(\bar{s}; \bar{S}), x(\bar{s}; \bar{S}), h^{S'}(\bar{s}; \bar{S}), l^{S'}(\bar{s}; \bar{S}), r^{G'}(\bar{s}; \bar{S}), \{a_j^l(\bar{s}, r_j^G, \varphi_j \mid r_j^G; \bar{S})\}_j, \chi(\bar{s}, r^G; \bar{S})\}$ , value functions  $\{V^{ND}(\bar{s}; \bar{S}), V^{ND,k}(\bar{s}; \bar{S}), V^D(\bar{s}; \bar{S}), V^{D,k}(\bar{s}; \bar{S}), V^{NP}(\bar{s}; \bar{S}), V^P(\bar{s}; \bar{S})\}$ , and the law of motion for  $\bar{S} = \{K, \omega, A, \Sigma\}$  such that: (i) individual decision rules and value functions solve each firm’s problems taking prices, gross profits per unit of capital, and law of motion for  $\bar{S} = \{K, \omega, A, \Sigma\}$  as given; (ii) both asset and goods markets clear; and (iii) the law of motion for  $\bar{S} = \{K, \omega, A, \Sigma\}$  is consistent with the individual firm’s decisions.

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<sup>35</sup>I show that this condition holds in Appendix A.6.

### 3.2.5 Public information case with implicit recourse

Although one might think that the public information case is uninteresting, it is an important benchmark. If originating firms could coordinate, they would not be providing implicit recourse in the case, when it does not serve as a tool that would distinguish the firm type. However, due to competition, firms tend to outbet each other.

Should promises always be credible, the optimal level of implicit recourse would be determined by the following FOC (note that the individual firm ignores the effects of this choice on aggregate variables):

$$\frac{\partial V^{ND}}{\partial r^G} = \frac{\partial V^{ND'}}{\partial (w' - cir')} \frac{\partial (w' - cir')}{\partial r^G} = 0.$$

I show in Appendix A.7 that this condition implies that  $q^j = 1$ , which means that as far as there are positive profits from securitization, the competition will drive the level of implicit recourse so high that profits from securitization are zero. However, when profits from securitization are zero, the punishment has zero costs, and the original non-defaulting ICC (3.11) is not satisfied. This leads us to the following conclusion.

**Proposition 5.** *As long as the implicit recourse is credible, firms find it optimal to increase it up to the level where  $q^j = 1$ . So the level of implicit recourse is defined by the maximum recourse, which can be sustained by the no-default condition (3.11).*

For details on the derivation, see Appendix A.7. The steady state, in this case, is characterized by the following propositions.

**Proposition 6.** *Suppose that the condition from Proposition 1 holds, then depending on parameter values, a deterministic steady state is characterized by one of the following cases:*

*Case 1: Only firms with access to high-quality projects issue credit, securitize loans, and provide implicit recourse  $r_{h,cred}^G$  ( $q^h > 1$ ,  $q^l < 1$ ,  $G_{cred}^h \geq r^h$ );*

*Case 2: Firms with access to high-quality projects issue credit, securitize loans, and provide implicit recourse  $r_{h,cred}^G$ , and firms with access to low-quality projects use a mixed strategy and issue credit with probability  $\phi$  and provide implicit recourse  $r_{l,cred}^G$  ( $q^h > 1$ ,  $q^l = 1$ ,  $r_{h,cred}^G \geq r^h$ ,  $r_{l,cred}^G = r^l$ );*

*Case 3: All firms with access to high- and low-quality projects issue credit, securitize, and provide implicit recourse  $r_{h,cred}^G$  and  $r_{l,cred}^G$ , respectively ( $q^h > 1$ ,  $q^l > 1$ ,  $r_{h,cred}^G \geq r^h$ ,  $r_{l,cred}^G \geq r^l$ ).*

Note that  $r_{k,cred}^G$  is the maximum implicit recourse that can be credibly provided by firms with a  $k \in \{h, l\}$  type of investment opportunity.

**Proposition 7.** *Compared to the public information case without implicit recourse, the amount of capital and output are higher, the allocation of capital is more in favor of high-quality projects and wealth is less concentrated inside firms with investment opportunities. This holds unless the provided implicit recourse has no value ( $r_{h,cred}^G = r^h$ ), and therefore the result is identical to the case without implicit recourse.*

### 3.3 Case of interest: Implicit recourse as a signal of loan quality

In this section, I analyze the case of interest, where the SGC is binding, there is asymmetric information about the distribution of firms to investment opportunities, and implicit recourse can signal the type of investment opportunity.

As proven in section 3.2.4, implicit recourse can be credibly provided in a reputation equilibrium. Under asymmetric information, implicit recourse can be interpreted as a signal of the loan quality. Investing firms (subset  $\mathcal{I}_t$ ) sell securitized cash flows from newly financed projects and provide implicit recourse  $r_{j,t+1}^G \in (0, \infty)$ . The fact that a particular firm sells securitized cash flows and provides  $r_{j,t+1}^G$  is the message that this firm is sending to potential buyers of its securitized cash flows. Saving firms (subset  $\mathcal{S}_t$ ), observing any message sent with positive probability, use Bayes' rule to compute the posterior assessment that the message comes from each type. Without restriction on out-of-equilibrium beliefs (beliefs about the types conditioned on observing messages that are not sent in equilibrium), there is a multiplicity of perfect Bayesian equilibria (PBE), generally both pooling and separating. I use the intuitive criterion (Cho and Kreps, 1987) as a refinement to eliminate the dominated equilibria with unreasonable out-of-equilibrium beliefs. As a result, when at least one separating PBE exists, after the application of intuitive criterion, we eliminate all except one unique separating equilibrium. When no separating PBE exists, the economy is in a pooling equilibrium. So in the dynamic version, when state variables change, the economy may be switching between a pooling and a separating equilibrium.

**Pooling equilibria:** In pooling equilibria, both firms with access to high- and low-quality investment opportunities choose to provide the same level of implicit recourse given the beliefs of investors (see Figure 3.8). They both provide  $r^{G*}$  with probability 1. Saving firms observe this message and use Bayes' rule to compute the posterior assessment that messages are sent by each type:



$$\varphi(j \in \mathcal{H}_t \mid r_j^G = r^{G*}) = \frac{\varphi(j \in \mathcal{H}_t) \cdot 1}{\varphi(j \in \mathcal{H}_t) \cdot 1 + \varphi(j \in \mathcal{L}_t) \cdot 1 + \varphi(j \in \mathcal{Z}_t) \cdot 0} = \frac{\mu\pi}{\mu\pi + (1 - \mu)\pi} = \mu.$$

Absent aggregate risk, there are several candidates for the pooling PBE:

**Case 1:** Firms with access to both high- and low-quality projects select with probability 1:  $r^{G*} = r_{l,cred,p}^G$ , where  $r_{l,cred,p}^G$  is the maximum implicit recourse that can be provided by firms with low-quality assets under pooling. Saving firms' out-of-equilibrium beliefs that sustain this equilibrium can be the following:  $\varphi(j \in \mathcal{H}_t \mid r_{l,cred,p}^G < r_j^G < r_{h,cred,s}^G) = 0$  and unrestricted for intervals  $0 < r_j^G < r_{l,cred,p}^G$ , and  $r_j^G > r_{h,cred,s}^G$ .<sup>36</sup> In this equilibrium, no firm defaults on implicit guarantees. None of the firms have the incentive to unilaterally decrease the implicit recourse or increase it.

Note that choosing  $r_j^G < r_{l,cred,p}^G$  is not an equilibrium, since both types will have incentives to increase implicit recourse to  $r_j^G = r_{l,cred,p}^G$  due to competition, no matter what the beliefs of investors are, since both types would fulfill the implicit recourse in this interval.

**Case 2:** Firms with access to both high and low-quality projects select  $r_j^G = r^{G*}$  such that:

$$r_{lb,p}^G \leq r^{G*} \leq \min(r_{minsep}^G, r_{h,cred,p}^G).$$

Saving firms' out-of-equilibrium beliefs that sustain this equilibrium can be the following:  $\varphi(j \in \mathcal{H}_t \mid r^{G*} < r_j^G < r_{h,cred,s}^G) = 0$ , and  $\varphi(j \in \mathcal{H}_t \mid 0 < r_j^G < r^{G*}) \leq \mu$  and unrestricted for the interval  $r_j^G > r_{h,cred,s}^G$ .

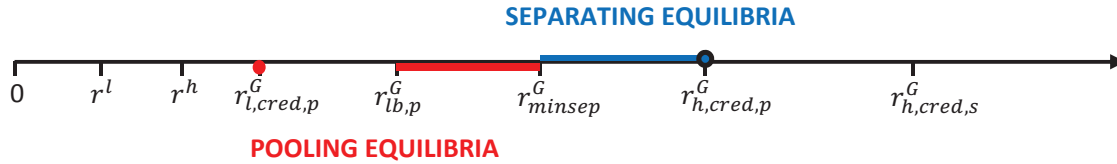
$r_{minsep}^G$  is the minimum level of implicit recourse, which the low types would not mimic under any beliefs (see derivation in Appendix A.10).  $r_{lb,p}^G$  is the lower bound on  $r^G$ , where firms with high-quality investments do not have incentives to deviate to  $r_{l,cred,p}^G$ . For  $r^G$  such that  $r_{l,cred,p}^G < r^G < r_{lb,p}^G$ , both types have incentives to decrease implicit recourse to  $r_j^G = r_{l,cred,p}^G$ , since equilibrium defaults on the implicit recourse of firms with low investment, which bring investors lower utility than when  $r^G = r_{l,cred,p}^G$ . This negative effect on price, together with potentially higher costs of higher implicit recourse (when  $r^G > r^h$ ), outweighs the positive effect of higher implicit recourse on the price.

**Separating equilibria:** There is potentially a continuum of separating equilibria, where firms with access to low-quality projects save and buy securitized assets from

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<sup>36</sup> $r_{h,cred,s}^G$  is the maximum level of implicit recourse that can be promised credibly by a firm with high-quality investment opportunities in a separating equilibrium (see below).

Figure 3.4. The case where the intuitive criterion selects a unique separating equilibrium



firms with access to high-quality projects (see Figure 3.7). Firms with access to high-quality projects invest, securitize, and provide implicit recourse  $r^{G^*} \in (r_{minsep}^G, r_{h,cred,s}^G)$  with probability 1, where  $r_{minsep}^G$  is the minimum implicit recourse that prevents mimicking by firms with low investment opportunities. Saving firms observe this message and use Bayes' rule to compute the posterior probability that the message is sent by each type:

$$\varphi(j \in \mathcal{H}_t | G_j = G^*) = \frac{\varphi(j \in \mathcal{H}_t) \cdot 1}{\varphi(j \in \mathcal{H}_t) \cdot 1 + \varphi(j \in \mathcal{L}_t) \cdot 0 + \varphi(j \in \mathcal{Z}_t) \cdot 0} = \frac{\mu\pi}{\mu\pi} = 1.$$

Saving firms' out-of-equilibrium beliefs that sustain this equilibrium can be the following:  $\varphi(j \in \mathcal{H}_t | r^{G^*} < r_j^G < r_{h,cred}^G) = 0$  and unrestricted for intervals  $0 < r_j^G < r^{G^*}$  and  $r_j^G > r_{h,cred,s}^G$ .

**Application of intuitive criterion:** If a separating equilibrium exists, then all pooling equilibria are dominated, and therefore fail the intuitive criterion (Cho and Kreps, 1987). In particular, due to competition among firms with access to high-quality investments, the intuitive criterion selects only one separating equilibrium, where firms with access to high-quality investments invest, securitize, and provide the maximum credible implicit recourse  $r^{G^*} = r_{h,cred,s}^G$ .<sup>37</sup> When there are multiple separating PBE, after applying the intuitive criterion, we eliminate all dominated equilibria with unreasonable out-of-equilibrium beliefs and obtain a unique separating equilibrium. In a case where no separating PBE exists, application of the intuitive criterion does not affect the potential multiplicity pooling equilibria. Below, I derive conditions for the uniqueness of pooling equilibrium.

**The condition for the existence of a separating equilibrium:**

Thanks to Proposition 5, we know that firms have incentives to unilaterally increase the provided implicit recourse up to the maximum credible level. But then, if low-quality firms are already at the maximum credible level, where the costs of default-

<sup>37</sup>This case is shown in Figure 3.4.

Figure 3.5. The case where there is no separating equilibrium



Figure 3.6. The case with unique pooling equilibrium



ing and keeping the implicit recourse are equalized, they are better off if they increase the implicit recourse without increasing the costs further, but potentially benefit from being mistaken for a firm with access to high-quality projects. Therefore, no separating equilibrium can exist in which firms with low-quality investment would provide a different level of implicit recourse. Firms with low-quality investments always prefer to mimic firms with high-quality investments rather than provide a lower implicit recourse and disclose their quality.

Therefore, separation can take place only when the costs of mimicking become so large that investing in high-quality assets is preferred. Under the deterministic case, this condition can be expressed analytically. The implicit recourse  $r^G$  has to be high enough to satisfy:

$$V^l | \text{mimicking} < V^l | \text{buying high loans}. \quad (3.13)$$

This brings us to one of the main findings in this paper.

**Proposition 8.** *Under asymmetric information, a separating equilibrium is possible in the deterministic steady state if and only if*

$$\frac{A^h}{A^l} > \frac{(1 - \theta B) q^h}{1 - \theta B q^h}, \quad (3.14)$$

where  $B \equiv \frac{q^G}{q^h} = \frac{r^G + \lambda q^h}{r^h + \lambda q^h}$  is the price premium for the equilibrium implicit guarantee. This implies that separating equilibrium:

(i) exists if and only if the level of aggregate productivity does not exceed the threshold level  $\tilde{A}$ ;

(ii) exists if and only if  $q^l < 1$ ; and

(iii) is more likely in the presence of reputation-based implicit recourse.

In a separating equilibrium, firms with low-quality investment projects save and buy securitized assets from firms with high investment opportunities.

**Sketch of proof:** The derivation of (3.14) comes directly from the no-mimicking condition 3.13.<sup>38</sup> Point (i) comes directly from Assumption 1 about the countercyclical relative difference of cash flows from projects of different quality. Since the ratio of TFP on the left-hand side (LHS) of (3.14) increases with aggregate TFP  $A$ , the mentioned threshold is defined as  $\Delta^h(\tilde{A})/\Delta^l(\tilde{A}) = (1 - \theta B)q^h / (1 - \theta Bq^h)$ .

Crucially, as I show in Appendix A.9, in a separating steady state, both  $q^h$  and  $B$  and, therefore, the whole right-hand side (RHS) of (3.14) are independent of the steady-state level of aggregate productivity  $A$  and are uniquely determined by the intensity of frictions and the punishment for default on implicit recourse.

After a substitution of the share of TFP by the ratio of prices from the asset market clearing condition, condition 3.14 can be rewritten as

$$q^l < \frac{1 - \theta Bq^h}{1 - \theta B},$$

which implies that in a separating equilibrium  $q^l < 1$ , since, by Proposition 1,  $q^h > 1$ .

