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Risk-Shifting, Fuzzy Capital Constraint, and the Risk-Taking Channel of Monetary Policy[*]

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Abstract: We construct a model where financial asset overpricing due to risk shifting can be moderated by capital requirements. Imperfect information about the level of capital per unit of risk, however, introduces uncertainty about the risk exposure of intermediaries. Overestimation of the level of capital of financial intermediaries, or the extent of regulatory arbitrage, may induce households to infer that higher asset prices are due to a decline of risk. This mechanism can explain the low risk premia paid by US financial intermediaries between 2000 and 2007 in spite of their increasing exposure to risk. Moreover, the underestimation of risk is larger the lower the level of the risk-free interest rate.

JEL Codes: G14, G21, E52

Keywords: Capital requirements, imperfect information, risk-taking channel of monetary policy

Résumé: Nous modélisons une économie où les bulles de prix d'actifs dues à une prise de risque excessive des intermédiaires financiers peuvent être atténuées par des contraintes en capital. Cependant, l'information imparfaite sur le ratio de capital effectif, ou dans le cadre de la crise des subprimes, sur l'étendue de l'arbitrage réglementaire induit de l'incertitude sur le degré réel d'exposition au risque des intermédiaires financiers. La sous-estimation de l'arbitrage réglementaire peut amener les ménages à interpréter la hausse des prix des actifs risqués comme une diminution du risque agrégé dans l'économie. Ce mécanisme permet d'expliquer la faible prime de risque payée par les intermédiaires financiers américains lors de la période 2000-2007 malgré une prise de risque accrue. Par ailleurs, le risque est d'autant plus sous-estimé que le niveau des taux d'intérêt sans risque est faible.

Classification JEL: G14, G21, E52

Mots-clés: Contraintes en capital, Information imparfaite, Canal du risque de la politique monétaire

1 Introduction

Many economists and institutions recognize that the wave of financial innovation that took place during the years leading up to the financial crisis may have contributed to financial instability. The increase in risk-taking on the part of financial intermediaries through various off-balance sheet innovations appears to have fed what will most likely go down in history as another episode of asset prices overpricing.

For many observers,[1] the engine of this overpricing was the creativity deployed by financial intermediaries in order to increase their return on capital through higher leverage and higher exposure to credit and liquidity risk. In the case of financial intermediaries subject to capital requirement, this creativity is usually labelled regulatory arbitrage. For other financial intermediaries, the use of off-balance sheet instruments was a way to hide partially the extent of leverage and the exposure to credit risks, as we document in Section 2 of the paper. This increase in risk taking, however, was not sanctioned by higher risk premia on intermediaries' debts: on the contrary, these premia remained low and non-increasing until the summer of 2007. More precisely, comparing the CDS on US banks and CDS on non financial economic sectors, the perception of the riskiness of banks relative to the riskiness of other sectors did not increase[2].

The goal of this paper is to understand why financial intermediaries were able to pay non-increasing risk premia while increasing their leverage or risk-taking, and to derive implications about the build-up of financial fragility. We also analyze whether the stance of monetary policy, as captured by the level of the interest rate, influences the perception of risk and the incentives

[1] Acharya *et al.* (2009), Blanchard (2008), Brender and Pisani (2010), Brunnermeier (2008), Greenlaw *et al.* (2008).

[2] Comparing CDS across sector allows controlling for a general trend in risk premia. For instance a "saving glut" may increase the demand for all assets and decrease risk premia on all assets. Nevertheless, comparing CDS across sectors reveals the percieved risk of a given sector compared to the rest of the economy (see Section 2).

of risk-taking.

To do so, we build a model of asset pricing where intermediaries can default on their debt in the bad state of the world, and where investors do not observe the risk associated to assets but extract information about risk from asset prices. We analyse this set-up in a general equilibrium model to derive asset prices and the interest rate margin[3] paid on the debt of intermediaries.

Our contribution is twofold. First, we show that the patterns of risk premia and leverage ratios observed in the US between 2000 and 2007 can be understood only if investors overestimated the level of intermediaries' capital per unit of risk taken (or equivalently the risk weighted level of capital), and thus underestimated the intermediaries' incentives to take risk. We show how rational investors may wrongly deduce from rising asset prices that the aggregate risk is decreasing, and thus charge a low risk premium on debt.

Second, we provide a theory for the risk taking channel of monetary policy. In particular, if uninformed investors underestimate leverage or the extent of regulatory arbitrage, low interest rates may amplify their underestimation of risk. This is because the effect of the interest rate on asset prices is higher the higher the leverage of intermediaries and hence the lower the level of capital per unit of risk. As a consequence, lower interest rates imply a larger effect of changes in the level of capital on the price of risky assets, and in turn on the perception of risk by investors[4].

