ASSET HOLDINGS, INFORMATION AGGREGATION IN SECONDARY MARKETS AND CREDIT CYCLES

2022

BANCO DE ESPAÑA
Eurosistema

Documentos de Trabajo
N.º 2214

Henrique S. Basso

ASSET HOLDINGS, INFORMATION AGGREGATION IN SECONDARY MARKETS AND CREDIT CYCLES

ASSET HOLDINGS, INFORMATION AGGREGATION IN SECONDARY MARKETS AND CREDIT CYCLES

Henrique S. Basso (*)

BANCO DE ESPAÑA

(*) Address: henrique.basso@bde.es. I thank, without implicating, Yunus Aksoy, Jim Costain, Federico Di Pace, Ourania Dimakou, Vincenzo Merella, Omar Rachedi and various seminar participants.

Documentos de Trabajo. N.º 2214

March 2022

ISSN: 1579-8666 (on line)

Abstract

Imperfect information aggregation in secondary credit markets has significant consequences for economic cycles. As banks put more weight on mark-to-market gains, they find it optimal to refrain from revealing information about adverse shocks. Consequently, default risk is mispriced, and loan volumes, and thus investment, are not appropriately reduced. Overinvestment lowers the price of capital, leading households to increase consumption without decreasing labour supply, generating a boom. Due to mispricing, banks subsequently face bigger losses and capital depletion. Output then decreases sharply due to credit supply shortages. In a model calibrated to the US economy, these instances of market dysfunction are crucial in amplifying credit cycles.

Keywords: information revelation, credit markets, mark-to-market, mispricing, bank compensation.

JEL classification: E32, E50, G01, G14.

Resumen

La agregación de información imperfecta en los mercados secundarios de crédito tiene consecuencias significativas para los ciclos económicos. A medida que los bancos dan más importancia a variaciones en el valor de mercado de sus carteras, concluyen que lo mejor es no revelar al mercado en general la información sobre *shocks* adversos. En consecuencia, el riesgo de incumplimiento se valora incorrectamente, y los volúmenes de préstamo y, por lo tanto, la inversión no se reducen adecuadamente. La sobreinversión reduce el precio del capital, y esto lleva a los hogares a aumentar el consumo sin disminuir la oferta laboral, lo que genera un auge económico. Debido a la fijación errónea de precios, los bancos tienen posteriormente mayores pérdidas y enfrentan una caída de su capital. Luego, la producción disminuye bruscamente, debido a la escasez de la oferta de crédito. En un modelo calibrado para la economía estadounidense, estos casos de disfunción del mercado son cruciales para ampliar los ciclos crediticios.

Palabras clave: revelación de información, mercados de crédito, valor de mercado, fijación errónea de precios, compensación en la banca.

Códigos JEL: E32, E50, G01, G14.

1 Introduction

Since the Great Recession, credit cycles have been at the forefront of the debate in policymaking and academia. Several features have been identified as important drivers behind the fluctuations observed in credit and consequently in economic activity. The most prominent involve problems of asymmetric information and adverse selection and the presence of non-linearities due to credit constraints. This work presents a novel mechanism generating amplified economic and credit cycles based on imperfect information aggregation in credit markets and mispricing.

Asset holdings of financial intermediaries have grown considerably since the early 1990s (Adrian and Shin (2010)). The share of assets allocated to the trading book, which is mark-to-market, has also increased substantially (Study on Mark-To-Market Accounting - SEC - US (2008)). Finally, bankers' compensation has been heavily skewed towards short-term payoff (Fahlenbrach and Stulz (2011) and Bolton, Mehran, and Shapiro (2015)). We incorporate these features, augmenting the banking sector in a macroeconomic model of credit frictions with risk shocks. We show that the combination of heterogenous information across bankers, secondary markets of credit, and short-term bias in payoffs provide incentives for incomplete information aggregation in credit markets, in which case credit assets become mispriced. Furthermore, employing the model calibrated to the US economy, we find that these instances of market dysfunction and mispricing generate initially a boom, and subsequently a prolonged recession, increasing macroeconomic volatility and amplifying credit cycles. Mispricing may therefore contribute in shaping financial cycles (Borio (2014)).

We build on the standard macroeconomic model of credit frictions with risk shocks (Christiano, Motto, and Rostagno (2014)). Entrepreneurs must borrow from banks to fund investment projects. Loan contracts are a function of the degree of riskiness of entrepreneurs' projects or the dispersion of the distribution of entrepreneurs returns, which is the only aggregate exogenous stochastic variable in the model. The key novelty of our framework is the introduction of a more realistic banking sector in which (i) bankers initiate every period with a set of loans in the balance sheet (bank asset holdings) and put a greater weight on current mark-to-market gains relative to future profits, (ii) bankers differ regarding their information on the expected degree of riskiness of entrepreneur projects, as only a random subset of bankers get a signal on riskiness (bankers who receive a signal are informed and the ones who do not, are uninformed), and (*iii*) bankers interact in a secondary market of credit through signalling games where by determining the new valuation of loans, an economy wide posterior view on the degree of riskiness emerges.

The key decision for an informed banker is whether to reveal its signal to uninformed bankers or avoid doing so. Informed bankers are all identical and set the same strategy in a series of signalling games between each informed banker and the collective of uninformed bankers, which then determines the equilibrium in secondary markets. On the one hand, if informed bankers fail to reveal adverse signals to uninformed ones by refraining from selling off credit assets, the equilibrium in credit markets is such that the mark-to-market value of assets in the balance sheet are preserved. However, by doing so informed bankers forgo gains from trading while exploiting informational advantages and as information does not become public, the valuation of new credit instruments does not appropriately reflect the risks undertaken - credit markets malfunction. As a result, the banking sector fails to set credit spreads that match the expected default rates, potentially increasing future losses. On the other hand, attempting to go short in the secondary market and revealing the signal leads to lower mark-to-market valuation of asset holdings. Nonetheless, informed bankers make trading profits and information is fully incorporated into loan rates. The banking sector sets credit spreads on new loans appropriately, avoiding future losses. Therefore, informed bankers effectively face a trade-off between the current mark-to-market valuation of asset holdings and their future profits from trading and newly issued loans.

The bigger the size of banks' balance sheets and the greater the short-term bias in the banker's payoff, the more likely it is that, after an adverse signal, informed bankers favour mark-to-market gains on current asset holdings to the detriment of future profits. Thus, in a series of signalling games informed bankers avoid revealing the signal and the equilibrium in secondary markets only partially reflects new information. As the adverse shock is effectively overlooked, markets remain bullish on entrepreneurs projects, failing to adjust funding conditions. Credit spreads are set relatively low, and total loans/investment relatively high based on the underlying risk, benefiting entrepreneurs. As a result of this overinvesment, the price of capital falls, decreasing the funds needed for households to save in physical capital. In turn, this boosts consumption without depressing labour supply, and ultimately, production increases in the current period. Subsequently, banks face bigger losses resulting in a significant decrease in banking capital, compromising their ability to fund new investment going forward. Output thereafter decreases sharply due to credit supply shortages. This boom and bust characterisation matches closely to what we observe during banking crises. Although defaults occur after an unanticipated averse shock, without mispricing they are unable to generate volatile macroeconomic outcomes. Banks are more protected and credit market stability is guaranteed. Hence, the added mechanism creating credit market dysfunctions incorporated here, relative to standard models of credit frictions (e.g. Bernanke et al. (1999) and Christiano et al. (2014)), is crucial in amplifying credit cycles.

The main element that drives economic fluctuations after imperfect or partial information revelation is the mispricing of risk. Contrary to Akerlof and Shiller (2009), who focus on 'animal spirits' (or behaviour biases), mispricing in our setting results from instances where information is not fully reflected into prices as bankers react to their payoff incentives.[1] Do we observe instances in which market prices do not fully reflect all available information? A cross market comparison of prices shows that agents may fail to require the correct compensation for the risk undertaken. Coval et al. (2009) show that the returns on credit default swaps on indexes and put options on these indexes, both of which reflect similar risk profiles, were significantly different. Comparatively, the differences of the lead bank's internal valuation of syndicated loans and the price paid by investors reported by Ivashina and Sun (2011) suggest that not all information on the quality of borrowers reaches the auction for these loans. The results presented in these contributions indicate that prices of instruments used in the funding of investment (through securitization or syndication) may not internalize all available information.

Employing a macro general equilibrium model allows us to associate instances of market dysfunction with the main features of the economy. We observe that bankers are more likely to refrain from going short in credit markets and revealing adverse shocks when the

[1] See DeLong (2011) and Lo (2008) for a discussion on the need to include incentive features and characteristics such as panics, liquidity, and market dysfunction leading to asset prices not reflecting fundamentals in the analysis of economic fluctuations.

volume of trading relative to the size of balance sheet is small and when banking profits are more procyclical. In both of these cases short-term mark-to-market valuation gains are boosted relative to future period losses and gains from trade. We find the opposite result for procyclical leverage ratios. Although under partial revelation the valuation of gains from primary market activity are boosted by procyclical leverage, actual mark-to-market valuations, due to the interplay between future leverage and the current price of capital, are not. Short-term gains are thus restricted and consequently, more procyclical leverage ratios increase the incentive to reveal information. Nonetheless, we find that in economies with higher average/steady state levels of leverage episodes of imperfect information diffusion are more likely to occur, as balance sheets are bigger.

Since the Great Recession several papers build macroeconomic models with a financial sector to analyse financial crises. The main papers in the literature exploit how asymmetric information and/or moral hazard problems may generate excessive and correlated risk taking (Farhi and Tirole (2012)), liquidity problems (Allen et al. (2009)), market freezes (Boissay et al. (2016)), collateral crises (Gorton and Ordonez (2014)), or endogenous risk due to non-linearities (Brunnermeier and Sannikov (2014)). Our framework differs inasmuch as we attempt to motivate the crisis based on mispricing of risk due to imperfect information revelation instead of negative shocks to banks' net worth or other market externalities, which can be complementary to the mechanism proposed here. Mispricing in our framework generates credit supply restrictions due to banking capital depletion. Financial crisis driven by credit supply restrictions related to balance sheet and liquidity issues have been confirmed empirically by Ivashina and Scharfstein (2010) and Cornett et al. (2011a). We provide a theoretical framework that generates these restrictions endogenously through the mispricing of credit assets. Finally, credit induced boom and busts are also analysed empirically by Di Maggio and Kermani (2017). Although they focus on changes in regulation as the driving force behind credit fluctuations, they confirm the role of positive credit supply shocks to riskier borrowers in generating periods of greater economic activity but subsequently also leading to higher loan delinquencies.

The key mechanism generating mispricing is closely related to the contributions on price information revelation in markets following Grossman and Stiglitz (1980). The closest contribution to ours, within this set of models, is Dasgupta and Prat (2008), who show that career concerns generate information inefficiency in markets. We alter the framework to focus on a payoff structure biased towards mark-to-market valuation of current asset holdings in a secondary market to highlight how partial information revelation occurs.[2] As such our work also relates to the CEO/traders compensation literature. In our framework payoff structures skewed towards short-term payments are found to generate information aggregation problems and mispricing of risk, while in that literature they are found to generate excessive risk taking (see Bolton et al. (2015) for executive compensation and risk taking and Kleinlercher et al. (2014) for laboratory evidence on the importance of trader bonuses for asset pricing and risk taking).

The remainder of the paper is structured as follows. Section 2 focuses on the model structure, presenting the features of our macroeconomic model and the equilibrium conditions in the secondary market of credit. Section 3 discusses the key aspects of our mechanism, looking at the bankers trade-off behind the imperfect information revelation and mispricing of credit. The calibration and computation method are discussed in Section 4. The main results on the feedbacks between imperfect information aggregation in markets and economic activity are presented in Section 5. Section 6 concludes.

2 Model

We build on the standard macroeconomic model of credit frictions with risk shocks (e.g. Christiano et al. (2014)). The key novelty is the introduction of an enhanced banking sector in which banks, who care more about current mark-to-market gains and have different information sets, interact in both the primary and secondary markets of credit.

[2]Other relevant contributions focus on learning to generate a deviation from assets prices from their fundamental value (see for instance Adam and Marcet (2011)). A key distinction is that our mechanism is asymmetric in nature, adverse shocks are not fully revealed in markets and are able to generate both increases in output and asset prices followed by a sharp fall in economic activity. Prices diverging from fundamentals can also be the result of behaviour biases (see Bénabou (2013)). Several new contributions look at the incentives of endogenous information acquisition by market participants and the subsequent adverse selection problems impacting credit and financial markets, leading to potential market collapses or inefficient equilibrium (e.g. Chari et al. (2014), Fishman and Parker (2015) and Bolton et al. (2016)). The mechanism underlying our results is distinct since we look at how market participant's payoff, which are influenced by their current portfolio holdings, alters their incentive to trade and reveal the information they already possess to the market.

The model economy is populated by a continuum $h \in [0, 1]$ of households, and a firm. The firm produces consumption goods using capital and labour. Each household is divided into continua of workers (of measure $1 - 2\eta$), entrepreneurs, and bankers (each of measure η). Households decide how much to consume and can save by buying capital or making bank deposits. Workers supply labour to the firm. Entrepreneurs are the main investors of the economy, undertaking risky projects that transform consumption goods into capital goods, which are then sold to the households. Bankers are responsible for financial intermediation, offering loans/funding contracts to entrepreneurs, and trade with each other basket of loans in the secondary market.

We divide each period in our economy into two stages. In the first stage of period t the credit market decisions in the primary and secondary market are taken. The terms of the loan contract between bankers and entrepreneurs are set in the primary market. In the secondary market baskets of loan/debt contracts are potentially traded. Information aggregation in these markets, summarised in the pricing of credit, reveals the information set available to all agents at stage 1.

In the second stage of each period, all uncertainty is revealed, the financial flows based on the decisions taken in stage 1 occur, entrepreneurs projects (signed in the previous period) mature, households and firms take consumption, labour, investment and production decisions, determining the general equilibrium. The key distinction between stage 2 and stage 1 decisions is the information set of agents. In stage 1, the information set $\Xi_{t,1}$ includes the information available at time $t-1$ plus the additional information generated in credit markets, while at stage 2 agents know the realisation of the shock thus $\Xi_{t,2}$ denotes all information of period t.

The firms, households and entrepreneurs sections of the model are very similar to the models presented in (Carlstrom and Fuerst (1997), Bernanke et al. (1999) and Christiano et al. (2014)), and thus we introduce them more briefly first and leave the details for Appendix A. The banking sector, the key sector behind the mechanism we highlight, is presented in more detail in section 2.4.

2.1 Firm

The firm produces final goods Y_t using the following constant returns to scale production function

$$Y_t = (u_t K_t)^{\xi_K} H_t^{\xi_L}, \tag{1}$$

where $u_t K_t$ is the fraction of the capital stock K_t that is utilized (u_t) in production and H_t is the labor used in production. The firm hires labor and rents capital to minimise costs subject to the production possibilities.

2.2 Households

Each household comprises of workers, entrepreneurs and bankers. Household[3] h selects consumption (C_t^h), investment (I_t), capital utilisation rate (u_t), deposits (D_t) at the household level and the labour supply of the workers within the household (N_t) to maximise its discounted lifetime utility. The proceeds from bankers and entrepreneurs activities (dividends), investment (physical and within the banking system), and labour are also aggregated at household level. Thus, formally,[4] household h

$$\max_{C_t, D_t, N_t, K_{t+1}, u_t} E\left[\sum_{t=0}^{\infty} \beta^t \left(\frac{(C_t^h - bC_{t-1})^{1-\nu_1}}{1-\nu_1} - \varsigma \frac{N_t^{1+\nu_2}}{1+\nu_2}\right) \Big| \Xi_{t,2}\right], \quad \beta, b \in (0,1) \quad \nu_1,\ \nu_2, \varsigma > 0$$

subject to the following budget constraint

$$\begin{aligned} q_t I_t + C_t^h + \eta D_t + a(u_t) K_t + \eta T_t^b + \eta T_t^e &\leqslant W_t N_t + \eta R_{t,d} D_{t-1} + r_t^k u_t K_t + \eta dv_t^B + \eta dv_t^E, \\ \text{where } I_t &= K_{t+1} - (1-d) K_t, \end{aligned}$$

d denotes the depreciation rate, $R_{t,d}$ is the rate of return on deposits D_{t-1}, W_t is the wage and q_t is the price of capital. We assume u_t is equal to 1 at steady state and the cost of changing utilization, $a(u_t)$, is an increasing convex function for which $a(1) = 0$ and $\sigma_a = \frac{a''(1)}{a'(1)}$.

[3]We drop the superscript h simplifying exposition, but leave it only on consumption at time t, to highlight that the habits term averages the consumption across all households, and thus habits are not internalised by each household. See Appendix A for more detail on the solution of the household problem.

[4]For $\nu_1 = 1$ we add a constant and approximate the utility to $ln(C_t^h - bC_{t-1})$. Given the calibrated value of b, for all shocks considered, $C_t^h - bC_{t-1} > 0$.

Finally, dv_t^B and dv_t^E denote the total dividends bankers and entrepreneurs pass on to the household and T_t^b and T_t^e are new equity investment done by the household to bankers and entrepreneurs.

2.3 Entrepreneurs

As in Carlstrom and Fuerst (1997) (*CF(1997)* henceforth), the introduction of entrepreneurs allows risky investment and a distribution of outcomes where a fraction of investors default to be incorporated in a parsimonious framework. Entrepreneur j, who starts the period t with net worth $n_{t,j}$, has access to a stochastic technology that transforms $\Upsilon_{t,j}$ consumption goods into $\omega_{t+1,j}\Upsilon_{t,j}$ units of capital in the next period. Thus, in our benchmark model projects have a maturity of one period.[5]

The investment return $\omega_{t,j}$ is a random variable privately observed by entrepreneur j only, i.i.d. across entrepreneurs, and log-normally distributed with its natural logarithm having mean μ_t and variance σ_t. The log of σ_t follows the process given by

$$\ln \sigma_t = (1-\rho^S)\ln \sigma_{SS} + \rho^S \ln \sigma_{t-1} + \iota_t \varepsilon_t^S, \qquad (2)$$

where σ_{SS} is the steady state value of the variance, ρ^S controls the persistence of the process, ε_t^S is normally distributed with mean zero and variance Z_s and is publicly known at the beginning of stage 1 of period t and ι_t takes the value of 1 with probability $1-p_\iota$, and the value of -1 with probability p_ι, and is known by the entrepreneur at stage 1 but is only publicly known at stage 2 of the period.[6] Thus, as $\Xi_{t,2}$ is defined as the information set of stage 2, $\ln\sigma_t$ is $\Xi_{t,2}-$measurable. Given that we are interested in a mean preserving shock, the mean of $\omega_{t,j}$, which we denote μ_ω is held constant, we thus set $\mu_t = \ln(\mu_\omega) - \sigma_t^2/2$. That way, the only aggregate disturbance in our model economy, which reflects the variation in economic conditions, effectively alters the uncertainty of entrepreneurs' investment. Gilchrist et al. (2014) look at uncertainty at the firm level both empirically and theoretically. They

[5] We also consider an extension where at every period a project that is running has a probability of ζ of maturing. As such, a project initiated at time t matures at time $t+s$ with probability $\zeta(1-\zeta)^s$ and pays out $\omega_{t+s,j}\Upsilon_{t,j}$, and hence the average duration of projects is $\frac{1}{\zeta}$. The details of this extension are presented in the Appendix D.

[6] This structure permits σ_t to take different values but simplifies the signal and information flow problem taking place in the secondary market of credit.

show that changes in uncertainty lead to movements in credit spreads and output. Bloom et al. (2014) provide evidence that during recessions the distribution of firm's productivity in the economy widens, implying that a bigger share of firms is further away from the mean productivity level of the economy. Fluctuations in σ would account for such a variation of the lower percentiles of the distribution, altering the mass of entrepreneurs who eventually default. Finally, Christiano et al. (2014) build a framework similar to the one here and show the importance of shocks to σ to explain business cycles fluctuations.

As their expected return is positive, entrepreneurs would like to invest more than their net worth and therefore seek for a loan. A banker offers a loan contract (Γ_t), which prescribe the total amount lent, $\Upsilon_{t,j} - n_{t,j}$, given the net worth $n_{t,j}$, and the interest rate R_t^f. Since the contract, formally defined in the next section, is designed to maximise the entrepreneurs expected payoff, entrepreneurs are always willing to take the loan and invest $\Upsilon_{t,j}$.[7]

The investment done in the previous period by entrepreneurs j matures at period t, providing an average return of $Z_t^j(\Gamma_{t-1,j}, n_{t-1,j})$ (this is formally defined when we determine the loan contract). We assume a fraction of γ_e of $Z_t^j(\Gamma_{t-1}, n_{t-1,j})$ is given to the household as dividend ($dv_t^E = \gamma_e Z_t^j(\Gamma_{t-1}, n_{t-1,j})$) and at each period each entrepreneur receives a fixed transfer of $T_t^e = \gamma_e \bar{n}$ as additional networth. As in Christiano et al. (2014) this ensures entrepreneurs' networth is never sufficiently high such that external finance is no longer needed. Thus, the flow of entrepreneurs networth is given by

$$n_{t+1,j} = (1 - \gamma_e) Z_t^j(\Gamma_{t-1}, n_{t-1,j}) + \gamma_e \bar{n}. \tag{3}$$

2.4 Banking Sector

We modify the banking sector relative to standard models of credit frictions, introducing heterogenous information across bankers (we use bankers and banks interchangeably), mark-to-market bias in payoff structure, and a secondary market of credit to study imperfect information aggregation, mispricing and credit cycles. At every period a random fraction of bankers receive a signal about the level of risk of entrepreneurs project, or a signal on the

[7] We later show that is the case even when partial information revelation occurs.

process (2), and thus are informed, and the remaining bankers are uninformed. Bankers take two key decisions, one is the loan contract they are willing to offer to entrepreneurs (primary market of credit) and the second is how they interact with each other in the secondary market of credit; informed and uninformed bankers play signalling games that determine the degree of information revelation at the equilibrium. Before we describe the details of the primary and secondary markets we introduce the balance sheet and leverage restrictions each banker faces.

2.4.1 Balance Sheet and Leverage Ratio

A banker starts the period with an amount of assets in the balance sheet, which may be traded in the secondary markets, and an amount of internal capital Ω_t, which constitutes the amount of liquid funds needed to operate a lending business. The bankers provide loans, $L_{t,j}$, to entrepreneurs, and receive deposits D_t from the households. The rate on deposits (done at time t) is the short-term rate $R_{t+1,d}$. Bankers thus set $L_t = D_t$ (thus capital is used as buffer and is not loaned out) and the credit market clearing condition is given by $L_t = \int_0^1 (\Upsilon_{t,j} - n_{t,j}) dj$.

Furthermore, at every period bankers must abide by a banking capital requirement given by $L_t \leqslant \varphi_t \Omega_t$, where φ_t denotes the leverage ratio at period t. Adrian and Shin (2010) and Kalemli-Ozcan et al. (2012) empirically show that financial business leverage ratio is strongly negatively correlated with riskiness and positively to total assets. As a result, we set leverage to be an exogenous function of expected degree of riskiness, defining

$$\varphi_t = \bar{\varphi} + \phi_{LT}(\ln(\sigma_{SS}) - E[\ln(\sigma_{t+1}) \mid \Xi_{t,1}]), \tag{4}$$

where $\bar{\varphi}$ is a steady state level of leverage and ϕ_{LT} the sensitivity of leverage to riskiness. In order to keep the model as simple as possible and focus on the new mechanism proposed here, that is, the interaction of secondary and primary markets affecting information revelation, the benchmark model employs this reduced form framework. We also consider an extension where leverage, φ_t, is endogenously set (see Appendix E).

A portion γ_b of the realised gains (V_t^F, defined in section 2.4.3) and banking capital Ω_t is paid as dividends (thus $dv_t^B = \gamma_b(V_t^F + \Omega_t)$). A portion $(1-\gamma_b)$ of retained gains and banking capital, and an additional investment (or transfer, $T_t^b = \gamma_b\bar{\Omega}$) made by the households form the new banking capital available to bankers in the next period. If bankers make losses such that the transfer T_t^b is not enough to generate positive banking capital we assume the households' transfer is set such that $\Omega_{t+1} = \tilde{\Omega} > 0$.[8] As in Gertler and Kiyotaki (2010) this dividend policy ensures bankers do not accumulate too much capital such that the constraint no longer binds. The flow of banking capital is therefore given by

$$\Omega_{t+1} = \max((1-\gamma_b)(\tilde{\Pi}_t^B + \Omega_t) + \gamma_b(\bar{\Omega}), \tilde{\Omega}). \tag{5}$$

2.4.2 Primary Market of Credit

We set up a standard costly state verification framework where the investment return of projects $\omega_{t,j}$ is a random variable privately observed by entrepreneur j only and bankers offer a standard debt contract to entrepreneurs, determining the total loan amount, $(\Upsilon_{t,j} - n_{t,j})$, and the loan interest rate, R_t^f.[9] The entrepreneur agrees to pay back $R_t^f(\Upsilon_{t,j} - n_{t,j})$ (capital goods) to the banker at the end of the next period. If, however, upon the realisation of $\hat{\omega}_{t,j}$ the total return from her investment is smaller than the contracted repayment, $\hat{\omega}_{t,j} < R_t^f(\Upsilon_{t,j} - n_{t,j})/\Upsilon_{t,j} \equiv \varpi_{t,j}$, then the entrepreneur defaults. In that case, the banker monitors the project, pays the cost $(\delta\Upsilon_{t,j})$ for observing the realisation $\hat{\omega}_{t,j}$, and confiscates all the remaining returns from the project.