Finally, when comparing the lower bound on the TFP ratio, consistent with the separating equilibrium in cases without implicit recourse (eq. 3.5) and in cases with implicit recourse (eq. 3.14), we can show that the latter is lower. This implies that in the case with implicit recourse, the separation condition (eq. 3.14) is more likely to be satisfied.<sup>39</sup>

#### **Uniqueness of pooling equilibrium:**

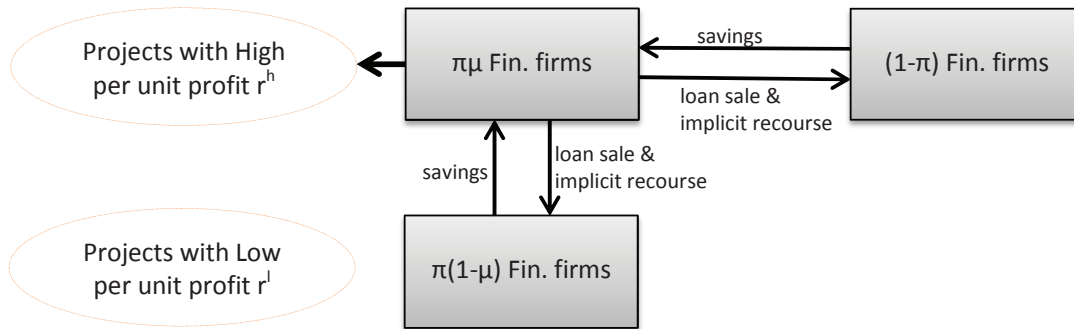
When a separating equilibrium does not exist, there is generally a continuum of pooling equilibria (see Figure 3.5). However, it turns out that for a large subset of parameter space, there is only one pooling equilibrium with  $r^{G*} = r_{l,cred,p}^G$ , independent of a specific type of out-of-equilibrium beliefs (see Figure 3.6). I calibrate the model to have only one pooling equilibrium. The advantage of this calibration is that punishment

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<sup>38</sup>See Appendix A.9 for the derivation.

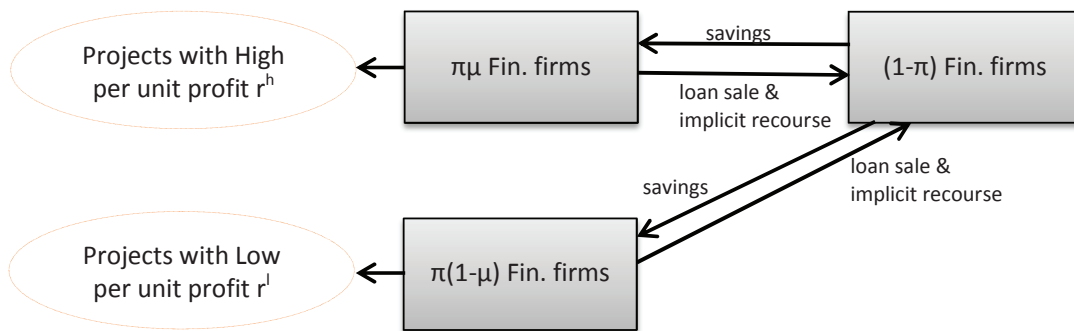
<sup>39</sup>The proof is in Appendix A.9.

Figure 3.7. A private information case with implicit recourse: separating equilibrium



Note: In the separating equilibrium, the implicit recourse provided by the firms with access to high-quality projects is high enough, so that it is not profitable for firms with access to low-quality projects to mimic them. They are better off buying high-quality projects.

Figure 3.8. A private information case with implicit recourse: pooling equilibrium



Note: In the pooling equilibrium, both firms with access to high-quality projects and firms with access to low-quality projects provide the same level of implicit recourse. They are indistinguishable, and, therefore, both types of firm invest in projects and sell them to firms with no investment opportunities.

is never triggered in equilibrium. It still provides the disciplining role, but the dynamic results are not influenced by the exercise of a particular punishment rule.<sup>40</sup>

To obtain such an equilibrium, I have to find parameter values such that  $r_{lb,p}^G > r_{h,cred,p}^G$ ; i.e., the minimum level of implicit recourse for which it pays off to provide recourse higher than  $r_{l,cred,p}^G$  is not credible in equilibrium, since it exceeds  $r_{h,cred,p}^G$ .

It turns out that this condition is satisfied for a low enough share of high-quality investment opportunities,  $\mu$ , and a high enough difference in type-specific TFP in a pooling equilibrium:

$$\mu < \frac{1 - \theta q^l}{q^h - \theta q^l}.$$

For details see Appendix A.10.

## 4 Dynamics and numerical examples

In this section, I show a solution of the fully stochastic version of the model with asymmetric information, binding SGC and implicit recourse. The allocation of projects to firms is still driven by an i.i.d. shock. The aggregate productivity for simplicity follows a two-state Markov chain  $A_t \in (A^H, A^L)$ <sup>41</sup> with a transition matrix  $P = [p, 1 - p; 1 - p, p]$ .<sup>42</sup>

When analyzing the dynamic properties of the model, I focus on the switching between the separating and the pooling equilibrium over the business cycle. Even though in the steady state there is a separating equilibrium, when the aggregate productivity increases and the economy is in the boom  $A_t = A^H$ , a separating equilibrium is no longer sustainable. The economy is in the pooling equilibrium, where both types of firms provide the same level of implicit support and both invest in new projects. This follows directly from Proposition 8. The intuition behind the result is the following. As the aggregate productivity increases, the relative difference in productivity of the two non-zero profit project types is reduced. Therefore, a higher implicit recourse is needed to satisfy the separation condition (3.13). Intuitively, following Proposition 8, the condition says that  $q^l < (1 - \theta B q^h) / (1 - \theta B) < 1$  is necessary for separation, but

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<sup>40</sup> Kuncel (2014a) generalizes this model and contains economy-wide defaults on the implicit recourse in a deep recession. But even in this case the punishment is not triggered, since it stops being renegotiation-proof.

<sup>41</sup>Note that the capital superscripts  $H, L$  refer to the aggregate state of the economy and not to the type of investment opportunity.

<sup>42</sup>The case when  $A_t$  follows a Markov chain is easier to calibrate but is not crucial for the results. An earlier version of this paper works with an AR(1) process for the aggregate TFP.

in a boom even the quality of low type projects is relatively high, and therefore one has to provide high implicit recourse to drive the prices of low-quality projects low enough. At some point, the level of implicit recourse required to achieve separation exceeds the maximum level that can be credibly provided, and the economy switches to the pooling equilibrium.

**Calibration of parameters:** Since I extend the model of Kiyotaki and Moore (2012), I use the same parameters for  $\alpha = 0.4$ ,  $\beta = 0.99$ , and  $\pi = 0.05$ . The persistence parameter for the productivity process is  $p = 0.86$ .<sup>43</sup> Parameters  $A^H, A^L$  are chosen to match the annual standard deviation of GDP in the United States, which is 2.8%.<sup>44</sup> The remaining parameters are chosen to replicate the performance (delinquency rates) of securitized assets, which has been at the core of recent debates over the efficiency of securitization—subprime residential mortgage-backed securities issued (RMBS) in the United States:  $\mu = 0.63$ ,  $\Delta^l(A^H) / \Delta^h(A^H) = 0.94$  and  $\Delta^l(A^L) / \Delta^h(A^L) = 0.71$ .<sup>45</sup> The annual depreciation  $\lambda = 0.78$  is chosen to replicate the weighted average life for RMBS of 54.5 months (Centorelli and Peristiani, 2012). And finally the fraction of loans that can be sold is set to  $\theta = 0.75$  to allow for the switching between pooling and separating equilibrium over the business cycle, which is supported by the empirical analysis in section 5.

**Solution method:** The fully stochastic model is solved using a global numerical approximation method.<sup>46</sup> In particular, I find the price and the value functions by iterating them on the grid of state variables until convergence.<sup>47</sup>

**Impulse responses:** Figure 4.1 shows how the economy behaves in a particular episode of three periods in a state with high aggregate TFP, followed by three periods in a state with low aggregate TFP. Then the productivity shocks are switched off and the economy converges to the steady state.<sup>48</sup> The point of this exercise is to show

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<sup>43</sup>This corresponds to an autocorrelation of TFP shocks at the quarterly frequency of 0.95.

<sup>44</sup>A similar approach is used in Nikolov (2012).

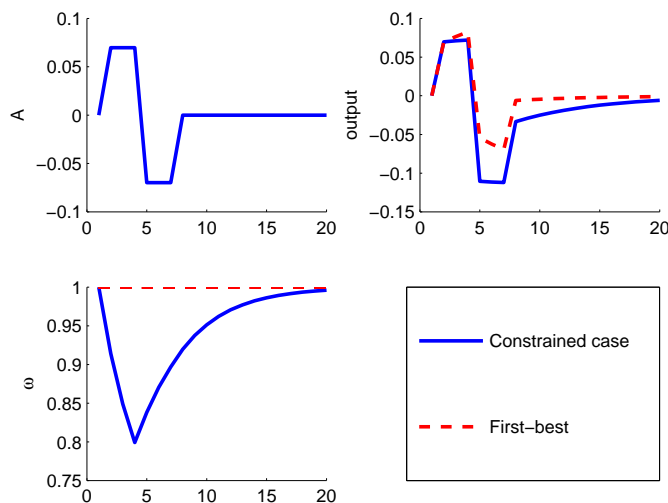
<sup>45</sup>For details see Appendix C.

<sup>46</sup>See, e.g., Judd (1998) for the description of global numerical methods and their distinction from local numerical methods.

<sup>47</sup>Details are in Appendix D.

<sup>48</sup>In this case with a Markov chain for aggregate productivity, the steady-state productivity is defined as the mean of the ergodic distribution across  $(A^H, A^L)$ , and in this zero-probability steady state, the expectations about the occurrence of either state are set to 50%.

Figure 4.1. Impulse responses



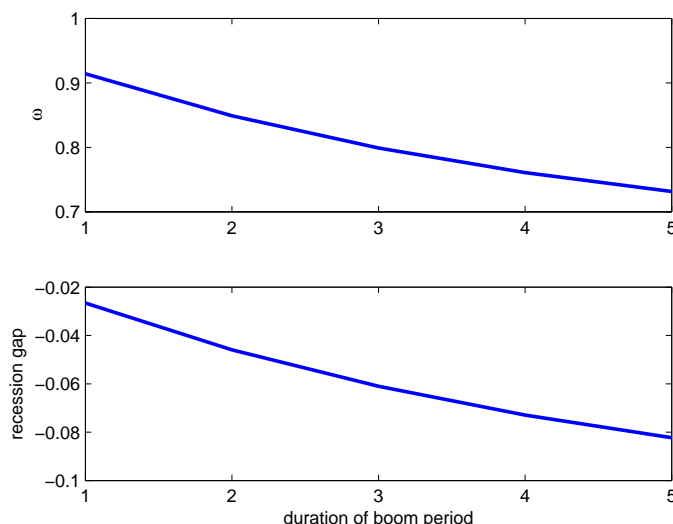
the switch from separating equilibrium to pooling and back and its effects on output. For comparison on the graph, I report impulse responses<sup>49</sup> of the constrained model under private information, with binding “skin in the game” and with an implicit recourse provision, as well as an unconstrained and efficient first-best case. Note that the graph depicts deviations from each model’s steady state. Only the share of high-quality assets on the balance sheets ( $\omega$ ) is shown in absolute value. So even though, on the graph, both the first-best and the constrained cases start at the same point, the first-best case is characterized by higher absolute levels of steady-state output and capital.

The figure shows that, as the constrained economy moves to the boom stage of the business cycle, the equilibrium type changes from separating to pooling; i.e., the share of high-quality projects ( $\omega$ ) decreases, while  $\omega$  remains constant in the first-best case at 100%. The lower share of high-quality projects in the constrained case slows the growth of output slightly, as well as the accumulation of capital already in the boom, but the effect is small, since in the boom stage the difference in the two qualities is rather small. However, the inefficiency in the allocation of capital continues to accumulate. As the economy exogenously moves to a recession with a higher difference in qualities, one can see that the accumulated inefficiency in the allocation of capital is more pronounced. Therefore, booms have almost the same relative size in a constrained and first-best case,

<sup>49</sup>The impulse responses start from a steady state to which they converge after a long period of zero-productivity shocks; i.e., aggregate productivity stays at the steady-state productivity. Then, I introduce the described sequence of productivity shocks after which the shocks are zero again.



Figure 4.2. The longer the boom stage, the deeper the subsequent recession



but busts that follow a boom stage are much deeper in a constrained case.

Figure 4.2 shows that the longer the boom period is preceding the recession, the larger the fraction is of low-quality assets accumulated in the pooling equilibrium, and the larger the difference in the depth of a recession is compared to the first-best case (a recession gap). This result follows directly from the above described property of the model, i.e., the existence of pooling equilibrium in the boom.

## 5 Empirical analysis

The main results of the theoretical model are the prediction that providing implicit support to the buyers of securitized assets can signal the quality of the underlying loans and the prediction that this signaling is less efficient for loans issued in the boom stage of the business cycle. In this section I test those model predictions on securitization deal-level data. I study the correlation between credit enhancement (credit protection provided to holders of the securitized assets which represents a risk retention directly by the issuer or paid for by the issuer)<sup>50</sup> and the delinquency rate on the collateral loans

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<sup>50</sup>Note that while in the model I focus on implicit risk retention (e.g. implicit credit enhancement), there is no direct data, which would measure the level of such implicit support. However, when the implicit credit enhancement is activated for instance in periods of lower than expected cash flows from the securitized products (higher than expected delinquency rates on collateral), it can be observed and often appears in the data. As anecdotal evidence let me cite the example reported originally by Mandel

(measure of the inverse of the quality of securitized assets). I find that higher lagged credit enhancement is negatively correlated with the delinquency rate in the United Kingdom, which supports the signaling hypothesis of credit enhancement. Moreover, I find that when signaling relationship is found, it disappears for the subset of loans issued in the boom stage of the business cycle. Those results are in line with the predictions of the theoretical model.

The empirical literature on the relationship between credit enhancements and the quality of the loans (typically approximated by the delinquencies on the collateral) is limited. The most relevant paper is the work by Mandel et al. (2012), where the authors test the signaling and the buffer hypotheses of credit enhancement (see below for description).

## 5.1 Hypotheses

I test the following two hypotheses from the theoretical model.

**Signaling hypothesis of credit enhancement.** According to this hypothesis the provision of higher credit enhancement should be positively correlated with the quality of securitized loans. Therefore, this hypothesis would suggest a negative correlation of lagged credit enhancements on the delinquency rates of the collateral. Alternatively, if positive correlation between (lagged) credit enhancements and delinquency rates is found, this could suggest that the **buffer hypothesis** credit enhancement mentioned e.g. in Mandel et al. (2012) is correct. According to the latter hypothesis, credit enhancement does not serve as a signal of quality of collateral but is rather provided as a buffer against observable risk.

**Hypothesis of lower efficiency of signaling for deals issued in the boom stage of the business cycle.** The model predicts that in the boom stage, economy is in a pooling equilibrium where both high- and low-quality assets are issued and bear the same level of implicit guarantees (which then transfer to higher explicit guarantees).

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et al. (2012) on the increase in credit enhancement by Chase Issuance Trust. The originator of the securitized assets increases credit enhancement on both future issuance as well as all outstanding securitized products. Note that they had no contractual obligation to provide higher credit enhancement on loans products issued in the past, so this is a typical case of implicit support that appears in the data only at the time when the implicit support is activated. Fitch: Chase Increases Credit Enhancement in Credit Card Issuance Trust (CHAIT),” <http://www.reuters.com/article/2009/05/12/idUS260368+12-May-2009+BW20090512>.

## 5.2 Data description

I use the Performance Data Services (PDS) database provided by Moody’s, which contains the quarterly data for the period 1998Q2-2013Q2 on delinquency rate of collateral (delinquency on the pool of loans), that can serve as a proxy for the quality of securitized assets. PDS also contains quarterly data on the credit enhancement provided to back securitized products. I have access to the part of the database which covers Residential Mortgage Backed Securities (RMBS) issued in European countries.<sup>51</sup>

Delinquency rate is the ratio of the amount of receivables that are 90 or more days past due to the original collateral pool balance. Delinquency rate is available on the pool level.<sup>52</sup> The PDS database contains various types of credit enhancement on tranche level data. I use the data for overcollateralization rate which is the difference between the collateral asset principal value and the principal value of the tranches in the deal normalized by the original collateral principal value. This type of credit enhancement is by definition the same for all tranches, i.e., it is available on the deal level. By contrast other popular forms of credit enhancement are by definition tranche specific (subordination) or are not always available for all tranches (reserve funds), which complicates the aggregation. The remaining forms of credit enhancement in the database such as letters of credit, spread accounts or cash collateral accounts are only rarely used in the available sample.