This risk-taking channel implies both misperception of risk by some agents (typically in-

[3]Throughout the paper we will call the interest rate margin a risk premium even if, within the model, agents are risk neutral. These agents require an interest rate margin that, *ex ante*, covers exactly the expected cost of default. Although they do not require a premium for the risk associated to this transaction, such a premium would only strengthen our argument.

[4]In fact, the model we use is real, and the interest rate is also real, rather than nominal. We assume that monetary policy can affect, possibly only temporarily, the level of the real interest rate on the storage asset. We discuss other factors such as the low level of interest rates in Section 4.

vestors) and an increased exposure to risk by others (e.g. the ones who manage to shift risk). Such misperception can result from opaque levels of capital at stake in the risk-taking process and in the incentive to take some risk. Many economists now argue that the capital positions of financial intermediaries were indeed opaque in the years leading up to the financial crisis (Rochet 2008 or Acharya and Schnabl 2009 among others). In a broader perspective, they are likely to be opaque during periods of major financial innovation or deregulation.

More specifically, we set up a model *à-la* Allen and Gale (2000), which is enriched in order to analyze the role of the level of capital. In this model, households can invest in risky assets only indirectly, by lending to financial intermediaries. Households require a risk premium on this loan because they anticipate that financial intermediaries will default in the bad state of the world. However, the limited liability of intermediaries in the case of default implies that they will take too much risk. A bubble therefore will result, in the sense that the price of the risky asset will be higher than in the case in which households can invest directly in such asset. Within this set-up we introduce capital requirements as a constraint put on intermediaries. We assume that they have to invest some of their own resources in order to finance investments in the risky asset. This constraint hence moderates the extent of risk-shifting on the part of intermediaries, and the distortions induced by their limited liability. Households, who do not observe the risk of the risky assets *ex ante*, try to infer the level of risk from the price of the risky asset.

We consider two assumptions on the information set of households. First, we assume that they can observe the exact amount of capital per unit of risk of intermediaries. They are then able to infer exactly the underlying risk of the risky asset from asset prices. In this case, an (anticipated) increase in leverage raises both the price of the risky asset and the premium charged on intermediaries' debt. This model therefore falls short of reproducing the build up of the subprime crisis during which the increased leverage of the banks did not imply higher risk premia.

Second, we assume that households cannot observe the exact extent of either regulatory constraint or market norm on capital, and thus the degree of risk-shifting. As argued by Acharya and Schnabl (2009), one of the reasons why the exact extent of the regulatory capital ratio can be opaque is that intermediaries use off-balance sheet conduits to "play" the level of capital. Uncertainty about the level of capital then implies uncertainty about the extent of risk associated with assets held by banks. We prove that households underestimate the risk of the risky assets if they overestimate the level of capital of intermediaries. The model can therefore replicate one of the most puzzling stylized facts of the banking crisis: risk premia did not increase because the depletion of capital that financial intermediaries effectively pledged to their riskiest investments was underestimated by uninformed investors (be they households, pension funds, regulators or even managers of the largest banks).

We then study the impact of monetary policy on risk perception and incentives within the context of our model. We find that the level of the riskless interest rate affects the signal extraction problem of households. When there is some uncertainty about banks' capital per unit of risk, lower real interest rates increase the scale of the underestimation of risk, which in turn amplifies the overpricing of risky assets. This mechanism can account for the build-up of financial fragility that occurs in times of major financial innovations, such as the originate-to-distribute business model and securitization activities that spread through the US financial system between 2000 and 2007.

Related literature.

This article focuses on the link between leverage, asset prices and capital "requirements". It relates to the results of Adrian and Shin (2008) and Geanakoplos (2009), who have highlighted the effects of financial intermediaries' leverage on asset prices. It also provides a theoretical underpinning for the empirical results of Ioanidou, Ongena and Peydro (2008), Maddaloni, Peydró and Scopel (2008), Ciccarelli, Maddaloni and Peydro (2009), Altunbas, Gambacorta and Marques-Ibanez (2009), Adrian and Shin (2008) and Shin (2009) who showed that accommodative monetary policy stance are associated with more risk taking by banks. We hence provide a theory for what Borio and Zhu (2009) and Adrian and Shin (2009) call the "risk-taking" channel of monetary policy.