As such, the expected gross income to entrepreneur j and the banker from the loan are, respectively, given by

[8] Given bank profitability and the standard deviation of shocks used in our calibration, households are not forced to increase bank transfer to ensure bank capital is positive in our simulations. We assume dividend and transfer flows are done equally across all bankers within the household, thus, all bankers in each household will hold the same amount of banking capital, being equal.

[9] Under costly state verification and no aggregate uncertainty a debt contract is optimal (Gale and Hellwig (1985)). Due to aggregate uncertainty a contingent loan contract may increase the entrepreneurs expected payoff. As most loans are not state contingent we assume banks, given their constraints, select the best possible debt contract to offer to entrepreneurs.

$$E\left\{q_{t+1}\Upsilon_{t,j}\left[\int_{\varpi_{t,j}}^{\infty}\omega\phi(\sigma_{t+1})d\omega-\varpi_{t,j}(1-\Phi(\varpi_{t,j};\sigma_{t+1}))\right]\right\}\equiv E\left\{q_t\Upsilon_{t,j}f(\varpi_{t,j};\sigma_{t+1})\right\}, \text{ and}$$

$$E\left\{q_{t+1}\Upsilon_{t,j}\left[\int_{0}^{\varpi_{t,j}}\omega\phi(\sigma_{t+1})d\omega-\delta\Phi(\varpi_{t,j};\sigma_{t+1})+\varpi_{t,j}(1-\Phi(\varpi_{t,j};\sigma_{t+1}))\right]\right\}\equiv E\left\{q_{t+1}\Upsilon_{t,j}g(\varpi_{t,j};\sigma_{t+1})\right\},$$

where as we set $\omega_{t,j}$ to be log-normally distributed, $\phi(\sigma_t)$ denotes the log-normal density function and $\Phi(\varpi_{t,j};\sigma_t)$ the log-normal cumulative probability distribution. Note that by assumption we have that the sum of the shares of the return allocated to the entrepreneur and the banker must be equal to the total return, thus, $f(\varpi_{t,j};\sigma_{t+1})+g(\varpi_{t,j};\sigma_{t+1})=\mu_\omega-\delta\Phi(\varpi_{t,j};\sigma_{t+1})$.

Information Structure

As all contracts are signed at the first stage of each period, uninformed bankers set a contract based on the publicly available information set at this stage, $\Xi_{t,1}$. Assume $\Xi_{t,1}$ does not contain all information known to informed bankers who receive a signal. As all credit spreads set on the primary market are known, if informed bankers decide to offer a contract using the additional information they possess that are not in $\Xi_{t,1}$, then this new information immediately becomes known to uninformed bankers and is incorporated into $\Xi_{t,1}$. Thus, if both credit markets are in equilibrium, $\Xi_{t,1}$ incorporates all information already revealed, and informed bankers also evaluate and offer contracts under $\Xi_{t,1}$, even if they have superior information. As we will see later on when we analyse the trade-offs informed bankers faced in the signalling game, they take into consideration that all loan contracts in the primary market are set under $\Xi_{t,1}$ while defining the strategy to be adopted in the secondary market, when the information set $\Xi_{t,1}$ is formed.

Loan Contract Design

As bankers are in competition to secure loans from entrepreneurs they offer the standard loan contract that maximises the entrepreneur j's expected return subject to two constraints. The first constraint states that the banker's expected return is not smaller than the cost of obtaining the funds plus a fixed profit margin from the loan. Contrary to *CF(1997)* we assume the banker has some bargaining power over entrepreneurs, allowing them to extract a share χ_t of the expected returns of entrepreneurs.[10] We observe that the ratio of financial business profits to GDP in the US is positively correlated to GDP. To incorporate this feature into the model we assume χ_t to be pro-cyclical setting $\chi_t = \bar{\chi} + \phi_\chi(E[Y_t|\Xi_{t,1}] - \bar{Y})$. The second constraint states that the banking capital requirement must hold. Note that it involves all lending done by the banker, not only the one done to entrepreneur j. Thus, this is an aggregate constraint from each entrepreneurs view point. Additionally, entrepreneurs expected return must be always positive, or $E[q_{t+1}\Upsilon_{t,j}f(\varpi_{t,j};\sigma_{t+1})] \geqslant n_{t,j}$. This occurs for all cases we analyse.

Formally, the problem that determines the loan contract is

$$\begin{aligned}
\max_{\{\Upsilon_{t,j},\varpi_{t,j}\}} \quad & E\{q_{t+1}\Upsilon_{t,j}f(\varpi_{t,j};\sigma_{t+1})|\Xi_{t,1}\} \\
\text{subject to} \quad \int_0^1 (\Upsilon_{t,j} - n_{t,j})dj \quad & \leqslant \quad \varphi_t\Omega_t, \text{ and} \\
E\{q_{t+1}\Upsilon_{t,j}g(\varpi_{t,j};\sigma_{t+1})|\Xi_{t,1}\} \quad & \geqslant \quad E\{R_{t+1,d}(\Upsilon_{t,j} - n_{t,j}) + \chi_t q_{t+1}\Upsilon_{t,j}f(\varpi_{t,j};\sigma_{t+1})|\Xi_{t,1}\}.
\end{aligned}$$

Let the lagrange multiplier for the first constraint be ξ_t. First note that the shadow value of the banking capital constraint is the same across entrepreneurs and thus is independent of j. Secondly, the first two conditions which determine $\varpi_{t,j}$ and the ratio $\frac{\Upsilon_{t,j}}{n_{t,j}}$ are only a function of aggregate variables $(q_t, \sigma_t, \xi_t, R_{t+1,d})$ and thus we can set $\varpi_{t,j} = \varpi_t$, and $\frac{\Upsilon_{t,j}}{n_{t,j}} = \frac{\Upsilon_t}{n_t}$. Then assuming the banking capital constraint binds at all times we have that[11]

$$\begin{aligned}
&[E\{q_{t+1}f(\varpi_{t,j};\sigma_{t+1})|\Xi_{t,1}\} - \xi_t]\left[\frac{E\{q_{t+1}g'(\varpi_{t,j};\sigma_{t+1})|\Xi_{t,1}\}}{E\{q_{t+1}f'(\varpi_{t,j};\sigma_{t+1})|\Xi_{t,1}\}} - \chi_t\right] \\
&\qquad = E\{R_{t+1,d} - q_{t+1}[g(\varpi_t;\sigma_{t+1}) - \chi_t f(\varpi_t;\sigma_{t+1})]|\Xi_{t,1}\} \qquad (6) \\
&\Upsilon_t = \frac{E\{R_{t+1,d}n_t|\Xi_{t,1}\}}{E\{R_{t+1,d} - q_{t+1}[g(\varpi_t;\sigma_{t+1}) - \chi_t f(\varpi_t;\sigma_{t+1})]|\Xi_{t,1}\}}, \qquad (7) \\
&\text{and } \varphi_t\Omega_t = \Upsilon_t - n_t. \qquad (8)
\end{aligned}$$

(8) determines total investment Υ_t, (7) determines ϖ_t and (6) gives ξ_t. The loan contract is then defined by the set $\Gamma_t \equiv (\Upsilon_t, \varpi_t, \varphi_t)$.

[10] This can be viewed as a reduced form to a monopolistic competition setting where all banks can extract a fixed mark-up on loan origination.

[11] While setting γ_b (see (5)), we ensure that at the steady state and its neighbourhood the banking capital constraint always binds.

Therefore, the banker designs the best possible standard debt contract to entrepreneurs such that the banker's net expected return from lending is maximised and capital regulation is met. Based on this loan contract we determine the banker's valuations of the baskets of loans at signature, which we denote $V_t^0(\Gamma_t, \sigma_{t+1}; \Xi_{t,1})$, highlighting that it depends on the contract terms defined by the bank, the stochastic variable describing the riskiness of entrepreneurs contracts σ_{t+1}, and the information set used to form expectations at signature $\Xi_{t,1}$. That is,

$$V_t^0(\Gamma_t, \sigma_{t+1}; \Xi_{t,1}]) = E\left\{q_{t+1}\Upsilon_t g(\varpi_t; \sigma_{t+1}) - R_{t+1,d}(\Upsilon_t - n_t)|\Xi_{t,1}\right\}. \tag{9}$$

Finally under this contract the average value at stage 2 of the entrepreneurs projects signed at stage 1 of the previous period is given by $Z_t(\Gamma_{t-1}, n_{t-1}) = q_t\Upsilon_{t-1}f(\varpi_{t-1}; \sigma_t)$.

2.4.3 Loan Revaluation and Bankers Payoff

At the first stage of period t, the baskets of loan contracts signed in the previous, which in $t-1$ were value at $V_{t-1}^0(\Gamma_{t-1}, \sigma_t; \Xi_{t-1,1})$ are (potentially) trade. At the equilibrium of the credit market all publicly available information generated, through the interaction of informed and uninformed bankers analysed in detail in the next section are contained in the information set $\Xi_{t,1}$. $\Xi_{t,1}$ allows bankers to update the prediction of risk process (2) and as the contract terms Γ_{t-1} are already set (depend on $\Xi_{t-1,1}$), the revaluation of the basket of loans signed in the stage 1 of the previous period is given by

$$V_t^{mtm}(\Gamma_{t-1}, \sigma_t; \Xi_{t,1}) = E\left\{q_t\Upsilon_{t-1}g(\varpi_{t-1}; \sigma_t) - R_{t,d}D_{t-1}|\Xi_{t,1}\right\} \tag{10}$$

At stage 2, the basket of loans matures and its final valuation (V_t^F) depends on the realisation of σ_t. As such we define

$$V_t^F(\Gamma_{t-1}, \sigma_t) = q_t\Upsilon_{t-1}g(\varpi_{t-1}; \sigma_t) - R_{t,d}D_{t-1} \tag{11}$$

At stage 1 of period t the informed bankers evaluate their payoff from credit markets using the information set available to all, $\Xi_{t,1}$, plus the added information from the signal

S_t they possess (which depending on the equilibrium of secondary markets analysed below may be part of $\Xi_{t,1}$ or not). We assume the payoff for a banker is given by

$$J_t^B(\Xi_{t,1}, S_t) = \Pi_t^B(\Xi_{t,1}) + \beta\alpha E\{J_{t+1}^B | \Xi_{t,1} \cup S_t\} \tag{12}$$

where

$$\begin{aligned} \Pi_t^B(\Xi_{t,1}) &= V_t^0(\Gamma_t, \sigma_{t+1}; \Xi_{t,1}) + \big(V_t^{mtm}(\Gamma_{t-1}, \sigma_t; \Xi_{t,1}]) - V_{t-1}^0(\Gamma_{t-1}, \sigma_t; \Xi_{t-1,1}])\big) + \\ &\quad + \big(V_{t-1}^F(\Gamma_{t-2}, \sigma_{t-1}) - V_{t-1}^{mtm}(\Gamma_{t-2}, \sigma_{t-1}; \Xi_{t-1,1})\big). \end{aligned} \tag{13}$$

Π_t^B is a measure of profits of banks, set at the end of stage 1, which is a function of the value of new contracts signed in the current period V_t^0, the change in valuation in the secondary market of the balance sheet asset holdings ($V_t^{mtm} - V_{t-1}^0$), and the gains from the final valuation gain of loan contracts settled in the previous period (assets that matured, $V_{t-1}^F - V_{t-1}^{mtm}$).[12] Note that we assume this final valuation, done at the end of period $t-1$, is accounted as gains to the banker at the first stage of period t. This assumption ensures secondary market valuations and final valuations are accounted as profits in different periods.[13] Note that the informed banker takes as given that the contract signed in the primary market of credit and the valuation of the basket of loans currently held in the balance sheet at the stage 1 of period t are evaluated based on the publicly available information in credit markets $\Xi_{t,1}$.[14] Nonetheless, the banker takes into consideration that they have a potentially larger information set which includes their private signal while evaluating the (predicted) changes in the value of the assets in the balance sheet going forward (J_{t+1}^B).

The two key characteristics of this payoff structure is that assets are mark-to-market when new information becomes available, at the signature, then due to the activity in secondary markets and finally at maturity when σ_t becomes known. Second α indicates the importance of short-term payoff relative to future gains. The rationale for this assumption is closely related to the current compensation structure in banking. The overwhelming majority of financial contracts signed by bankers are scheduled to mature many years after performance compensation on the bankers activities is defined. The most appropriate performance related

[12] The existence of a secondary market is crucial to introduce a difference between valuation at origination, at the mark-to-market and at maturity into the payoff structure.

[13] This assumption can be relaxed in the extension where loan contracts last more than one period - see Appendix D.

[14] If that is not the case $\Xi_{t,1}$ cannot be considered as a product of an equilibrium of the credit markets.

measure would be the actual gains obtained at maturity (so only V^F from $t-1$ onwards would be part of J_t^B). However, writing a contract based on this measure might not always be feasible and thus shareholders are forced to use a measure of performance related to the current valuation of the portfolio (Π_t^B).[15] A skewed payoff structure to current valuation could also be exacerbated by bankers' turn over. Given that assets maturities are significantly bigger than bankers tenure, realised profits at maturity might be more heavily discounted than mark-to-market gains.

The type of payoff structure incorporated in our model is in line with the empirical literature on executive compensation. Fahlenbrach and Stulz (2011) report data on CEOs for 95 bank holding companies and find the ratio of annual compensation (equity + bonuses + salary) to the value of inside ownership for the mean bank to be 0.14. This number implies that an observed gain in the value of equity during a year in a range of 6% would lead to a total compensation structure of roughly 70% of short-term payment and 30% of long-term payment for these CEOs in a year. In this calculation, return on equity holdings is considered a long-term payment. The usage of data on deferred compensation only as long-term payment for banks is advocated by Bolton et al. (2015) due to leveraging with risky debt. They argue the value of equity stakes can be increased with activities geared to obtain short-term gains, hence, a CEO could still perceive variations in the value of inside ownership as a short-term payment. Deferred compensation and pensions are more easily classified as long-term payments. The ratio of annual compensation and the total debt the bank owns to the CEO for the mean bank in the sample is 0.6. That characterises a payment structure heavily reliant on short-term payments (i.e. bank debt to CEOs must increase by almost 30% in value to generate the same 70/30 ratio between long-term and short-term payments).

Aiming at simplifying the bankers' payoff structure we show in the following lemma that from $t+2$ onwards future mark-to-market revaluation gains and losses are expected to be zero, thus only the value of loan contracts at signature remain.

[15] Households own banks and receive their realised profits. We do not model the principal-agent problem between the households and bankers that determine such payoff structure. Baker et al. (1994) discusses appropriate and observable performance measures in incentive contracts, providing theoretical support for the use of payoffs based on current/mark-to-market valuation.

Lemma 1. *$E\{\Pi^B_{t+j}|\Xi_{t,1}\cup S_t\} = E\{V^0_{t+j}(\Gamma_{t+j},\sigma_{t+j+1};\Xi_{t+j,1})|\Xi_{t,1}\cup S_t\}$ for $j\geqslant 2$*

The key reason behind this result is that at the end of period t the informational advantage of the fraction of informed bankers no longer plays a role when ι_t, and thus σ_t, is revealed. Therefore, for all contracts signed after t no banker can do better than the market equilibrium, and there are no expected revaluations. The formal proof is shown in the Appendix B.

Therefore, the payoff of bankers is simplified in the following proposition.

Proposition 1. *The bankers' payoff can be written as*

$$\begin{aligned} J^B_t(\Xi_{t,1},S_t) = {} & V^0_t(\Gamma_t,\sigma_{t+1};\Xi_{t,1}) + (V^{mtm}_t(\Gamma_{t-1},\sigma_t;\Xi_{t,1}) - V^0_{t-1}(\Gamma_{t-1},\sigma_t;\Xi_{t-1,1}]) \\ & +(V^F_{t-1}(\Gamma_{t-2},\sigma_{t-1}) - V^{mtm}_{t-1}(\Gamma_{t-2},\sigma_{t-1};\Xi_{t-1,1})) \\ & +E\Bigg[\alpha\beta(V^{mtm}_{t+1}(\Gamma_t,\sigma_{t+1};\Xi_{t+1,1}) - V^0_t(\Gamma_t,\sigma_{t+1};\Xi_{t,1}]) \\ & +\alpha\beta(V^F_t(\Gamma_{t-1},\sigma_t) - V^{mtm}_t(\Gamma_{t-1},\sigma_t;\Xi_{t,1}])|\Xi_{t,1}\cup S_t\Bigg] + \alpha\beta E[J_{0,t+1}|\Xi_{t,1}\cup S_t] \\ & \text{where } J_{0,t+1} = \sum_{j=0}^{\infty}\alpha^j\beta^j V^0_{t+1+j} \end{aligned} \tag{14}$$

Proof. Expanding 12, using 13, applying Lemma 1 and collecting V^0_{t+1+j} $\forall j\geqslant 0$ in $J_{0,t+1}$ gives the result. □

2.4.4 Secondary Market of Credit

Bankers must update the valuation of the basket of loans. Contracts terms are already set and the only stochastic variable is the riskiness of loans, and thus the new price of loans has a one-to-one relationship with $E[\ln\sigma]$. At the beginning of stage 1 of period t, ε^S_t is made public and the bankers common prior on ι_t, denominated $\tilde{\iota}_t$, is set. At each period an independent and randomly selected subset of bankers gets a signal (S_t) of the true value of ι_t. Bankers who receive a signal are informed, being able to better predict $E[\ln\sigma]$ (see (2)), and the ones who do not, are uninformed. Bankers, when the secondary market opens, differ only on the basis of information (whether they received the signal or not). As a result, the no trade theorem applies; prices will instantaneously reflect the revealed information such that bankers no longer have an incentive to trade and bankers asset holdings remain the same. Abstracting from balance sheet changes simplifies the framework allowing us to focus on price revelation. We relax this assumption in an extension, presented in the Appendix F, in which bankers who are behaviour/noise traders are included and as a result trade occurs at the equilibrium. The mechanism highlighted in the benchmark model continues to be in effect.[16]

Therefore, the secondary market of credit can be concisely described as a set of signalling games simultaneously played between informed bankers and the set of uninformed bankers. This collective of uninformed bankers who observe market interactions or new prices is denominated the 'market'. We start by considering a single game between the 'market' (Player 2), and an informed banker who receives a signal (Player 1).[17] We then describe how the equilibrium of the secondary credit market materialises when a continuum of informed bankers play these signalling games.

An informed banker receives a signal S_t and forms a posterior view on ι_t. We denote this as $S_t \Rightarrow \iota_t$. This banker (Player 1) then contends with two possible actions (A_t) while participating in the secondary market. She can set $A_t = \iota_t$, thus the action reveals the signal received or $A_t = \tilde{\iota}_t$, whereby her market activity does not reveal the signal, only confirming the market status quo/prior.[18] Acting to reveal the signal could be construed as attempting to sell (buy) baskets of loans if the signal is bad (good), while a passive activity confirms the market status quo/prior. Define $\lambda_t = \Pr(A_t = \iota_t | S_t \Rightarrow \iota_t)$ as the probability Player 1 will reveal the signal to the 'market'. Player 1 then, upon observing the signal, sets λ_t to maximize her payoff ($J_t^B(\Xi_{t,1}, S_t)$). If Player 1 sets $\lambda_t = 1$, the signal is revealed with

[16]Our framework does not incorporate other potential reasons for trading to occur in the secondary market (e.g. risk sharing or capital reallocation). Once again, including such motives increase the complexity of the model without affecting the main mechanism. While all bankers (informed and uninformed) would like to trade to better allocate capital, informed bankers might be willing to trade more extensively due to information advantage. At this point the trade-off presented here becomes effective.

[17]Given that ultimately the information available to the collective of uninformed bankers is what constitute the equilibrium in the secondary market, we denominate Player 2 in the game the 'market'.

[18]The only relevant case is when a signal indicates a change from the market's prior/status quo. A signal confirming the prior is trivial as the secondary market is irrelevant. Therefore, we focus on the cases where when $S_t \Rightarrow -1$ ($S_t \Rightarrow 1$), then $\tilde{\iota}_t = 1$ ($\tilde{\iota}_t = -1$) or in a more concise way $\tilde{\iota}_t \in \{-1, 1\} \backslash S_t$. Note that we exclude the possibility that bankers who received no signal act in the market pretending a signal was revealed to them (bankers are assume to be enable to generate price movements when they have not received a signal).

probability 1, and when $0 \leqslant \lambda_t < 1$, there is a likelihood the signal may be hidden, thus despite receiving good or bad news, Player 1 may attempt to confirm the status quo.

Player 2, the 'market', knows the process for $\ln \sigma_t$, the values of $\ln \sigma_{t-1}$ and ε_t^S, and has a prior on ι_t, which we denote as the market status quo $\tilde{\iota}_t$. She then observes the action of the informed banker and must form a posterior view on ι_t. If the banker reveals the signal, the 'market' directly sets ι_t according to the signal S_t. But if they observe participation consistent with the status quo $\tilde{\iota}_t$, it must assign a probability that indeed $\iota_t = \tilde{\iota}_t$, or conclude that $\iota_t \neq \tilde{\iota}_t$ and the informed banker has hidden her signal. In other words, in order to better predict ι_t, the 'market' must assign the probability that the true value of ι_t is $\tilde{\iota}_t$, upon observing an action that confirms the prior ($A_t = \tilde{\iota}_t$), setting $r(\lambda_t) = \Pr(\iota_t = \tilde{\iota}_t | A_t = \tilde{\iota}_t)$. Using Bayes rule, and noting that $\Pr(A_t = \tilde{\iota}_t | S_t \Rightarrow \tilde{\iota}_t) = 1$, that is, a signal confirming the status quo is always revealed, and that $\Pr(A_t = \tilde{\iota}_t)$ comprises the probability that $\iota_t = \tilde{\iota}_t$ plus the probability that $\iota_t \neq \tilde{\iota}_t$ but a signal was hidden, we have that the optimal response of the 'market' is to set

$$
\begin{aligned}
r(\lambda_t) &= \Pr(\iota_t = \tilde{\iota}_t | A_t = \tilde{\iota}_t) \\
&= \frac{\Pr(A_t = \tilde{\iota}_t | \iota_t = \tilde{\iota}_t) \Pr(\iota_t = \tilde{\iota}_t)}{\Pr(A_t = \tilde{\iota}_t)} = \frac{\Pr(\iota_t = \tilde{\iota}_t)}{\Pr(\iota_t = \tilde{\iota}_t) + (1 - \Pr(\iota_t = \tilde{\iota}_t))(1 - \lambda_t)}.
\end{aligned} \tag{15}
$$

For instance, assume $\tilde{\iota}_t = -1$, and $S_t = \iota_t = 1$, then $r(\lambda_t) = \frac{1-p_\iota}{(1-p_\iota)+p_\iota(1-\lambda_t)}$.[19] If $\lambda_t = 1$, the signal is revealed (with probability 1 the banker with a signal who acts in the secondary market reveals her signal), the 'market' concludes that $A_t = \iota_t = 1$. However, if $\lambda_t < 1$, the 'market' knows there is an incentive for a banker who is informed to hide the signal and it updates the probability accordingly, setting $r(\lambda_t) < 1$. Although the adjustment is made, the 'market' is not capable of extracting the signal perfectly as it cannot accurately distinguish between situations in which the banker who received a signal decided to hide it from the ones in which the signal confirmed the prior/market status quo.

The Perfect Bayesian Equilibrium (PBE) of the signalling game between a banker and the 'market' is then the pair (r^*, λ^*), such that λ^* maximises the bankers' payoff $J_t^B(\Xi_{t,1}, S_t)$, and $r^*(\lambda^*)$ is set according to (15).

[19] Recall that we assume the probability $\iota_t = -1$ is $(1 - p_\iota)$.

The figure 1 depicts the time line with a summary of the signaling game.