Since the analysis focuses on the changing nature of the relationship between securitized assets quality and credit enhancement over the business cycle, I use the real output data for the countries in the sample, which are obtained from Eurostat. I construct the output gap using the Hodrick-Prescott (HP) filter with the smoothing parameter 1600.

## 5.3 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  $t$ ):

$$\begin{aligned} DelinqRate_{i,t} = & \alpha_i + \alpha_t + \beta Overcollat_{i,t-1}^D + \gamma Overcollat_{i,t-1}^D \times D_i^{originated\ in\ boom} \\ & + \iota Z_{i,t} + \varepsilon_{i,t}, \end{aligned} \tag{5.1}$$

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<sup>51</sup>In the Appendix E in the Table 2, I report the data summary statistics. I would like to thank the European Central Bank for providing me with the access to this part of the PDS database.

<sup>52</sup>A 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 proper aggregation. Thus I obtain unique deal pool pairs and have delinquency available also on the deal level.

where  $DelinqRate_{i,t}$  is the ratio of the amount of receivables that are 90 or more days past due to the original pool balance,  $Overcollat_{i,t-1}^D$  stands for 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<sup>53</sup>;  $D_i^{originated\ in\ boom}$  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.<sup>54</sup>

**Regression results.** Table 1 shows the results for the three largest European countries by securitization activity for residential mortgage loans: the United Kingdom (UK), Spain (SP) and Netherlands (NL). I show results for the whole set and for individual countries separately to illustrate the country differences.

For the United Kingdom the results are in line with the signaling hypothesis (coefficient of  $Overcollat_{i,t-1}^D$  (i.e.,  $\beta$ ) is significantly negative). Moreover, for a subset of deals issued in the boom stage of the business cycle the signaling hypothesis is rejected (coefficient of  $Overcollat_{i,t-1}^D \times D_i^{originated\ in\ boom}$  (i.e.,  $\gamma$ ) is significantly positive with value comparable or exceeding the coefficient of  $Overcollat_{i,t-1}^D$ ).<sup>55</sup>

On the whole sample of countries I cannot find support for signaling hypothesis. But I find an opposite effect, which would correspond to the buffer hypothesis, for the subset of deals issued in the boom stage of the business cycle. The same findings apply for Spain.<sup>56</sup>

Signs of the coefficients for control variables is not surprising. I find that delin-

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<sup>53</sup>To avoid spurious regression problem due to 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 closing date of the deal) as explanatory variables. Moreover, I try to clear the main explanatory variable of interest *Overcollat* from potential trend and persistence in a first-stage regression prior to using it in the main regression (5.1). Details are reported in Appendix E.2. In the Appendix E, I show that the results without this first-stage regression step are qualitatively unchanged.

<sup>54</sup>Control variables are lagged delinquency rate  $DelinqRate_{i,t-1}$ , interaction term of overcollateralization with dummy for boom periods  $Overcollat_{i,t-1}^D \times D_{i,t}^{boom}$ , number of quarters since the closing date of the deal *Deal age* and the output gap  $Output\ gap = \ln(GDP_{i,t}) - \ln(GDP_{i,t}^{HP})$ , where  $GDP_{i,t}^{HP}$  is the smoothed level of the real Gross Domestic Product (*GDP*) of the respective country obtained by applying the HP filter.

<sup>55</sup>In Appendix E, 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.

<sup>56</sup>In the case of Spain, non-existing support for the signaling hypothesis is not surprising. Because unlike in other countries, the Spanish regulator treated off-balance sheet assets (i.e. all securitized products) in the same way as on-balance sheet assets. (See Acharya and Schnabl (2009) for detailed description of the regulatory differences across countries.) Therefore, the securitization in Spain was not used to transfer risk, but rather to obtain more liquidity (see e.g., Almazan et al., 2013). In Spain, securitization was not related to adverse selection problems, which were so typical of practices in other countries. As a result credit enhancement did not serve as a signaling tool.

quency rate is persistent with high and positive coefficient of lagged delinquency rate. Coefficient of output gap is negative implying that in boom stage the delinquency rate is lower. To understand the negative coefficient of *Deal age*, recall that delinquency rate is ratio of delinquent receivables to the original pool. Over time, as some of the loans in the deal come to their maturity, the numerator decreases, while the denominator remains unchanged. Therefore, delinquency rate tends to decrease over lifetime of the deal.

In Appendix E, I also report several robustness checks of those results: regression on sub-sample excluding the crisis and post crisis period, regression when both delinquency rates and overcollateralization rates are winsorized at the 2.5%-level to control for potential data errors or outliers and regression without controlling for trend and persistence in overcollateralization rate. Results are robust to those alternative specifications.

To conclude, I find support for the signaling hypothesis of credit enhancement in the case of the United Kingdom. Moreover, I find that such signaling is less efficient for loans issued in the boom stage of the business cycle. These findings are in line with the predictions of the theoretical model. However, while I tried to control for potential endogeneity in the first-stage regression, due to data limitations, it is impossible to identify with certainty an exogenous variation in the mentioned variables. Therefore, the found correlations are not conclusive about the causal links.

Table 1. Overcollateralization as a signal of deal quality over the business cycle<sup>ab</sup>

	(1)	(2)	(3)	(4)
Countries <sup>c</sup>	UK, SP, NL	UK	SP	NL
$DelinqRate_{i,t-1}$	0.890*** (0.008)	0.869*** (0.010)	0.828*** (0.021)	0.897*** (0.016)
$Overcoll_{i,t-1}^D$	0.001 (0.005)	-0.062** (0.027)	-0.003 (0.004)	0.010 (0.011)
$Overcoll_{i,t-1}^D \times D_i^{origin\ in\ boom}$	0.021*** (0.008)	0.073*** (0.028)	0.030** (0.015)	0.017 (0.015)
$Deal\ age_{i,t}$	-0.003*** (0.000)	-0.025*** (0.003)	-0.000 (0.000)	0.000 (0.000)
$Overcoll_{i,t-1}^D \times D_{i,t}^{boom}$	-0.008 (0.007)	0.028 (0.032)	0.004 (0.008)	-0.021 (0.019)
$Output\ gap_{i,t}$	-8.587*** (1.932)			
Observations	13,226	3,949	5,486	3,791
R-squared	0.860	0.895	0.734	0.867
Number of deals	612	190	227	195

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

<sup>b</sup> Robust standard errors are clustered by deals and reported in parentheses (\*\* p<0.01, \*\* p<0.05, \* p<0.1).

<sup>c</sup> Time period is the 1998Q2-2013Q2 for the whole sample, but for individual countries the observation time period differs: UK data covers 2000Q2-2013Q2, Spanish data covers 1998Q3-2013Q2 and Dutch data covers 1998Q2-2013Q2.

## 6 Conclusion

Motivated by the recent harsh criticism of securitization practices, I investigate the efficiency of financial intermediation through securitization in a DSGE model. In particular, I focus on analyzing the potential of explicit and implicit guarantees provided to the holders of securitized assets to address the problem asymmetry of information about the quality of collateral, which is at the core of the mentioned criticism.

In this paper, I show that reputation concerns allow originators of securitized products to signal the quality of securitized loans by providing implicit recourse (guarantees) and thus they reduce the problem of private information typical for securitization. However, there are limits to the efficiency of these reputation-based tools, which become more pronounced in boom stages of the business cycles. The minimum level of implicit recourse that would prevent mimicking by firms with investment projects of lower quality exceeds the level that can be credibly promised. In the resulting pooling equilibrium, the information about the quality of loans is lost, and the investment allocation becomes more inefficient. Due to this mechanism, large inefficiencies in the allocation of capital can be accumulated during the boom period of the business cycle. The accumulated inefficiencies can then amplify a subsequent downturn of the economy. Additionally, the longer the duration of the boom stage of the business cycle the deeper will be the fall of output in a subsequent recession.

In the empirical section, I test hypotheses from the theoretical model on the level of securitization deals using data for residential mortgage backed securities issued in the United Kingdom, Spain and Netherlands. Lagged credit support provided to holders of securitized assets is found to have a positive relation to the loan quality in the United Kingdom, which is in line with the signaling hypothesis. The effect disappears for assets that have been issued in a boom stage of the business cycle. This is in line with higher likelihood of a pooling equilibrium in a boom which is derived in the theoretical model. Some of the results variation across countries could be explained by significant differences in regulatory frameworks and in the practice of securitization.

The mechanism presented in this paper can contribute to the understanding of the recent financial crisis, since it describes the experience of securitization markets prior to and during the recent financial crisis. In the period preceding the crisis, 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.

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# Appendices

## A Proofs

### A.1 First-best case

Due to logarithmic utility, firms always consume  $1 - \beta$  fraction of their wealth:  $c = (1 - \beta) h (r^h + \lambda)$ . This policy function is linear, so it is trivial to aggregate it across the continuum of firms to obtain the equation describing the evolution of aggregate variables:  $C = (1 - \beta) H (r^h + \lambda)$ .

From the market clearing condition, we know that  $X = Y - C = Hr^h - C$ . And from the law of motion for capital, we know that in the steady state  $X = (1 - \lambda)H$ . Combining these two conditions, we obtain:

$$Hr^h - C = (1 - \lambda)H.$$

Substituting for aggregate consumption we get:

$$\begin{aligned} Hr^h - (1 - \beta)H(r^h + \lambda) &= (1 - \lambda)H, \\ r^h + \lambda &= \frac{1}{\beta}. \end{aligned}$$

### A.2 Proof of Proposition 1

In the first-best equilibrium,  $q^h = 1$ . Should the SGC be binding, then by Proposition 1,  $q^h > 1$ . Let us consider the least restricted case where still only firms with access to high-quality loans are originating new projects and securitize their cash flows, and the SGC is not sufficiently binding to allow a firm with access to low-quality investment opportunities to profitably issue loans  $q^l < 1$ .

Under the binding SGC, the aggregate investment into high-quality projects will be (obtained as an aggregation of eq. 3.4):

$$X_t^H = \pi\mu \frac{\beta (H_t ((A_t + \Delta^h) K_t^{\alpha-1} + \lambda q_t^h) + L_t ((A_t + \Delta^l) K_t^{\alpha-1} + \lambda q_t^l))}{(1 - \theta q_t^h)}. \quad (6.1)$$

Prices of particular assets are determined from the Euler equations of saving firms. In equilibrium, these firms are indifferent between investing in high- or low-quality projects:

$$E_t \left[ \frac{\frac{r_{t+1}^h + \lambda q_{t+1}^h}{q_t^h}}{\left( \omega_{t+1} \frac{r_{t+1}^h + \lambda q_{t+1}^h}{q_t^h} + (1 - \omega_{t+1}) \frac{r_{t+1}^l + \lambda q_{t+1}^l}{q_t^l} \right)} \right] = 1 \quad (6.2)$$

$$E_t \left[ \frac{\frac{r_{t+1}^l + \lambda q_{t+1}^l}{q_t^l}}{\left( \omega_{t+1} \frac{r_{t+1}^h + \lambda q_{t+1}^h}{q_t^h} + (1 - \omega_{t+1}) \frac{r_{t+1}^l + \lambda q_{t+1}^l}{q_t^l} \right)} \right] = 1, \quad (6.3)$$

where  $\omega_t$  is the share of high-quality projects in the overall assets in the economy:  $\omega_t = H_t/K_t$ . The derivation of these conditions can be found in Appendix B.

Finally, the goods market clearing condition has to hold, too:

$$Y_t = C_t + X_t. \quad (6.4)$$

**Case 1: Only firms with access to high-quality projects originate new projects and securitize their cash flows:**

Condition 6.1 and a combination of 6.2 and 6.3, 6.4 can be rewritten when in steady state:

$$\begin{aligned} (1 - \lambda)(1 - \theta q^h) &= \pi\mu\beta(r^h + \lambda q^h), \\ \frac{A^h}{q^h} &= \frac{A^l}{q^l}, \\ r^h &= (1 - \lambda) + (1 - \beta)(r^h + \lambda q^h). \end{aligned}$$

Combining these equations, we can obtain

$$\begin{aligned} q_H^h &= \frac{(1 - \lambda)(1 - \pi\mu)}{(1 - \lambda)\theta + \pi\mu\lambda}, \\ K_H &= \left[ \frac{(1 - \lambda) + \frac{(1 - \beta)\lambda(1 - \lambda)(1 - \pi\mu)}{(1 - \lambda)\theta + \pi\mu\lambda}}{\beta A^h} \right]^{\frac{1}{\alpha - 1}}. \end{aligned} \quad (6.5)$$

As long as  $q^h = 1$ , we find  $K_H = \left[ \frac{1}{A^h} \left( \frac{1}{\beta} - \lambda \right) \right]^{\frac{1}{\alpha - 1}}$ , which is the first-best level of capital. If  $(1 - \lambda)(1 - \pi\mu) > (1 - \lambda)\theta + \pi\mu\lambda$ , then  $q^h > 1$ . The deterministic steady-state level of capital is then lower than in the first-best case:

$$K_H = \left[ \frac{(1 - \lambda) + (1 - \beta)\lambda q_H^h}{\beta A^h} \right]^{\frac{1}{\alpha - 1}} < \left[ \frac{(1 - \lambda) + (1 - \beta)\lambda}{\beta A^h} \right]^{\frac{1}{\alpha - 1}} = K_{FB}.$$

### A.3 Proof of Proposition 2

Proposition 2 claims that the steady-state equilibrium can be of three types depending on the parameter values. In the proof of Proposition 1 above, I already described the least restricted case, where only a firm with access to high-quality projects will be issuing and securitizing loans. By continuing to tighten the SGC, we will increase the price of the low-quality asset to 1 ( $q^l = 1$ ). At this point, the firms with access to low-quality loans will be indifferent between buying high-quality securitized assets or issuing and securitizing their own loans. Origination of more low-quality projects counterweights the effect of tightening the SGC, and therefore the prices stay at the same levels ( $q^l = 1$ ,  $q^h = A^h/A^l$ ). For an interval of  $\theta$ , there will be a steady state in which firms with access to low-quality investment will play a mixed strategy when

giving credit with probability  $\phi$ . As  $\theta$  decreases (“skin in the game” rises),  $\phi$  increases all the way up to 1, where a third type of steady state takes place. In this case, firms with access to both high- and low-quality projects will all be issuing credit and always securitizing.