In the risk-shifting literature, our paper relates first to Allen and Gale (2000)'s contribution, where they showed how limited liability on the part of debt issuers leads to over-investment in risky assets. This is because debt issuers would then care only about the upside of the return distribution. Barlevy (2008) proved that risk-shifting also implies bubbles within more general frameworks of financial intermediation (i.e. when the formation of financial contracts is endogenous); he also generalized risk-shifting to a continuous-time dynamic framework. Challe and Ragot (2008) expand the risk-shifting model to the case in which the supply of loans is endogenous[5].

Our paper is also linked to the literature discussing the opacity around the real cost of risk-taking for financial intermediaries in terms of the level of capital. Acharya and Schnabl (2009) show how, in the last decade, banks have been able to under-report their "effective" leverage

[5] It is also important to underline the difference between the risk-shifting literature and the literature on endogenous credit constraints. The latter analyses how asymmetric information introduces external finance premiums and collateral constraints. This literature accounts well for the financial accelerator, either in the boom phase, when the rising price of collateral releases credit constraints (Kiyotaki and Moore, 1997) or in the bust phase, when the collapse in asset prices tightens the credit constraint considerably (Holmstrom and Tirole, 1997). However, these models face some difficulties in explaining why there are equilibria with too much credit and overinvestment in the risky asset.

ratio through pseudo off-balance sheet operations. Despite the transfer of risky assets to Special Purpose Vehicle, the unwinding of the crisis demonstrates that risks were still, explicitly or implicitly, on financial intermediaries' books, either because banks were tied by explicit liquidity and credit enhancement contracts, or for reputational reasons: ABSs have frequently been brought back to intermediaries' balance sheets after 2007, once in the bad state of the world. Then, the regulatory arbitrage added to the complexity of the capital requirements calculus (Rochet 2008), blurring the informational content of the capital ratio for banks' counterparts. The contribution of our paper is to formalize the role of capital for risky investments, and to show how opacity on the true level of capital pledged by financial intermediaries leads to endogenous uncertainty.

Our paper also shares some common features with the paper by Fahri and Tirole (2009). They study the case where intermediaries do not bear the full cost of their choices because they benefit ex post from a bailout. In their model, the risk-shifting is between intermediaries and their creditors on the one hand, and the tax payers on the other hand. We focus instead on the risk-shifting between intermediaries and their creditors. It can be argued that the examples of US banks' failures since 2008[6] and the dramatic jump in risk premia charged on banks' debt at the start of the financial crisis, show that there was a significant misperception of the real risk borne by financial intermediaries' bondholders.

Finally, two other papers more recent this one developped models on similar issues. Dell'Aricia, Laeven and Marquez (2010) developped another model of the risk taking channel of monetary policy framed in a moral hasard set up for banks'capital. Challe, Mojon and Ragot (2012) show that the proportion of banks that prefer a risky investment portfolio over a diversified, less risky, one decreases with the level of interest rates.

[6]In Washington Mutual Bank's bankruptcy, around $13 billions of debt were left by the rescuer (JP Morgan) according to FDIC. An estimated 10,000 uninsured depositors lost over $270 million because of IndyMac failure.

The paper proceeds as follows. Section 1 documents the stylized facts about the crisis. Section 2 presents the model. Section 3 solves the model with symmetric information. Section 4 presents the results with asymmetric information. Section 5 concludes. All figures are gathered in section 6. Section 7 is the appendix.

2 Stylized facts on the pre-subprime crisis

2.1 Debt and risk premia

We dig out two major stylized facts from the literature and from our own observation of the pre-subprime crisis period in the US: in brief, the US banking sector increased its exposure to credit risk and liquidity risk, while at the same time the perceived riskiness of US financial intermediaries did not increase.

1. Risk-taking in the US banking sector

As discussed by many commentators of the pre-crisis period, US financial intermediaries increased their risk exposure during the decade leading up to the crisis. This took the form of increased leverage on the part of US investment banks. For instance, the Security and Exchange Commission (henceforth, SEC) reports that, between 2003 and 2007, the mean leverage ratio (defined as the ratio between overall debt and bank's equity) of the 5 major investment banks[7] jumped from 22 to 30. As shown in Acharya and Schnabl (2009), it turns out that this increase in leverage was mainly due to higher investment on the part of US banks in marketables securities, in particular in the ones which bore very low capital requirements under the Basel rules, such as AAA-rated senior tranches of ABS.

[7] i.e. Lehman Brothers, Bear Stern, Merril Lynch, Goldman Sachs and Morgan Stanley.