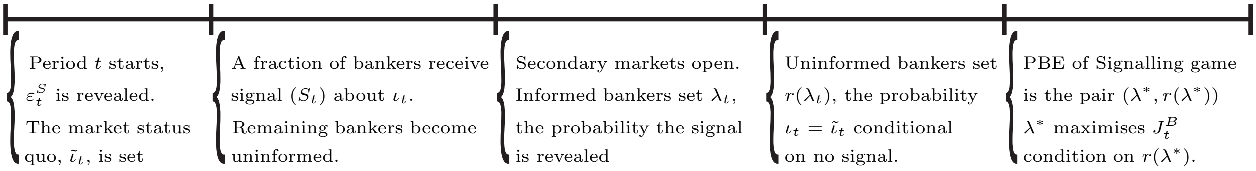

Figure 1: Timeline - Signalling Game

At the aggregate, the collective of uninformed bankers ('market') is faced with a series of signalling games with the continuum of bankers who received the signal. Assume that it is optimal for each informed banker to select a mixed strategy in the PBE above (in which only a single game per period is evaluated) with $0 < \lambda_i^* < 1$, for $i \in$ informed bankers. As there are an infinite number of games played between the informed and the set of uninformed bankers and each informed banker randomizes between being active and revealing the signal or not, following the weak law of large numbers, as we increase the number of games played, in a proportion $\lambda_i^* = \lambda^* > 0$ (as all informed bankers are equal) of these games the informed banker is active and the signal is revealed. Recall that λ^* is equal to the probability the informed banker is active and the signal is revealed, conditional on a relevant signal being received. Upon observing an active informed banker in one game, uninformed bankers immediately conclude a relevant signal was received updating their prior.[20] As such, if $\lambda_i^* > 0, \forall i$, then the signal is eventually revealed and the equilibrium in credit markets and the payoff for each informed banker is equivalent to the payoff when $\lambda_i^* = 1, \forall i$. All informed bankers are aware of that and thus recognize that their possible strategies at the aggregate are either to set $\lambda_i^* = 0$ or $\lambda_i^* = 1$ (since setting $0 < \lambda_i^* < 1$ is equivalent at the aggregate to setting $\lambda_i^* = 1$). Thus, the aggregate symmetric Perfect Bayesian Equilibrium, where all bankers play the same strategy in a series of signalling games, only contemplates pure strategies, with $\lambda^* \in \{0, 1\}$. If it is optimal for one informed banker to select $\lambda^* = 0$, hiding the signal with probability one, no other informed banker deviates, giving the signal, as doing so would reduce their payoff. Therefore, at the aggregate the series of signalling games is such that the signal is only partially revealed. If it is optimal for an informed

[20] Note informed bankers cannot reveal a signal they have not received and as the 'market' is aware that all informed bankers are equal, if in one game the signal was revealed the uninformed bankers conclude that the relevant signal was received and in the other games in which the signal was not revealed the informed bankers were inactive in an attempt to hide the signal.

bankers to select $\lambda_i^* = 1$, then the signal is transferred (the subsequent games are irrelevant), with all informed bankers ultimately maximising their payoff.

The equilibrium of the secondary market, reflecting the series of games played, determines $\Xi_{t,1} \in \{\Xi_{t-1,2}, \varepsilon_t^S, \tilde{\iota}_t, \lambda^*, r^*\}$. Thus, observing the actions of the informed bankers, who using their choice of λ^* can predict $\Xi_{t,1}$ to evaluate $J_t^B(\Xi_{t,1}, S_t)$, maximizing it, the 'market' sets r^* and the expected riskiness level to be

$$\begin{aligned} E[\ln \sigma_t | \Xi_{t,1}] &= E[\ln \sigma_t | \ln \sigma_{t-1}, \varepsilon_t^S, \tilde{\iota}_t, \lambda^*, r^*] \\ &= (1-\rho^S)\ln \sigma_{SS} + \rho^S \ln \sigma_{t-1} + \big(\lambda^* \iota_t + (1-\lambda^*)(r^* \tilde{\iota}_t + (1-r^*)\iota_t)\big)\varepsilon_t^S. \end{aligned} \tag{16}$$

Hence, if $\lambda^* = 1$, then $\Xi_{t,1} = \Xi_{t,2}$ and $\ln \sigma_t$ is $\Xi_{t,1}-$measurable. If $\lambda^* = 0$, then $\Xi_{t,1} \subsetneq \Xi_{t,2}$ and since $0 < r^* < 1$, $E[\ln \sigma_t | \Xi_{t,1}] \neq \ln \sigma_t$. Finally, as contract terms are already set and the only stochastic variable is the riskiness of entrepreneurs projects, the new valuation of the basket loans has a one-to-one relationship with $E[\ln \sigma | \Xi_{t,1}]$, thus bankers are able to set $V_t^{mtm}(\Gamma_{t-1}, \sigma_t; \Xi_{t,1})$.

2.5 General Equilibrium

The recursive equilibrium consists of decision rules for $\{C_t,\ Y_t,\ K_{t+1},\ u_t,\ H_t,\ N_t,\ \Omega_{t+1},\ Z_t,\ \Pi_t^B,\ J_t^B,\ V_t^0,\ V_t^{mtm},\ V_t^F,\ n_{t+1}\}$, for prices $\{W_t,\ R_{t+1,d},\ q_t, r_t^k\}$, for the loan contract terms $\{\xi_t, \varphi_t, \Upsilon_t, \varpi_t\}$ and for the secondary market outcome $\{\Xi_{t,1}\}$, which are all functions of the state variables $\{K_t,\ n_t,\ \Omega_t,\ Y_{t-1},\ \sigma_{t-1},\ \varpi_{t-1},\ \Upsilon_{t-1},\ V_{t-1}^0,\ V_{t-1}^{mtm},\ V_{t-1}^F\}$ such that:[21]

a. Households set consumption, labour supply and savings to maximise expected utility; *b*. The loan contract is the debt contract that maximises entrepreneurs expected returns subject to the leverage and funding constraints *c*. Bankers secondary market strategy maximises expected payoff J_t^B; *e*. Capital, consumption good, credit and labour markets clear.

3 Banker's trade-off and Credit Market Equilibrium

In this section we look closely at the bankers trade-off and decision of whether to reveal the signal, setting $\lambda_t^* = Pr(A_t = \iota_t \mid S_t = \iota_t) = 1$, or becomes passive and confirms the

[21]Details on the recursive system are shown in the Appendix A.

status quo, setting $\lambda_t^* = 0$, characterizing the equilibrium in credit markets. For simplicity we assume the economy is at steady state and thus $(V_{t-1}^F - V_{t-1}^{mtm}) = 0$ and the signal $S_t = \iota_t$. To simplify the exposition we only include the information set within the variables that drive the values of baskets, thus $V_t^0(\Gamma_t, \sigma_{t+1}; \Xi_{t,1})$ becomes $V_t^0(\Xi_{t,1})$. We start by looking at the payoff under full and partial information in the following two propositions (proofs are shown in the Appendix B)

Proposition 2. *In the case of full information revelation ($\lambda = 1$), the bankers' payoff is given by*

$$J_t^B(\Xi_{t,2}) = V_t^0(\Xi_{t,2}) + (V_t^F(\Xi_{t,2}) - V_{t-1}^0(\Xi_{t-1,1})) + \alpha\beta E[J_{0,t+1}^F] \tag{17}$$

Under full information, $\lambda = 1$, as such $\Xi_{t,1} = \Xi_{t,1} \cup S_t = \Xi_{t,2}$, therefore $\ln \sigma_t$ is $\Xi_{t,1}-$measurable. Therefore, the valuation of the basket of loans at stage 1 in the secondary market and at stage 2, at maturity, is the same. Furthermore, the expected equilibrium in tomorrow's secondary market is the same as today's primary market, since both would be evaluated under the same information set.

Proposition 3. *In the case of partial information revelation ($\lambda = 0$), the bankers' payoff is given by*

$$\begin{aligned} J_t^B(\Xi_{t,1}, S_t) \;&=\; V_t^0(\Xi_{t,1}) + (V_t^{mtm}(\Xi_{t,1}) - V_{t-1}^0(\Xi_{t-1,1})) && (18)\\ &\quad +\alpha\beta\Bigg[(V_{t+1}^{mtm}(\Xi_{t,2})]) - V_t^0(\Xi_{t,1})) && (19)\\ &\quad +(V_t^F(\Xi_{t,2}) - V_t^{mtm}(\Xi_{t,1})) + E[J^P{}_{0,t+1}]\Bigg]. && (20) \end{aligned}$$

When $\lambda = 0$, the secondary market equilibrium does not reflect all information available, and thus knowing $\Xi_{t,1}$ is not enough to correctly predict $\ln \sigma_t$ or $\Xi_{t,1} \subsetneq \Xi_{t,1} \cup S_t = \Xi_{t,2}$, and $\ln \sigma_t$ is not $\Xi_{t,1}-$measurable. Thus, by signing loan contracts at time t based on $\Xi_{t,1}$ implies, in the next period, (i) a revaluation $(V_{t+1}^{mtm}(\Xi_{t,2})) - V_t^0(\Xi_{t,1})) \neq 0$ is expected and (ii) the secondary market valuation $V_t^{mtm}(\Xi_{t,1})$ does not fully reflect all information and thus the value at maturity is expected to change and $(V_t^F(\Xi_{t,2}) - V_t^{mtm}(\Xi_{t,1})) \neq 0$.

This highlights the interaction between secondary and primary markets at period t. If the information is not fully revealed in the secondary market, the primary market also operates under the same restriction and thus newly signed contracts are incorrectly priced. Even the banker who has received the signal undertake these incorrectly priced contracts. While evaluating whether it is optimal to hide the signal or not the banker internalises that newly signed contracts may not reflect the full information but also incorporates the future known (to them) adjustment on these newly signed contracts including their estimated revaluations.

Simply combining propositions 2 and 3 we obtain the following corollary,

Corollary 1. *Bankers then are willing to set* $\lambda = 0$ *if and only if*

$$
\begin{aligned}
J_t^B(\Xi_{t,1}, S_t) \quad - \quad & J_t^B(\Xi_{t,2}) + \qquad\qquad (21)\\
= \quad & \underbrace{(1-\alpha\beta)(V_t^0(\Xi_{1,t}) - V_t^0(\Xi_{2,t}))}_{\textit{Relative Valuation under primary markets}} + \underbrace{(1-\alpha\beta)(V_t^{mtm}(\Xi_{t,1}) - V_t^F(\Xi_{t,2}))}_{\textit{Relative Valuation under MTM vs maturity}} + \\
+ \quad & \underbrace{\alpha\beta(V_{t+1}^{mtm}(\Xi_{2,t}) - V_t^0(\Xi_{2,t}))}_{\textit{Future Adjustment under Partial Information}} + \underbrace{\alpha\beta E({J^P}_{0,t+1} - J_{0,t+1}^F)}_{\textit{Continuation Value}} > 0
\end{aligned}
$$

In order to characterized the key properties of the trade-off in place in the bankers decision to reveal or not the signal without fully determining the general equilibrium, which can only be done numerically, we make the following assumptions.[22]

Assumption 1. *Fluctuations in the price of capital (q_t) due to changes in riskiness are of second order comparing to changes in total investment Υ_t, the cutoff point ϖ_t and the payoff functions $g(\varpi_{t,j}; \sigma_{t+1})$, $f(\varpi_{t,j}; \sigma_{t+1})$.*

Assumption 2. *A small fraction (less than %50) of entrepreneurs default in equilibrium. As such, the loan contract cutoff point (ϖ) is below the average return on projects, thus* $\ln(\mu_\omega) - (\tilde{\sigma})^2/2 - \ln(\tilde{\varpi}) > 0$.

Assumption 3. *Raising loan interest rates (higher ϖ_t in newly signed contracts) offsets the positive effect of the fatter right tail in the distribution of ω when σ_{t+1} increases such that the expected returns to entrepreneurs (given by $f(\varpi_t; \sigma_{t+1})$) does not increase.*

[22] These are not restrictive and hold for all numerical simulations under our calibration.

Under these assumptions each of the four elements of (21) can be characterised in the following three propositions (proofs are provided in the Appendix B). The first proposition looks at the relative gain/loss from keeping mark-to-market valuation higher (term *Relative Valuation under MTM vs maturity*) and shows that partial revelation increases bankers' payoff only when an adverse shock is signalled.

Proposition 4. *Under assumption 1 and 2, the term* Relative Valuation under MTM vs maturity *in* (21) *is positive when* $E\{\ln \sigma_t \mid \Xi_{t,1}\} < E\{\ln \sigma_t \mid \Xi_{t,2}\} = \ln \sigma_t$ *and negative otherwise.*

The second proposition looks at the differences between signing new loan contracts under full information $V_t^0(\Xi_{2,t})$ and under partial information $V_t^0(\Xi_{1,t})$ and shows partial revelation increases bakers payoff only when an adverse shock is signalled. The key driver of this result is that under higher risk, leverage and investment are lower and thus profits of banks from lending decrease.

Proposition 5. *Under assumption 1, 2, and 3 the term* Relative Valuation under primary markets *is positive only when* $E\{\ln \sigma_t \mid \Xi_{t,1}\} < E\{\ln \sigma_t \mid \Xi_{t,2}\} = \ln \sigma_t$.

Finally, when bankers are restricted to offering optimal loan contracts that maximises entrepreneurs expected returns at time t then future adjustments can only be negative, thus expected adjustment to the detriment of entrepreneurs are unfeasible. Moreover, the *Continuation Value* can only be negative since they depend on banking capital, which get more severely depleted under partial information. Hence,

Proposition 6. *The terms* Future Adjustment under Partial Information *and* Continuation Value *are non-positive.*

Combining Propositions 4, 5 and 6 we have that if partial revelation implies $E\{\ln \sigma_t \mid \Xi_{t,1}\} > E\{\ln \sigma_t \mid \Xi_{t,2}\} = \ln \sigma_t$, or if a benign shock that decreases risk is overlooked, then $J_t^B(\Xi_{t,1}, S_t) - J_t^B(\Xi_{t,2}) < 0$ (all four terms are smaller or equal to zero). Thus, bankers never find it optimal to partially reveal a beneficial signal. Good news increases asset prices today, immediately increasing payoffs, thus bankers that care more about short-term gains are willing to reveal the signal. In contrast, if bankers receive an adverse signal, they might find it optimal to refrain from going short in the secondary market and revealing the signal ($J_t^B(\Xi_{t,1}, S_t) - J_t^B(\Xi_{t,2}) > 0$) such that, at equilibrium, $E\{\ln \sigma_t \mid \Xi_{t,1}\} < E\{\ln \sigma_t \mid \Xi_{t,2}\} = \ln \sigma_t$. This occurs when by not revealing information bankers' short-term gains from postponing mark-to-market losses in secondary markets and sustaining robust profits in primary markets (second and first terms, respectively in (21)) are bigger than the discounted future adjustment due to mispricing in the primary markets (third term) and losses due to a decrease in banking capital (forth term). The trade-off in place in the informed bankers decision to reveal or not the signal is hence evident and depicted in Figure 2. On the one hand not revealing adverse information leads to short-term mark-to-market gains, which increase with the size of the bank's balance sheet. On the other hand, revealing the signal avoids future expected losses due to incorrectly pricing of newly signed loan contracts and further long-term losses due to depleted banking capital, which increase with the size of the primary market.

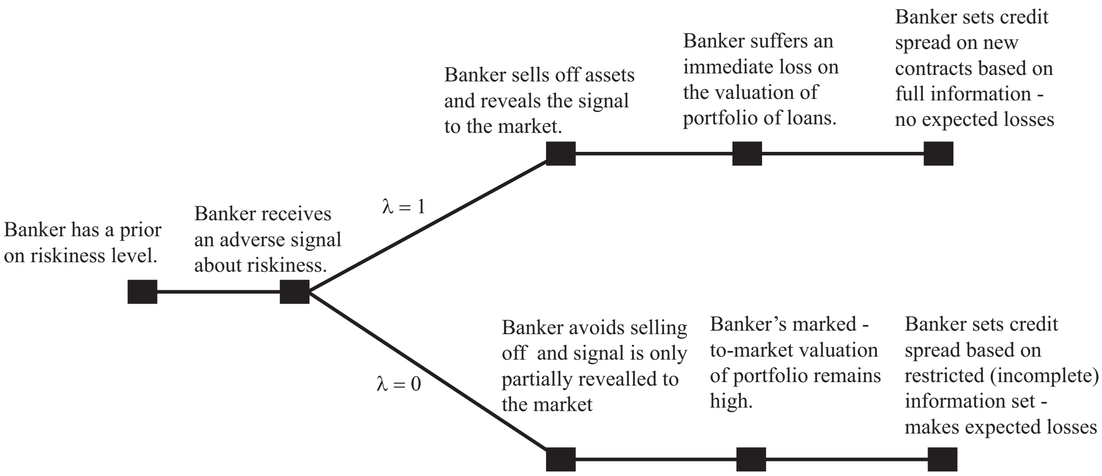

Figure 2: Banker's trade-off after adverse signal

After adverse shocks, given that the first two terms in (21), which are positive, increase as α decreases, and in the limit the two non-positive terms approach zero as α decreases, an important corollary of Propositions 4 - 6 describes how $J_t^B(\Xi_{t,1}, S_t) - J_t^B(\Xi_{t,2})$ varies with α. That is

Corollary 2. *After an adverse shock,* $J_t^B(\Xi_{t,1}, S_t) - J_t^B(\Xi_{t,2}) > 0$ *if* $\alpha = 0$. *Then if for some* $0 < \tilde{\alpha} \leqslant 1$, $J_t^B(\Xi_{t,1}, S_t) - J_t^B(\Xi_{t,2}) < 0$, *then there is a* $0 \leqslant \alpha_{lim} < \tilde{\alpha} < 1$ *such that for any*

$\alpha \leqslant \alpha_{lim}$, $J_t^B(\Xi_{t,1}, S_t) - J_t^B(\Xi_{t,2}) \geqslant 0$ *and* $\lambda^* = 0$ *and for* $\alpha > \alpha_{lim}$, $J_t^B(\Xi_{t,1}, S_t) - J_t^B(\Xi_{t,2}) < 0$ *and* $\lambda^* = 1$.

In other words, the greater the bias in the bankers' payoff structure towards short-term gains, or the smaller α, the greater the importance of short-term gains (*Relative Valuation under primary markets* and *Relative Valuation under MTM vs maturity*) compared to future losses (*Future Adjustment under Partial Information* and *Continuation Value*), increasing the incentives for bankers to avoid actively attempting to trade credit assets and revealing information to markets (setting $\lambda = 0$). Therefore, the greater the short-term bias, the higher the possibility an adverse shock leads to the mispricing of credit.

An important element of the mechanism is that when information is not revealed in the secondary market, the primary market also functions under the same information restriction. We already established that the bankers who have the information and decided to conceal it, find it optimal not to use it in the primary market since that would signal the information to the 'credit market' as a whole in the same way as going short in the secondary market would. As such, the bankers who find it optimal not to sell off credit in the secondary market after an adverse signal, also refrain from changing the terms of new loan contracts in the primary market to reflect the actual level of risk.[23] How about entrepreneurs, would they accept a loan contract set under limited information ($E[\ln \sigma_t \mid \Xi_{t,1}]$), since they know the true risk level (σ_t)? As only adverse shocks are partially revealed and given the limited liability nature of the loan contract, entrepreneurs are better off under a contract set based on a distribution with lower risk than warranted. Such contract prescribes higher investment and lower fixed interest rate and although default becomes more likely, conditional on not defaulting, entrepreneurs profits are amplified. Thus, entrepreneurs have no incentive to reveal the additional information in the primary market either.

Given the no trade theorem, informed bankers cannot make profits by selling baskets of loans to uninformed bankers. We modify the secondary market of the model, building on the trading model of Easley and O'Hara (1987), to consider a case where trading occurs

[23] In short, bankers recognize the risks but do not go against the market. This is somewhat similar to the situation described by the former CEO of Citigroup in 2007, "as long as the music is playing, you've got to get up and dance" - The Financial Times (2007)

at equilibrium. A detail exposition of this extension is provided in the Appendix F. We show that under this new specification, the condition that determines partial revelation of information in the secondary market now includes an additional term that depends on gains from trading, pushing bankers towards trading and revealing information relative to our benchmark model.

4 Calibration and Computational Method

We first discuss the rationale behind the main parameters used in the simulations and then consider the issues regarding the computational method. Each period in the model represents a quarter and thus we set $\beta = 0.99$, implying an annual rate of interest of roughly 4%. $\nu_1 = \nu_2 = 1$, implying a log utility on consumption and a Frisch elasticity of labor of 1. The production technology is assumed to be Cobb-Douglas with a capital share of 0.36. The depreciation rate (d) is set to 0.025. Finally we set the habits in consumption parameter to be $b = 0.75$ (as in Christiano et al. (2014)) and the elasticity to changes in utilization (σ_a) to 0.01 (as in Christiano et al. (2005)).[24]

CF(1997) claim δ, the parameter controlling liquidation costs, should be in the range of 0.2 to 0.36. They set it to 0.25. Christiano et al. (2014) in a model similar to ours, estimated it to be equal to 0.21. We follow their work and set $\delta = 0.21$. We set $\bar{n}$ and $\bar{\Omega}$, the new equity investment of households to entrepreneurs and banks to be 7.5% of the entrepreneurs' steady state networth and 7.5% of bank capital, ensuring the leverage constraint binds and entrepreneurs require external funding at the equilibrium. The key parameters left then are the ratio of total investment that is internally financed (n/Υ), the mean of the distribution of entrepreneurs' returns (μ_w), the steady state value of risk (σ_{SS}), and Z_s, the variance of the risk shock (ε^S). Christiano et al. (2014) separate shocks to risk to be anticipated and unanticipated, with standard deviations estimated to be equal to 0.028 and 0.07, respectively. Given that we do not do this differentiation, we set the variance of the risk shock as the sum of both of these orthogonal shocks used in their framework, thus $Z_s = (0.0754)^2$. Under our calibration an increase in σ due to a one standard deviation shock increases the default rate

[24]We discuss the effects of altering these two parameters when we present the results.

by one percentage point. The degree of internal finance is set to match quarterly bankruptcy rates in the US. While *CF(1997)* set this rate to be equal to 1% and Christiano et al. (2014) estimate it to be 0.54%, we observe that the average delinquency rate of total loans and leases at commercial banks provided by the Federal Reserve Bank is around 3.5%. In fact Christiano et al. (2014) show that although in their model movements in default rates track well empirical delinquency rates, model estimates are systematically lower. As we intend to use movements in delinquency rates to back-out the disturbances of σ during the last crisis we set the bankruptcy rate at steady state to 3.5%. As a result the share of internal funds in total investment is set to 35% (under the *CF(1997)* calibration that is equal to 38%). μ_ω, the mean return from entrepreneurs' projects, is normally set to 1. However, as we allow banks to have some bargaining power, extracting a portion of returns from the projects we set $\mu_\omega = 1.015$, and as such the internal rate of return for entrepreneurs is around 5% (close to the one set by *CF(1997)*). Regarding σ_{SS}, Christiano et al. (2014) estimate it at 0.26, while *CF(1997)* set it equal to 0.207. Given that we increase the bankruptcy rate relative to those studies we select the lower value used in *CF(1997)*, thus $\bar{\sigma} = 0.207$, but test the robustness of our results by altering its value.[25]

Finally, given that we modify the banking sector to include bank profits, banking capital and leverage we need to set parameters $\bar{\chi}$, which controls profits at steady state, $\bar{\varphi}$, which controls the leverage ratio, as well as ϕ_χ and ϕ_{LT}, which control the change in profitability during the business cycle and the change in leverage ratio as a function of risk. Financial Business Profits reported in the Federal Reserve Flow of Funds database during the last decade were on average roughly equal to 2.5% of the GDP. We set $\bar{\chi}$ to match this statistic. Leverage of commercial banks have been around 12 to 14 during the period 2000-2007 but decreased to 9 after the crisis (see Kalemli-Ozcan et al. (2012)). We set leverage at the steady state to be equal to 12, the lower bound of the estimated values for commercial banks before the crisis. Finally, we set (*i*) $\phi_\chi = 1.5$, implying that after a benign (decrease in σ) one standard deviation shock, GDP increases and the ratio of profits over GDP increases 0.05 percentage points (from 2.5% to 2.55%)[26]; (*ii*) $\phi_{LT} = 4$, implying that after a standard

[25] Note that the higher σ_{SS}, the higher the credit spread will be at steady state.

[26] Note that the correlation between the change of financial business profits and real GDP in the U.S. is strongly positive (around 60% in the last decade).