**Case 2: Firms with access to low-quality projects originate new projects with probability  $\phi$ :**

Steady-state conditions are the following:

$$(1 - \lambda) (1 - \theta q^h) \omega = \pi \mu \beta (\omega (r^h + \lambda q^h) + (1 - \omega) (r^l + \lambda q^l)), \quad (6.6)$$

$$(1 - \lambda) (1 - \theta q^l) (1 - \omega) = \pi (1 - \mu) \phi \beta (\omega (r^h + \lambda q^h) + (1 - \omega) (r^l + \lambda q^l)), \quad (6.7)$$

$$\frac{A^h}{q^h} = \frac{A^l}{q^l}, \quad (6.8)$$

$$q^l = 1, \quad (6.9)$$

$$\omega r^h + (1 - \omega) r^l = (1 - \lambda) + (1 - \beta) (\omega (r^h + \lambda q^h) + (1 - \omega) (r^l + \lambda q^l)). \quad (6.10)$$

Let us define

$$q \equiv \frac{q^h}{A^h} = \frac{q^l}{A^l}, \quad (6.11)$$

and

$$D \equiv \omega A^h + (1 - \omega) A^l. \quad (6.12)$$

Using (6.11) and (6.12), and combining equations (6.6), (6.7), and (6.8), we obtain:

$$(1 - \lambda) (1 - \theta q D) = \pi (\mu + \phi (1 - \mu)) \beta D (K^{\alpha-1} + \lambda q),$$

$$(1 - \lambda) - \pi (\mu + \phi (1 - \mu)) \beta D K^{\alpha-1} = q D [(1 - \lambda) \theta + \pi (\mu + \phi (1 - \mu)) \beta \lambda]. \quad (6.13)$$

We can also rewrite (6.10):

$$\beta D K^{\alpha-1} = 1 - \lambda + (1 - \beta) D \lambda q. \quad (6.14)$$

Combining (6.13) and (6.14), we obtain:

$$q_M = \frac{(1 - \lambda) (1 - \pi (\mu + \phi (1 - \mu)))}{(1 - \lambda) \theta + \pi (\mu + \phi (1 - \mu)) \beta \lambda} \frac{1}{D}. \quad (6.15)$$

Substituting (6.15) back into (6.14), we obtain:

$$K_M = \left[ \frac{(1-\lambda) + \frac{(1-\beta)\lambda(1-\lambda)(1-\pi(\mu+\phi(1-\mu)))}{(1-\lambda)\theta + \pi(\mu+\phi(1-\mu))\lambda}}{\beta D} \right]^{\frac{1}{\alpha-1}}. \quad (6.16)$$

**Case 3: Firms with access to both high- and low-quality projects are always originating new projects:**

The deterministic steady state is defined by

$$(1-\lambda)(1-\theta q^h)\omega = \pi\mu\beta(\omega(r^h + \lambda q^h) + (1-\omega)(r^l + \lambda q^l)), \quad (6.17)$$

$$(1-\lambda)(1-\theta q^l)(1-\omega) = \pi(1-\mu)\beta(\omega(r^h + \lambda q^h) + (1-\omega)(r^l + \lambda q^l)), \quad (6.18)$$

$$\frac{A^h}{q^h} = \frac{A^l}{q^l}, \quad (6.19)$$

$$\omega r^h + (1-\omega)r^l = (1-\lambda) + (1-\beta)(\omega(r^h + \lambda q^h) + (1-\omega)(r^l + \lambda q^l)). \quad (6.20)$$

Using (6.11) and (6.12), and combining equations (6.17), (6.18), and (6.19), we obtain:

$$(1-\lambda)(1-\theta q D) = \pi\beta D(K^{\alpha-1} + \lambda q),$$

$$(1-\lambda) - \pi\beta D K^{\alpha-1} = q D[(1-\lambda)\theta + \pi\beta\lambda]. \quad (6.21)$$

We can also rewrite (6.20):

$$\beta D K^{\alpha-1} = 1 - \lambda + (1-\beta) D \lambda q. \quad (6.22)$$

Combining (6.21) and (6.22), we get:

$$q_B = \frac{(1-\lambda)(1-\pi)}{(1-\lambda)\theta + \pi\lambda} \frac{1}{D}. \quad (6.23)$$

Substituting (6.23) back into (6.22), we get:

$$K_B = \left[ \frac{(1-\lambda) + \frac{(1-\beta)\lambda(1-\lambda)(1-\pi)}{(1-\lambda)\theta + \pi\lambda}}{\beta D} \right]^{\frac{1}{\alpha-1}}. \quad (6.24)$$

The second part of the proposition claims that  $K_H > K_M > K_B$ . To show this, let us first focus on the part of the formula within brackets for capital: since in Case

$1 - q_H^l < 1$ , then  $q_H^h < \frac{A^h}{A^l}$ . And since  $q_M^l = 1$ , then  $\frac{(1-\lambda)(1-\pi(\mu+\phi(1-\mu)))}{(1-\lambda)\theta+\pi(\mu+\phi(1-\mu))\lambda} = \frac{D_M}{A^l}$ . The following inequality then holds:

$$\frac{(1-\lambda) + (1-\beta)\lambda q_H^h}{\beta A^h} < \frac{(1-\lambda)}{\beta A^h} + (1-\beta)\lambda \frac{1}{\beta A^l} < \frac{(1-\lambda)}{\beta D_M} + (1-\beta)\lambda \frac{1}{\beta A^l} = \frac{(1-\lambda) + \frac{(1-\beta)\lambda(1-\lambda)(1-\pi(\mu+\phi(1-\mu)))}{(1-\lambda)\theta+\pi(\mu+\phi(1-\mu))\lambda}}{\beta D_M}.$$

This implies that

$$K_H = \left[ \frac{(1-\lambda) + (1-\beta)\lambda q_H^h}{\beta A^h} \right]^{\frac{1}{\alpha-1}} > \left[ \frac{(1-\lambda) + \frac{(1-\beta)\lambda(1-\lambda)(1-\pi(\mu+\phi(1-\mu)))}{(1-\lambda)\theta+\pi(\mu+\phi(1-\mu))\lambda}}{\beta D_M} \right]^{\frac{1}{\alpha-1}} = K_M.$$

Similarly, we can show that  $K_M > K_B$ . Since  $w_B < w_M$ , then  $D_B < D_M$ . And since  $q_B^l > 1$ , then  $\frac{(1-\lambda)(1-\pi)}{(1-\lambda)\theta+\pi\lambda} > \frac{D_B}{A^l}$ . This implies that

$$\frac{(1-\lambda) + \frac{(1-\beta)\lambda(1-\lambda)(1-\pi(\mu+\phi(1-\mu)))}{(1-\lambda)\theta+\pi(\mu+\phi(1-\mu))\lambda}}{\beta D_M} = \frac{(1-\lambda)}{\beta D_M} + (1-\beta)\lambda \frac{1}{\beta A^l} < \frac{(1-\lambda)}{\beta D_B} + (1-\beta)\lambda \frac{1}{\beta A^l} < \frac{(1-\lambda) + \frac{(1-\beta)\lambda(1-\lambda)(1-\pi)}{(1-\lambda)\theta+\pi\lambda}}{\beta D_B},$$

$$K_M = \left[ \frac{(1-\lambda) + \frac{(1-\beta)\lambda(1-\lambda)(1-\pi(\mu+\phi(1-\mu)))}{(1-\lambda)\theta+\pi(\mu+\phi(1-\mu))\lambda}}{\beta D_M} \right]^{\frac{1}{\alpha-1}} > \left[ \frac{(1-\lambda) + \frac{(1-\beta)\lambda(1-\lambda)(1-\pi)}{(1-\lambda)\theta+\pi\lambda}}{\beta D_B} \right]^{\frac{1}{\alpha-1}} = K_B.$$

#### A.4 Proof of Proposition 3

When we introduce asymmetric information about the allocation of investment opportunities and condition 3.5 is satisfied, capital and output levels are lower than in the first-best case due to the inefficient allocation of capital. This is true even when the SGC is not binding enough to influence prices.

When the SGC is not binding, the average gross profit from one unit of invested capital in the economy equals

$$\bar{r} = \mu r^h + (1-\mu)r^l = \frac{1}{\beta} - \lambda.$$

The level of capital in this private information case  $K_{private}$  is determined by

$$K_{private} = \left[ \frac{1}{\mu A^h + (1-\mu)A^l} \left( \frac{1}{\beta} - \lambda \right) \right]^{\frac{1}{\alpha-1}} < \left[ \frac{1}{A^h} \left( \frac{1}{\beta} - \lambda \right) \right]^{\frac{1}{\alpha-1}} = K_{FB}.$$

Suppose now that  $(1-\pi)(1-\lambda) > \pi\lambda + (1-\lambda)\theta$ , in which case the SGC starts to bind. The steady-state conditions then collapse into the two following equations in  $(K_{private}, q)$ :

$$(1-\lambda)(1-\theta q) = \pi\beta(\mu r^h + (1-\mu)r^l + \lambda q),$$



$$\mu r^h + (1 - \mu)r^l = (1 - \lambda) + (1 - \beta) (\mu r^h + (1 - \mu)r^l + \lambda q),$$

where  $q = \mu q^h + (1 - \mu) q^l$ . From this we can easily derive:

$$\begin{aligned} q &= \frac{(1 - \pi)(1 - \lambda)}{\pi\lambda + (1 - \lambda)\theta}, \\ K_{private} &= \left[ \frac{(1 - \lambda) + (1 - \beta)\lambda q}{\beta(\mu A^h + (1 - \mu)A^l)} \right]^{\frac{1}{\alpha-1}}. \end{aligned} \tag{6.25}$$

In the proof of Propositions 1 and 2, we already proved that  $K_{FB} > K_H > K_M > K_B$ . To prove Proposition 3, it suffices to prove that  $K_B > K_{private}$ , where  $K_{private}$  is the level of capital under private information about the allocation of investment opportunities. To obtain  $K_B > K_{private}$ , we need:

$$K_B^{\alpha-1} < K_{private}^{\alpha-1},$$

$$\frac{(1 - \lambda) + \frac{(1-\beta)\lambda(1-\lambda)(1-\pi)}{(1-\lambda)\theta+\pi\lambda}}{\beta(\omega A^h + (1 - \omega)A^l)} < \frac{(1 - \lambda) + \frac{(1-\beta)\lambda(1-\lambda)(1-\pi)}{(1-\lambda)\theta+\pi\lambda}}{\beta(\mu\Delta A^h + (1 - \mu)A^l)},$$

$$\omega > \mu.$$

Writing equations (6.17) and (6.18) into a ratio, we obtain:

$$\frac{(1 - \lambda)(1 - \theta q^h)\omega}{(1 - \lambda)(1 - \theta q^l)(1 - \omega)} = \frac{\pi\mu\beta(\omega(r^h + \lambda q^h) + (1 - \omega)(r^l + \lambda q^l))}{\pi(1 - \mu)\beta(\omega(r^h + \lambda q^h) + (1 - \omega)(r^l + \lambda q^l))}.$$

Since  $q^h > q^l$ , we obtain:

$$\frac{\omega}{(1 - \omega)} = \frac{(1 - \theta q^l)}{(1 - \theta q^h)} \frac{\mu}{(1 - \mu)} > \frac{\mu}{(1 - \mu)},$$

and this implies that  $\omega > \mu$ .

## A.5 Proof of Proposition 4

Under the private information case, firms with low-quality investment opportunities prefer to buy high-quality loans rather than to mimic firms with high-quality investment

opportunities if

$$\begin{aligned}
R \mid \text{mimicking} &< R \mid \text{buying high loans}, \\
\frac{r^l + \lambda q^l}{\frac{1-\theta q^h}{1-\theta}} &< \frac{r^h + \lambda q^h}{q^h}, \\
\frac{(1-\theta) q^h}{1-\theta q^h} &< \frac{r^h + \lambda q^h}{r^l + \lambda q^l} = \frac{q^h}{q^l}, \\
q^l &< \frac{1-\theta q^h}{1-\theta}.
\end{aligned}$$

Substituting for  $q$  from (6.5) and using  $\frac{A^h}{q^h} = \frac{A^l}{q^l}$ , we get:

$$\frac{A^h}{A^l} > \frac{(1-\pi\mu)(1-\lambda)(1-\theta)}{\pi\mu\lambda + (1-\lambda)\theta\pi\mu}.$$

## A.6 Credibility of the trigger punishment strategy

A necessary condition for the existence of the reputation equilibrium in which implicit recourse is being provided is the credibility of the punishment rule. The saving firm, which observes default on the implicit recourse, has to prefer punishing the defaulting firm rather than non-punishing it, even ex post. This is expressed in condition (3.12). Here, I derive analytically both elements of that inequality in the case of the pooling steady state, where the level of aggregate TFP is constant. In the fully stochastic version, this can be solved numerically. Following the same steps as in Appendix A.10, we can find that the value function of the firm that always punished, and therefore has a reputation of being a “tough investor,” is

$$V^P(w) = \frac{\log[(1-\beta)w]}{1-\beta} + \frac{\beta \log(\beta)}{(1-\beta)^2} + \frac{\beta}{(1-\beta)^2} \left( \pi\mu \log(R^{h,IR}) + \pi(1-\mu) \log(R^{l,IR}) + (1-\pi) \log(R^s) \right),$$

and the value function of the firm that failed to punish and therefore lost its reputation of being a “tough investor” is

$$V^{NP}(w) = \frac{\log[(1-\beta)w]}{1-\beta} + \frac{\beta \log(\beta)}{(1-\beta)^2} + \frac{\beta}{(1-\beta)^2} \left( \pi \log(R^{h,IR}) + \pi(1-\mu) \log(R^{l,IR}) + (1-\pi) \log(R^{s,NP}) \right).$$

If a firm loses its reputation of being a “tough investor,” other firms will expect that this firm will never punish in the future, and, as a consequence, they will never again provide implicit support to this firm. So when a firm without the reputation of being a “tough investor” buys assets with implicit support issued in the primary market, its return is  $R^{s,NP} = \frac{\mu(r^h + \lambda q^h) + (1-\mu)(r^l + \lambda q^l)}{q^G}$ . Firms with a “tough investors” reputation have a return of  $R^s = \frac{r^G + \mu\lambda q^h + (1-\mu)\lambda q^l}{q^G}$ . Note that firms without a reputation cannot obtain a lower price from originators of securitized assets without implicit recourse, since granting a lower and fair price would reveal the identity of low-quality assets of the issuing firm. Similarly, if firms without a “tough investor” reputation buy assets without

implicit recourse on the secondary (resale) markets, they are also in a disadvantageous position. When firms with a “tough investor” reputation sell high-quality assets to firms with a reputation, they charge a market price  $q^h$ . However, if firms without a “tough investor” reputation have the outside option of only buying on the primary market, they will be willing to buy a high-quality asset even for the price  $q^G$ . The price for which a high-quality asset is sold on the secondary market to the firms without a reputation is somewhere in the interval  $q^{h,NP} \in (q^h, q^G)$ , depending on the bargaining power of sellers and buyers. Unless all bargaining power is on the side of firms without reputation, then  $q^{h,NP} > q^h$ . This implies that  $R^{s,NP} < R^s$ , and therefore saving firms are better off punishing, and inequality (3.12) would be satisfied.

It is well known that trigger strategies are often not renegotiation-proof. While in this paper I do not address this problem in detail and rule out renegotiation by assumption, it can be shown that for a large set of parameter space and relative bargaining power of different agents in the economy, renegotiation is not optimal. Therefore, a trigger strategy will be robust even in the case when renegotiation is allowed.

Suppose one firm decides to default on the implicit support (which is the case when the ICC for non-defaulting, eq. 3.11, does not hold). Other firms decide whether to punish this firm and face lower returns in the future  $R^{s,NP}$ , as shown above, or whether not to punish and negotiate for better terms with the defaulted firms, i.e., buy the assets from them for a lower price  $q^{h,RN} < q^h$ , giving it a return  $R^{s,RN} > R^s$ . However, those benefits from renegotiation are limited by the fact that the defaulted firm would be selling the assets only with probability  $\pi\mu$ , and the quantity of assets the firm can sell is limited and proportional to its equity. Even if the quantity of the assets sold by the defaulted firm is large enough, renegotiation would not be optimal as long as

$$R^s > \pi\mu R^{s,RN} + (1 - \pi\mu) R^{s,NP}.$$

This depends on prices  $q^h, q^{h,NP}, q^{h,RN}$ , which themselves depend upon the relative bargaining power of different agents in the economy.

## A.7 Proof of Proposition 5

I claimed that if the implicit recourse were to be credible, the optimal level of promise would mean  $q^j = 1$ , and therefore zero profit for securitizing firms. The relevant FOC can be transformed in the following way.

Let us consider FOC for firms with high-quality investment opportunities. I guess

and verify that the remaining firms would not invest at all:

$$\begin{aligned}\frac{\partial V^{ND}}{\partial r^G} &= \frac{\partial V^{ND'}}{\partial (w' - cir')} \frac{\partial (w' - cir')}{\partial r^G} = 0, \\ \frac{\partial V^{ND'}}{\partial (w' - cir')} \frac{\partial}{\partial r^G} \frac{(1 - \theta) \beta w (r^{j'} + \lambda q^j) - \theta \beta w (r^G - r^j)}{1 - \theta q^G} &= 0, \\ \frac{\partial V^{ND'}}{\partial (w' - cir')} \frac{\partial}{\partial r^G} \frac{\beta w (r^{j'} + \lambda q^j - \theta (r^G + \lambda q^j))}{1 - \theta q^G} &= 0.\end{aligned}$$

After substituting in this case with constant aggregate productivity  $q^G = \frac{r^G + \lambda q^j}{r^{j'} + \lambda q^j} q^j$ , this condition implies that

$$\frac{\partial V^{ND'}}{\partial (w' - cir')} \frac{\partial}{\partial r^G} \frac{\beta w (r^{j'} + \lambda q^j) \left(1 - \theta \frac{q^G}{q^j}\right)}{1 - \theta q^G} = 0,$$

and since  $\frac{\partial V^{ND'}}{\partial (w' - cir')} > 0$ , and as long as higher  $r^G$  credibly brings value to buyers  $\frac{\partial q^G}{\partial r^G} > 0$ , the above condition simplifies to

$$\frac{\partial}{\partial q^G} \frac{\left(1 - \theta \frac{q^G}{q^j}\right)}{1 - \theta q^G} = \frac{\theta (q^j - 1)}{q^j (1 - \theta q^G)^2} = 0. \quad (6.26)$$

This implies  $q^j = 1$  conditional that the level of  $r^G$  is credible, i.e. is not defaulted upon at least in some states of the world.