Moreover, according to Fed Flow of Funds figures, the ratio between US households' debt and US nominal GDP rose from 70% to 98% between end-2000 and end-2007. This increase in US private debt coincided with an expansion of the size of US banks' balance sheet: the ratio between the debt of the US commercial banking sector and nominal GDP rose from 59% to 76% between 1999Q4 and 2007Q4.

This expansion in the size of the banks' balance sheets was accompanied by an increase in "off-balance sheet leverage": the growing popularity of securitization activities led to an expansion of off-balance sheet products such as credit lines or liquidity enchancements provided by banks to firms and SPV (including bank's own off-balance sheet vehicles). As such, "off-balance sheet" leverage differs from the leverage *stricto sensu*, since these off-balance sheet commitments tie up only limited financial resources of the bank, until they are exercised. Indeed, as documented in Acharya and Schnabl (2009), these "optional" products charged very low capital requirements. Nevertheless, they allowed financial intermediaries to generate profits without the need of additional funding in compensation for their commitment to potentially bear future losses: in nfact, the unit of risk born by each dollar of the US banking system's equity had increased markedly.

2. The perceived riskiness of financial intermediaries were stable

US banks, however, benefited from very low level of risk premia paid on their debt. A look at the 10-year interest rate spread between commercial paper of US banks and US government bonds (Fig. 1) shows, for instance, that the premia paid on the risk of banks' default had been non-increasing from 2000 to mid 2007: the price of credit risk for banks had even declined somewhat between 2002 and 2007. A similar conclusion can be reached from the spread between Libor and T-Bill rates for shorter maturities (3 and 6 months), or from time series of the premia paid by individual investment banks.

The evolution of banks' expected default frequencies (henceforth, EDFs) is another indicator of the easiness for banks to have access to market funding during 2002-2007. The EDF is an implied probability of default computed from the share price of a firm (or, in the present case, of a bank), which reflects both the expected probability of default of a firm as perceived by market participants, and the risk premium required by investors to bear the firm's default risk. Therefore, the worldwide decreasing trend which occurred in banks' EDFs between 2002 and 2007 (see Figure 2) suggests either that market investors were considering lower probabilities of banks' defaults, or that they were requiring lower risk premia to invest in banks' capital.

Because of accomodative Fed's monetary policy, and historically low long-term rates due to the "savings glut", all US economic sectors benefited from extremely favorable funding conditions during this period. Nevertheless the low risk premia paid by US banks were allowed by the non increasing perceived riskiness of US financial intermediaries. In Figures 3 and 4, we present the historical evolution of the spread between the premium associated with CDS contracts on US banks and financial intermedaries, and the premium for CDS contracts on others economic sectors. These Figures emphasize the absence of increasing trend in this spread from 2004 to mid-2007: at that time, the perceived riskiness of US banking sector, compared to the others sectors, was not increasing.

To sum up, we observe that, during the years leading up to the crisis, the US banking sector experienced very favorable funding conditions, and faced very low risk premia on its debt, while at the same time increasing its leverage (for investment banks) or, more generally, its exposure to credit risk and liquidity risk *via* off-balance sheet vehicles. We also notice that the increase in banks' assets was concentrated on assets which require very low capital funding. These products, considered as quite safe by regulatory standards, were however at the root of significant losses for banks, be it for credit or liquidity risk, after the beginning of the financial crisis. In the next section we study in more depth the determinants of the banking regulation, and review the reasons which could have led to an underestimation of risk for some financial assets.

2.2 The evolution of capital requirements

Several factors explain the favorable (for banks) norms of capital requirements during this period. Concerning US investment bank regulation, Blinder (2009) and Stiglitz (2009) emphazised a change in the SEC rules regarding the reserve requirements imposed to US investment banks in 2004, which could have allowed them to increase significantly their leverage.

With respect to the international Basel capital regulation framework, Blundell-Wignall and Atkinson (2008) highlight the difficulty for outsiders to extract extensive information on the extent of risk undertaken by financial intermediaries; the 'capture' of regulators in order to obtain looser capital standards; and the procyclicality of the Basel rules. Rochet (2008) focuses on the lobbying on the part of the financial industry in the definition of Basel II . He also stresses that the Internal Rating Based (IRB) approach may have deliberately geared regulation toward complexity in the mapping from risky assets to capital requirements. Such complexity can only have favoured interpretations and implementation of capitalization that would align with the vested interest of the industry. Finally, the accounting rules concerning the consolidation of off-balance sheet entities were singled out by the Financial Stability Forum for creating "a belief that risk did not lie with arrangers and led market participants to underestimate firms' risk exposures" (April 2008).[8]