Table 1: Calibration Parameters

Parameter	Value	Target/Source
Time Discount Factor	$\beta = 0.99$	Standard Value
Frisch elasticity of labor	$\nu_2 = 1$	Standard Value
Share of Capital	$\xi_k = 0.36$	Standard Value
Habits in consumption	$b = 0.75$	Christiano et al. (2014)
Changes in utilization	$\sigma_a = 0.01$	Christiano et al. (2005)
Liquidation costs	$\delta = 0.21$	Christiano et al. (2014)
New equity entrepreneurs	$\bar{n} = 0.075 n_{SS}$	Standard Value
New equity bankers	$\bar{\Omega} = 0.075\Omega_{SS}$	Standard Value
Variance of risk shock	$Z_s = (0.0754)^2$	Christiano et al. (2014)
Mean Return	$\mu_w = 1.05$	Delinquency Rate (FED) = 3.5%
Steady state value of risk	$\sigma_{SS} = 0.207$	CF(1997)
Leverage at the steady state	$\bar{\varphi} = 12$	Kalemli-Ozcan et al. (2012)
Profits at steady state	$\bar{\chi} = 0.3$	Financial Business Profits (FED) = 2.5%
Cyclical Profits	$\phi_\chi = 1.5$	Profits over GDP increases 0.05 percentage
Cyclical Leverage	$\phi_{LT} = 4$	Leverage increases by 2%

deviation shock, leverage increases by 2%.[27] We provide a sensitive analysis on these for parameters while discussing the main results. The table 1 shows the calibrated parameters.

The main computational challenge we face is to account for the two different information sets in the solution methodology. As shown in the Appendix A, after log-linearization, the system of equations can be represented in matrix form by

$$\mathcal{E}[\alpha_0\Psi_{t+1} + \alpha_1\Psi_t + \alpha_2\Psi_{t-1} + \beta_0 s_t + \beta_1 s_{t+1}] = 0 \tag{22}$$

where Ψ_t is the vector of endogenous variables and $s_t = [\hat{\sigma}_t \quad \hat{\sigma}_t^{mtm}]^T$, where we define $\ln \sigma_t^{mtm} = E[\ln \sigma_t | \Xi_{t,1}]$, is the vector of shocks (both in deviations to the steady state). Although (22) is in the standard format after applying a simple pertubation method (see for instance Fernandez-Villaverde et al. (2016)), the expectation operator $\mathcal{E}$ is non-standard since it involves two traditional expectation operators, one in which the information set is $\Xi_{t,1}$ and one in which the information set equals $\Xi_{t,2}$.

Christiano (1998) presents a perturbation method that can accommodate for different information sets within (22). The main methodology described in Christiano (1998) focuses on the case where $\Xi_{t,2}$ would include the shock (information) of period t and $\Xi_{t,1}$ would

[27] Adrian and Shin (2010) report a positive correlation between asset and leverage growth for commercial and investment banks, although they do not provide exact statistics we could use to improve calibration.

include the shock (information) of period $t-1$. Our case is slightly more complex since both information sets describe information (partially or fully) about the shock in period t and are related to the information set $\Xi_{t-1,2}$ (the full realization of the shock in the previous period). Nonetheless, the standard methodology in Christiano (1998) can be adapted such that a subset of the vector of endogenous variables (Ψ_t) does not react to $\hat{\sigma}_t$ ($\Xi_{t,2}$), but only reacts to $\hat{\sigma}_t^{mtm}$ ($\Xi_{t,1}$). The details are discussed in the Appendix C.

5 Partial Information Revelation, Mispricing and its Aftermath

In this section we present the numerical results. We first analyse how an economy responds to σ_t shocks derived from the last cycle during the period 2002 - 2009, contrasting the case where partial information revelation in secondary markets occurs and the full information case. For this analysis we consider two values of α, a low value for which after an adverse shock, $\lambda^* = 0$ is optimal and a high value for which $\lambda^* = 1$ is optimal. In the following subsection we look closer at the role of short-term bias in bankers' payoffs. By focusing on the value of α for which bankers are indifferent between setting $\lambda^* = 0$, or 1, we identify the different economic conditions that favour instances of imperfect aggregation of information. We finalize this section by assuming a process for α and analysing the effects of partial revelation and mispricing of credit on the volatility of the main macroeconomic variables.

5.1 Boom, Bust and Crisis

Our focus here is to study the business cycle dynamics after a sizable adverse shock. Figure 3 presents the impulse responses of a boom, described as three consecutive periods of positive shocks that lead default rates to decrease to around 1.5%, followed by a strong adverse shock that pushes the default rate to about 8%, matching the FED data on delinquency rates during the period 2002 - 2009 (see the graph on the bottom left corner of Figure 3). We compare two cases, one (straight line - Full Information) in which bankers fully participate in secondary markets and all signals are revealed to the 'market' ($\lambda^* = 1$) and one in which when an adverse shock is received, bankers find optimal to set $\lambda^* = 0$, and thus partial revelation occurs (dotted line with circles - Partial Revelation).[28]

In an economy where the equilibrium in the secondary markets incorporates all information, agents are aware that entrepreneurs' projects become riskier in period 4, when the adverse shock is revealed. Therefore, the loan contracts signed in the primary market, at stage 1 in that period, prescribe higher credit spreads, lower total credit, and hence, total investment decreases. Bankers, recognizing the greater uncertainty, lower leverage ratios.

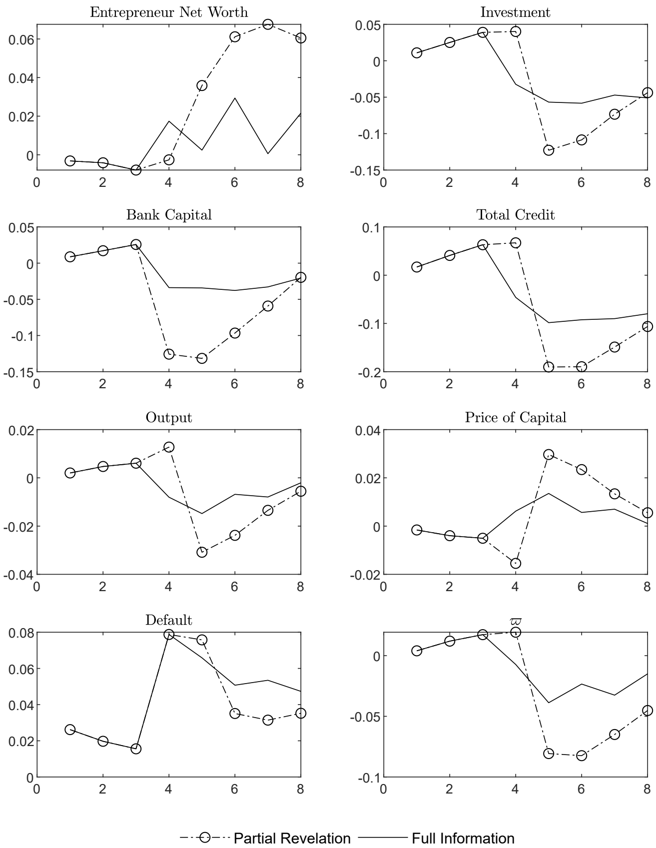

Figure 3: Boom and bust in the presence of partial information revelation

Note: Impulse Responses of a boom (three consecutive periods of positive shocks with default rates decreasing to 1.5%), followed by a strong adverse shock (default rate increases to 8%). We compare two cases, 1) straight line - Full Information ($\lambda^* = 1$) and 2) dotted line with circles - Partial Revelation ($\lambda^* = 0$)

Although the default rate increases substantially in period 4, bankers are from then on prepared, having increased spreads to cover for any potential losses. Banking capital, therefore,

[28] Therefore, for the first case we set α high enough such that bankers attempt to sell-off assets and in the second case we fix α such that after the adverse shock bankers find it optimal to avoid selling off in the secondary market of credit, setting $\lambda^* = 0$. Not that even when bankers (Player 1) set $\lambda^* = 0$, due to the Bayesian updating done by 'market' (Player 2) some information is revealed into prices in the PBE equilibrium, thus signals are never completely ignored. For all simulations we set $p_\iota = 0.5$.

decreases only due to effect of the unanticipated risk shock on maturing contracts. Despite the fact that we have introduced a significant adverse shock we are not able to replicate a deep recession that is otherwise observed under a credit crisis. In short, if banks are aware of the potential risks and take them into consideration, then one is not able to replicate a credit crisis with a standard model of imperfect credit markets with risk shocks alone.

In contrast, when bankers refrain from going short in the market such that adverse signals are not revealed in the secondary market during the first stage of period 4, mark-to-market valuations display a bias towards benign expectations of continued low uncertainty of entrepreneurs' projects. As such, new loan contracts signed in the primary market charge too low credit spreads and leverage ratios are maintained too high considering the actual lending risk. Under this scenario, total credit and output continue to increase reaching even higher levels than the ones observed after three periods of consecutive positive shocks.

The two main reasons output continues to grow are, first, that entrepreneurs, who draw a favorable realization on the project undertaken and do not default, benefit from lower credit spreads and are expected to obtain higher returns from investment. Second, higher investment than it is warranted under the new uncertainty level (overinvestment) depresses the price of capital, decreasing the funds needed for households to save in physical capital. In turn, this boosts consumption without depressing labour supply, as wages also increase. Finally, variable capital utilization amplifies the output response to these instances of overinvestment.[29] Thus, the mispricing of credit risk resulting from secondary market dysfunction boosts output, although default increases substantially in the same period.

The period following the boom sees a dramatic drop in total credit. Banks are left with depleted balance sheets, with lower capital resulting from the effects of unexpected losses, which are boosted by incorrect risk assessment. That implies firms are not able to raise funds, investment falls significantly, leading to a deep recession. Output remains low in the subsequent periods as banking capital recovers to its full information level. Despite the

[29]To illustrate the role of capital utilization changes in amplifying output fluctuations we plot the response to an adverse shock under full information for our benchmark economy and one in which capital utilization is fixed. As shown by Christiano et al. (2014), risk shocks are important drivers of business cycles since they affect the marginal efficiency of investment. Variable capital utilization then increases the elasticity of output to a shock since it allows for an additional channel of adjustment (although King and Rebelo (1999) employ a standard RBC model, they also find variable capital utilization increases the responses of output to a shock). Results are shown in the Appendix G.

increase in uncertainty over entrepreneurs' projects, the sizeable drop in credit observed is clearly due to supply problems. Banks are not prepared to extend credit given their weakened balance sheets.

Despite some initial controversy, it is undoubted that we observed a credit crunch after 2007. Different indicators highlighting the sharp decrease in credit could be used: one is the volume of outstanding Commercial Papers (CP) in the U.S. (FED Statistical data); from the peak of the credit cycle (mid 2007) till the end of 2009 the volume of CP outstanding fell by 60%. Another indicator is the volume of new syndicated loans to large borrowers. Ivashina and Scharfstein (2010) report that this volume fell by 79% from the peak to the bottom of the credit cycle. They show that banks that were more heavily exposed to failure/default reduced their lending to a greater extent, demonstrating that balance sheet weakness was particularly important. Finally, Cornett et al. (2011b) show that banks that held more loans, mortgage-backed and asset-backed securities tended to decrease investment in loans and new commitments to lend more significantly since these assets were more likely to decrease in value and lead to future balance sheet shortages. Our results are in line with these accounts, since the sharp drop in credit is predominantly supply driven with banks' balance sheets becoming weaker due to the mispricing of the risk of default.

The behaviour of the economy pre and post-bust described here matches closely to the one depicted in Reinhart and Rogoff (2008). Firstly, we observe the clear inverted v-shape in output with the peak at the period before the bust. Note that the clear v-shape dynamics would only occur under partial revelation, and the increase in output due to lower credit spreads is substantial.[30] Secondly, both credit spreads (implied by the inverse of ϖ) and the price of capital are at their lowest in the period preceding the credit crunch, as such both credit and equity prices (linked to the potential gain from buying and operating capital) are at their highest.

An important characteristic that emerges from our model is that output starts recovering in period 6 (period after the crash) although total credit still remains as low as in the previous period. That occurs since entrepreneurs accumulate internal funds as their returns

[30] The pattern, mispricing of risk leading to a boom and a subsequent recession, obtained here does not depend on the initial series of positive shocks adopted in this simulation. The boom-bust is also observed when we have an economy initially at steady state in which partial revelation occurs (See Figure A.2).

from investment increases. Hence, after a strong credit crisis, investment and output recovery is creditless, relying on firms' accumulation of networth. Abiad et al. (2011) report that creditless recoveries do often occur and are more common after banking crises and credit booms, since impaired financial intermediation seems to be the key factor behind it. Furthermore, data from the FED Flow of Funds support this finding. The holdings of liquid assets by corporations have increased by 27% from 2007 to 2011.

Default leads to bank's balance sheet weakness due to the fact that risk was effectively mispriced following the interplay between secondary and primary markets where prices did not incorporate all information available. As discussed in the introduction, there is evidence indicating that the market prices may not fully reflect the risks based on information that was potentially available at the time.[31] If markets correctly price the probability of default on entrepreneurs' projects then fluctuations in σ would not have resulted in the amplified volatility we obtained. This excess volatility is driven by the failure of markets to correctly reflect all information available. Partial information diffusion is a result of the optimal decision of agents who refrain from selling off and revealing their information when their payoff structure is biased towards mark-to-market valuations.[32] Hence, we do not rely on 'probability zero' aggregate shocks to deliver a crash.

We perform a series of robustness exercises, varying the core parameters of the benchmark model and analysing boom and busts in two model extensions, one in which loan contracts have greater maturity and one in which banking leverage is endogenous. The pattern of boom, generated by low credit spreads and overinvestment, and bust, due to credit supply problems, remain in all specifications. Details are provided in the Appendix G.

5.2 Short-term Bias and Partial Revelation

In the previous section we show that partial information revelation (when $\lambda^* = 0$) is crucial in generating boom and busts. In section 3 we show that as we increase α, decreasing the degree of short-term bias in bankers' payoff, optimal signal revelation (λ^*) moves from zero

[31] See Coval et al. (2009) and Ivashina and Sun (2011) for evidence that suggests that information flows across markets/participants is imperfect.

[32] Even when some investors go short, revealing their information, core market makers/participants, with large balance sheets, fail to adjust and continue to operate under the status quo (see Lewis (2011)).

to one, with $J_t^B(\Xi_{t,1}, S_t) - J_t^B(\Xi_{t,2})$ becoming negative as α increases. We can also determine the cut off point (α_{lim}) such that bankers are indifferent between setting $\lambda = 0$ or $\lambda = 1$, or when $J_t^B(\Xi_{t,1}, S_t) - J_t^B(\Xi_{t,2}) = 0$. To illustrate the importance of the short-term bias in the payoff structure of banks for the mechanism that generates boom and busts, in figure 4 we show how $J_t^B(\Xi_{t,1}, S_t) - J_t^B(\Xi_{t,2})$ varies with α.[33] Thus, greater the short-term bias (the lower α), the more likely it is that partial revelation of information occurs.

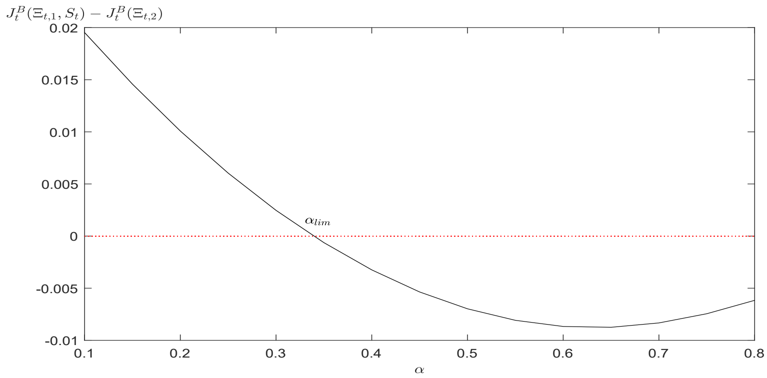

Figure 4: Signal Revelation and Short-term Bias

Note: The figure plots the difference between the bankers' payoff under partial and full information revelation ($J_t^B(\Xi_{t,1}, S_t) - J_t^B(\Xi_{t,2})$), for different degrees of short-term bias (α). When ($J_t^B(\Xi_{t,1}, S_t) - J_t^B(\Xi_{t,2})$) is positive, partial information revelation is optimal.

In our benchmark model entrepreneurs projects have a maturity of one period. We consider an extension (details are presented in the Appendix D) where at every period a project that is running has a probability of ζ of maturing. As such, the average duration of projects is $\frac{1}{\zeta}$. In figure 5 we look at the effect of increasing loan contract maturity on α_{lim}. We find that $\alpha_{lim} = 0.34$ for one quarter contracts ($\zeta = 1$) and $\alpha_{lim} = 0.65$ for the extension with one year loan contracts ($\zeta = 0.25$).[34] Thus, partial revelation of information is increasingly more likely to occur when long duration contracts are in place. The main reason for this result is that as we increase duration we are effectively increasing the banks' balance sheet holdings relative to the size of the primary market (which is related to investment, consumption and output at a quarterly frequency). As such, mark-to-market valuation of

[33] Note that positive values of $J_t^B(\Xi_{t,1}, S_t) - J_t^B(\Xi_{t,2})$ imply $\lambda^* = 0$. For high values of α, the relative weight on the immediate periods after mispricing, when banking capital is low, decreases, and thus the continuation values under partial (${J^P}_{0,t+1}$) and full information ($J^F_{0,t+1}$) become closer, such that $J_t^B(\Xi_{t,1}, S_t) - J_t^B(\Xi_{t,2})$, being still negative, increases slightly with α. Recall $E({J^P}_{0,t+1} - J^F_{0,t+1})$ is itself a non-linear function of α.

[34] We do not increase duration further since we assume that all information is fully revealed at the end of each period (a quarter). This assumption is questionable when longer-term contracts are in place. Altering this one period revelation feature of the model complicates substantially the solution method.

legacy assets gains importance relative to potential errors of mispricing of newly issued assets within the quarter. Note that even in the case of short-term contracts our results do not seem unreasonable in light of the empirical literature in banking CEO compensation. As previously discussed short-term payoffs may easily account for 70% of the total payoff of bank managers.

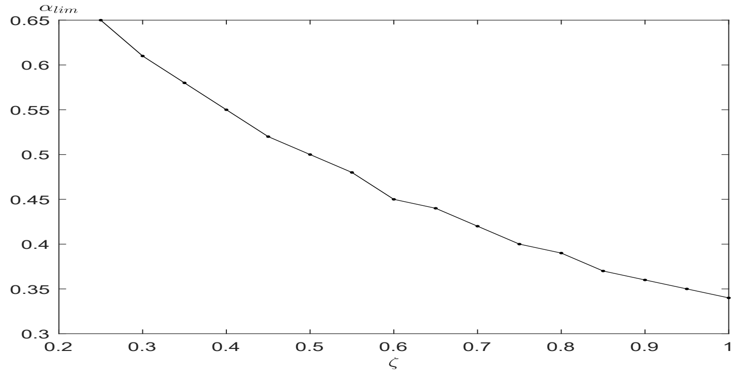

Figure 5: Loan Contract Maturity ($1/\zeta$) and α_{lim}

Note: The figure plots the cut-off point of the degree of short-term bias (α_{lim}) such that the bankers is indifferent between full and partial information revelation for different values ζ. The implied loan contract maturity in quarters is given by $1/\zeta$. Higher levels of α_{lim} imply partial revelation is more likely to occur.

Next we calculate α_{lim} for different specifications of the model (Results are shown in table 2), first varying the set of parameters that influence the loan contract signed between entrepreneurs and banks, $\varrho = \{\chi, \phi_\chi, \varphi, \phi_{LT}, \sigma_{SS}\}$ (first two rows in table 1, one for $\zeta = 1$ and one for $\zeta = 0.25$). We start by looking at the effect of altering the variables that affect the steady state of the economy. We find that α_{lim} increases when profitability, leverage and variance of returns are greater. In all these cases it is more likely that given a shock, bankers short-term gains are relatively higher than future losses.

Table 2: α_{lim} for different specifications and structural parameters

	Benchmark	$\bar{\chi}$ (Bank Profits)	$\bar{\varphi}$ (Leverage)	σ_{SS} (Var. Ret.)	Φ_χ	Φ_{LT}
$\alpha_{lim}(\zeta = 1)$	0.34	0.36	0.38	0.41	0.35	0.30
$\alpha_{lim}(\zeta = 0.25)$	0.65	0.67	0.69	0.72	0.66	0.61
	With trading μ_1=0.05, μ_2=0.35, $\frac{Q}{\Upsilon}$=0.01	Higher volume μ_1=0.05, μ_2=0.35, $\frac{Q}{\Upsilon}$=0.05	Less informed traders μ_1=0.05, μ_2=0.5, $\frac{Q}{\Upsilon}$=0.01	More noise traders μ_1=0.55, μ_2=0.165, $\frac{Q}{\Upsilon}$=0.01		
α_{lim}	0.31	0.21	0.28	0.31		

Note: This table reports the cut-off point of the degree of short-term bias (α_{lim}) for different model specifications. First line looks at the benchmark model under different structural parameters, increasing each parameter of interest by 20%, and the second line presents the model extension with trading at equilibrium.

We now focus on the elasticity variables (two last columns of row one and two in Table 2) since those might be important for the design of counter cyclical policy. We start by looking at the effect of variations of profits across the business cycle (controlled by parameter ϕ_χ). We find that the greater this parameter is, the higher α_{lim} will be. If profit margins are greater when the economy is performing well, acknowledging an adverse signal has not only an impact on profits due to the reduction in total amount of lending but also on the amount of profits generated for each loan executed, thus $(V_t^0(\Xi_{t,1}) - V_t^0(\Xi_{t,2}))$ tends to the bigger. Future losses also increase since having lower banking capital in periods when output, and thus profit margin, is lower hurts future profitability. Nonetheless, short-term effects are stronger such that the incentive to refrain from revealing information increases with the procyclicality of profits.

We initially set leverage to be sensitive to risk such that it increases 2% for a standard deviation shock (parameter ϕ_{LT}). Surprisingly, as we increase the sensitivity of the leverage ratio to an increase in uncertainty of entrepreneurs' projects, the less likely it is that partial revelation occurs. As expected, the loss from mispricing is higher, since, given the higher risk, banks would be forced to decrease leverage more abruptly and thus by not doing so they become more exposed to default risk. The losses due to lower banking capital also increase since banks are forced to restrict lending further while reducing leverage. However, as opposed to what one would expect, we do not observe an increase in short-term gains. While under partial revelation contracts signed in the current period deliver higher gains (more leverage), thus $(V_t^0(\Xi_{t,1}) - V_t^0(\Xi_{t,2}))$ is larger under higher ϕ_{LT}, the gains from postponing mark-to-market $(V_t^{mtm} - V_t^F)$ are in fact reduced. As risk increases, lower future leverage ratios imply lower future investment in capital formation, leading to an increase in the price of capital at time t. This asset price increase offsets lower (physical) returns on projects sustaining the overall profitability after a risk shock is fully revealed ($V_t^{mtm} = V_t^F$ is higher). As a result, postponing mark-to-market is not as attractive as before. As gains do not increase as much as losses, α_{lim} in fact decreases as leverage becomes more procyclical and partial revelation of signals is less likely to occur. We find a similar result when we compare the benchmark model with the model with endogenous leverage. The extension with endogenous leverage generates more volatile and procyclical leverage ratios as compared to the benchmark model and hence α_{lim} in this case decreases to 0.3. Finally, contrasting the first and second rows in table 2, we find that the sensitivity of α_{lim} to changing the parameters is similar for short ($\zeta = 1$) and longer-term loan contracts ($\zeta = 0.25$).

We now consider the impact of trading at equilibrium on the likelihood that partial revelation of information occurs (detail on the extension with bankers trading basket of loans at the equilibrium are presented in the Appendix E). Similarly to the benchmark model, we obtain α_{lim} such that informed bankers are indifferent between trading with market makers, exploiting informational advantages and revealing the signal or becoming market makers, being able to extract a spread from noise traders/bankers.

In addition to the four elements of the trade-off in the benchmark model, α_{lim} in this case is also impacted by the size of the *Gains from Trading vs Market Making (MM)*, which itself will depend on the share of informed bankers willing to buy/sell, noisy traders, the share of uninformed bankers at each period and the volume of trades allowed. We obtain α_{lim} when we set noise traders to be 5% of all bankers (μ_1), uninformed traders/market makers to be 35% of bankers (μ_2) and order size (Q) to be 1% of banks balance sheets. As expected α_{lim} decreases as the potential to exploit information advantages allow bankers to offset some of the mark-to-market losses while revealing the information. Results are displayed in row three of Table 2. We also report the effects of altering the shares of each banker type and increasing the order size to %5 of the balance sheet (note that in this case each market maker trades almost 10% of their balance sheet, using most of its buffer capital). The size of the *Gains from Trading vs MM* increases and α_{lim} decreases as the size order increases (*Higher Volume*), and as the share of informed bankers relative to market makers decreases (*Less informed traders*). In both of these cases informed bankers are able to sell (buy) a bigger share of their balance sheet when the signal is adverse (good). Keeping the ratio of uniformed and informed bankers constant, the importance of *Gains from Trading vs MM* increases as the share of noise traders increases (*More noise traders*). Under this case spreads are smaller, market making becomes a relatively worse business, and profits from informed trading increases, pushing informed bankers towards trading and revealing information.