Note that for when the level of  $r^G$  satisfies this condition, the return from investing and securitizing is equal to the return from investing but not securitizing, i.e., securitization does not increase the return:

$$\begin{aligned}R \mid \text{investing \& securitizing} &= R \mid \text{investing} \\ \frac{(r^j + \lambda q^j - \theta (r^G + \lambda q^j))}{1 - \theta \frac{r^G + \lambda q^j}{r^j + \lambda q^j} q^j} &= \frac{r^j + \lambda q^j}{1}.\end{aligned}$$

When you substitute in the above condition  $q^j = 1$ , the condition is exactly satisfied for all parameter values.

## A.8 Explicit risk retention

In this paper I focus mostly on implicit risk-retention because explicit risk retention (or guarantee) is in reality more costly due to the existence of regulation. In this appendix I would like to show that indeed if explicit risk retention is sufficiently more costly than implicit, it is not used in equilibrium. I also show the equilibrium solution when explicit guarantee is not more costly, and therefore is used in equilibrium. For tractability, I

derive this solution for the steady state with constant aggregate productivity.

**Costly explicit guarantees.** Due to regulatory or similar costs, when explicit guarantees are issued by the originator, the originator suffers additional costs proportional to the guarantee  $r^{G,EX}\tau$ .<sup>57</sup> I show that if  $\tau$  is high enough, the originator does not want to provide explicit guarantees. This holds when the derivative of the firms' value function is decreasing in explicit guarantee:

$$\begin{aligned} \frac{\partial V^{ND}}{\partial r^{G,EX}} &= \frac{\partial V^{ND'}}{\partial (w' - cir')} \frac{\partial (w' - cir')}{\partial r^{G,EX}} < 0, \\ \frac{\partial V^{ND'}}{\partial (w' - cir')} \frac{\partial}{\partial r^{G,EX}} \frac{\beta w (r^{j'} + \lambda q^j - \theta (r^{G,EX} (1 + \tau) + \lambda q^j))}{1 - \theta q^G} &< 0. \end{aligned}$$

After substituting in this case with constant aggregate productivity  $q^G = \frac{r^{G,EX} + \lambda q^j}{r^{j'} + \lambda q^j} q^j$ , this condition implies that

$$\frac{\partial V^{ND'}}{\partial (w' - cir')} \frac{\partial}{\partial r^{G,EX}} \frac{\beta w (r^{j'} + \lambda q^j) \left(1 - \theta \frac{q^{G,j}}{q^j}\right) - \theta r^{G,EX} \tau}{1 - \theta q^{G,j}} < 0,$$

and since  $\frac{\partial V^{ND'}}{\partial (w' - cir')} > 0$ , and  $\frac{\partial q^{G,j}}{\partial r^{G,EX}} = \frac{q^j}{r^{j'} + \lambda q^j}$ , the above condition simplifies to

$$\frac{\theta}{(1 - \theta q^G)^2} \left[ q^j - 1 - \tau \left( (r^{j'} + \lambda q^j) (1 - \theta q^G) + r^{G,EX} q^j \right) \right] < 0,$$

which is satisfied for large enough  $\tau$ .

**When explicit guarantees have no additional costs, the economy is in the first-best case.** When the ICC for non-defaulting on implicit guarantees (eq. 3.11) does not limit the level of  $r^G$ , we can choose  $r^G$  such that the FOC in (6.26) is satisfied, i.e.,  $q^h = 1$ . As a result, the allocation of resources in the economy is the first-best: only high quality projects are being financed and the amount of investment and output is optimal since  $r^h + \lambda = \frac{1}{\beta}$  (see Appendix A.1).

## A.9 Proof of Proposition 8

To complete the proof of Proposition 8 sketched in the main text, I first need to derive from (3.13) the (3.14) and show that the RHS of equation (3.14) is independent of the level of aggregate productivity  $A$ . This means that variables  $B$  and  $q^h$  should be independent of the level of aggregate productivity  $A$ .

<sup>57</sup> $r^{G,EX}$  is the explicitly promised minimum gross profit per unit of invested capital and  $\tau$  is the cost parameter.

Under separation, steady-state conditions are as follows:

$$(1 - \lambda) (1 - \theta q^G) = \pi \mu \beta (r^h + \lambda q^h), \quad (6.27)$$

$$r^h = (1 - \lambda) + (1 - \beta) (r^h + \lambda q^h), \quad (6.28)$$

$$\frac{r^G + \lambda q^h}{q^G} = \frac{(A + \Delta^h) K^{\alpha-1} + \lambda q^h}{q^h}, \quad (6.29)$$

$$V^{ND}(w' - cir') = V^D(w'). \quad (6.30)$$

Using the following property given by the logarithmic utility function:

$$\begin{aligned} V(w) &= \log((1 - \beta)w) + \beta \log((1 - \beta)\beta R w) + \beta^2 \log((1 - \beta)\beta^2 R^2 w) + \beta^3 \log((1 - \beta)\beta^3 R^3 w) \dots \\ &= \frac{1}{1 - \beta} \log(w) + \log((1 - \beta)) + \beta \log((1 - \beta)\beta R) + \beta^2 \log((1 - \beta)\beta^2 R^2) + \beta^3 \log((1 - \beta)\beta^3 R^3) \dots \\ &= \frac{1}{1 - \beta} \log(w) + V(1), \end{aligned}$$

we can transform the no-default condition expressed in (6.30) in the following way:

$$\begin{aligned} V^D(w') &= V^D\left(w\beta \frac{(1 - \theta)(r^h + \lambda q^h)}{(1 - \theta q^G)}\right) = V^D(w) + \frac{1}{1 - \beta} \log\left(\beta \frac{(1 - \theta)(r^h + \lambda q^h)}{(1 - \theta q^G)}\right) \\ V^{ND}(w' - cir') &= V^{ND}\left(w\beta \frac{(1 - \theta)\left(r^h + \lambda q^h - \frac{\theta}{1 - \theta}(r^G - r^h)\right)}{(1 - \theta q^G)}\right) \\ &= V^{ND}(w) + \frac{1}{1 - \beta} \log\left(\beta \frac{(1 - \theta)\left(r^h + \lambda q^h - \frac{\theta}{1 - \theta}(r^G - r^h)\right)}{(1 - \theta q^G)}\right). \end{aligned}$$

For simplicity, let us express the value functions separately from individual wealth in the following way, which is easy to do given the log utility:  $V(w) = V(1) + \frac{1}{1 - \beta} \log(w)$ . We can also find solutions for value functions with wealth normalized to unity, which we can denote simply as  $V = V(1)$ :

$$\begin{aligned} V^{ND} &= \log(1 - \beta) + \beta \left(\pi \mu V^{ND}(\beta R^{h,IR}) + \pi(1 - \mu) V^{ND}(\beta R^l) + (1 - \pi) V^{ND}(\beta R^z)\right) \\ &= \log(1 - \beta) + \beta \left(\frac{\pi \mu \log(\beta R^{h,IR})}{1 - \beta} + \pi(1 - \mu) \frac{\log(\beta R^l)}{1 - \beta} + (1 - \pi) \frac{\log(\beta R^z)}{1 - \beta} + V^{ND}\right) \\ &= \frac{\log(1 - \beta)}{1 - \beta} + \frac{\beta \log(\beta)}{(1 - \beta)^2} + \frac{\beta}{(1 - \beta)^2} \left(\pi \mu \log(R^{h,IR}) + \pi(1 - \mu) \log(R^l) + (1 - \pi) \log(R^z)\right). \end{aligned}$$

$$\begin{aligned} V^D &= \log(1 - \beta) + \beta \left(\pi \mu V^D(\beta R^{h,D}) + \pi(1 - \mu) V^D(\beta R^l) + (1 - \pi) V^D(\beta R^z)\right) \\ &= \log(1 - \beta) + \beta \left(\frac{\pi \mu \log(\beta R^{h,D})}{1 - \beta} + \pi(1 - \mu) \frac{\log(\beta R^l)}{1 - \beta} + (1 - \pi) \frac{\log(\beta R^z)}{1 - \beta} + V^D\right) \\ &= \frac{\log(1 - \beta)}{1 - \beta} + \frac{\beta \log(\beta)}{(1 - \beta)^2} + \frac{\beta}{(1 - \beta)^2} \left(\pi \mu \log(R^{h,D}) + \pi(1 - \mu) \log(R^l) + (1 - \pi) \log(R^z)\right). \end{aligned}$$

Substituting the above derived conditions into the no-default condition (6.30) and can-

celing the terms equal for both value functions, we obtain:

$$\log \left( \beta (1 - \theta) \left( r^h + \lambda q^h - \frac{\theta}{1 - \theta} (r^G - r^h) \right) \right) + \frac{\beta \pi \mu}{1 - \beta} \log (R^{h,IR}) = \log \left( \beta (1 - \theta) (r^h + \lambda q^h) \right) + \frac{\beta \pi \mu}{1 - \beta} \log (R^{h,D}),$$

where the LHS shows the utility from consumption when wealth is reduced by repayment of implicit recourse and from the future discounted benefit of having a good reputation. The RHS, then, shows higher immediate utility from savings on implicit recourse, but the future utility is lower, since the firm can no longer issue and sell new loans. This equation can further be simplified using (6.29) and substituting for the returns:

$$\begin{aligned} \log \left( \frac{r^h + \lambda q^h - \theta (r^G + \lambda q^h)}{(1 - \theta) (r^h + \lambda q^h)} \right) &= -\frac{\beta \pi \mu}{1 - \beta} \log \left( \frac{R^{h,IR}}{R^{h,D}} \right) \\ &= -\frac{\beta \pi \mu}{1 - \beta} \log \left( \frac{(1 - \theta) \left( r^h + \lambda q^h - \frac{\theta}{1 - \theta} (r^G - r^h) \right)}{(1 - \theta q^G)} \frac{1}{(r^h + \lambda q^h)} \right) \\ &= -\frac{\beta \pi \mu}{1 - \beta} \log \left( \frac{r^h + \lambda q^h - \theta (r^G + \lambda q^h)}{r^h + \lambda q^h - \theta q^h (r^G + \lambda q^h)} \right). \end{aligned}$$

Now let us denote the price premium for the equilibrium implicit guarantee  $B \equiv \frac{q^G}{q^h} = \frac{r^G + \lambda q^h}{r^h + \lambda q^h}$ . Then we can express the above equation as follows:

$$\log \left( \frac{1 - \theta B}{1 - \theta} \right) = \frac{\beta \pi \mu}{1 - \beta} \log \left( \frac{1 - \theta B q^h}{1 - \theta B} \right), \quad (6.31)$$

which is an equation in two unknown endogenous variables  $(B, q^h)$  depending on time preference parameters  $\beta$  and parameters defining the strength of the financing frictions  $(\pi, \mu, \theta)$ .

We can express a second steady-state condition in two endogenous variables  $(B, q^h)$  combining two remaining conditions for the steady state (6.27, 6.28):

$$(1 - \lambda) (1 - \theta B q^h) = \pi \mu (1 - \lambda + \lambda q^h). \quad (6.32)$$

Combining the two equations (6.31, 6.32), we can obtain the solution to both the price of the high-quality asset  $q^h$  and the price premium for the equilibrium implicit guarantee  $B$ . Crucially, the solution does not depend on the level of aggregate productivity  $A$ , which is one step we needed to show to complete the proof of Proposition 8.

The second step is to derive (3.14) from (3.13). Note that in the separating equilibrium, selected by the intuitive criterion, mimicking firms with access to low-quality projects would find it optimal to default on implicit recourse, since in a separating equilibrium,  $r^{G*} > r_{l,cred,s}^G$ .

As with condition 6.30, we can transform the following condition for separation

(3.13):

$$\begin{aligned}
V^l(\text{mimicking \& default}) &< V^l(\text{buying high loans}) \\
\log\left(\frac{\beta(1-\theta)(r^l + \lambda q^l)}{(1-\theta q^G)}\right) + \frac{\beta\pi\mu}{1-\beta} \log(R^{h,D}) &< \log\left(\beta\frac{(r^h + \lambda q^h)}{q^h}\right) + \beta\pi\mu \log(R^{h,IR}) \\
-\frac{\beta\pi\mu}{1-\beta} \log\left(\frac{R^{h,IR}}{R^{h,D}}\right) &< \log\left(\frac{(1-\theta q^G)}{(r^l + \lambda q^l)(1-\theta)}\frac{(r^h + \lambda q^h)}{q^h}\right) \\
\frac{\beta\pi\mu}{1-\beta} \log\left(\frac{1-\theta B q^h}{1-\theta B}\right) &< \log\left(\frac{(1-\theta B q^h)}{(1-\theta)}\frac{1}{q^l}\right).
\end{aligned}$$

Using (6.31) and the preceding transformations, we can replace the LHS to get:

$$\begin{aligned}
\log\left(\frac{1-\theta B}{1-\theta}\right) &< \log\left(\frac{(1-\theta B q^h)}{(1-\theta)}\frac{1}{q^l}\right) \\
q^l &< \frac{1-\theta B q^h}{1-\theta B}. \tag{6.33}
\end{aligned}$$

If we divide (6.33) by  $q^h$  and substitute the ratio of prices by the steady-state asset market clearing condition  $A^h/q^h = A^l/q^l$ , then we obtain:

$$\frac{A^h}{A^l} > \frac{(1-\theta B) q^h}{1-\theta B q^h}.$$

Proposition 8 (iii) also claims that the inequality in (3.5) is less likely to be satisfied than in (3.14). To prove that, let us first rewrite the denominator of (3.5) using (6.5), which says:

$$(1-\theta q^h)(1-\lambda) = \pi\mu(1-\lambda + \lambda q^h),$$

to obtain:

$$\frac{A^h}{A^l} > \frac{(1-\theta)(1-\lambda)}{\pi\mu\left(\frac{1-\lambda}{q^h} + \lambda\right)}.$$

Similarly, let us rewrite the denominator of (3.14) using (6.32) to obtain:

$$\frac{A^h}{A^l} > \frac{(1-\theta B)(1-\lambda)}{\pi\mu\left(\frac{1-\lambda}{q^h} + \lambda\right)}.$$

We can show that

$$\frac{1-\lambda}{\pi\mu} = \frac{(1-\theta)(1-\lambda)}{\pi\mu\left(\frac{1-\lambda}{q^h} + \lambda\right)} \Big| \text{no implicit recourse} > \frac{(1-\theta B)(1-\lambda)}{\pi\mu\left(\frac{1-\lambda}{q^h} + \lambda\right)} \Big| \text{implicit recourse},$$

because the price premium for implicit recourse  $B$  is, by definition, higher than one,



and  $q^h \mid \text{no implicit recourse} > q^h \mid \text{implicit recourse}$ . The latter comes directly from comparing (6.5) and (6.32), which when combined give:

$$\frac{1 - \lambda + \lambda q^h}{1 - \theta q^h} \mid \text{no implicit recourse} = \frac{1 - \lambda + \lambda q^h}{1 - \theta B q^h} \mid \text{implicit recourse}.$$

Further, this can be satisfied only if  $q^h \mid \text{no implicit recourse} > q^h \mid \text{implicit recourse}$ .