We focus on these facts, on which there is widespread agreement, because they are the most relevant to test the model's conclusions and its ability to replicate the build up of financial

[8] This question is actually one of the point in the agenda of the G20 and similar concerns about off-balance sheet vehicules has been brought up by academics (see Acharya and Schnabl 2009), official regulators and central bankers (see for instance speeches of C. Noyer and B. Bernanke in 2008)

fragility which has been witnessed during the last decade. We deliberately ignore the dynamics of the crisis itself, including the intertwined collapse of asset prices and flight to quality. Models of these phenomena include Holmstrom and Tirole (1997), Kiyotali and Moore (1997) and He and Krishnamurthy (2008), among others. The main goal of our paper is instead to understand how it was possible for intermediaries to increase their debt level without facing an increasing risk premium.

3 The model

There are two dates $t = 1, 2$. The economy comprises three assets and four types of agents: households, financial intermediaries, entrepreneurs and initial sellers. We first describe the asset structure and then the program of the agents.

3.1 Assets

Agents make their investment choices at date 1 and get assets returns at date 2. Three financial assets are available in the economy:

1. A safe asset whose supply X_S is variable, and whose return is r_S. The safe asset will be issued by entrepreneurs who have access to an iso-elastic production function $f(.) = X^{1-\eta}/(1-\eta), \eta < 1$, but results are robust to the introduction of more general production functions.

2. A risky asset in fixed supply X_R, whose return is R^*. R^* equals R with probability π and 0 with probability $(1-\pi)$,which is the extent of "*economic risk*" in the model. This asset is priced P on the financial market at date 1. The assumption of fixed supply simplifies the model, but it can be relaxed provided that the production function for the risky assets is not too price sensitive.

We make moreover the following technical assumption, which relates the concavity of the production function η and the extent of economic risk $1-\pi$.

$$\eta > 1 - \pi \tag{1}$$

As we show below, this assumption, which insures uniqueness of the equilibrium, is satisfied for reasonable values of the parameters.

3. A storage asset F, which has a constant return τ. This third asset is available in infinite supply.

Financial assets in this economy can be interpreted in a number of ways:

- The storage asset may for instance represent deposit facilities at the central bank, or cash. Indeed, it allows agents to invest without limit at a low and constant rate. In what follows, we will use the return on the storage asset as a proxy for the interest rate set by the monetary policy authority.

- The safe asset accounts for bonds, issued by AAA-rated states or firms. It can be interpreted as a loan to the "real" sector in order to finance investment or production.

- Finally, the risky asset encompasses all types of investments whose expected returns are higher than the return on bonds. It can be either real estate mortgages, junk bonds or stocks.

3.2 Agents

3.2.1 Initial sellers

Initial sellers are agents who sell the risky assets to intermediaries at period 1, consume and leave the economy. These agents are only introduced as a simple way of creating a supply of the risky asset at the beginning of period 1. Initial sellers have no choices to make, and simply consume in period 1 the amount obtained from the sale of the risky asset:

$$c^i = PX_R$$

3.2.2 Financial intermediaries

There is a unit mass of financial intermediaries (which we henceforth also designate as "banks"), who are risk-neutral, and who receive an endowment W^f at the beginning of date 1. Intermediaries maximize their consumption over the two periods with a discount factor β, such that:

$$\beta < 1/\tau \tag{2}$$

This assumption implies that the intermediaries are comparatively impatient, so that they want to borrow in period 1. In addition, they enjoy a private benefit U from being intermediaries. This benefit guarantees that these agents accept to operate as intermediaries rather than consuming all their endowment in period 1. They thus seek to maximize $c_1^f + \beta E\left[c_2^f\right] + U$, where c_1^f and c_2^f are the period 1 and period 2 consumption levels.

Financial intermediaries can invest in all existing assets. They never invest in the storage asset because they have access to the safe asset, which yields a higher return. Thus, their balance sheet is composed of a risky asset, PX_R, and a safe asset, X_S, on the asset side, whereas their liabilities are either equity, K, or debt, B. The amount K stands for the fraction of resources invested by the intermediaries themselves in their business. We assume that banks are subject to norms of "risk coverage" or "capital requirements" by either financial regulation or market discipline[9]. Banks have to invest from their endowment at least Δ per unit value of the risky

[9] Indeed, the level of capital requirement need not exclusively be the one set by regulators. It can also be the market norm on the acceptable level of capital for a given level of risk-taking.