Summarizing, as long as the share of noise traders are not substantial, new information is not concentrated on a small set of bankers, who can exploit many market makers, and order size is not a substantial fraction of bank's balance sheets, the incentive to maintain high mark-to-market valuation may lead to partial revelation of information and malfunction in credit markets, with informed bankers favouring market making activities instead of trading to exploit informational advantages.

5.3 Partial Information Revelation and Volatility

Having built a structural model we are able to generate simulated moments of the key macroeconomic variables resulting from a random series of shocks to the dispersion of entrepreneurs returns. The focus is on the relative change in volatility in the model economy where partial revelation may occur versus the full information case. As discussed in the previous section, episodes where prices in the secondary market of credit do not reflect full information are closely linked to periods in which the weight of short-term payments in bankers' payoff is higher (or α is lower). We therefore assume α follows different processes such that episodes of partial revelation occur at different frequencies.

We generally set $\alpha_0 = \alpha_t = 1.5(\alpha_{lim})$ if at $t-1$ partial revelation occurs, and $\alpha_t = \mathfrak{w}\alpha_{t-1} + (1-\mathfrak{w})\frac{1}{1+e^{-\phi_\alpha \hat{Y}_t}}$, where $\hat{Y}_t = \frac{Y_t - \bar{Y}}{\bar{Y}}$, otherwise. When markets malfunction α resets to a high value where full revelation occurs. In contrast, as long as markets function well, the greater the output deviations from steady state or the better economic conditions are, the more skewed towards short-term payments the payoff of bankers will be. Parameter ϕ_α controls the strength of this effect, the higher ϕ_α the more volatile is α_t. Moreover, by changing $\mathfrak{w}$ we alter the persistence of α_t.

Table 3: Relative Volatility and Partial Revelation in Secondary Markets

	$\phi_\alpha = 100, \mathfrak{w} = 0.5$ $\zeta = 1$	$\phi_\alpha = 200, \mathfrak{w} = 0.5$ $\zeta = 1$	$\phi_\alpha = 100, \mathfrak{w} = 0.8$ $\zeta = 1$	$\phi_\alpha = 100, \mathfrak{w} = 0.5$ $\zeta = 0.5$	$\phi_\alpha = 100, \mathfrak{w} = 0.5$ $\zeta = 0.25$
Consumption	1.009	1.013	1.005	1.012	1.001
Labor	1.014	1.021	1.006	1.023	1.011
Output	1.040	1.074	1.017	1.058	1.046
Investment	1.012	1.019	1.006	1.017	1.019
Bank Profits	1.043	1.086	1.016	1.099	1.171
Partial Inf.	3.8%	7.7%	1.5%	10.8%	24.0%

Note: This table reports the ratio of the volatility of the key economic variables under partial and full information revelations for different parameter specification using the benchmark model and the model with longer loan contract maturities.

Table 3 presents the results. For each simulation the ratio between the standard deviations obtained for the economy under (potential) partial revelation and full information is calculated. In the last line we show the percentage of periods for which bankers avoid going short in the credit markets such that partial revelation obtains. For our first specification with $\phi_\alpha = 100$ and $\mathfrak{w} = 0.5$ a signal is not fully revealed 3.8% of the times. These instances of partial revelation generate an increase of 4% in the standard deviation of output, 0.9% of consumption and 1.2% increase in the volatility of investment. As ϕ_α increases, the occurrence of partial revelation episodes increases, leading to higher volatility in all main macroeconomic variables. The opposite occurs when $\mathfrak{w}$ increases; α becomes less volatile such that $\alpha_t < \alpha_{lim}$ only in 1.4% of the time. Even in this case output volatility increases by almost 2%. Finally, we study the impact of increasing the duration of contracts. We find that partial revelation of information is more likely to occur, but when it does, given that a smaller share of assets is actually mispriced, output and investment volatility are relatively less responsive (this is a product of the assumption that information imperfection lasts only for one period).

6 Conclusion

We propose a macroeconomic model that explicitly allows for instances where prices do not reflect all information available to agents. Starting from a standard macroeconomic model with credit frictions, and augmenting it to consider trading and information revelation in the secondary markets of credit, we are able to generate instances where after an adverse shock the incentive to maintain mark-to-market valuation high leads to imperfect signal extraction such that the economy/market hangs onto the view that economic conditions are benign. Based on that, credit spreads are relatively low, loan volumes and asset prices high, leading the way to an economic boom. This process is characterized by the mispricing of default risk. Subsequently, when defaults do occur, banks are unprotected; losses lead to a significant decrease in banking capital and compromise the ability of banks to fund new investment. Output decreases sharply due to credit supply problems. This characterization matches closely to what we observe during banking crises.

The key mechanism to generate partial information revelation in markets is the decision of whether bankers should reveal their adverse signals or should avoid going short in the secondary market such that information does not flow to markets. Despite potential gains from trading and exploiting informational advantages, avoidance allow bankers to maintain the valuation of their balance sheet holdings high, increasing short-term gains. However, such strategy affects long-term profits negatively as loans in the primary market are priced based on a smaller information set. Analyzing the trade-off between these two off-setting incentives we obtain a few important results.

First we observe that market dysfunction is more likely to occur when banks have greater profit margin, higher average leverage and are unable to trade a significant portion of their balance sheet in the secondary market at once. Moreover, the more procyclical profits are and the more countercyclical leverage ratios are, the more likely it is that bankers may refrain from going short on credit and revealing signals. In all those cases the immediate loss in acknowledging worsening economic fundamentals is more relevant than the potential future losses due to mispricing of credit risk. Finally, we show that instances of imperfect information aggregation lead to an increase in the volatility of the main macroeconomic variables.

The payoff structure that generates the incentive to avoid selling off in the secondary markets upon receiving signals is directly related to the biases towards short-term mark-to-market gains relative to realized payoffs in the banking industry. The CEO compensation numbers reported by Fahlenbrach and Stulz (2011) indicate a banking payoff structure heavily tilted towards short-term payments and thus payoff functions with $\alpha < 0.3$ seem to be the current norm in the industry. As such, our framework assumes the short-term bias as given. Analyzing the drivers that generate such payoff structure, potentially exploring both bankers tenure relative to the maturity of banks' portfolios and the agency problems of writing contracts on imperfectly observed performance measures (see Baker et al. (1994) and more recently Plantin and Tirole (2018)) could further increase our understanding of how imperfect information revelation and mispricing of risk occurs.

References

Abiad, A., B. G. Li and G. Dell'Ariccia (2011). *Creditless recoveries,* IMF Working Paper 11/58, International Monetary Fund.

Adam, K., and A. Marcet (2011). "Internal rationality, imperfect market knowledge and asset prices", *Journal of Economic Theory*, 146(3), pp. 1224-1252.

Adrian, T., and H. S. Shin (2010). "Liquidity and leverage", *Journal of Financial Intermediation*, 19(3), pp. 418-437.

Akerlof, G. A., and R.J. Shiller (2009). *Animal Spirits: How Human Psychology Drives the Economy, and Why It Matters for Global Capitalism,* Princeton University Press.

Allen, F., A. Babus and E. Carletti (2009). "Financial crises: Theory and evidence", *Annual Review of Financial Economics*, 1(1), pp. 97-116.

Baker, G., R. Gibbons and K. J. Murphy (1994). "Subjective performance measures in optimal incentive contracts", *The Quarterly Journal of Economics*, 109(4), pp. 1125-1156.

Bénabou, R. (2013). "Groupthink: Collective Delusions in Organizations and Markets", *Review of Economic Studies*, 80(2), pp. 429-462.

Bernanke, B. S., M. Gertler and S. Gilchrist (1999). "The financial accelerator in a quantitative business cycle framework", in J. B. Taylor and M. Woodford (eds.), *Handbook of Macroeconomics*, Vol. 1, Chap. 21, Elsevier, pp. 1341-1393.

Bloom, N., M. Floetotto, N. Jaimovich, I. Saporta-Eksten and S. J. Terry (2014). *Really Uncertain Business Cycles,* Working Papers, No. 14-18, Center for Economic Studies, U.S. Census Bureau.

Boissay, F., F. Collard and F. Smets (2016). "Booms and Banking Crises", *Journal of Political Economy*, 124(2), pp. 489-538.

Bolton, P., H. Mehran and J. Shapiro (2015). "Executive Compensation and Risk Taking", *Review of Finance*, 19(6), pp. 2139-2181.

Bolton, P., T. Santos and J. A. Scheinkman (2016). "Cream-Skimming in Financial Markets", *Journal of Finance*, 71(2), pp. 709-736.

Borio, C. (2014). "The financial cycle and macroeconomics: What have we learnt?", *Journal of Banking & Finance*, 45(C), pp. 182-198.

Brunnermeier, M. K., and Y. Sannikov (2014). "A Macroeconomic Model with a Financial Sector", *American Economic Review,* 104(2), pp. 379-421.

Carlstrom, C. T., and T. S. Fuerst (1997). "Agency costs, net worth, and business fluctuations: A computable general equilibrium analysis", *American Economic Review*, 87(5), pp. 893-910.

Chari, V. V., A. Shourideh and A. Zetlin-Jones (2014). "Reputation and persistence of adverse selection in secondary loan markets", *American Economic Review*, 104(12), pp. 4027-4070.

Christiano, L. J. (1998). *Solving Dynamic Equilibrium Models by a Method of Undetermined Coefficients,* NBER Technical Working Papers, No. 0225, NBER.

Christiano, L. J., M. Eichenbaum and C. L. Evans (2005). "Nominal rigidities and the dynamic effects of a shock to monetary policy", *Journal of Political Economy*, 113(1), pp. 1-45.

Christiano, L. J., R. Motto and M. Rostagno (2014). "Risk Shocks", *American Economic Review*, 104(1), pp. 27-65.

Cornett, M. M., J. J. McNutt, P. E. Strahan and H. Tehranian (2011a). "Liquidity risk management and credit supply in the financial crisis", *Journal of Financial Economics*, 101(2), pp. 297-312.

Cornett, M. M., J. J. McNutt, P. E. Strahan and H. Tehranian (2011b). "Liquidity risk management and credit supply in the financial crisis", *Journal of Financial Economics*, 101(2), pp. 297-312.

Coval, J. D., J. W. Jurek and E. Stafford (2009). "Economic catastrophe bonds", *American Economic Review*, 99(3), pp. 628-666.

Dasgupta, A., and A. Prat (2008). "Information aggregation in financial markets with career concerns", *Journal of Economic Theory*, 143(1), pp. 83-113.

DeLong, J. B. (2011). "Economics in crisis", *The Economists' Voice*, 8(2), p. 2.

Di Maggio, M., and A. Kermani (2017). "Credit-Induced Boom and Bust", *Review of Financial Studies*, 30(11), pp. 3711-3758.

Easley, D., and M. O'Hara (1987). "Price, trade size, and information in securities markets", *Journal of Financial Economics*, 19(1), pp. 69-90.

Fahlenbrach, R., and R. M. Stulz (2011). "Bank CEO incentives and the credit crisis", *Journal of Financial Economics*, 99(1), pp. 11-26.

Farhi, E., and J. Tirole (2012). "Collective Moral Hazard, Maturity Mismatch, and Systemic Bailouts", *American Economic Review*, 102(1), pp. 60-93.

Fernández-Villaverde, J., J. Rubio-Ramírez and F. Schorfheide (2016). "Solution and Estimation Methods for DSGE Models", in J. B. Taylor and H. Uhlig (eds.), *Handbook of Macroeconomics*, Vol. 2, *Handbook of Macroeconomics*, Chap. 0, Elsevier, pp. 527-724.

Fishman, M. J., and J. A. Parker (2015). "Valuation, Adverse Selection, and Market Collapses", *Review of Financial Studies*, 28(9), pp. 2575-2607.

Gale, D., and M. Hellwig (1985). "Incentive-compatible debt contracts: The one-period problem", *Review of Economic Studies*, 52(4), pp. 647-63.

Gertler, M., and N. Kiyotaki (2010). "Financial intermediation and credit policy in business cycle analysis", in B. M. Friedman and M. Woodford (eds.), *Handbook of Monetary Economics*, Vol. 3, Chap. 11, Elsevier, pp. 547-599.

Gilchrist, S., J. W. Sim and E. Zakrajsek (2014). *Uncertainty, Financial Frictions, and Investment Dynamics,* NBER Working Papers, No. 20038, NBER.

Gorton, G., and G. Ordóñez (2014). "Collateral Crises", *American Economic Review*, 104(2), pp. 343-378.

Grossman, S. J., and J. E. Stiglitz (1980). "On the Impossibility of Informationally Efficient Markets", *American Economic Review*, 70(3), pp. 393-408.

Ivashina, V., and D. Scharfstein (2010). "Bank lending during the financial crisis of 2008", *Journal of Financial Economics*, 97(3), pp. 319-338.

Ivashina, V., and Z. Sun (2011). "Institutional demand pressure and the cost of corporate loans", *Journal of Financial Economics*, 99(3), pp. 500-522.

Kalemli-Ozcan, S., B. Sorensen and S. Yesiltas (2012). "Leverage across firms, banks, and countries", *Journal of International Economics*, 88(2), pp. 284-298.

King, R. G., and S. T. Rebelo (1999). "Resuscitating real business cycles", in J. B. Taylor and M. Woodford (eds.), *Handbook of Macroeconomics*, Vol. 1, *Handbook of Macroeconomics*, Cahp. 14, Elsevier, pp. 927-1007

Kleinlercher, D., J. Huber and M. Kirchler (2014). "The impact of different incentive schemes on asset prices", *European Economic Review*, 68(C), pp. 137-150.

Lewis, M. (2011). *The Big Short: Inside the Doomsday Machine*, W. W. Norton.

Lo, A. W. (2008). *Hedge funds, systemic risk, and the financial crisis of 2007-2008. Written Testimony of Andrew W. Lo Prepared for the U.S. House of Representatives*.

Plantin, G., and J. Tirole (2018). "Marking to market versus taking to market", *American Economic Review*, 108(8), pp. 2246-2276.

Reinhart, C. M., and K. S. Rogoff (2008). "Is the 2007 us sub-prime financial crisis so different? an international historical comparison", *American Economic Review*, 98(2), pp. 339-344.

SEC - US (2008). *Report and recommendations pursuant to section 133 of the emergency economic stabilization act of 2008: Study on mark-to-market accounting,* United States Securities and Exchange Commission - Office of the Chief Accountant.

The Financial Times (2007). "Citigroup chief stays bullish on buy-outs", *The Financial Times,* 9 July.

Appendix A. Recursive Equilibrium

Formally, firms $\min_{K_t,H_t} W_t H_t + r_t^k u_t K_t$, subject to (1). We normalize and set the price of the final good to 1. The conditions that determine the wage W_t and the rental rate of physical capital r_t^k are

$$r_t^k = \frac{\xi_K Y_t}{u_t K_t}, \text{ and} \tag{A.1}$$

$$W_t H_t = \xi_L Y_t. \tag{A.2}$$

The households first order conditions are

$$\psi_t = (C_t - bC_{t-1})^{-\sigma} - \beta b E[(C_{t+1} - bC_t)^{-\sigma} | \Xi_{t,2}] \tag{A.3}$$

$$\psi_t = \beta E\left[R_{t+1,d}\psi_{t+1} | \Xi_{t,2}\right], \tag{A.4}$$

$$W_t = \varsigma \frac{N_t^{\nu_2}}{\psi_t}, \tag{A.5}$$

$$r_t^k = a'(u_t), \text{ and} \tag{A.6}$$

$$q_t = \frac{1}{R_{t+1,d}} E\left[r_{t+1}^k u_{t+1} + a(u_{t+1}) + (1-d)q_{t+1} | \Xi_{t,2}\right]. \tag{A.7}$$

Market clearing conditions: there are four markets in this economy: capital, consumption good, credit and labour markets. The labour market, capital and consumption good clearing conditions are stated below.[35] By Walras law credit markets will also clear.

$$H_t = (1-2\eta)N_t \tag{A.8}$$

$$\eta n_t + \eta\Omega_t + Y_t = (1-\eta)C_t + \eta\Upsilon_t + \eta n_{t+1} + \eta\Omega_{t+1} + a(u_t)k_t, \text{ and} \tag{A.9}$$

$$K_{t+1} = (1-d)K_t + \eta\Upsilon_{t-1}(\mu_\omega - \delta\Phi(\varpi_{t-1};\sigma_t)). \tag{A.10}$$

Then the Recursive equilibrium can be described by the system of equations below.

$$\Upsilon_t = \frac{R_{t,d}^{E1} n_t}{R_{t,d}^{E1} - q_{t+1}^{E1}[g(\varpi_t;\sigma_{t+1}^{E1}) - \chi_t f(\varpi_t;\sigma_{t+1}^{E1})]} \tag{A.11}$$

$$\chi_t = \bar{\chi} + \phi_\chi(E[Y_t|\Xi_{t,1}] - \bar{Y}) \tag{A.12}$$

[35] Note that entrepreneurs savings that are passed from one period to the next (n_{t+1}) and bank retained earnings (Ω_{t+1}) are stored consumptions goods, and thus are included in the goods market clearing condition.

$$\varphi_t \Omega_t = \Upsilon_t - n_t \tag{A.13}$$

$$\varphi_t = \bar{\varphi} + \phi_{LT}(\ln(\sigma_{SS}) - \ln(\sigma_t^{E1})) \tag{A.14}$$

$$V_t^0(\Gamma_t, \sigma_{t+1}^{E1}) = \chi_t q_{t+1}^{E1} \left(\varphi_t \Omega_t + n_t\right) f(\varpi_t; \sigma_{t+1}^{E1}) \tag{A.15}$$

$$V_t^{mtm}(\Gamma_{t-1}, \sigma_t^{mtm}) = E[q_t|\Xi_{t,1}]\Upsilon_{t-1} g(\varpi_{t-1}; \sigma_t^{mtm}) - R_{t,d} D_{t-1} \tag{A.16}$$

$$V_t^F(\Gamma_{t-1}, \sigma_t) = q_t \Upsilon_{t-1} g(\varpi_{t-1}; \sigma_t) - R_{t,d} D_{t-1} \tag{A.17}$$

$$\Pi_t^B = V_t^0 + (V_t^{mtm} - V_{t-1}^0) + (V_{t-1}^F - V_{t-1}^{mtm}) \tag{A.18}$$

$$D_t = \Upsilon_t - n_t \tag{A.19}$$

$$Z_t = q_t \Upsilon_{t-1} f(\varpi_{t-1}; \sigma_t) \tag{A.20}$$

$$Y_t = (1-\eta) C_t + \eta \Upsilon_t + \eta(n_{t+1} - n_t) + \eta(\Omega_{t+1} - \Omega_t) + a(u_t) K_t \tag{A.21}$$

$$K_{t+1} = (1-d) K_t + \eta \Upsilon_{t-1}(\mu_\omega - \delta \Theta_{1,t}(\varpi_{t-1}; \sigma_t)) \tag{A.22}$$

$$Y_t = (u_t K_t)^{\xi_K} H_t^{\xi_L} \tag{A.23}$$

$$\frac{\xi_L Y_t}{H_t} = \varsigma \frac{\left(\frac{H_t}{(1-2\eta)}\right)^{\nu_2}}{\psi_t} \tag{A.24}$$

$$\Omega_{t+1} = (1-\gamma_b)(V_t^F + \Omega_t) + \gamma_b(\Omega^i) \tag{A.25}$$

$$n_{t+1} = (1-\gamma_e) Z_t + \gamma_e n^i \tag{A.26}$$

$$\psi_t = (C_t - bC_{t-1})^{-\sigma} - \beta b E[(C_{t+1} - bC_t)^{-\sigma}|\Xi_{t,2}] \tag{A.27}$$

$$\psi_t = \beta E\left[R_{t+1,d} \psi_{t+1}|\Xi_{t,2}\right] \tag{A.28}$$

$$q_t = \frac{1}{R_{t+1,d}} E\left[\frac{\xi_K Y_{t+1}}{u_{t+1} K_{t+1}} + a(u_{t+1}) + (1-d) q_{t+1}|\Xi_{t,2}\right] \tag{A.29}$$

$$a'(u_t) = \frac{\xi_K Y_t}{u_t K_t}, \text{and} \tag{A.30}$$

$$J_t^B = \Pi_t^B + \beta \alpha J_{t+1}^B. \tag{A.31}$$

Note that given the definition of $f(\tilde{\varpi}; \tilde{\sigma})$ and $g(\tilde{\varpi}; \tilde{\sigma})$ we have that, for any pair $(\tilde{\varpi};\tilde{\sigma})$,

$$f(\tilde{\varpi}; \tilde{\sigma}) = \mu_\omega \Theta_{2,t}(\tilde{\varpi}; \tilde{\sigma}) - \tilde{\varpi}(1 - \Theta_{1,t}(\tilde{\varpi}; \tilde{\sigma})),$$

$$g(\tilde{\varpi}; \tilde{\sigma}) = \mu_\omega - \delta \Theta_{1,t}(\tilde{\varpi}; \tilde{\sigma}) - f(\tilde{\varpi}; \tilde{\sigma}),$$

$$\Theta_{1,t}(\tilde{\varpi}; \tilde{\sigma}) = \Phi_N\left(\frac{\ln(\tilde{\varpi}) - \ln(\mu_\omega) + (\tilde{\sigma})^2/2}{\tilde{\sigma}}\right), \text{ and}$$

$$\Theta_{2,t}(\tilde{\varpi}; \tilde{\sigma}) = \Phi_N\left(\frac{\ln(\mu_\omega) + (\tilde{\sigma})^2/2 - \ln(\tilde{\varpi})}{\tilde{\sigma}}\right),$$

where Φ_N is the standard normal cumulative function.[36]

Then the system of equation (A.11) - (A.31) can be represented by

$$\mathcal{E}[\alpha_0 \Psi_{t+1} + \alpha_1 \Psi_t + \alpha_2 \Psi_{t-1} + \beta_0 s_t + \beta_1 s_{t+1}] = 0$$

where for the first six equations $\mathcal{E} = E[\cdot \mid \Xi_{1,t}]$ and for the remaining $\mathcal{E} = E[\cdot \mid \Xi_{2,t}]$.

Appendix B. Proofs

Proof of Lemma 1

Proof. Set j = 2. Then by the tower property of conditional expectation,

$$\begin{aligned}
&E[V^{mtm}_{t+2}(\Gamma_{t+1}(\Xi_{t+1,1}), \sigma_{t+2}; \Xi_{t+2,1})|\Xi_{t,1} \cup S_t] \\
&= E[E_t \left\{ q_{t+2} \Upsilon_{t+1} g(\varpi_{t+1}; \sigma_{t+2}) - R_{t+2,d} D_{t+1} | \Xi_{t+2,1} \right\} |\Xi_{t,1} \cup S_t] \\
&= E[q_{t+2} \Upsilon_{t+1} g(\varpi_{t+1}; \sigma_{t+2}) - R_{t+2,d} D_{t+1} |\Xi_{t,1} \cup S_t]
\end{aligned}$$

and

$$\begin{aligned}
&E_t[V^{0}_{t+1}(\Gamma_{t+1}, \sigma_{t+2}; \Xi_{t+1,1})]|\Xi_{t,1} \cup S_t] \\
&= E[E_t \left\{ q_{t+2} \Upsilon_{t+1} g(\varpi_{t+1}; \sigma_{t+2}) - R_{t+2,d} D_{t+1} | \Xi_{t+1,1} \right\} |\Xi_{t,1} \cup S_t] \\
&= E[q_{t+2} \Upsilon_{t+1} g(\varpi_{t+1}; \sigma_{t+2}) - R_{t+2,d} D_{t+1} |\Xi_{t,1} \cup S_t]
\end{aligned}$$

Thus, $E[V^{mtm}_{t+2}(\Gamma_{t+1}(\Xi_{t+1,1}), \sigma_{t+2}; \Xi_{t+2,1}) - V^{0}_{t+1}(\Gamma_{t+1}, \sigma_{t+2}; \Xi_{t+1,1})|\Xi_{t,1} \cup S_t] = 0$. And,

$$\begin{aligned}
E[V^{mtm}_{t+1}(\Gamma_t(\Xi_{t,1}), \sigma_{t+1}; \Xi_{t+1,1})|\Xi_{t,1} \cup S_t] &= E[E \left\{ q_{t+1} \Upsilon_t g(\varpi_t; \sigma_{t+1}) - R_{t+1,d} D_t | \Xi_{t+1,1} \right\} |\Xi_{t,1} \cup S_t] \\
&= E[q_{t+1} \Upsilon_t g(\varpi_t; \sigma_{t+1}) - R_{t+1,d} D_t |\Xi_{t,1} \cup S_t] = E[V^{F}_{t+1}(\Gamma_t(\Xi_{t,1}), \sigma_{t+1})|\Xi_{t,1} \cup S_t]
\end{aligned}$$

[36] In order to obtain the above we use $\Phi(\tilde{\varpi}; \tilde{\sigma}) = \Phi_N \left(\frac{\ln(\tilde{\varpi}) - \mu_t}{\tilde{\sigma}} \right) = \Phi_N \left(\frac{\ln(\varpi) - \ln(\mu_\omega) + (\tilde{\sigma})^2/2}{\tilde{\sigma}} \right)$ and $\int_{\tilde{\varpi}}^{\infty} \omega \phi(\tilde{\sigma}) d\omega = \exp(\mu_t + (\tilde{\sigma})^2/2) \Phi_N \left(\frac{\ln(\mu_\omega) + (\tilde{\sigma})^2/2 - \ln(\varpi)}{\tilde{\sigma}} \right) = \mu_\omega \Phi_N \left(\frac{\ln(\mu_\omega) + (\tilde{\sigma})^2/2 - \ln(\varpi)}{\tilde{\sigma}} \right)$.