## A.10 Other derivations from section 3.3

**Conditions for the minimum level of implicit recourse needed for separation  $G_{minsep}$ :**

At  $G_{minsep}$ , firms with low-quality investments are indifferent between mimicking and separating:

$$\begin{aligned} V^l \mid \text{mimicking \& default} &= V^l \mid \text{buying high loans} \\ \log \left( \frac{\beta (1 - \theta) (r^l + \lambda q^l)}{(1 - \theta q^G)} \right) + \beta \pi \mu \log (R^{h,D}) &= \log \left( \beta \frac{(r^h + \lambda q^h)}{q^h} \right) + \beta \pi \mu \log (R^{h,IR}) \\ -\beta \pi \mu \log \left( \frac{1 - \theta B_{min}}{1 - \theta} \right) &= \log \left( \frac{(1 - \theta B_{min} q^h)}{(1 - \theta)} q^l \right). \end{aligned} \quad (6.34)$$

Combining (6.34) with the following equilibrium investment condition

$$(1 - \lambda) (1 - \theta B_{min} q^h) = \pi \mu (1 - \lambda + \lambda q^h), \quad (6.35)$$

where  $B_{min} \equiv \frac{q^G}{q^h} = \frac{(A + G_{minsep}) K^{\alpha-1} + \lambda q^h}{r^h + \lambda q^h}$ , gives  $\{G_{minsep}, q^h, B_{min}\}$ .

### Conditions for a unique pooling equilibrium:

A necessary condition for firms to have incentives to increase  $G$  above  $G_{cred,p}^l$  is that it must be considered as profitable to, at least, individually deviate above  $G_{cred,p}^l$ . The following condition should, therefore, be satisfied:

$$\frac{\partial V^{ND}}{\partial r^G} = \frac{\partial V^{ND}}{\partial R^{h,IR}} \frac{\partial R^{h,IR}}{\partial r^G} > 0.$$

Since  $\frac{\partial V^{ND}}{\partial R^{h,IR}} > 0$ , this becomes:

$$\frac{\partial R^{h,IR}}{\partial r^G} = \frac{\partial}{\partial r^G} \frac{\left( (r^h - \frac{\theta}{1-\theta} (r^G - r^h)) + \lambda q^h \right) (1 - \theta)}{1 - \theta \frac{(\mu r^G + (1-\mu)r^l) + \lambda(\mu q^h + (1-\mu)q^l)}{r^h + \lambda q^h} q^h} > 0.$$

In taking the derivative, we obtain:

$$-\theta K^{\alpha-1} \left( 1 - \theta \frac{(\mu r^G + (1-\mu)r^l) + \lambda(\mu q^h + (1-\mu)q^l)}{r^h + \lambda q^h} q^h \right) + \frac{\theta \mu q^h K^{\alpha-1}}{r^h + \lambda q^h} \left( r^h - \frac{\theta}{1-\theta} (r^G - r^h) + \lambda q^h \right) (1-\theta) > 0,$$

$$\begin{aligned} \left( r^h - \frac{\theta}{1-\theta} (r^G - r^h) + \lambda q^h \right) (1-\theta) \mu q^h &> r^h + \lambda q^h - \theta (\mu r^G + (1-\mu)r^l) \\ &+ \lambda (\mu q^h + (1-\mu)q^l) q^h \\ (\mu q^h - 1) (r^h + \lambda q^h) &> \theta q^h (\mu - 1) (r^l + \lambda q^l). \end{aligned} \quad (6.36)$$

As long as  $(\mu q^h - 1) > 0$ , the condition (6.36) always holds, since  $\mu < 1$ . When  $(\mu q^h - 1) < 0$ , then we get:

$$(r^h + \lambda q^h) < \theta \frac{q^h (1-\mu)}{(1-\mu q^h)} (r^l + \lambda q^l),$$

which is not satisfied if

$$\frac{A^h}{A^l} > \theta \frac{q^h (1-\mu)}{(1-\mu q^h)},$$

or when rewritten:

$$\mu < \frac{1 - \theta q^l}{q^h - \theta q^l}.$$

This implies that the share of high-quality assets has to be low enough, or, in a pooling equilibrium, the relative difference in TFP has to be large enough.

### A.11 Endogenizing the “skin in the game”

So far the “skin in the game” (or equivalently, the share of loans that can be sold,  $\theta$ ) has been taken as an exogenous parameter. In this Appendix, I will sketch a simple moral hazard problem, which rationalizes the existence of this constraint.

Consider that firms can divert funds from the sale of current period loans needed to cover the unit investment costs. This cannot be immediately verified. To eliminate this problem, investors require the issuing firms to retain a sufficiently large “skin in the game”  $(1-\theta)$ , i.e., to finance a fraction  $1-\theta$  of funds in the project from their own resources. The incentive compatible constraint then determines a sufficiently high

$\theta$  that would prevent this moral hazard problem<sup>58</sup>:

$$V^D(w\beta R' \mid \textit{diverting funds}) \leq V^{ND}(w\beta R' \mid \textit{investing properly}),$$

where the return from diverting funds is  $R' \mid \textit{diverting funds} = \left(\frac{\theta q^G}{1-\theta}\right)^x$ , with  $x$  being the number of times the individual recycles the returns from this operation to issue and sell new “castles-in-the-air” projects. Since I do not restrict the practice of the sequential issuance of loans, which is technically needed even under proper investing, the ICC will always fail unless  $\theta q^G \leq (1 - \theta)$ , which translates to

$$\theta \leq \frac{1}{q^G + 1}. \tag{6.37}$$

Thus, the higher the sale price of loans  $q^G$ , the more “skin in the game”  $(1 - \theta)$  is required to prevent the stated moral hazard problem.

Note that in this version of the model I have two sources of asymmetric information. The first is the potential diversion of resources needed to invest properly, which cannot be immediately observed. The “skin in the game” is found to be an efficient tool to prevent this behavior, while the loss of reputation and subsequent punishment are not efficient. The second source of information asymmetry is the unobserved allocation of investment opportunities among firms. According to Proposition 4 the “skin in the game” is not an efficient tool to eliminate this asymmetry, while reputation-based implicit recourse has higher potential to overcome the related inefficiencies.

Even with an endogenous “skin in the game”, the main qualitative result of the paper, which is the endogenous switching between the pooling and separating equilibrium, remains unchanged.<sup>59</sup>

In the remaining of this Appendix, I would like to show briefly that the main results concerning the provision of implicit recourse and the endogenous switching between the pooling equilibrium and the separating equilibrium hold.

First, we have to check whether firms have the incentive to provide implicit support. The check is equivalent to the proof of Proposition 5 as discussed in section A.7 and which boils down to show that

$$\frac{\partial}{\partial q^{G,j}} \frac{\left(1 - \theta \frac{q^{G,j}}{q^j}\right)}{1 - \theta q^{G,j}} = \frac{(q^j - 1)}{q^j (1 - \theta q^{G,j})^2} \frac{\partial \theta q^{G,j}}{\partial q^{G,j}} \geq 0.$$

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<sup>58</sup>It is intuitive to assume that if a firm would divert funds, other firms will use at least the same punishment tools as for the case of implicit recourse default.

<sup>59</sup>Note that the assumption of the moral hazard problem is absolutely essential since without it, the solution would be first-best even under asymmetric information. Under first-best, securitization is not profitable; therefore, firms with access to low-quality investment do not have any incentives to mimic firms with high-quality investments. Therefore, neither reputation equilibria, nor implicit recourse would take place.

Since  $\frac{\partial \theta q^{G,j}}{\partial q^{G,j}} = \frac{\partial}{\partial q^{G,j}} \frac{q^{G,j}}{q^{G,j+1}} = \frac{1}{(q^{G,j+1})^2} > 0$ , the above condition corresponds again to  $q^j \geq 1$ . This means that in equilibrium, implicit recourse will be provided.

Given (6.37), the separating equilibrium in the deterministic steady state is defined by:

$$\begin{aligned} (1 - \lambda)(1 - \theta B q^h) &= \pi \mu (1 - \lambda + \lambda q^h) \\ \log\left(\frac{1 - \theta B}{1 - \theta}\right) &= \frac{\beta \pi \mu}{1 - \beta} \log\left(\frac{1 - \theta q^h B}{1 - \theta B}\right) \\ \theta &= \frac{1}{B q^h + 1}. \end{aligned}$$

Which simplifies into two equations, which are independent on the level of TFP  $A$ :

$$\begin{aligned} (1 - \lambda) \left( \frac{1}{B q^h + 1} \right) &= \pi \mu (1 - \lambda + \lambda q^h) \\ \log\left(\frac{B(q^h - 1) + 1}{B q^h}\right) &= \frac{\beta \pi \mu}{1 - \beta} \log\left(\frac{1}{B(q^h - 1) + 1}\right). \end{aligned}$$

The conditions for the existence of a separating equilibrium (3.14) becomes:

$$\frac{A^h}{A^l} > q^h (B(q^h - 1) + 1).$$

## B Derivation of firms' policy functions

In this section, I derive the policy functions of firms in the most general case. It is convenient to rewrite the firm's problem characterized in section 3.1.3 in a recursive formulation:

$$\begin{aligned} V^{ND}(\bar{s}, w - cir; \bar{S}) &= \pi (\mu V^{ND,h}(\bar{s}, w - cir; \bar{S}) + (1 - \mu) V^{ND,l}(\bar{s}, w - cir; \bar{S})) \\ &\quad + (1 - \pi) V^{ND,z}(\bar{s}, w - cir; \bar{S}), \\ V^D(\bar{s}, w; \bar{S}) &= \pi (\mu V^{D,h}(\bar{s}, w; \bar{S}) + (1 - \mu) V^{D,l}(\bar{s}, w; \bar{S})) + (1 - \pi) V^{D,z}(\bar{s}, w; \bar{S}), \\ V^{ND,k}(\bar{s}, w; \bar{S}) &= \max_{c,x,\{a'_j\}_j, h^{S^l}, l^{S^l}, r^{G^l}} [\log(c) + \beta E [\max(V^{ND}(\bar{s}', w' - cir'; \bar{S}'), V^D(\bar{s}', w'; \bar{S}'))]], \\ V^{D,k}(\bar{s}, w; \bar{S}) &= \max_{c,x,h^l,l^l} [\log(c) + \beta E V^D(\bar{s}', w'; \bar{S}')], \end{aligned}$$

subject to the budget constraints that take the following form for investing firms for which the SGC is binding:

$$c_{i,t} + \frac{(1 - \theta q_{i,t}^G)}{(1 - \theta)} h_{i,t+1} + cir_{i,t} = \sum_{j \in \mathcal{I}_{t-1}} a_{i,j,t} (r_{j,t}^{\hat{G}} + \lambda q_{j,t}) + h_{i,t}^S (r_t^h + \lambda q_t^h) + l_{i,t}^S (r_t^l + \lambda q_t^l) \quad \forall i \in \mathcal{H}_t \cap \mathcal{I}_t,$$

$$c_{i,t} + \frac{(1 - \theta q_{i,t}^G)}{(1 - \theta)} l_{i,t+1} + cir_{i,t} = \sum_{j \in \mathcal{I}_{t-1}} a_{i,j,t} \left( r_{j,t}^{\hat{G}} + \lambda q_{j,t} \right) + h_{i,t}^S (r_t^h + \lambda q_t^h) + l_{i,t}^S (r_t^l + \lambda q_t^l) \quad \forall i \in \mathcal{L}_t \cap \mathcal{I}_t.$$

The ICCs, which have to be satisfied in equilibrium for reputation-based implicit recourse to exist, are the following:

$$\begin{aligned} V^{ND}(\bar{s}, w - cir; \bar{S}) &\geq V^D(\bar{s}, w; \bar{S}), \\ V^P(\bar{s}; \bar{S}) &\geq V^{NP}(\bar{s}; \bar{S}), \end{aligned}$$

where  $V^{ND}$ ,  $V^D$ ,  $V^P$  and  $V^{NP}$  are the value functions if the firm never defaulted, defaulted, always punished a default on implicit recourse or failed to punish, respectively.

From FOC, we can obtain the following Euler equations in cases where the SGC is binding for all investing firms:

$$E_t \left[ \beta \frac{c_{i,t}}{c_{i,t+1}} \frac{r_{t+1}^{\hat{G}} + \lambda q_{j,t+1}}{q_{j,t}^G} \right] = 1 \quad \forall i \in \mathcal{S}_t, \forall j \in \mathcal{I}_t, \quad (6.38)$$

$$E_t \left[ \beta \frac{c_{i,t}}{c_{i,t+1}} \frac{r_{t+1}^h + \lambda q_{t+1}^h}{q_t^h} \right] = 1 \quad \forall i \in \mathcal{S}_t, \quad (6.39)$$

$$E_t \left[ \beta \frac{c_{i,t}}{c_{i,t+1}} \frac{r_{t+1}^l + \lambda q_{t+1}^l}{q_t^l} \right] = 1 \quad \forall i \in \mathcal{S}_t, \quad (6.40)$$

$$E_t \left[ \beta \frac{c_{i,t}}{c_{i,t+1}} \frac{r_{t+1}^h + \lambda q_{t+1}^h}{\frac{(1 - \theta q_t^G)}{(1 - \theta)}} \right] = 1 \quad \forall i \in \mathcal{H}_t \cap \mathcal{I}_t, \quad (6.41)$$

$$E_t \left[ \beta \frac{c_t^l}{c_{t+1}^l} \frac{r_{t+1}^l + \lambda q_{t+1}^l}{\frac{(1 - \theta q_t^{G,l})}{(1 - \theta)}} \right] = 1 \quad \forall i \in \mathcal{L}_t \cap \mathcal{I}_t. \quad (6.42)$$

I guess and verify that all investing firms provide the same level of implicit support  $r_{j,t+1}^G = r_{t+1}^G \quad \forall j \in \mathcal{I}_t$  (see the discussion in section 3.3 for details). Then, I guess and verify that policy functions have the following form.

Due to the logarithmic utility function, all firms consume a  $(1 - \beta)$  fraction of their wealth:

$$c_{i,t} = (1 - \beta) \left( \sum_{j \in \mathcal{I}_{t-1}} a_{i,j,t} \left( r_{j,t}^{\hat{G}} + \lambda q_{j,t} \right) + h_{i,t}^S (r_t^h + \lambda q_t^h) + l_{i,t}^S (r_t^l + \lambda q_t^l) \right) \quad \forall i.$$

Under binding SGC, firms with access to high-quality investment opportunities  $\mathcal{H}_t$  invest all of the unconsumed part of their wealth into new projects and sell the maximum fraction of investment  $\theta$  to saving firms:

$$h_{i,t+1} = a_{i,i,t+1} = \frac{\beta \left( \sum_{j \in \mathcal{I}_{t-1}} a_{i,j,t} \left( r_{j,t}^{\hat{G}} + \lambda q_{j,t} \right) + h_{i,t}^S (r_t^h + \lambda q_t^h) + l_{i,t}^S (r_t^l + \lambda q_t^l) \right)}{\frac{(1-\theta q_{i,t}^G)}{(1-\theta)}} \quad \forall i \in \mathcal{H}_t \cap \mathcal{I}_t,$$

$$l_{i,t+1} = 0 \quad \forall i \in \mathcal{H}_t \cap \mathcal{I}_t.$$

In the pooling equilibrium, firms with access to low-quality investment opportunities  $\mathcal{L}_t$  also invest all of the unconsumed part of their wealth into new projects, and if the SGC is binding, they sell the maximum fraction of the investment  $\theta$  to saving firms:

$$l_{i,t+1} = a_{i,i,t+1} = \frac{\beta \left( \sum_{j \in \mathcal{I}_{t-1}} a_{i,j,t} \left( r_{j,t}^{\hat{G}} + \lambda q_{j,t} \right) + h_{i,t}^S (r_t^h + \lambda q_t^h) + l_{i,t}^S (r_t^l + \lambda q_t^l) \right)}{\frac{(1-\theta q_{i,t}^G)}{(1-\theta)}} 1 \quad \forall i \in \mathcal{L}_t \cap \mathcal{I}_t,$$

$$h_{i,t+1} = 0 \quad \forall i \in \mathcal{L}_t \cap \mathcal{I}_t.$$

If the economy is in a separating equilibrium, the intersection  $\mathcal{L}_t \cap \mathcal{I}_t = \emptyset$  is an empty set, and firms with access to low-quality investment opportunities  $\mathcal{L}_t$  are not investing in new projects, but rather are buying securitized assets from other firms  $\mathcal{L}_t \subset \mathcal{S}_t$ .