asset:

$$K \geq \Delta P X_R$$

Banks decide their level of capital after an unobservable technology shock which makes the minimum capital constraint more or less stringent. One can think about this technology shock as the extent to which they can use off-balance sheet operations. The level of capital requirement can take two values in period 1:[10] Δ^{up} with a probability p^{up}, and $\Delta^{low} < \Delta^{up}$ with a probability p^{low}, with $p^{low} + p^{up} = 1$.

$$\Delta = \begin{cases} \Delta^{up} \text{ with probability } p^{up} \\ \Delta^{low} \text{ with probility } p^{low} \end{cases} \tag{3}$$

Financial intermediaries know the value of Δ, whereas households don't. They know the support of its realisation, Δ^{up} and Δ^{low}, and have a prior on p^{up} and p^{low}. This amounts to a "capital requirement risk" for households, and is motivated by the complex evolution of regulation and financial innovation discussed in the previous section. For instance, the parameter Δ could be thought of as the original Cooke ratio of 0.08. In fact, regulation evolved in order to allow for smaller values of capital requirements (Rochet 2008). Likewise, US investment banks were authorized by the SEC in 2004 to increase their leverage.

Following Allen and Gale (2000), we assume that financial intermediaries raise some funds using debt contracts, and that lenders are not able to fully observe the investment decisions of financial intermediaries. Lenders cannot discriminate between banks because these are identical *ex post*. Hence, they will demand the same interest rate r whatever the size of the loan they grant to the financial intermediary. Financial intermediaries are given the option of defaulting on their debt. In this case, lenders can seize the residual value of the assets and financial intermediaries are left with no income to consume.

[10] For the sake of simplicity, economic risk (that is, the return on the risky asset) and capital requirement risks are independent. This can be easily generalized.

Financial intermediaries therefore choose their debt level B, and the composition of their portfolio (X_S, X_R) solving the following program

$$\max_{K,B,X_R,X_S} c_1^f + \beta E\left[c_2^f\right] + U \tag{4}$$

$$\begin{aligned} \text{s.t } c_1^f &\leq W^f - K \\ c_2^f &\leq \max\{R^* X_R + r_S X_S - rB, 0\} \quad (5) \\ PX_R + X_S &= B + K \quad (6) \\ K &\geq \Delta P X_R \\ \Delta &= \Delta^{up} \text{ or } \Delta = \Delta^{low} \quad (7) \end{aligned}$$

In the constraint (5), the max operator indicates the intermediaries' option to default. This option will be considered depending on the value of the stochastic return R^*.

3.2.3 Entrepreneurs

There is a unit mass of entrepreneurs who maximize period 2 consumption, denoted as c^e. They have no wealth and they need to borrow in period 1 to produce in period 2. Their production function is $f(X) = X^{1-\eta}/(1-\eta)$. They borrow an amount denoted as X_S^e from the market at a rate r_S, to maximize their consumption $c^e = f(X_S^e) - r_S X_S^e$:

$$\max_{X_S} f(X_S^e) - r_S X_S^e$$

This yields the simple relationship

$$r_s = f'(X_S^e) \tag{8}$$

3.2.4 Households

Finally, there is a unit mass of households, who are risk-neutral and who receive an endowment W^H at the beginning of date 1. To simplify the algebra, and without any loss of generality, households maximize their date 2 consumption only.

Households face two sources of uncertainty: the economic risk pertaining to the return on the risky asset, R^*, and the regulatory risk pertaining to the level of capital requirement, Δ.

More specifically, households do not observe Δ, the effective level of capital per unit of risk, nor $(1-\pi)$, the exogenous level of risk that the risky asset bears no fruit. We also assume that they can't observe the structure of the composition of banks' assets, X_R and X_S[11].

We further assume that households form a prior on Δ such that $\Delta = \Delta^{up}$ with a probability p^{up}, or $\Delta = \Delta^{low} < \Delta^{up}$ with a probability p^{low} and that they try to infer $(1-\pi)$ from the level of asset prices.

Discussion of the information structure

Our assumptions concerning the information structure are meant to reflect the fact that it is very difficult for households, investors, or even rating agencies to understand the extent of risk undertaken by financial intermediaries. We show that when households can observe Δ (the effective amount of capital pledged by financial intermediaries against the risk of their portfolio), and can therefore assess financial intermediaries' incentive to take risk, they are able to infer the riskiness of the "risky asset" X_R, together with the associated risk of banks' default, from observable asset prices. We show in Section 5 below that, in this case, prices are fully revealing.