As such, using (13), only the first term, the value of contracts at signature, is different than zero. The same argument applies for $j > 2$. $\square$

Proof of Proposition 2

Proof. Under full information $\Xi_{t,1} = \Xi_{t,1} \cup S_t = \Xi_{t,2}$, thus $\ln \sigma_t$ is $\Xi_{t,1}-$measurable. Firstly,

$$\begin{aligned} V_t^{mtm}(\Gamma_{t-1}, \sigma_t; \Xi_{t,1}) &= E\left\{q_t \Upsilon_{t-1} g(\varpi_{t-1}; \sigma_t) - R_{t,d} D_{t-1} | \Xi_{t,1}\right\} \\ &= E\left\{q_t \Upsilon_{t-1} g(\varpi_{t-1}; \sigma_t) - R_{t,d} D_{t-1} | \Xi_{t,2}\right\} \\ &= q_t \Upsilon_{t-1} g(\varpi_{t-1}; \sigma_t) - R_{t,d} D_{t-1} \\ &= V_t^F, \end{aligned}$$

or as signal is revealed, the shock to entrepreneurs riskiness is already known at stage 1 and hence, the valuation at stage 1 and stage 2 at maturity is the same. Second,

$$\begin{aligned} V_t^0(\Gamma_t, \sigma_{t+1}; \Xi_{t,1}) &= E\{q_{t+1} \Upsilon_t g(\varpi_t; \sigma_{t+1}) - R_{t+1,d}(\Upsilon_t - n_t) | \Xi_{t,1}\} \\ &= E\{q_{t+1} \Upsilon_t g(\varpi_t; \sigma_{t+1}) - R_{t+1,d}(\Upsilon_t - n_t) | \Xi_{t,2}\} \\ &= E\{E\{q_{t+1} \Upsilon_t g(\varpi_t; \sigma_{t+1}) - R_{t+1,d}(\Upsilon_t - n_t) | \Xi_{t+1,1}\} | \Xi_{t,2}\} \\ &= E[V_{t+1}^{mtm}(\Gamma_t, \sigma_{t+1}; \Xi_{t+1,1}) | \Xi_{t,2}], \end{aligned}$$

or the expected equilibrium in tomorrow's secondary market is the same as today's primary market. $\square$

Proof of Proposition 3

Proof. When $\lambda = 0$, the secondary market equilibrium does not reflect all information available, and thus $\Xi_{t,1} \subset \Xi_{t,1} \cup S_t = \Xi_{t,2}$ and $\ln \sigma_t$ is not $\Xi_{t,1}-$measurable. The result is a directly application of this result and (14). $\square$

Proof of Proposition 4

Proof.

$$
\begin{aligned}
V_t^{mtm}(\Xi_{t,1}) - V_t^F(\Xi_{t,2}) &= E\left\{q_t \Upsilon_{t-1} g(\varpi_{t-1};\sigma_t) - R_{t,d} D_{t-1} | \Xi_{t,1}\right\} - q_t \Upsilon_{t-1} g(\varpi_{t-1};\sigma_t) - R_{t,d} D_{t-1} \\
&= \Upsilon_{t-1}[E\{q_t g(\varpi_{t-1};\sigma_t)|\Xi_{t,1}\} - q_t g(\varpi_{t-1};\sigma_t)] \\
& \quad \text{Thus, under Assumption 1, } V_t^{mtm}(\Xi_{t,1}) - V_t^F(\Xi_{t,2}) > 0 \text{ if} \\
& \quad E\{g(\varpi_{t-1};\sigma_t)|\Xi_{t,1}\} - g(\varpi_{t-1};\sigma_t) > 0
\end{aligned}
$$

As ϖ_{t-1} is given, it is therefore sufficient to show that $g(\varpi_{t-1};\sigma_t)$ decreases with σ_t. For any pair $(\varpi;\sigma)$, we can write

$$
\begin{aligned}
f(\varpi;\sigma) &= \mu_\omega \Theta_{2,t}(\varpi;\sigma) - \varpi(1 - \Theta_{1,t}(\varpi;\sigma)), \\
g(\varpi;\sigma) &= \mu_\omega - \delta\Theta_{1,t}(\varpi;\sigma) - f(\varpi;\sigma), \\
\Theta_{1,t}(\varpi;\sigma) &= \Phi_N\left(\frac{\ln(\varpi) - \ln(\mu_\omega) + (\sigma)^2/2}{\sigma}\right), \text{ and} \\
\Theta_{2,t}(\varpi;\sigma) &= \Phi_N\left(\frac{\ln(\mu_\omega) + (\sigma)^2/2 - \ln(\varpi)}{\sigma}\right),
\end{aligned}
$$

where Φ_N is the standard normal cumulative function. Under assumption 2,

$$
\frac{\partial\Theta_{1,t}(\varpi;\sigma)}{\partial\sigma} = \frac{1}{\sqrt{2\pi}} \exp\left(\frac{1}{2}\left[\frac{\ln(\varpi) - \ln(\mu_\omega) + (\sigma)^2/2}{\sigma}\right]^2\right)\left(\frac{\ln(\mu_\omega) - \ln(\varpi) + (\sigma)^2/2}{\sigma^2}\right)\left(\frac{\ln(\mu_\omega) - \ln(\varpi) - (\sigma)^2/2}{\sigma}\right) > 0
$$
$$
\frac{\partial\Theta_{2,t}(\varpi;\sigma)}{\partial\sigma} = \frac{1}{\sqrt{2\pi}} \exp\left(\frac{1}{2}\left[\frac{\ln(\mu_\omega) - \ln(\varpi) + (\sigma)^2/2}{\sigma}\right]^2\right)\left(\frac{\ln(\mu_\omega) - \ln(\varpi) + (\sigma)^2/2}{\sigma}\right)\left(\frac{\ln(\mu_\omega) - \ln(\varpi) - (\sigma)^2/2}{\sigma^2}\right) > 0
$$

Thus,

$$
\begin{aligned}
\frac{\partial f(\varpi;\sigma)}{\partial\sigma} &= \mu_\omega \frac{\partial\Theta_{2,t}}{\partial\sigma} + \varpi\frac{\partial\Theta_{1,t}}{\partial\sigma} > 0 \\
\frac{\partial g(\varpi;\sigma)}{\partial\sigma} &= -\delta\frac{\partial\Theta_{1,t}}{\partial\sigma} - \frac{\partial f(\varpi;\sigma)}{\partial\sigma} < 0
\end{aligned}
$$

□

Proof of Proposition 5

Proof. First note that if $E\{\ln\sigma_t \mid \Xi_{t,1}\} < E\{\ln\sigma_t \mid \Xi_{t,2}\} = \ln\sigma_t$ then $E\{\ln\sigma_{t+1} \mid \Xi_{t,1}\} < E\{\ln\sigma_{t+1} \mid \Xi_{t,2}\}$ as $E[\varepsilon^S_{t+1}] = 0$.

Then under the optimal contract

$$V^0_t(\Gamma_t, \sigma_{t+1}; \Xi_{t,1}]) = E\left\{q_{t+1}\Upsilon_t g(\varpi_t; \sigma_{t+1}) - R_{t+1,d}(\Upsilon_t - n_t)|\Xi_{t,1}\right\} = E\left\{\chi_t q_{t+1}\Upsilon_t f(\varpi_t; \sigma_{t+1})|\Xi_{t,1}\right\}$$

First note that $\Upsilon_t = \varphi_t\Omega_t - n_t$, and as Ω_t and n_t are already set and $\frac{\partial\varphi_t}{\partial E\{\ln\sigma_t]} < 0$, total investment ($\Upsilon_t$) is lower under $\Xi_{t,2}$. Lower investment implies lower output (Y), and as $\chi_t = \bar{\chi} + \phi_\chi(E[Y_t|\Xi_{t,1}] - \bar{Y})$, the bankers' mark-up fall under $\Xi_{t,2}$. Under assumption 1 and 3 (the effect of higher interest rates, i.e. higher ϖ_t, is an offsetting force keeping entrepreneurs return $f(\varpi_t; \sigma_{t+1})$ from increasing under higher risk) all first order components driving V^0_t decrease with higher risk, thus $E\left\{\chi_t q_{t+1}\Upsilon_t f(\varpi_t; \sigma_{t+1})|\Xi_{t,1}\right\} > E\left\{\chi_t q_{t+1}\Upsilon_t f(\varpi_t; \sigma_{t+1})|\Xi_{t,2}\right\}$.

□

Proof of Proposition 6

Proof. If $V^{mtm}_{t+1}(E[\sigma_{t+1}|\Xi_{2,t}]) > V^0_t(E[\sigma_{t+1}|\Xi_{2,t}])$, then for a given $E[\ln\sigma_{t+1}|\Xi_{2,t}]$ the banker offered contract terms Γ_t to entrepreneurs and later obtained an expected (known) revaluation that increases its payoff to the detriment of entrepreneurs. That invalidates the condition that the banker, given a distribution of returns known to the entrepreneur, must offer an optimal loan contract that maximises entrepreneurs expected returns. Finally, as the expected level of risk from $t+1$ onwards are the same under partial and full signal revelation, differences in continuation values are only a function of banking capital. Banking capital changes are dependent on realised gains at maturity (V^F) and thus can only be lower under partial revelation when bankers sign suboptimal contracts at time t. □

Appendix C. Solution Method

Although the model is solved based on a simple first order pertubation method (see Fernandez-Villaverde et al. (2016) for a review on different methodologies to solve DSGE models with a unique information set), the key feature of our model is that we have two traditional expectation operators in our set of equations, one in which the information set is $\Xi_{t,1}$ and one in which the information set equals $\Xi_{t,2}$. To tackle this issue we first set $\hat{\sigma}_{mtm} = \hat{\sigma}_{t-1}$ in (22), thus $s_t = [\hat{\sigma}_t \quad \hat{\sigma}_{t-1}]^T$ and solve the model as if $\Xi_{t,1} = \Xi_{t-1,2}$, employing the standard methodology in Christiano (1998).[37]

Under this specification we obtain a solution such that $\Psi_t = A\Psi_{t-1} + Bs_t$ where $B = [B_1 \quad B_2]$ and B_1 is partitioned such that $B_1 = \begin{bmatrix} \mathbf{0} \\ \breve{B}_1 \end{bmatrix}$ where $\mathbf{0}$ is a vector of zeros since the first eight variables are set when σ_t is unknown. We can then exploit the differences in the stochastic processes of $\hat{\sigma}_t^{mtm}$ and $\hat{\sigma}_{t-1}$ to adjust the submatrices of B and the innovations to each process to find the final solution. Note that the solution to matrix A is independent of s_t and thus no adjustment in A is needed.

First, given that $\hat{\sigma}_t^{mtm} = \rho^S \hat{\sigma}_{t-1} + \digamma(\lambda^*, r^*)\varepsilon_t^S$, then as we replace $\hat{\sigma}_{t-1}$ by $\hat{\sigma}_t^{mtm}$, we need to divide B_2 by ρ^S. Second, at period t there might be an innovation to $\hat{\sigma}_t^{mtm}$ equal to $\digamma(\lambda^*, r^*)\varepsilon_t^S$, while $\hat{\sigma}_{t-1}$ was given at time t. Third, since B_1 denotes the additional impact of knowing $\hat{\sigma}_t$ relative to $\hat{\sigma}_t^{mtm}$ instead of $\hat{\sigma}_{t-1}$, we need to adjust the innovation to $\hat{\sigma}_t$. As such we set $\hat{\sigma}_t = \hat{\sigma}_t^{mtm} + (\varepsilon_t^S - \digamma(\lambda^*, r^*)\varepsilon_t^S)$. Note that in the case $\lambda^* = 1$, information is fully revealed and $\digamma(\lambda^*, r^*) = 1$. Our solution then would be equivalent to solving the standard system obtaining the solution $\Psi_t = A\Psi_{t-1} + \tilde{B}\hat{\sigma}_t$, and thus $\tilde{B} = B_1 + B_2/\rho^S$.[38] The final solution to our system of equation is given by

$$\Psi_t = A\Psi_{t-1} + \begin{bmatrix} \mathbf{0} & \frac{B_2}{\rho_S} \\ \breve{B}_1 & \end{bmatrix} [\hat{\sigma}_t \quad \hat{\sigma}_t^{mtm}]^T$$

Finally, note that $\digamma(\lambda^*, r^*)$ only enters in the innovation to s_t. Thus, we discretize $\lambda \in [0, 1]$, calculate r following (17) and obtain numerically the pair(λ^*, r^*) that maximizes J_B for a given draw of ε_t^S and ι_t. That way we appropriately set $\digamma(\lambda^*, r^*)$, or $\hat{\sigma}_t$ and $\hat{\sigma}_t^{mtm}$ for each period t.

[37] Thus, we alter β_0 and β_1 in (22) accordingly.

[38] The adjustments done here are essentially equivalent to altering Φ in the projection of $P[\theta_t \mid R_i\theta_t, \theta_{t-1}]$, where θ_t is the vector of shocks, in the general methodology discussed in the Appendix in Christiano (1998).

Appendix D. Extension - Long-term Financial Contracts

In this section we describe the key conditions under the assumption that a loan contract signed at time t, matures at time $t+s$ (if it has not done so until then) with probability $\zeta(1-\zeta)^{s-1}$, and thus have average maturity equal to $1/\zeta$. We focus on the problems and equilibrium conditions that differ from the ones in the benchmark model. In order facilitate notation, we denote $\mathbb{N}_t$ to be the set of entrepreneurs signing contracts at time t, $\mathbb{Z}_{t-1}$ to be the set of loan contracts signed before t that have not yet matured. These include the contracts signed at time $t-1$ ($\mathbb{N}_{t-1}$) and the contracts signed before $t-1$ that were yet to mature at the end of $t-1$ (continuing or legacy contracts). We denote this last set by $\mathbb{L}_{t-1}$. Finally, we denote $\mathbb{M}_{t-1}$ to be the set of loan contracts signed before $t-1$ that have matured in period $t-1$. To facilitate notation we denote $\ln\sigma^{E1,t} = \{\ln\sigma_t^{mtm}, E[\ln\sigma_{t+1}|\Xi_{t,1}], E[\ln\sigma_{t+2}|\Xi_{t,1}], \ldots, E[\ln\sigma_{t+\tau}|\Xi_{t,1}], \ldots\}$.

The firm equilibrium conditions remain the same. The household problem is altered since (i) deposits now have a similar maturity structure then entrepreneur projects, (ii) the flow of entrepreneur networth take into account that a fraction of projects mature every period and the bankers problem is altered since the balance sheet of the bank incorporates projects signed before the current period and that have not yet mature. Thus,

The budget constraint of the household is not given by

$$\begin{aligned} q_tI_t + C_t + \eta D_t^* + a(u_t)K_t + \eta T_t^b + \eta T_t^e &\leqslant W_tN_t + \eta R_{\mathbb{M}_t,d}D_{\mathbb{M}_t} + r_t^k u_t K_t + \eta dv_t^B + \eta dv_t^E, \\ \text{where } I_t &= K_{t+1} - (1-d)K_t, \end{aligned}$$

where $R_{\mathbb{M}_t,d}$ is the rate of return on maturing deposits $D_{\mathbb{M}_t}$ [39]

That way the euler equation (A.4) now becomes

$$\psi_t = E\left[\sum_{s=1}^{\infty}\zeta(1-\zeta)^{s-1}\beta^s R_{t,d}^*\psi_{t+s}|\Xi_{t,2}\right].$$

[39] More specifically $R_{\mathbb{M}_t,d}D_{\mathbb{M}_t} = \int_{m\in\mathbb{M}_t} R_{m,d}D_m dm$. Loans and deposits maturation is therefore matched.

At stage 2 a fraction of the projects undertaken in the previous periods mature ($m \in \mathbb{M}_t$), providing a return of $Z_{\mathbb{M}_t} = \int_{m\in\mathbb{M}_t} Z(\Gamma_m, \sigma_t)dm$, where is $Z(\Gamma_m, \sigma_t)$ is formally defined when the loan contract is discussed. We assume a fraction of γ_e of $Z(\Gamma_m, \sigma_t)$ is given to the household as dividend (thus at the aggregate $dv_t^E = \gamma_e Z_{\mathbb{M}_t}$) and the entrepreneurs with matured projects receive a transfer of $n^{i,m}$ as additional networth (thus at the aggregate $T_t^e = n^i$).[40] Thus, the flow of entrepreneur's m networth is given by[41]

$$\begin{aligned} n_{t+1,m} &= (1-\gamma_e)Z(\Gamma_m, \sigma_t) + n^{i,m}, \quad m \in \mathbb{M}_t, \\ \text{and aggregating we have } \int_{j\in\mathbb{N}_{t+1}} n_{t+1,j}dj &= (1-\gamma_e)Z_{\mathbb{M}_t} + n^i. \end{aligned}$$

At each period bankers set new loans in the balance sheet equal to new deposits (D_t^*), thus capital is used as buffer and is not loaned out. The credit market clearing condition is given by $\int_{j\in\mathbb{N}_t} \Lambda_{t,j} = \int_{j\in\mathbb{N}_t}(\Upsilon_{t,j} - n_{t,j})dj = D_t^*$. Given that at every period a fraction ζ of the entrepreneurs have new projects the bank allocates $\Omega_{t,\mathbb{N}_t} = \Omega_t\zeta$ of its internal capital as buffer for the new loans. We assume that at every period bankers must abide by a leverage constraint, dependent on the allocated level of internal capital, given by[42]

$$\int_{j\in\mathbb{N}_t} \Lambda_{t,j} \leqslant \varphi_t \Omega_{t,\mathbb{N}_t},$$

We assume that at the end of every period, equity holdings and realized profits ($\tilde{\Pi}_t^B = V_{t,\mathbb{M}_t}^F$) of all bankers are returned to the household (recall that $\mathbb{M}_t$ denote the set of entrepreneurs with contracts that mature at the end of the period)

[40] As in Christiano et al. (2014) dividends ensure entrepreneurs' networth is never sufficiently high such that external finance is no longer needed. We also consider an extension to our model where entrepreneurs are more impatient than households and must decide how much to save and consume at each period. This framework is more closely related to *CF(1997)*. The results of this alternative specification are qualitatively similar to the ones of the benchmark model displayed here.

[41] At period $t+1$, $n_{t+1,m}$ denote the networth an entrepreneur that will be re-investing holds, thus $\int_{m\in\mathbb{M}_t} n_{t+1,m} = \int_{j\in\mathbb{N}_{t+1}} n_{t+1,j}$.

[42] Note that this leverage constraint holds only for new loans. We also solve the model assuming a general constraint of the form $\int_0^1(\Upsilon_{t,i} - n_{t,i})di = \varphi_t\Omega_t$. Results for high ζ are similar to the results discussed here. However, in the cases when ζ is small, new loans take a small proportion of the bank's balance sheet and risk shocks that affect φ_t, Ω_t and n_t could lead to instances were investment would have to be negative for the constraint to hold and as such no equilibrium is feasible.

The flow of banking capital is therefore given by

$$\Omega_{t+1} = max((1-\gamma_b)(V^F_{\mathbb{M}_t} + \Omega_t) + \gamma_b(\Omega^i), \tilde{\Omega}).$$

We now turn to the loan contract. An entrepreneur j at stage 1 who is ready to invest must decide, given its networth $n_{t,j}$, total investment, $\Upsilon_{t,j}$. At every time $t+s$, the investment, if still running, matures with probability ζ and pays $\omega_{t+s,j}\Upsilon_{t,j}$. Entrepreneurs default when $\hat{\omega}_{t+s,j} < R^f_t(\Upsilon_{t,j} - n_{t,j})/\Upsilon_{t,j} \equiv \varpi_{t,j}$. The gross income to entrepreneur j and the banker from a loan at maturity are, respectively,

$$q_{t+s}\Upsilon_{t,j}\left[\int_{\varpi_{t,j}}^{\infty} \omega\phi(\sigma_{t+s})d\omega - \varpi_{t,j}(1-\Phi(\varpi_{t,j};\sigma_{t+s}))\right] \equiv q_{t+s}\Upsilon_{t,j}f(\varpi_{t,j};\sigma_{t+s}), \text{ and}$$
$$q_{t+s}\Upsilon_{t,j}\left[\int_0^{\varpi_{t,j}} \omega\phi(\sigma_{t+s})d\omega - \delta\Phi(\varpi_{t,j};\sigma_{t+s}) + \varpi_{t,j}(1-\Phi(\varpi_{t,j};\sigma_{t+s}))\right] \equiv q_{t+s}\Upsilon_{t,j}g(\varpi_{t,j};\sigma_{t+s}).$$

As such the expected income for entrepreneur j and the banker of a loan made at time t are

$$E\left[\sum_{s=1}^{\infty} \zeta(1-\zeta)^{s-1} q_{t+s}\Upsilon_{t,j}f(\varpi_{t,j};\sigma_{t+s}) \mid \Xi_{1,t}\right], \text{ and}$$
$$E\left[\sum_{s=1}^{\infty} \zeta(1-\zeta)^{s-1} q_{t+s}\Upsilon_{t,j}g(\varpi_{t,j};\sigma_{t+s}) \mid \Xi_{1,t}\right].$$

The problem that determines the terms of the loan contract is now

$$\max_{\{\Upsilon_{t,j},\varpi_{t,j}\}} \quad E\left[\sum_{s=1}^{\infty} \zeta(1-\zeta)^{s-1} q_{t+s}\Upsilon_{t,j}f(\varpi_{t,j};\sigma_{t+s})|\Xi_{1,t}\right]$$

$$\text{s.t} \quad E\left[\sum_{s=1}^{\infty} \zeta(1-\zeta)^{s-1} q_{t+s}\Upsilon_{t,j}g(\varpi_{t,j};\sigma_{t+s})|\Xi_{1,t}\right] \geqslant E\left[\sum_{s=1}^{\infty} \zeta(1-\zeta)^{s-1}(R^*_{t,d}(\Upsilon_{t,j}-n_{t,j}) + \chi_t q_{t+s}\Upsilon_{t,j}f(\varpi_{t,j};\sigma_{t+s}))\right]$$
$$\int_{j\in\mathbb{N}_t}(\Upsilon_{t,j}-n_{t,j})dj \leqslant \varphi_t\Omega_{t,\mathbb{N}_t}.$$

Then, the conditions that determine the loan contract are,

$$\frac{\Upsilon^*_t}{n^*_t} = \frac{E\left[\sum_{s=1}^{\infty} \zeta(1-\zeta)^{s-1} R^*_{t,d} \mid \Xi_{1,t}\right]}{E\left[\sum_{s=1}^{\infty} \zeta(1-\zeta)^{s-1}[(R^*_{t,d} - q_{t+s}(g(\varpi^*_t;\sigma_{t+s}) - \chi_t f(\varpi^*_t;\sigma_{t+s})))] \mid \Xi_{1,t}\right]},$$
$$\text{and} \qquad \varphi_t\Omega_{t,\mathbb{N}_t} = \int_{j\in\mathbb{N}_t}(\Upsilon_{t,j} - n_{t,j})dj$$