Saving firms  $\mathcal{S}_t$  are, in equilibrium, indifferent between investing in different types of assets. All of them try to diversify their investment, so I guess and verify that, in equilibrium, all will allocate the same fraction of wealth into different types of assets:

$$h_{i,t+1}^S = \frac{\zeta^{hS} \beta \left( \sum_{j \in \mathcal{I}_{t-1}} a_{i,j,t} \left( r_{j,t}^{\hat{G}} + \lambda q_{j,t} \right) + h_{i,t}^S (r_t^h + \lambda q_t^h) + l_{i,t}^S (r_t^l + \lambda q_t^l) \right)}{q_t^h} \quad \forall i \in \mathcal{S}_t,$$

$$l_{i,t+1}^S = \frac{\zeta^{lS} \beta \left( \sum_{j \in \mathcal{I}_{t-1}} a_{i,j,t} \left( r_{j,t}^{\hat{G}} + \lambda q_{j,t} \right) + h_{i,t}^S (r_t^h + \lambda q_t^h) + l_{i,t}^S (r_t^l + \lambda q_t^l) \right)}{q_t^l} \quad \forall i \in \mathcal{S}_t,$$

$$\begin{aligned} h_{i,t+1}^P &= \sum_{j \in \mathcal{H}_t \cap \mathcal{I}_t} a_{i,j,t+1} \\ &= \frac{\zeta^{hP} \beta \left( \sum_{j \in \mathcal{I}_{t-1}} a_{i,j,t} \left( r_{j,t}^{\hat{G}} + \lambda q_{j,t} \right) + h_{i,t}^S (r_t^h + \lambda q_t^h) + l_{i,t}^S (r_t^l + \lambda q_t^l) \right)}{q_t^G} \quad \forall i \in \mathcal{S}_t, \end{aligned}$$

$$\begin{aligned}
l_{t+1}^P &= \sum_{j \in \mathcal{L}_t \cap \mathcal{I}_t} a_{i,j,t+1} \\
&= \frac{\zeta^{lP} \beta \left( \sum_{j \in \mathcal{I}_{t-1}} a_{i,j,t} \left( r_{j,t}^{\hat{G}} + \lambda q_{j,t} \right) + h_{i,t}^S (r_t^h + \lambda q_t^h) + l_{i,t}^S (r_t^l + \lambda q_t^l) \right)}{q_t^G} \quad \forall i \in \mathcal{S}_t,
\end{aligned}$$

where  $\zeta^{hS} + \zeta^{lS} + \zeta^{hP} + \zeta^{lP} = 1$ .

The consumption of the firms in the following period depends on the return from their investment:

$$\begin{aligned}
c_{i,t+1} &= (1 - \beta) [h_{i,t+1}^S (r_{t+1}^h + \lambda q_{t+1}^h) + l_{i,t+1}^S (r_{t+1}^l + \lambda q_{t+1}^l) \\
&\quad + h_{i,t+1}^P (r_{t+1}^{\hat{G},h} + \lambda q_{t+1}^h) + l_{i,t+1}^P (r_{t+1}^{\hat{G},l} + \lambda q_{t+1}^l)] \quad \forall i \in \mathcal{S}_t, \\
c_{i,t+1} &= (1 - \beta) (h_{i,t+1} (r_{t+1}^h + \lambda q_{t+1}^h)) \quad \forall i \in \mathcal{H}_t \cap \mathcal{I}_t, \\
c_{i,t+1} &= (1 - \beta) (l_{i,t+1} (r_{t+1}^l + \lambda q_{t+1}^l)) \quad \forall i \in \mathcal{L}_t \cap \mathcal{I}_t.
\end{aligned}$$

Using these guesses and substituting in (6.41) and (6.42), we can see that these conditions always hold.

The remaining Euler equations (6.39), (6.40) and (6.38), after substitutions, can be rewritten into:

$$E_t \left[ \frac{\frac{r_{t+1}^h + \lambda q_{t+1}^h}{q_t^h}}{\Xi_{t+1}} \right] = 1,$$

$$E_t \left[ \frac{\frac{r_{t+1}^l + \lambda q_{t+1}^l}{q_t^l}}{\Xi_{t+1}} \right] = 1,$$

$$E_t \left[ \frac{\frac{r_{t+1}^{\hat{G}} + \lambda q_{t+1}}{q_t^G}}{\Xi_{t+1}} \right] = 1,$$

where  $\Xi_{t+1} = \zeta^{hS} \frac{r_{t+1}^h + \lambda q_{t+1}^h}{q_t^h} + \zeta^{lS} \frac{r_{t+1}^l + \lambda q_{t+1}^l}{q_t^l} + \zeta^{hP} \frac{r_{t+1}^{\hat{G},h} + \lambda q_{t+1}^h}{q_t^G} + \zeta^{lP} \frac{r_{t+1}^{\hat{G},l} + \lambda q_{t+1}^l}{q_t^G}$ .

The allocation of saving firms (those with zero-profit projects) between high and low investment projects have to satisfy the market clearing conditions on both primary and secondary markets for high and low projects:

$$\begin{aligned}
\lambda H_t &= \zeta^{hS} \beta \sum_{i \in \mathcal{S}_t} \left( \sum_{j \in \mathcal{I}_{t-1}} a_{i,j,t} \left( r_{j,t}^{\hat{G}} + \lambda q_{j,t} \right) + h_{i,t}^S \left( r_t^h + \lambda q_t^h \right) + l_{i,t}^S \left( r_t^l + \lambda q_t^l \right) \right), \\
\lambda L_t &= \zeta^{lS} \beta \sum_{i \in \mathcal{S}_t} \left( \sum_{j \in \mathcal{I}_{t-1}} a_{i,j,t} \left( r_{j,t}^{\hat{G}} + \lambda q_{j,t} \right) + h_{i,t}^S \left( r_t^h + \lambda q_t^h \right) + l_{i,t}^S \left( r_t^l + \lambda q_t^l \right) \right), \\
\theta &= \frac{\beta \sum_{i \in \mathcal{H}_t \cap \mathcal{I}_t} \left( \sum_{j \in \mathcal{I}_{t-1}} a_{i,j,t} \left( r_{j,t}^{\hat{G}} + \lambda q_{j,t} \right) + h_{i,t}^S \left( r_t^h + \lambda q_t^h \right) + l_{i,t}^S \left( r_t^l + \lambda q_t^l \right) \right)}{(1 - \theta q_t^G)} \\
&= \frac{\zeta^{hP} \sum_{i \in \mathcal{S}_t} \left( \sum_{j \in \mathcal{I}_{t-1}} a_{i,j,t} \left( r_{j,t}^{\hat{G}} + \lambda q_{j,t} \right) + h_{i,t}^S \left( r_t^h + \lambda q_t^h \right) + l_{i,t}^S \left( r_t^l + \lambda q_t^l \right) \right)}{q_t^G}, \\
\theta &= \frac{\beta \sum_{i \in \mathcal{L}_t \cap \mathcal{I}_t} \left( \sum_{j \in \mathcal{I}_{t-1}} a_{i,j,t} \left( r_{j,t}^{\hat{G}} + \lambda q_{j,t} \right) + h_{i,t}^S \left( r_t^h + \lambda q_t^h \right) + l_{i,t}^S \left( r_t^l + \lambda q_t^l \right) \right)}{(1 - \theta q_t^G)} \\
&= \frac{\zeta^{lP} \sum_{i \in \mathcal{S}_t} \left( \sum_{j \in \mathcal{I}_{t-1}} a_{i,j,t} \left( r_{j,t}^{\hat{G}} + \lambda q_{j,t} \right) + h_{i,t}^S \left( r_t^h + \lambda q_t^h \right) + l_{i,t}^S \left( r_t^l + \lambda q_t^l \right) \right)}{q_t^G}.
\end{aligned}$$

And the goods market clears, too:  $Y_t = C_t + X_t$ .

## C Calibration of the parameters used in section 4

In section 4, I explain the choice of most of the model parameters. Here I would like to specifically comment on the choice of the share of high-quality investment opportunities  $\mu$  and the dispersion of the type-specific component of high- and low-quality projects in the two Markov states  $\Delta^l(A^H) / \Delta^h(A^H)$ ,  $\Delta^l(A^L) / \Delta^h(A^L)$ .

I choose these parameters to replicate the performance (delinquency rates) of securitized assets, which has been at the core of recent debates over the efficiency of securitization—subprime RMBS. Demyanyk and Van Hemert (2011) study the delinquency rates of subprime mortgage loans. In Figure 6.1, which is taken from Demyanyk and Van Hemert (2011), they report the actual delinquency rates of these loans in the left panel, and in the right panel they report the delinquency rates adjusted by the effect of various observable characteristics of the loans and the economy. They conclude that the quality of the loans measured by the adjusted delinquency rates has deteriorated significantly since 2004. This finding is consistent with the switching mechanism presented in this paper. As can be seen in the left panel of Figure 6.2, the United States emerged from a recession in 2003, and in 2004, the output again reached its potential. The model predicts that, as the economy moves to the boom stage of a business cycle, the equilibrium in the signalling game becomes pooling, and as a consequence, low-quality loans start to be financed. As shown in the right panel of Figure 6.1, the boom period of 2004-2007 is associated with lower-quality loans, and the economic downturn of 2001-2003 is associated with higher-quality loans.

I used the reported delinquency rates by Demyanyk and Van Hemert (2011) to



calibrate the model parameters.<sup>60</sup> I particularly want to match the delinquency rate of high-quality loans after 12 months in the low state to the delinquency of the 2001 vintage, which is 12.5%; the delinquency rate of high-quality loans after 12 months in the high state to the average of the delinquency of the 2002 and 2003 vintage, which is approximately 7%; the delinquency rate of a mix of high- and low-quality loans after 12 months in the high state to the delinquency of the 2005 vintage, which is 9.5%; and the delinquency rate of the mix of high- and low-quality loans after 12 months in the low state to the delinquency of the 2007 vintage, which is 22.5%. This gives the following:  $\Delta^l(A^H)/\Delta^h(A^H) = 0.94$  and  $\Delta^l(A^L)/\Delta^h(A^L) = 0.71$ .

Calibration of the share of high-quality investment opportunities  $\mu$  is more complicated, since I do not have disaggregated data for the United States. However, assuming that the growth in the volume of subprime mortgage loans between 2003 and 2004 was driven mainly by the entry of firms with access to low-quality loans into the market, we would obtain  $\mu = 0.6$ . Since this estimate is rather rough, I use loan level data from Moody's Performance Data Services (PDS) database for the United Kingdom, which according to the empirical analysis in section 5 seems to be in line with the model predictions. When we compare the delinquency rates of the collateral of the RMBS in the period with the lowest output gap, i.e., in the period 2009Q3, on the one hand for loans issued in previous boom stages of the business cycle, i.e., in 2005Q3-2008Q1 (left panel of Figure 6.3), and on the other hand for loans issued in previous recessions, i.e., in periods 2001Q3-2003Q2 and 2004Q3-2005Q2 (right panel of Figure 6.3), we find a significant difference. In particular, it seems that we can distinguish two relatively clear-cut groups in the subset of RMBS issued in the boom period. One has very low delinquency rates (below 4%) and the other has, at times, much higher delinquency rates. When I use the threshold delinquency rate of 4% to identify high- and low-quality assets and combine the reported frequency with volumes, I find the share of high-quality investment opportunities  $\mu = 0.63$ . This is approximately consistent with my initial guess for the subprime mortgage loans in the United States, so I use this parameter level.

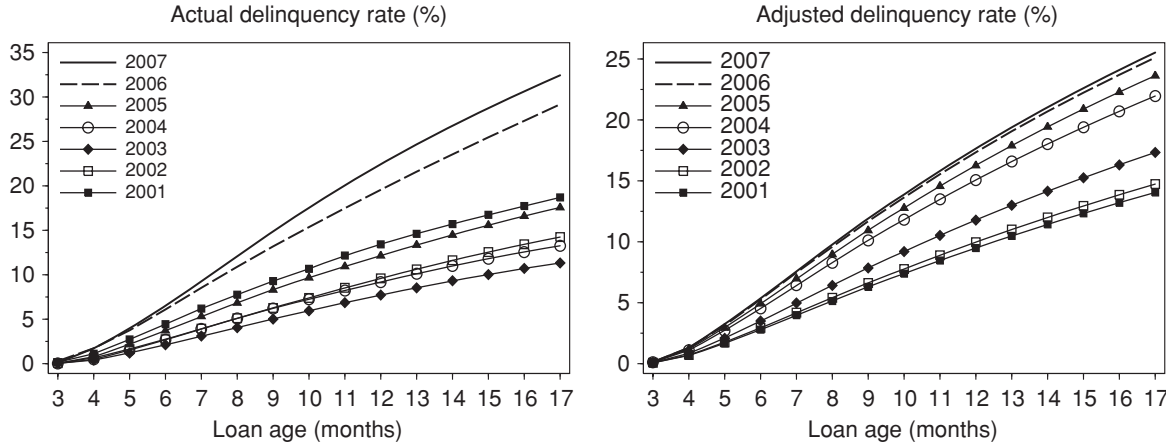
## D Numerical solution of the fully stochastic dynamic model

Since, depending on the state variables, the economy is switching between a separating and a pooling equilibrium, I use global numerical approximation methods for model solution. Perturbation methods used frequently in the macroeconomic literature, which obtain linear approximations for the equilibrium conditions around a steady state and find solutions to the resulting linear system of equations, would fail to capture the switching between different types of equilibrium in this model. I find numerical approximation on a grid of state variables  $A$ ,  $K$ , and  $\omega$  by iteration. This solution captures different behavior of the model in different states of the economy.

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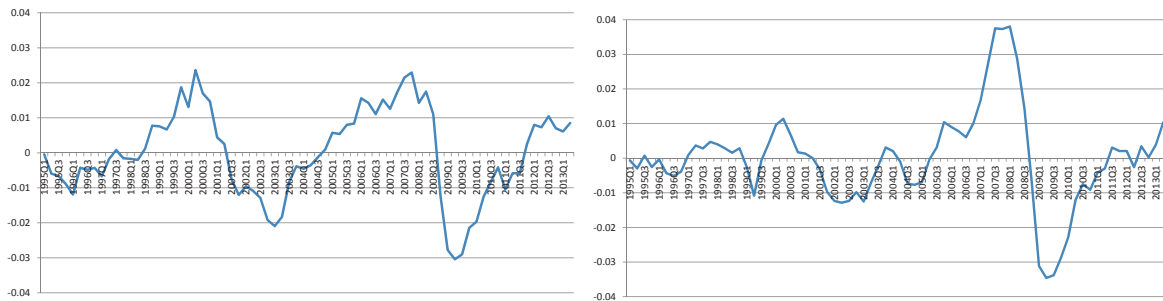
<sup>60</sup>The model presented in this paper does not model loan repayments explicitly. If I assume that a delinquent fraction of loans/projects do not generate cash flows in the current period, then I can compute the ratio of gross profits in the two types of projects.

Figure 6.1. Actual and adjusted delinquency rates for subprime mortgages by Demyanyk and Van Hemert (2011).