The perhaps more interesting case in which households have to form expectations about intermediaries' incentives to take risk is studied in Section 6. The way uncertainty is modeled is the following "nature" chooses $\Delta = \Delta^{up}$ or $\Delta = \Delta^{low}$ with probability p^{up} and p^{low}. Agents do not observe the true Δ and for rational expectations according to the probabilities p^{up} and p^{low}. As a consequence, agents may, over-estimate or under-estimate the true capital constraint. The interesting case is the case where they over-estimate capital constraint, because it can explain

[11] This implies that the households do not know the production function of entrepreneurs $f(.)$.

the interest rate charged to banks.

An alternative explanation is that agents are involved in a learning process. Their prior over capital constraint is p^{up} and p^{low}, whereas the true probabilities is $p^{up} = 0$ and $p^{low} = 1$. As the model is a two period model, there is no learning dynamics[12] and the model yield the same outcome as for the previous interpretation. For the sake of simplicity, we favor the rational expectation explanation in the rest of the paper.

Market segmentation

As in Allen and Gale (2000), we introduce the following form of market segmentation. Households cannot directly invest in the risky asset, and they can only either invest in the storage asset, or lend to financial intermediaries an amount B at the interest rate r. This assumption captures the advanced skills and accumulated rents (asset management abilities, private information, and so on) needed to trade corporate bonds and, in general, sophisticated financial products.

Households choose the composition of their financial portfolio in order to maximize their final consumption, taking market prices, their expectations of aggregate risk and the capital ratio of banks as given:

$$\max_{F,B^H} E\left[c^H\right] \tag{9}$$

$$F + B^H \leq W^H \text{ (at date 1)} \tag{10}$$

$$c^H \leq \rho B^H + \tau F \text{ (at date 2)} \tag{11}$$

where $E\left[.\right]$ is the expectation operator. The expectations are formulated on the two sources of uncertainty R^* and Δ. In the budget constraints, F is the amount invested in the storage asset,

[12] It would be very simple to introduce a learning dynamics. The results of the paper would hold in the transition process if households overestimate the severity of the capital constraint.

and B^H is the amount lent to intermediaries. For households, the stochastic interest rate ρ that they receive *ex-post* on their loans to financial intermediaries is uncertain, and depends on the probability of intermediaries defaulting. If the intermediaries do not default, they get the return defined *ex ante* r. In case of default, households get the residual value of the banks' portfolio $r_S X_S + R^* X_R$ for the realized value of R^*, so that the *ex post* return per unit of loan in case of default is $(r_S X_S + R^* X_R)/B^H$:

$$\rho = \begin{cases} r & \text{if no default} \\ \frac{r_S X_S + R^* X_R}{B^H} & \text{if default} \end{cases}$$

3.3 Market Clearing and equilibrium definition

As there is a unit mass of 1 for all types of agents, the equilibrium on the risky asset market, the safe asset market and the debt market are simply given by

$$X_R = 1 \tag{12}$$

$$X_S = X_S^e \tag{13}$$

$$B = B^H \tag{14}$$

An equilibrium for this economy is a set of values for $P, r, r_s, X_S, X_S^e, B, B^H, K$ and F such that

1. K, B, X_R, X_S solve the program of financial intermediaries (4) given the price P, the interest rates r, r_s and knowledge of the true capital requirement Δ.

2. F and X_S^e solve the program of the households, (9), given P, r and r_s and knowledge of the distribution of Δ, i.e. $\{\Delta^{up}, \Delta^{low}\}$, with the relevant probabilities.

3. X_S solves the program of entrepreneurs (8), given r_s.

4. Financial markets clear, equality (12)-(14) are fulfilled.

Finally, the structure of the model is summarized in Fig. 5.

3.4 Pareto Efficient Equilibria

Before solving the model for each of the two above-mentioned information structures, we derive the set of Pareto efficient allocations. In order to do this, we maximize a general welfare function, which weights the utility of the four types of agents. This can be written, with obvious notations for the Pareto weights

$$W = \omega^H c^H + \omega^f \left(c_1^f + \beta E c_2^f \right) + \omega^i c^i + \omega^e c^e \tag{15}$$

$$\text{with } \omega^H, \omega^f, \omega^i, \omega^e > 0 \text{ and } \omega^H + \omega^f + \omega^i + \omega^e = 1$$