Based on the solution of the loan contract we can now determine the banker's valuations of the loan contracts at different points. Each contract that have just been signed at time t has value $V_t^0(\Gamma_t^*, \sigma_{t+s}; \Xi_{t,1})$. $V_t^{mtm}(\Gamma_z, \sigma_{t+s}; \Xi_{t,1})$ denotes the valuation at closing of secondary market of a contract $z \in \mathbb{Z}_{t-1}$ signed before t that is yet to mature,[43] and $V_{t-1}^F(\Gamma_m, \sigma_{t-1})$ the final valuation of contract $m \in \mathbb{M}_{t-1}$, which matured at the end of stage 2 in period $t-1$. These are

$$
\begin{aligned}
V_t^0(\Gamma_t^*, \sigma_{t+s}; \Xi_{t,1}) &= E\left[\sum_{s=1}^{\infty} \zeta(1-\zeta)^{s-1} q_{t+s} \Upsilon_t^* g(\varpi_t^*; \sigma_{t+s}) - R_{t,d}^*(\Upsilon_t^* - n_t^*) \mid \Xi_{1,t}\right] \\
V_{t,\mathbb{N}_t}^0 &= \int_{j \in \mathbb{N}_t} V_t^0(\Gamma_t^*, \sigma_{t+s}; \Xi_{t,1}) dj \\
V_t^{mtm}(\Gamma_z, \sigma_{t+s}; \Xi_{t,1}) &= E\left[\sum_{s=0}^{\infty} \zeta(1-\zeta)^{s} q_{t+s} \Upsilon_z g(\varpi_z; \sigma_{t+s}) - R_{z,d}(\Upsilon_z - n_z) \mid \Xi_{1,t}\right], \\
V_{t,\mathbb{Z}_{t-1}}^{mtm} &= \int_{z \in \mathbb{Z}_{t-1}} V_t^{mtm}(\Gamma_z, \sigma_{t+s}; \Xi_{t,1}) dz \\
V_{t-1}^F(\Gamma_m, \sigma_{t-1}) &= q_{t-1} \Upsilon_m g(\varpi_m; \sigma_{t-1}) - R_{m,d}(\Upsilon_m - n_m) \\
V_{t-1,\mathbb{M}_{t-1}}^F &= \int_{m \in \mathbb{M}_{t-1}} V_{t-1}^F(\Gamma_m, \sigma_{t-1}) dm
\end{aligned}
$$

Where $R_{z,d}$ is the set rate of deposits yet to mature and $R_{m,d}$ the set rate of deposits that just matured. We can now determine $\Pi_t^B(V_{t-1,\mathbb{M}_{t-1}}^F, V_{t,\mathbb{Z}_{t-1}}^{mtm}, V_{t,\mathbb{N}_t}^0)$. Profits comprise the gains from new loans and the re-valuations of existing assets, thus

$$
\begin{aligned}
\Pi_t^B &= V_{t,\mathbb{N}_t}^0 + V_{t,\mathbb{Z}_{t-1}}^{mtm} + V_{t-1\mathbb{M}_{t-1}}^F - V_{t-1,\mathbb{Z}_{t-1}\cup\mathbb{M}_{t-1}}^{mtm} \\
&= V_{t,\mathbb{N}_t}^0 + V_{t,\mathbb{Z}_{t-1}}^{mtm} + V_{t-1\mathbb{M}_{t-1}}^F - V_{t-1,\mathbb{Z}_{t-2}}^{mtm} - V_{t-1,\mathbb{N}_{t-1}}^0 \\
&= V_{t,\mathbb{N}_t}^0 + (V_{t,\mathbb{Z}_{t-1}}^{mtm} - V_{t-1,\mathbb{Z}_{t-2}\cap\mathbb{Z}_{t-1}}^{mtm} - V_{t-1,\mathbb{N}_{t-1}\cap\mathbb{Z}_{t-1}}^0) + (V_{t-1,\mathbb{M}_{t-1}}^F - V_{t-1,\mathbb{Z}_{t-2}\cap\mathbb{M}_{t-1}}^{mtm}),
\end{aligned}
$$

where we use $V_{t-1,\mathbb{Z}_{t-1}\cup\mathbb{M}_{t-1}}^{mtm} = V_{t-1,\mathbb{N}_{t-1}\cup\mathbb{L}_{t-1}\cup\mathbb{M}_{t-1}}^{mtm} = V_{t-1,\mathbb{L}_{t-1}\cup\mathbb{M}_{t-1}}^{mtm} + V_{t-1,\mathbb{N}_{t-1}}^0 = V_{t-1,\mathbb{Z}_{t-2}}^{mtm} + V_{t-1,\mathbb{N}_{t-1}}^0$. Note that $\mathbb{Z}_{t-2} = \mathbb{L}_{t-1} \cup \mathbb{M}_{t-1} = \mathbb{N}_{t-2} \cup \mathbb{L}_{t-2}$. As such the bankers' measure of profit accrues the gains from newly signed contracts, the updated mark-to-market valuation of contracts that remain in the bank's balance sheet, and the realized payoff relative to previous mark-to-market valuation for maturing contracts, respectively.

[43]Some of these mature in the current period, hence the summation in this case starts at time 0 or t.

We can also determine the value of a maturing contract denoted $Z_m(\Gamma_m, \sigma_t)$.

$$Z_{\mathbb{M}_t} = \int_{m \in \mathbb{M}_t} q_t \Upsilon_m f(\varpi_m; \sigma_t) dm$$

Finally, the labor market, capital and consumption good clearing conditions are stated below.[44] By Walras law credit markets will also clear.

$$\begin{aligned} H_t &= (1-2\eta)N_t \\ \eta \int_{j \in \mathbb{N}_t} n_t^* dj + \eta\Omega_t + Y_t &= C_t + \eta \int_{j \in \mathbb{N}_t} \Upsilon_t^* dj + \eta \int_{j \in \mathbb{N}_{t+1}} n_{t+1}^* dj + \eta\Omega_{t+1} + a(u_t)k_t, \\ \text{and } K_{t+1} &= (1-d)K_t + \int_{m \in \mathbb{M}_t} \eta \Upsilon_m \left(\mu_\omega - \delta\Phi(\varpi_m; \sigma_t)\right) dm. \end{aligned}$$

Given that there is a continuum $[0,1]$ of entrepreneurs undertaking projects in stage 2 and that the arrival of the maturity is memoryless across all projects,[45] we have that $\int_{m \in \mathbb{M}_t} (\Upsilon_m) dm = \zeta \int_0^1 \Upsilon_{t,i} di$ and $\int_{l \in \mathbb{L}_t} (\Upsilon_l) dl = (1-\zeta) \int_0^1 \Upsilon_{t,i} di$, and therefore as $\mathbb{Z}_{t-1} = \mathbb{L}_{t-1} \cup \mathbb{N}_{t-1} = \mathbb{L}_t \cup \mathbb{M}_t$

$$\begin{aligned} \int_0^1 \Upsilon_{t,i} di = \int_{z \in \mathbb{Z}_{t-1}} \Upsilon_z dz &\equiv \Upsilon_t = \int_{j \in \mathbb{N}_{t-1}} \Upsilon_{t-1}^* dj + \int_{l \in \mathbb{L}_{t-1}} \Upsilon_l dl = \zeta \Upsilon_{t-1}^* + (1-\zeta)\Upsilon_{t-1} \\ & \text{Equivalently} \\ \int_0^1 n_{t,i} di &\equiv n_t = \zeta n_{t-1}^* + (1-\zeta) n_{t-1} \\ \int_0^1 \varpi_{t,i} di &\equiv \varpi_t = \zeta \varpi_{t-1}^* + (1-\zeta)\varpi_{t-1} \\ \int_0^1 R_{i,t,d} di &\equiv R_{t,d} = \zeta R_{t-1,d}^* + (1-\zeta) R_{t-1,d}. \end{aligned}$$

We can find the same condition that determine when $\lambda^* = 0$ and the cut off point (α_{lim}) such that bankers are indifferent between setting $\lambda = 0$ or $\lambda = 1$. They are

$$\begin{aligned} J_t^B(\Xi_{t,1}) - J_t^B(\Xi_{t,2}) = & \underbrace{\left(V_{t,\mathbb{N}_t}^0(\Xi_{t,1}) - V_{t,\mathbb{N}_t}^0(\Xi_{t,2})\right)}_{\text{Gain - new positions in primary markets}} + \\ & \underbrace{V_{t,\mathbb{Z}_{t-1}}^{mtm}(\Xi_{t,1}) - V_{t,\mathbb{Z}_{t-1}}^{mtm}(\Xi_{t,2}) + \alpha\beta \left[V_{t+1,\mathbb{L}_t \cap \mathbb{Z}_{t-1}}^{mtm}(\Xi_{t,2}) + V_{t,\mathbb{M}_t \cap \mathbb{Z}_{t-1}}^{F}(\Xi_{t,2}) - V_{t,\mathbb{Z}_{t-1}}^{mtm}(\Xi_{t,1})\right]}_{\text{Gain - postponing MTM valuation}} \\ & + \underbrace{\alpha\beta \left[V_{t+1,\mathbb{Z}_t \cap \mathbb{N}_t}^{mtm}(\Xi_{t,2}) - V_{t,\mathbb{N}_t}^0(\Xi_{t,1})\right]}_{\text{Loss - Primary Markets under Partial Information}} + \underbrace{\alpha\beta({J^P}_{0,t+1} - J_{0,t+1}^F)}_{\text{Loss - Lower Bank capital}} > 0 \end{aligned}$$

[44] Note that entrepreneurs savings that are passed from one period to the next (n_{t+1}^*) and bank retained earnings (Ω_{t+1}) are stored consumptions goods, and thus are included in the goods market clearing condition.

[45] The same properties are used to simplify the price index in price stickiness models.

$$\alpha_{lim,\zeta<1} = \frac{\overbrace{(V^0_{t,\mathbb{N}_t}(\Xi_{t,1}) - V^0_{t,\mathbb{N}_t}(\Xi_{t,2})) + (V^{mtm}_{t,\mathbb{Z}_{t-1}}(\Xi_{t,1}) - V^{mtm}_{t,\mathbb{Z}_{t-1}}(\Xi_{t,2}))}^{\text{Total period } t \text{ gains from partial revelation}}}{\underbrace{\mid \beta \left\{ \left[V^{mtm}_{t+1,\mathbb{L}_t \cap \mathbb{Z}_{t-1}}(\Xi_{t,2}) + V^F_{t,\mathbb{M}_t \cap \mathbb{Z}_{t-1}}(\Xi_{t,2}) - V^{mtm}_{t,\mathbb{Z}_{t-1}}(\Xi_{t,1}) \right] + \left[V^{mtm}_{t+1,\mathbb{Z}_t \cap \mathbb{N}_t}(\Xi_{t,2}) - V^0_{t,\mathbb{N}_t}(\Xi_{t,1}) \right] + (J^P{}_{0,t+1} - J^F_{0,t+1}) \right\} \mid}_{\text{Future losses from postponing MTM, mispricing and banking capital effects}}}$$

The set of conditions that determine the equilibrium is now given by

$$\mathfrak{h}_{1,t} = E\left[\sum_{s=1}^{\infty} \zeta(1-\zeta)^{s-1} q_{t+s} g(\varpi_t^*; \sigma_{t+s}) \mid \Xi_{1,t}\right] \tag{A.32}$$

$$\mathfrak{h}_{2,t} = E\left[\sum_{s=1}^{\infty} \zeta(1-\zeta)^{s-1} q_{t+s} f(\varpi_t^*; \sigma_{t+s}) \mid \Xi_{1,t}\right] \tag{A.33}$$

$$\mathfrak{h}_{3,t} = E\left[\sum_{s=0}^{\infty} \zeta(1-\zeta)^{s} q_{t+s} g(\varpi_z; \sigma_{t+s}) \mid \Xi_{1,t}\right] \tag{A.34}$$

$$\mathfrak{f}_{1,t} = R^*_{t,d} - \mathfrak{h}_{1,t} + \chi_t \mathfrak{h}_{2,t} \tag{A.35}$$

$$\Upsilon_t^* = \frac{n_t^* R^*_{t,d}}{\mathfrak{f}_{1,t}} \tag{A.36}$$

$$\chi_t = \bar{\chi} + \phi_\chi (Y_t - \bar{Y}) \tag{A.37}$$

$$\varphi_t \Omega_{t,\mathbb{N}_t} = \int_{j \in \mathbb{N}_t} (\Upsilon_{t,j} - n_{t,j}) dj \tag{A.38}$$

$$\varphi_t = \bar{\varphi} + \phi_{LT}(\ln(\sigma_{SS}) - \ln(\sigma_t^{mtm})) \tag{A.39}$$

$$V^0_{t,\mathbb{N}_t} = \int_{j \in \mathbb{N}_t} E\left[\Upsilon_t^* \mathfrak{h}_{1,t} - R^*_{t,d}(\Upsilon_t^* - n_t^*) \mid \Xi_{1,t}\right] dj \tag{A.40}$$

$$V^{mtm}_{t,\mathbb{Z}_{t-1}} = \int_{z \in \mathbb{Z}_{t-1}} E\left[\Upsilon_z \mathfrak{h}_{3,t} - R_{z,d}(\Upsilon_z - n_z) \mid \Xi_{1,t}\right] dz \tag{A.41}$$

$$\Pi_t^B = V^0_{t,\mathbb{N}_t} + V^{mtm}_{t,\mathbb{Z}_{t-1}} + V^F_{t-1,\mathbb{M}_{t-1}} - V^{mtm}_{t-1,\mathbb{Z}_{t-2}} - V^0_{t-1,\mathbb{N}_{t-1}} \tag{A.42}$$

$$V^F_{t,\mathbb{M}_t} = \int_{m \in \mathbb{M}_t} [q_t \Upsilon_m g(\varpi_m; \sigma_t) - R_{m,d}(\Upsilon_m - n_m)] dm \tag{A.43}$$

$$Z_{t,\mathbb{M}_t} = \int_{m \in \mathbb{M}_t} q_t \Upsilon_m f(\varpi_m; \sigma_t) dm \tag{A.44}$$

$$Y_t = C_t + \eta \int_{j \in \mathbb{N}_t} \Upsilon_t^* dj + \eta \left(\int_{j \in \mathbb{N}_{t+1}} n^*_{t+1} - \int_{j \in \mathbb{N}_t} n_t^* dj \right) + \eta(\Omega_{t+1} - \Omega_t) + a(u_t) K_t \tag{A.45}$$

$$K_{t+1} = (1-d)K_t + \int_{m \in \mathbb{M}_t} \eta \Upsilon_m \left(\mu_\omega - \delta \Phi(\varpi_m; \sigma_t)\right) dm \tag{A.46}$$

$$Y_t = (u_t K_t)^{\xi_K} H_t^{\xi_L} \tag{A.47}$$

$$\xi_L Y_t \psi_t = \varsigma H_t \left(H_t/(1-2\eta)\right)^{\nu_2} \tag{A.48}$$

$$\Omega_{t+1} = (1-\gamma_b)(V^F_{t,\mathbb{M}_t} + \Omega_t) + \Omega^i \tag{A.49}$$

$$\int_{j \in \mathbb{N}_{t+1}} n^*_{t+1} dj = (1-\gamma_e) Z_{t,\mathbb{M}_t} + n^i \tag{A.50}$$

$$\psi_t = E\left[\left(\zeta \beta R^*_{t,d} + \beta(1-\zeta) \frac{R^*_{t,d}}{R^*_{t+1,d}}\right) \psi_{t+1} | \Xi_{t,2}\right] \tag{A.51}$$

$$q_t = \frac{\beta \psi_{t+1}}{\psi_t} E\left[(\xi_K Y_{t+1})/K_{t+1} - a(u_{t+1}) + (1-d) q_{t+1} | \Xi_{t,2}\right] \tag{A.52}$$

$$a'(u_t) = (\xi_K Y_t)/(u_t K_t) \tag{A.53}$$

$$J_t^B = \Pi_t^B + \beta \alpha J^B_{t+1} \tag{A.54}$$

$$\Upsilon_{t+1} = \zeta \Upsilon_t^* + (1-\zeta) \Upsilon_t \tag{A.55}$$

$$n_{t+1} = \zeta n_t^* + (1-\zeta) n_t \tag{A.56}$$

$$\varpi_{t+1} = \zeta \varpi_t^* + (1-\zeta) \varpi_t \tag{A.57}$$

$$R_{t+1,d} = \zeta R^*_{t,d} + (1-\zeta) R_{t,d} \tag{A.58}$$

Appendix E. Extension - Endogenous Leverage

An increase in leverage, given the loan contract terms and banking capital increases realised bank profits by

$$MP_t = q_t \Omega_t g(\varpi_{t-1}; \sigma_t)$$

The increase in cost of increasing φ from its steady state level (matched to the same level as in the benchmark model), denoted φ_{SS} is assume to be equal to

$$MC_t = \vartheta_t(\varphi_t - \varphi_{SS}),$$

where we assume $\vartheta_t = \bar{\vartheta} + \vartheta_\sigma(\ln(\sigma_t) - \ln(\sigma_{SS}))$, thus the cost parameter is assumed to vary with the level of riskiness in the economy.

Banks set φ_t such the marginal cost and profits are equated. We thus obtain a condition that replaces (4). We set ϑ_σ and $\bar{\vartheta}$ such that the increase in leverage during the boom matches the observed increase when the reduced form condition (4) is used.

Appendix F. Extension - Incorporating Trading at Equilibrium in the Secondary Market of Credit

Model

We modify the framework of the secondary market to consider trading of baskets of credit at equilibrium. The framework adopted here is a simplification of the trading game in Easley and O'Hara (1987). As before, σ_t follows the stochastic process; $\ln \sigma_t = (1 - \rho^S) \ln \sigma_{SS} + \rho^S \ln \sigma_{t-1} + \iota_t \varepsilon_t^S$, where ε_t^S is known at at the beginning of stage 1 of period t and ι_t takes the value of 1 with probability $1 - p_\iota$ and the value of -1 with probability p_ι. At the start of stage 1, the continuum of bankers is divided into three types. A share μ_1

of bankers become behaviour/noise traders. Half of those are willing to buy and half are willing to sell given the posted prices. A share μ_2 of bankers are uninformed and thus act as market makers. A share (1-μ_1-μ_2) of bankers receive an accurate signal of ι_t with probability p_σ. Market makers are responsible for posting prices to buy credit baskets (P_t^B) and to sell credit baskets (P_t^S) for a given order size Q. As in the benchmark model we only consider symmetric equilibria where all bankers within their types behave equally. Market makers are competitive and thus they set buy and sell prices such that their expected gain is zero. The valuation of baskets before the secondary market is $V(\Gamma_{t-1}, E[\ln \sigma_t \mid \ln \sigma_{t-1}])$ and thus $P_t^B \geqslant (V(\Gamma_{t-1}, E[\ln \sigma_t \mid \ln \sigma_{t-1}]))/\Upsilon_{t-1} \geqslant P_t^S$.

Informed bankers, upon receiving a signal, must decide whether to trade under the posted prices or to behave as if no signal was actually given and also post prices becoming a market maker. If informed bankers decide to trade and exploit their informational advantage, they buy baskets when the signal is good and sell when the signal is adverse. Without loss of generality, assume $\varepsilon_t^S > 0$. Then if $\iota_t = 1$, signal is adverse as σ_t or risk increases. We denote this case as σ_t^A. As a result of an adverse signal the true value of credit baskets is then given by $V(\Gamma_{t-1}, \sigma_t^A)$. If $\iota_t = -1$, signal is good and we denote the riskiness level as σ_t^G and the new value of baskets as $V(\Gamma_{t-1}, \sigma_t^G)$. Given the proportion of informed bankers and market makers in the secondary market, market makers face a buy or sell order from informed traders of $\frac{(1-\mu_1-\mu_2)Q}{\mu_2}$, losing either $\frac{(1-\mu_1-\mu_2)Q}{\mu_2}(V(\Gamma_{t-1}, \sigma_t^G)/\Upsilon_{t-1} - P_t^B)$ if signal is good or $\frac{(1-\mu_1-\mu_2)Q}{\mu_2}(P_t^S - V(\Gamma_{t-1}, \sigma_t^A)/\Upsilon_{t-1})$ if signal is adverse.

Bankers who are noise/behaviour traders buy and sell baskets of loans from marker makers. Given the proportion of behaviour traders and market makers in the secondary market the total volume of trades in this case is $\frac{Q\mu_1}{\mu_2}$. As there are an equal number of noise traders buying and selling, the profit made by market makers on these trades is $\frac{Q\mu_1}{2\mu_2}(P_t^B - P_t^S)$.

Given the observed volume of trades when informed traders participate, market markets obtain the information and thus the secondary market of credit functions well. In this case market makers make profits from trades with noise traders and make losses from trades with informed traders.

If informed bankers decide not to take advantage of the signal, or did not receive any signal, they become market markers and only trades between behaviour traders and market makers occur. Given the proportion of behaviour traders and market makers in the secondary market in this case, the total volume of trades is $\frac{Q\mu_1}{(1-\mu_1)}$. As there are an equal number of noise traders buying and selling the profit made by market makers on these trades is $\frac{Q\mu_1}{2(1-\mu_1)}(P_t^B - P_t^S)$. We assume in this case information does not flow to the secondary market, credit markets malfunction and the valuation of baskets in the market remain $V(\Gamma_{t-1}, E[\ln \sigma_t \mid \ln \sigma_{t-1}])$.[46] By observing trade volumes, informed bankers are able to detect whether other informed bankers trade with market makers. As a result, if one informed trader deviates, information is revealed and all other informed bankers also trade. Therefore, a single informed banker cannot exploit informational advantages alone, capturing alone the trading gains of the entire measure $(1-\mu_1-\mu_2)$ of informed bankers. Consequently, we can focus on the a 'representative' informed banker considering whether to trade or become a market maker.

Let $\lambda_h = \{0, 1\}$ be the indicator function denoting whether informed traders decide to trade with market makers or not for each the two shock cases $h = \{A, G\}$. We also define $\Delta v_t^G = (V(\Gamma_{t-1}, \sigma_t^G) - V(\Gamma_{t-1}, E[\ln \sigma_t \mid \ln \sigma_{t-1}]))/\Upsilon_{t-1}$ and $\Delta v_t^A = (V(\Gamma_{t-1}, E[\ln \sigma_t \mid \ln \sigma_{t-1}]) - V(\Gamma_{t-1}, \sigma_t^A))/\Upsilon_{t-1}$, as the difference between the initial value of one unit of the basket of loans and their value after a good and adverse shocks respectively. As we set $p = 0.5$ and thus good and adverse shocks are equally likely and as noise traders buy and sell an equal amount of baskets in the secondary market it is optimal for maker makers to set $P_t^B - V(\Gamma_{t-1}, E[\ln \sigma_t \mid \ln \sigma_{t-1}])/\Upsilon_{t-1} = V(\Gamma_{t-1}, E[\ln \sigma_t \mid \ln \sigma_{t-1}])/\Upsilon_{t-1} - P_t^S = Sp_t/2$ thus spread is centred around the current value of credit baskets. We can then define the expected profits of market makers (Π_t^{MM}) as

$$\begin{aligned} E[\Pi_t^{MM}] &= ((1-p_\sigma) + p_\sigma p_\iota(1-\lambda_G) + p_\sigma(1-p_\iota)(1-\lambda_A))\frac{Q\mu_1}{2(1-\mu_1)}Sp_t \\ &\quad + (p_\sigma p_\iota \lambda_G + p_\sigma(1-p_\iota)\lambda_A)\frac{Q\mu_1}{2\mu_2}Sp_t \\ &\quad - \frac{(1-\mu_1-\mu_2)Q}{\mu_2}(p_\sigma p_\iota \lambda_G(\Delta v_t^G - Sp_t/2) + p_\sigma(1-p_\iota)\lambda_A(\Delta v_t^A - Sp_t/2)) \end{aligned}$$

[46] This outcome is the same as the one under the PBE considered in the Benchmark model when $\lambda_t = 0$ and $p = 0.5$. Note that for simplicity we assume uninformed marker makers are not Bayesian updating their view in this extension.