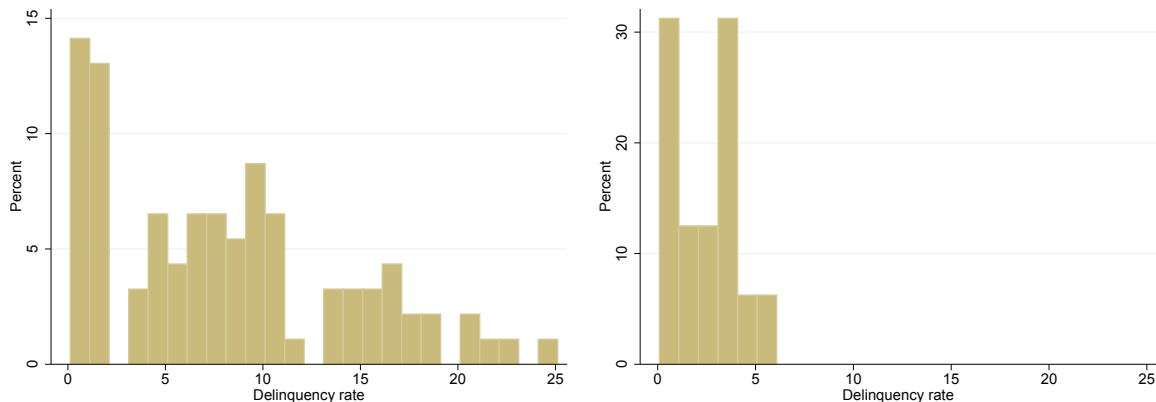
Note: On p.1, Demyanyk and Van Hemert (2011) describe their figure: “The figure shows the age pattern in the actual (left panel) and adjusted (right panel) delinquency rate for the different vintage years. The delinquency rate is defined as the cumulative fraction of loans that were past due 60 or more days, in foreclosure, real-estate owned, or defaulted, at or before a given age. The adjusted delinquency rate is obtained by adjusting the actual rate for year-by-year variation in FICO scores, loan-to-value ratios, debt-to-income ratios, missing debt-to-income ratio dummies, cash-out refinancing dummies, owner-occupation dummies, documentation levels, percentage of loans with prepayment penalties, mortgage rates, margins, composition of mortgage contract types, origination amounts, MSA house price appreciation since origination, change in state unemployment rate since origination, and neighborhood median income.”

Figure 6.2. Log of the output gap in the United States (left panel) and the United Kingdom (right panel)



Note: Data are from Eurostat for the United Kingdom and from FRED (St. Louis FED) for the United States. I construct the output gap using the Hodrick-Prescott filter with the smoothing parameter 1600.

Figure 6.3. Histograms of delinquency rates for collateral of the RMBS issued in the United Kingdom in 2009Q3 for loans issued in the boom (left panel) and for loans issued in the bust (right panel)



Note: The figure shows histograms of the delinquency rates of the collateral for the RMBS, which are defined as the amount of receivables that are 90 or more days past due divided by the original collateral balance (in %). The source of the data is Moody's PDS database. The left panel shows the delinquency rate for the subset of RMBS issued in the boom periods 2005Q3-2008Q1, and the right panel shows the RMBS issued in recessions in the periods 2001Q3-2003Q2 and 2004Q3-2005Q2.

The model solution can be reduced to finding the solution for the set of three non-predetermined endogenous variables  $q^h(\bar{S})$ ,  $q^l(\bar{S})$  and  $V^{diff}(\bar{S}) \equiv V^{ND}(\bar{S}) - V^D(\bar{S})$ , which I will denote as  $\bar{\Gamma}(\bar{S}) = \{q^h, q^l, V^{diff}\} | \bar{S}$ . Expectations about their next-period values determine the current level of all endogenous variables. Once I know the value of  $\bar{\Gamma}(\bar{S})$ , I can find the remaining endogenous variables, including the law of motion for the endogenous state variables  $K$  and  $\omega$ . Therefore, all equilibrium conditions can be rewritten as

$$E(\bar{\Gamma}, \bar{\Gamma}', \bar{S}'(\bar{\Gamma})) | \bar{S} = 0.$$

I use the following algorithm to find the numerical approximation to the model solution.

**Initiation:** I construct a grid for the three aggregate state variables  $\bar{S} = (A, K, \omega)$ . The aggregate productivity takes only two values, so I have a vector  $\bar{A} = \{A^H, A^L\}$ . I choose  $n$  values for  $K$  with equal distances among them and the median being the steady-state value of  $K$ , and obtain a vector  $\bar{K}$  of size  $n$ . Finally, I choose  $n$  values of  $\omega$  from the interval of possible values that  $\omega$  can take, i.e., from  $(\mu, 1)$ , and obtain a vector  $\bar{\omega}$  of size  $n$ . Then I construct a three-dimensional grid  $\mathcal{S}$  of state variables as all possible combinations of  $\bar{A}$ ,  $\bar{K}$  and  $\bar{\omega}$ .

I make an initial guess for the value function difference on the grid:  $\bar{V}_0^{diff}(\mathcal{S}) = \{V_0^{diff}\} | \bar{S} \in \mathcal{S}$ . I choose the stopping criterion  $\varepsilon > 0$  and set the value function iteration counter to zero,  $l = 0$ .

**Step 1:** I do nested iteration to find out the values of  $\{q^h, q^l\} | \bar{S} \in \mathcal{S}$  for the partic-

ular guess of the value function difference  $V_l^{diff}$ .<sup>61</sup> I make an initial guess for remaining non-predetermined endogenous variables of interest on the grid:  $\{\bar{q}_0^h(\mathcal{S}), \bar{q}_0^l(\mathcal{S})\} = \{q_0^h, q_0^l\} \mid \bar{S} \in \mathcal{S}$  and set the price iteration counter to zero,  $k = 0$ .

- **Step 1a:** For all combinations of state variables on the grid  $\bar{S} \in \mathcal{S}$ , I compute  $V_{l+1}^{diff}$  and  $q_{k+1}^h, q_{k+1}^l$ , which satisfies<sup>62</sup>

$$E(\bar{\Gamma}_{l+1, k+1}, \bar{\Gamma}'_{l, k}, \bar{S}'(\bar{\Gamma}_{l, k})) \mid \bar{S} = 0.$$

Note that to compute the next-period values of  $\bar{\Gamma}'_{l, k}$ , I need to know the next-period values of the state variables  $\bar{S}'(\bar{\Gamma}_{l, k})$ . And since those might be in between the grid points, I use linear interpolation on the values of the neighboring grid points on the state space.

- **Step 1b:** If the difference between the values of the two subsequent iterations for prices is smaller than the stopping criterion, i.e., if

$$\|\bar{q}_{k+1}^h(\mathcal{S}) - \bar{q}_k^h(\mathcal{S})\| + \|\bar{q}_{k+1}^l(\mathcal{S}) - \bar{q}_k^l(\mathcal{S})\| < \varepsilon,$$

then I move to Step 2; otherwise, I go back to Step 1a with the price iteration counter  $k$  increased by one.

**Step 2:** If the difference between the values of the two subsequent iterations for the difference in value functions is smaller than the stopping criterion, i.e., if

$$\|\bar{V}_{l+1}^{diff}(\mathcal{S}) - \bar{V}_l^{diff}(\mathcal{S})\| < \varepsilon,$$

then I move to Step 3; otherwise, I go back to Step 1 with the iteration counter  $l$  increased by one.

**Step 3:** I declare  $\bar{\Gamma}_{l, k}(\mathcal{S})$  the final approximate solution and compute the remaining endogenous variables in the model.

## E Appendix to the empirical analysis

### E.1 Data summary statistics

Table 2 shows the summary statistics for the main variables of interest from the PDS database as well as their properties before and after winsorizing and controlling for trend and persistence in the first-stage regression. The statistics are reported separately for different (groups of) countries.

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<sup>61</sup>Note that the subscript for  $V_l^{diff}$  denotes the value function iteration number.

<sup>62</sup>First subscript of  $\bar{\Gamma}$  denotes the number of the value function iteration and the second subscript the number of the price function iteration:  $\bar{\Gamma}_{l+1, k+1} = \{q_{k+1}^h, q_{k+1}^l, V_{l+1}^{diff}\}$ .

## E.2 First-stage regression

To avoid spurious regression problem due to potential common trend or persistence of the variables, I use lagged delinquency rate and *Deal age* (number of quarters since the closing date of the deal) as explanatory variables. Moreover, I try to clear the main explanatory variable of interest *Overcollat* from potential trend and persistence in a first-stage regression, which I run on the level of individual deals (for every  $i$ ) in order to account for heterogeneity:

$$Overcollat_{i,t} = \alpha_i^{FS} + \beta_i^{FS} Overcollat_{i,t-1} + \gamma_i^{FS} Deal\ age_{i,t} + \epsilon_{i,t} \forall i,$$

and I use residuals from the regression equation  $Overcollat_{i,t}^D \equiv \epsilon_{i,t} \forall i$  in the second-stage, i.e., in equation 5.1.

## E.3 Robustness checks

In this section I also report several robustness checks of the regression results from the Table 1.

First, I run the same regression on the sub-sample excluding the late-2000s crisis (and post crisis) period in Table 3. Similar results suggest that the crisis episode does not determine the results.

Second, I winsorize both delinquency rates and the overcollateralization rates at the 2.5%-level to account for potential data errors and limit the effect of potential outliers. The regression results reported in the Table 4 are qualitatively similar to the results in the Table 1.

Third, I show that the results are not driven by controlling for trend and persistence of the  $Overcollat^D$  variable. Without running the first-stage regressions, and using the actual *Overcollat* in the main regression of interest, I obtain the results reported in the Table 5. Those are again qualitatively similar to benchmark regression.

Finally, I show in Table 6 that when the regression is run on the subset of deals issued in the boom stage of the business cycle, I cannot find any significant relationship among delinquency rate and lagged overcollateralization rate, i.e., neither the signaling relationship in the UK. This result is in line with the hypothesis of weaker or non-existent signaling for deals issued on the boom stage.

Table 2. Data summary statistics

	Definition	Transformation	Country	(1) Obs.	(2) Mean	(3) Std. Dev.	(4) Min	(5) Max
<i>DelinqRate</i>	Ratio of the amount of receivables 90 or more days past due to the original pool balance (in percent)	-	UK, SP, NL	14,508	1.75	3.25	0	26.65
			UK	4,373	4.55	4.54	0	26.65
			SP	5,933	0.53	0.93	0	13.41
		winsorized	UK, SP, NL	14,508	1.67	2.89	0	11.96
			UK	4,373	4.28	3.88	0	11.96
			SP	5,933	0.53	0.92	0	11.96
<i>Overcollat</i>	Difference between the collateral asset principal value and the principal value of the tranches in the deal normalized by the original collateral principal value (in percent)	-	UK, SP, NL	14,991	-0.47	4.63	-117.48	90.64
			UK	4,564	0.18	5.08	-99.71	52.47
			SP	6,009	-0.63	2.16	-32.04	34.21
		winsorized	UK, SP, NL	14,991	-0.42	1.34	-6.18	1.87
			UK	4,564	-0.18	1.38	-6.18	1.87
			SP	6,009	-0.57	1.06	-6.18	1.87
		detrended	UK, SP, NL	14,349	-0.00	1.23	-31.12	72.77
			UK	4,360	0.00	0.75	-21.66	21.64
			SP	5,781	0.00	1.07	-26.63	24.45
		winsorized & detrended	UK, SP, NL	14,349	0.00	0.32	-1.15	1.00
			UK	4,360	-0.00	0.26	-1.15	1.00
			SP	5,781	0.01	0.32	-1.15	1.00

Table 3. Robustness Check: Regression on pre-crisis subsample<sup>ab</sup>

Countries <sup>a</sup>	(1) UK, SP, NL	(2) UK	(3) SP	(4) NL
$DelinqRate_{i,t-1}$	0.841*** (0.022)	0.766*** (0.027)	0.411* (0.213)	0.681*** (0.033)
$Overcoll_{i,t-1}^D$	0.000 (0.003)	-0.109** (0.054)	-0.001 (0.001)	-0.003 (0.002)
$Overcoll_{i,t-1}^D \times$ $D_i^{origin\ in\ boom}$	0.004 (0.004)	0.122** (0.056)	-0.001 (0.003)	0.002 (0.003)
$Deal\ age_{i,t}$	-0.011*** (0.003)	-0.050*** (0.011)	-0.003*** (0.001)	-0.002*** (0.001)
$Overcoll_{i,t-1}^D \times$ $D_{i,t}^{boom}$	-0.006* (0.003)	0.027 (0.061)	0.002 (0.002)	0.000 (0.003)
$Output\ gap$	5.306 (3.925)			
Observations	3,860	1,010	1,584	1,266
R-squared	0.691	0.762	0.254	0.579
Number of deals	338	115	118	105

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

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

<sup>c</sup> Time period excludes the late-2000s financial crisis and the following period. Therefore, for the whole sample of countries the time period is 1998Q2-2007Q2, for the UK 2000Q2-2007Q2, for Spain 1998Q3-2007Q2 and 1998Q2-2013Q2 for Netherlands.

Table 4. Robustness Check: Regression on Winsorized data<sup>a,b</sup>

Countries	(1) UK, SP, NL	(2) UK	(3) SP	(4) NL
$DelinqRate_{i,t-1}^W$	0.898*** (0.007)	0.872*** (0.009)	0.831*** (0.023)	0.885*** (0.014)
$Overcoll_{i,t-1}^{D,W}$	-0.026* (0.015)	-0.126* (0.070)	-0.016 (0.023)	-0.004 (0.007)
$Overcoll_{i,t-1}^{D,W} \times$ $D_i^{origin\ in\ boom}$	0.092*** (0.031)	0.220*** (0.083)	0.122** (0.056)	-0.014 (0.009)
$Deal\ age_{i,t}$	-0.004*** (0.001)	-0.022*** (0.004)	-0.000 (0.000)	-0.000 (0.000)
$Overcoll_{i,t-1}^{D,W} \times$ $D^{boom}$	0.007 (0.021)	0.022 (0.088)	0.013 (0.034)	0.001 (0.009)
$Output\ gap_{i,t}$	-5.063*** (1.478)			
Observations	13,226	3,949	5,486	3,791
R-squared	0.864	0.899	0.738	0.918
Number of deals	612	190	227	195

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

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



Table 5. Robustness Check: Without first-stage regression<sup>ab</sup>

Countries	(1) UK, SP, NL	(2) UK	(3) SP	(4) NL
$DelinqRate_{i,t-1}$	0.858*** (0.009)	0.835*** (0.012)	0.807*** (0.022)	0.895*** (0.012)
$Overcoll_{i,t-1}$	-0.005 (0.009)	-0.046*** (0.011)	-0.001 (0.003)	0.009 (0.006)
$Overcoll_{i,t-1} \times$ $D_i^{origin\ in\ boom}$	0.030* (0.017)	0.046** (0.021)	0.042*** (0.015)	0.032 (0.030)
$Deal\ age_{i,t}$	-0.007*** (0.001)	-0.034*** (0.004)	-0.001 (0.001)	-0.002 (0.003)
$Overcoll_{i,t-1} \times$ $D_{i,t}^{boom}$	-0.011 (0.009)	0.004 (0.013)	0.001 (0.006)	-0.020 (0.017)
$Output\ gap$	-6.610*** (2.173)			
Observations	13,820	4,141	5,703	3,976
R-squared	0.845	0.885	0.734	0.883
Number of deals	618	194	227	197

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

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

Table 6. Robustness Check: Regression on subset of loans issued in the boom stage<sup>ab</sup>

Countries	(1) UK, SP, NL	(2) UK	(3) SP	(4) NL
$DelinqRate_{i,t-1}$	0.864*** (0.010)	0.861*** (0.010)	0.826*** (0.018)	0.896*** (0.022)
$Overcoll^D$	0.026** (0.011)	0.006 (0.010)	0.029 (0.018)	0.040 (0.032)
$Deal\ age$	-0.009*** (0.001)	-0.023*** (0.004)	-0.001 (0.001)	-0.000 (0.001)
$Overcoll^D \times D^{boom}$	-0.019* (0.011)	0.039 (0.049)	-0.008 (0.021)	-0.041 (0.033)
$Output\ gap$	-15.530*** (2.926)			
Observations	6,574	2,459	2,420	1,695
R-squared	0.859	0.895	0.758	0.855
Number of deals	325	112	111	102

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

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