The equilibrium spread Sp_t is set to ensure expected profits of market markets is zero. That is

$$Sp_t = \frac{(1-\mu_1-\mu_2)p_\sigma(p_\iota\lambda_G\Delta v_t^G + (1-p_\iota)\lambda_A\Delta v_t^A)}{((1-p_\sigma)+p_\sigma p_\iota(1-\lambda_G)+p_\sigma(1-p_\iota)(1-\lambda_A))\frac{\mu_1\mu_2}{2(1-\mu_1)} + (p_\sigma p_\iota\lambda_G + p_\sigma(1-p_\iota)\lambda_A)\frac{1-\mu_2}{2}} \tag{A.59}$$

Finally, given that at the end of the period some bankers might make additional profits due to trading relative to others we modify the bank dividend such that bankers start each period with the same amount of capital, behaving equally in the primary market and starting every period with the same balance sheet. As before all equity holdings and realized profits of a banker j ($\tilde{\Pi}_t^{B,j}$) are returned to the household. A portion γ_b^j of that is kept as dividends (thus $dv_t^{B,j} = \gamma_b^j(\tilde{\Pi}_t^{B,j} + \Omega_t)$). A portion $(1-\gamma_b^j)$ of retained profits and banking capital, and an additional investment (or transfer, $T_{j,t}^b = \gamma_b^j\bar{\Omega}^j$) made by the households form the new banking capital available to bankers in the next period. If the sum of profits of bankers is negative such that the sum of transfer $T_t^b = \sum_j \gamma_b^j\bar{\Omega}^j$ is not enough to generate positive banking capital we assume the households' transfer is set such that $\Omega_{t+1} = \tilde{\Omega} > 0$. We then set γ_b^j and $\bar{\Omega}^j$ such that

$$\Omega_{t+1}^j = \Omega_{t+1} = \max\left(\frac{1}{\eta}\sum_j\{(1-\gamma_b^j)(\tilde{\Pi}_t^{B,j}+\Omega_t) + \gamma_b^j(\bar{\Omega}^j)\}, \tilde{\Omega}\right). \tag{A.60}$$

Inspecting the Mechanism

We now look closely at how informed bankers set λ_h for $h = \{A, G\}$. If informed bankers decide to trade ($\lambda_h = 1$), information is revealed to the secondary market and $\ln\sigma_t^{mtm} = \ln\sigma_t$. The payoff of informed bankers is given by

$$\begin{aligned}
J_t^B(\Xi_{2,t}) &= V_t^0(\Xi_{2,t}) + \left(1 + I_h\frac{Q\mu_2}{\Upsilon_{t-1}(1-\mu_1-\mu_2)}\right)(V_t^F(\sigma_t) - V_{t-1}^0) + \alpha\beta[J_{0,t+1}^F] \\
&\quad + \frac{Q\mu_2}{(1-\mu_1-\mu_2)}(\Delta v_t^h - Sp_t|_{\lambda_h=1}/2) \\
&= V_t^0(\Xi_{2,t}) + (V_t^F(\sigma_t) - V_{t-1}^0) + \alpha\beta[J_{0,t+1}^F] + \frac{2Q\mu_2}{(1-\mu_1-\mu_2)}\left(\Delta v_t^h - Sp_t|_{\lambda_h=1}/2\right)
\end{aligned}$$

where I_h take the value of 1 if the signal is good, with informed banks adding baskets to their balance sheet and -1 if the signal is adverse, with informed banks selling baskets from their balance sheet.[47]

If informed bankers decide to act as market makers ($\lambda_h = 0$), choosing not to exploit the gains from informed trading their payoff becomes,

$$\begin{aligned} J_t^B(\Xi_{1,t}) &= V_t^0(\Xi_{1,t}) + (V_t^{mtm}(\Xi_{1,t}) - V_{t-1}^0) + \alpha\beta\left[(V_{t+1}^{mtm}(\Xi_{2,t}) - V_t^0(\Xi_{1,t}))\right] \\ &\quad + \alpha\beta\left[(V_t^F(\sigma_t) - V_t^{mtm}(\Xi_{1,t})) + J^P{}_{0,t+1}\right] + \frac{Sp_t|_{\lambda_h=0} Q\mu_1}{2(1-\mu_1)}. \end{aligned}$$

As bankers sell and buy an equal amount of baskets, maintaining their balance sheet, but making a profit depended on the spread they can set as a market maker.

As such no revelation of information in the secondary market occurs when

$$\begin{aligned} J_t^B(\Xi_{1,t}) - J_t^B(\Xi_{2,t}) &= \underbrace{(V_t^0(\Xi_{1,t}) - V_t^0(\Xi_{2,t}))}_{\text{Relative Valuation under primary markets}} + \underbrace{(1-\alpha\beta)(V_t^{mtm}(\Xi_{1,t}) - V_t^F(\sigma_t))}_{\text{Relative Valuation under MTM vs maturity}} + \\ &+ \underbrace{\alpha\beta(V_{t+1}^{mtm}(\Xi_{2,t}) - V_t^0(\Xi_{1,t}))}_{\text{Expected Adjustment under Partial Information}} + \underbrace{\alpha\beta(J^P{}_{0,t+1} - J_{0,t+1}^F)}_{\text{Continuation Value}} \\ &- \underbrace{\left(\frac{2Q\mu_2}{(1-\mu_1-\mu_2)}(\Delta v_t^h - Sp_t|_{\lambda_h=1}/2) - \frac{Sp_t|_{\lambda_h=0} Q\mu_1}{2(1-\mu_1)}\right)}_{\text{Gains from Trading versus Market Making}} > 0 \end{aligned} \quad \text{(A.61)}$$

The first four terms are the same as in the benchmark model and thus the analysis there caries over. A fifth term, *Gains from Trading versus Market Making*, must be subtracted in case trading occurs at equilibrium. Given that at equilibrium the spread in the market is such that $V(\Gamma_{t-1}, \sigma_t^G) \geqslant P_t^B \geqslant (V(\Gamma_{t-1}, E[\ln \sigma_t \mid \ln \sigma_{t-1}]))/\Upsilon_{t-1} \geqslant P_t^S \geqslant V(\Gamma_{t-1}, \sigma_t^A)$, exploiting information and trading is always more profitable than making gains as a market market. The share of behaviour traders and relative share of uninformed and informed traders impact the size of *Gains from Trading versus Market Making.* Nonetheless, as μ_1 and μ_2 increases, the spread (Sp_t) at equilibrium also decreases such that the *Gains from Trading versus Market Making* is always positive, pushing bankers towards trading and revealing information relative to our Benchmark model.

[47] Given the definition of Δv_t^h and Sp_t the profit from trading can be concisely written as $\frac{Q\mu_2}{(1-\mu_1-\mu_2)}(\Delta v_t^h - Sp_t/2)$ without the use of an indicator function. Note that the second equality uses the fact that ate steady state $V_{t-1}^0 = V(\Gamma_{t-1}, E[\ln \sigma_t \mid \ln \sigma_{t-1}])$.

Appendix G. Additional Results - Robustness Boom and Bust

We start by looking at the impulse response for a adverse shock under full information in the benchmark model and in the model without changes in capital utilization. As in capital utilization increases the elasticity of output to a shock. This in turn affects entrepreneurs investment, providing an additional feedback effect to credit markets, further lowering total credit and banking capital.

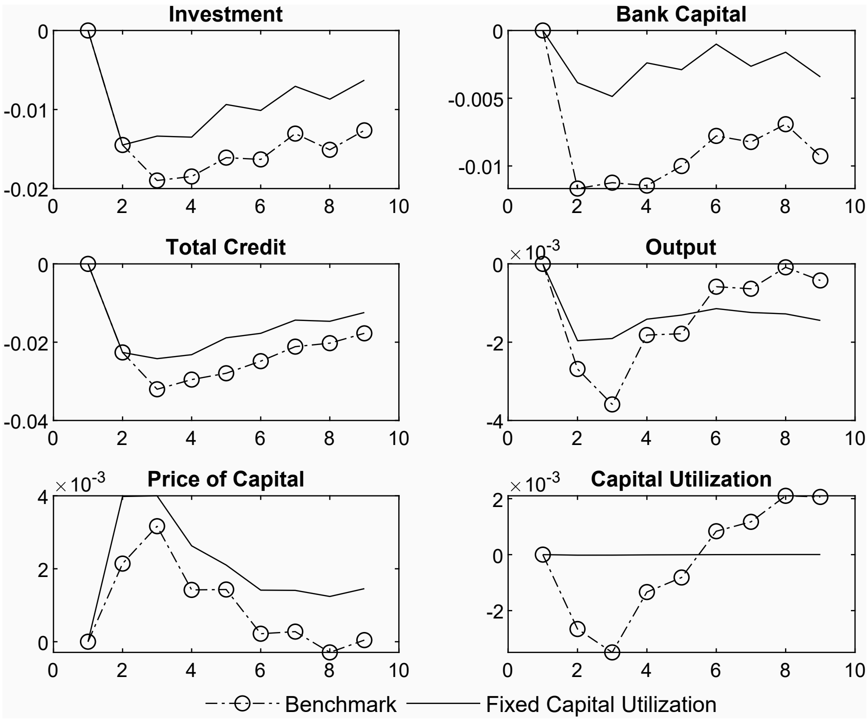

Figure A.1: Benchmark model versus Fixed Capital Utilization

We perform a series of robustness exercises. We first look at the changes in the boom and bust movement in output, starting from the steady state, after a one standard deviation shock that increases σ_t is partially revealed and mispricing of credit is observed (we fix α such that bankers set $\lambda^* = 0$). We perform this exercise for a different set of structural parameters ($\varrho = \{\chi, \phi_\chi, \varphi, \phi_{LT}, \sigma_{SS}\}$) which influence profit margins, leverage and risk. We increase each parameter of interest by 20%. We find that altering parameters that control leverage and profits have little effect on output movements while a lower σ_{SS} increases the amplitude of output movements after partial revelation. The pattern of boom, generated by low credit spread benefiting entrepreneurs that do not default, and bust, due to credit supply problems, remain in all specifications. Results are displayed in figure A.2.[48]

Robustness - Boom and Bust for different parameter values.

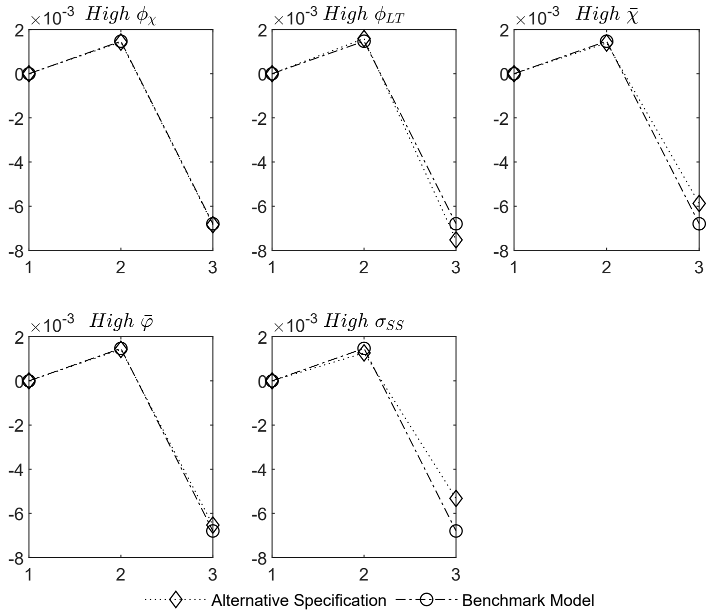

Figure A.2: Output Response - Boom and bust for different structural parameters

We also consider the effects of risk shocks based on the last cycle while employing the model extension in which contracts last for more than one period (See Appendix D for details). Under this framework the average contract duration is $\frac{1}{\zeta}$. The impulse responses when $\zeta = 0.25$ is shown in figure A.3. We observe a small attenuation of the boom and bust observed due to mispricing of credit risk. This is the case since mispricing occurs only within the quarter and as average maturity increases, a relatively small share of assets in the banks and entrepreneurs balance sheets is affected. Hence, both the benefits of low credit spreads on funding, that result in the boom, and the detriments on bank capital, that result in the bust, are dampened. Note that a model where mispricing events last for more than a quarter would deliver more amplification also for the cases where ζ is small. Nonetheless, the key patterns depicted in Figure 3 are also observed when duration increases with $\zeta < 1$.

[48]As the consumption habit parameter, b, decreases, the volatility of the price of capital also decreases, dampening the output amplification observed. The same occurs as σ_a increases. As expected a smaller response of capital utilization reduces the volatility of output. The overall pattern of boom and bust is not affected when these parameters are changed.

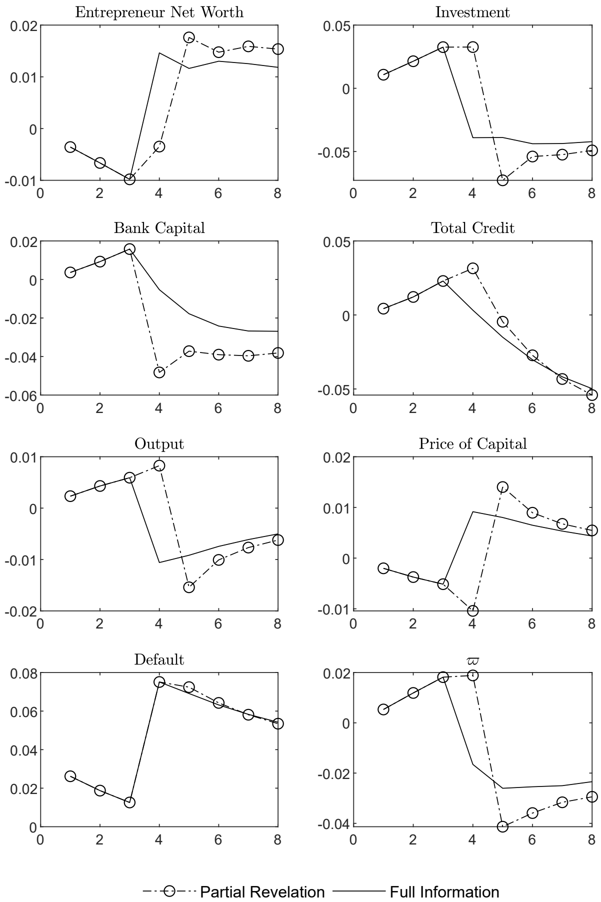

Figure A.3: Boom and bust in the presence of partial information revelation - Duration 4 quarters

Finally, we consider an extension where leverage (φ) is endogenously set by banks. Higher leverage, given a level of banking capital and the terms of the loan contract increases bank profits. We assume that as banks increase leverage from the steady state level, their cost of funding rises at an increasing rate. Banks select leverage optimally to maximize profits and minimize costs. We calibrate the sensitivity of deposit rates to leverage such that the increase in leverage during the boom is the similar to the exogenously set path in the benchmark model. As such we can compare the drop in leverage in the benchmark model and in the case leverage is endogenous during the bust. We find that leverage, when endogenously set, drops more significantly in the bust (an additional decrease of 5%), increasing the amplitude of output movements (an additional one percent drop). The details of the model extensions are shown in the Appendix E, figure A.4 shows the changes in leverage and output.

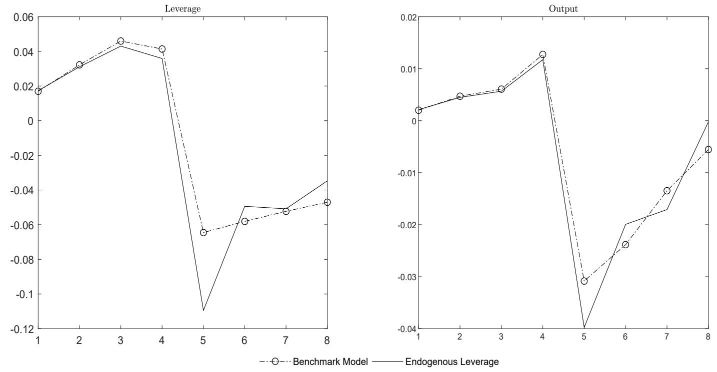

Figure A.4: Output and Leverage - Boom and bust under endogenous banking leverage

Note: Impulse Responses of a boom, described as three consecutive periods of positive shocks that lead default rates to decrease to around 1.5%, followed by a strong adverse shock that pushes the default rate to about 8% are shown. We compare the benchmark model with the extension where leverage is endogenous.

BANCO DE ESPAÑA PUBLICATIONS

WORKING PAPERS

2040 GABRIEL JIMÉNEZ, DAVID MARTÍNEZ-MIERA and JOSÉ-LUIS PEYDRÓ: Who Truly Bears (Bank) Taxes? Evidence from Only Shifting Statutory Incidence.

2041 FELIX HOLUB, LAURA HOSPIDO and ULRICH J. WAGNER: Urban air pollution and sick leaves: evidence from social security data.

2042 NÉLIDA DÍAZ SOBRINO, CORINNA GHIRELLI, SAMUEL HURTADO, JAVIER J. PÉREZ and ALBERTO URTASUN: The narrative about the economy as a shadow forecast: an analysis using Banco de España quarterly reports.

2043 NEZIH GUNER, JAVIER LÓPEZ-SEGOVIA and ROBERTO RAMOS: Reforming the individual income tax in Spain.

2101 DARÍO SERRANO-PUENTE: Optimal progressivity of personal income tax: a general equilibrium evaluation for Spain.

2102 SANDRA GARCÍA-URIBE, HANNES MUELLER and CARLOS SANZ: Economic uncertainty and divisive politics: evidence from the *Dos Españas*.

2103 IVÁN KATARYNIUK, VÍCTOR MORA-BAJÉN and JAVIER J. PÉREZ: EMU deepening and sovereign debt spreads: using political space to achieve policy space.

2104 DARÍO SERRANO-PUENTE: Are we moving towards an energy-efficient low-carbon economy? An input-output LMDI decomposition of CO_2 emissions for Spain and the EU28.

2105 ANDRÉS ALONSO and JOSÉ MANUEL CARBÓ: Understanding the performance of machine learning models to predict credit default: a novel approach for supervisory evaluation.

2106 JAVIER ANDRÉS, ÓSCAR ARCE and PABLO BURRIEL: Market polarization and the Phillips curve.

2107 JUAN de LUCIO and JUAN S. MORA-SANGUINETTI: New dimensions of regulatory complexity and their economic cost. An analysis using text mining.

2108 DANILO LEIVA-LEON and LUIS UZEDA: Endogenous time variation in vector autoregressions.

2109 CORINNA GHIRELLI, ANDREA GONZÁLEZ, JOSÉ LUIS HERRERA and SAMUEL HURTADO: Weather, mobility and the evolution of the Covid-19 pandemic.

2110 KLODIANA ISTREFI, FLORENS ODENDAHL and GIULIA SESTIERI: Fed communication on financial stability concerns and monetary policy decisions: revelations from speeches.

2111 YUNUS AKSOY, HENRIQUE S. BASSO and CAROLYN ST AUBYN: Time Variation in Lifecycle Consumption and Income.

2112 JENNIFER PEÑA and ELVIRA PRADES: Price setting in Chile: micro evidence from consumer on-line prices during the social outbreak and Covid-19.

2113 NEZIH GUNER, YULIYA A. KULIKOVA and ARNAU VALLADARES-ESTEBAN: Does the added worker effect matter?

2114 RODOLFO G. CAMPOS and JACOPO TIMINI: Unequal trade, unequal gains: the heterogeneous impact of MERCOSUR.

2115 JAVIER QUINTANA: Import competition, regional divergence, and the rise of the skilled city.

2116 PATRICK MACNAMARA, MYROSLAV PIDKUYKO and RAFFAELE ROSSI: Marginal Tax Changes with Risky Investment.

2117 RODOLFO G. CAMPOS, JACOPO TIMINI and ELENA VIDAL: Structural gravity and trade agreements: does the measurement of domestic trade matter?

2118 ALESSANDRO MELCARNE, JUAN S. MORA-SANGUINETTI and ROK SPRUK: Democracy, technocracy and economic growth: evidence from 20 century Spain.

2119 ÁNGEL ESTRADA and DANIEL SANTABÁRBARA: Recycling carbon tax revenues in Spain. Environmental and economic assessment of selected green reforms.

2120 ALEJANDRO FERNÁNDEZ-CEREZO, BEATRIZ GONZÁLEZ, MARIO IZQUIERDO and ENRIQUE MORAL-BENITO: Firm-level heterogeneity in the impact of the COVID-19 pandemic.

2121 EDUARDO GUTIÉRREZ and CÉSAR MARTÍN MACHUCA: The effect of tariffs on Spanish goods exports.

2122 JACOPO TIMINI: Revisiting the 'Cobden-Chevalier network' trade and welfare effects.

2123 ALEJANDRO BUESA, JAVIER J. PÉREZ and DANIEL SANTABÁRBARA: Awareness of pandemics and the impact of COVID-19.

2124 ALICIA AGUILAR and DIEGO TORRES: The impact of COVID-19 on analysts' sentiment about the banking sector.

2125 SILVIA ALBRIZIO, IVÁN KATARYNIUK, LUIS MOLINA and JAN SCHÄFER: ECB euro liquidity lines.

2126 ANTHONY BALD, ERIC CHYN, JUSTINE HASTINGS and MARGARITA MACHELETT: The causal impact of removing children from abusive and neglectful homes.

2127 IRMA ALONSO, PEDRO SERRANO and ANTONI VAELLO-SEBASTIÀ: The impact of heterogeneous unconventional monetary policies on the expectations of market crashes.

2128 MARÍA T. GONZÁLEZ-PÉREZ: Lessons from estimating the average option-implied volatility term structure for the Spanish banking sector.

2129 SIMÓN A. RELLA, YULIYA A. KULIKOVA, EMMANOUIL T. DERMITZAKIS and FYODOR A. KONDRASHOV: Rates of SARS-COV-2 transmission and vaccination impact the fate of vaccine-resistant strains.

2130 MATÍAS LAMAS and DAVID MARTÍNEZ-MIERA: Sectorial holdings and stock prices: the household-bank nexus.

2131 ALBERT BANAL-ESTAÑOL, ENRIQUE BENITO, DMITRY KHAMETSHIN and JIANXING WEI: Asset encumbrance and bank risk: theory and first evidence from public disclosures in Europe.

2132 ISABEL ARGIMÓN and MARÍA RODRÍGUEZ-MORENO: Business complexity and geographic expansion in banking.

2133 LUIS GUIROLA: Does political polarization affect economic expectations?: Evidence from three decades of cabinet shifts in Europe.

2134 CHRISTIANE BAUMEISTER, DANILO LEIVA-LEÓN and ERIC SIMS: Tracking weekly state-level economic conditions.

2135 SERGI BASCO, DAVID LÓPEZ-RODRÍGUEZ and ENRIQUE MORAL-BENITO: House prices and misallocation: The impact of the collateral channel on productivity.

2136 MANUEL ARELLANO, STÉPHANE BONHOMME, MICOLE DE VERA, LAURA HOSPIDO and SIQI WEI: Income risk inequality: Evidence from Spanish administrative records.

2137 ANGELA ABBATE and DOMINIK THALER: Optimal monetary policy with the risk-taking channel.

2138 MARTA BAŃBURA, DANILO LEIVA-LEÓN and JAN-OLIVER MENZ: Do inflation expectations improve model-based inflation forecasts?

2139 MÁXIMO CAMACHO, MARÍA DOLORES GADEA and ANA GÓMEZ LOSCOS: An automatic algorithm to date the reference cycle of the Spanish economy.

2140 EDUARDO GUTIÉRREZ, AITOR LACUESTA and CÉSAR MARTÍN MACHUCA: Brexit: Trade diversion due to trade policy uncertainty.

2141 JULIO A. CREGO and JULIO GÁLVEZ: Cyclical dependence in market neutral hedge funds.

2142 HERVÉ LE BIHAN, MAGALI MARX and JULIEN MATHERON: Inflation tolerance ranges in the new keynesian model.

2143 DIEGO COMIN, JAVIER QUINTANA, TOM SCHMITZ and ANTONELLA TRIGARI: Measuring TFP: the role of profits, adjustment costs, and capacity utilization.

2144 ROBERTO PASCUAL: Do analysts forecast differently in periods of uncertainty? An empirical analysis of target prices for Spanish banks.

2145 BEATRIZ GONZÁLEZ, GALO NUÑO, DOMINIK THALER and SILVIA ABRIZIO: Firm heterogeneity, capital misallocation and optimal monetary policy.

2201 RYAN BANERJEE and JOSÉ-MARÍA SERENA: Dampening the financial accelerator? Direct lenders and monetary policy.

2202 JUAN S. MORA-SANGUINETTI and ISABEL SOLER: La regulación sectorial en España. Resultados cuantitativos.

2203 JORGE E. GALÁN, MATÍAS LAMAS and RAQUEL VEGAS: Roots and recourse mortgages: handing back the keys.

2204 MONICA MARTINEZ-BRAVO and CARLOS SANZ: Inequality and psychological well-being in times of COVID-19: evidence from Spain.

2205 CORINNA GHIRELLI, DANILO LEIVA-LEÓN and ALBERTO URTASUN: Housing prices in Spain: convergence or decoupling?

2206 MARÍA BRU MUÑOZ: Financial exclusion and sovereign default: The role of official lenders.

2207 RICARDO GIMENO and CLARA I. GONZÁLEZ: The role of a green factor in stock prices. When Fama & French go green.

2208 CARLOS MONTES-GALDÓN and EVA ORTEGA: Skewed SVARs: tracking the structural sources of macroeconomic tail risks.

2209 RODOLFO G. CAMPOS, ILIANA REGGIO and JACOPO TIMINI: Thick borders in Franco's Spain: the costs of a closed economy.

2210 MARCO CELENTANI, MIGUEL GARCÍA-POSADA and FERNANDO GÓMEZ POMAR: Fresh start policies and small business activity: evidence from a natural experiment.

2211 JOSE GARCIA-LOUZAO, LAURA HOSPIDO and ALESSANDRO RUGGIERI: Dual returns to experience.

2212 ADRIÁN CARRO and PATRICIA STUPARIU: Uncertainty, non-linear contagion and the credit quality channel: an application to the Spanish interbank market.

2113 MARIO IZQUIERDO, ENRIQUE MORAL-BENITO, ELVIRA PRADES and JAVIER QUINTANA: The propagation of worldwide sector-specific shocks.

2214 HENRIQUE S. BASSO: Asset holdings, information aggregation in secondary markets and credit cycles.