Expectations in the objective function are only taken on the economic risk, R^*. Budget constraints are:

$$W^f + W^h = c_1^f + F + X_S + c^i \tag{16}$$

$$\tau F + f(X_S) + R X_R = c^H + c_2^f + c^e \tag{17}$$

As $\tau < 1/\beta$, forming the Lagrangian for the maximization of (15) subject to the constraints (16) and (17), one can check that the solution has the following properties

$$F = 0 \text{ and } f'(X_S) = \frac{1}{\beta}$$

The allocation of the central planner can be achieved in the decentralized economy if we remove any market segmentation and allow for lump sum transfers. In this case, households can directly lend to entrepreneurs and buy the safe asset. In this equilibrium, the interest rate on the safe asset is $1/\beta$ and the price of the risky asset is equal to its fundamental value:

$$P^* = \beta \pi R \tag{18}$$

We will say that there is a bubble when the asset price is above the value given by the previous equality.

4 Asset Prices

In this section we derive the price of the risky asset by solving the program of financial intermediaries. The intuition for the main mechanism of the model can be derived from the determination of this price.

We solve the program of financial intermediary under two conjectures. The first is that the capital requirement constraint is always binding, hence $K = \Delta P X_R$. This case is of course the relevant one for this model. We derive below the condition for the constraint to be binding. The second conjecture is that financial intermediaries default in the bad state of the world, in which the return on the risky asset is 0. We show below that this is always the case in equilibrium, as in Allen and Gale (2000). Indeed, in this case, the cost of the repayment of the debt is always higher than the return on the safe asset, and the intermediaries have an incentive to default.

Their program can be written as

$$\max_{K,B,X_R,X_S} W^f - K + \beta(\pi (RX_R + r_S X_S - rB) + (1-\pi) \times 0) + U$$

$$\begin{aligned} PX_R + X_S &= B + K \\ K &\geq \Delta P X_R \end{aligned}$$

The capital requirement is binding if financial intermediaries are sufficiently impatient, i.e.

$$\pi r < 1/\beta \tag{19}$$

This inequality stipulates that the expected cost of the debt πr (because the debt is repaid only in the case in which the return is high, which occurs with probability π) must not be too high. If the expected cost of the debt is too high, intermediaries would want to invest all of their wealth to decrease their expected debt burden, and the regulatory constraint would therefore not bind. As r is determined in equilibrium, we show below that the condition (19) is fulfilled for a wide range of parameter values.

The investment decisions of banks yield the price of the risky asset:

$$P = \frac{\beta \pi R}{\Delta + \beta \pi r\,(1 - \Delta)} \tag{20}$$

This asset price equilibrium is the main equation of the model. First note that when there is no capital requirement ($\Delta = 0$), the price is simply $P = R/r$, which is the case studied by Allen and Gale (2000).[13] As intermediaries default in the case of a bad aggregate shock, their demand for the risky asset is always higher than under the first best equilibrium. Indeed, as $\pi r < 1/\beta$, one finds $P > P^*$. Asset prices are thus too high. Second, when capital requirements increase, the price of the risky asset decreases. Taking r as given, increasing Δ implies a cost in the form of additional foregone consumption in period 1, an effect that dominates the reduction in size of the loan that needs to be repaid with probability π.

Thus, in partial equilibrium, the price of the risky asset can increase for two reasons: either because π increases, which means that the expected return of the risky asset is higher, or because Δ decreases (the amount of *ex ante* risk-shifting increases).

Maximization with respect to the demand for the safe asset X_S yields that the funding cost of financial intermediaries is equal to the return on the safe asset, as in Allen and Gale (2000)

$$r = r_s$$

This is necessary and sufficient in order to avoid infinite riskless profit opportunities on the part of financial intermediaries, while guaranteeing a positive demand in equilibrium.

The demand for the safe asset yields

[13] In their model, Allen and Gale show how incomplete debt contracts limit debtors' losses in the bad state of the world (losses fall on lenders). In other words, debt contracts act as call options for borrowers. This implies that borrowers only focus on the good state of the world when deciding the composition of their portfolio: the share of the portfolio at risk is higher and the price of risky assets is inflated above its level in a world without segmentation or complete contracts.

$$f'(X_S) = r_S = r \Longrightarrow X_S = \left[f'(r)\right]^{-1} \tag{21}$$

The previous equalities are valid whatever the beliefs on the part of households about the economic environment. These beliefs will however determine the interest rate charged by households. We now determine this interest rate for each of our two polar assumptions on the information available to households.

5 Solution without capital requirement uncertainty

In this section we assume that there is no capital requirement uncertainty $\Delta^{low} = \Delta^{up} \equiv \Delta$. Uncertainty only concerns the payoff of the risky asset in period 2. We first present the main results and then derive the main equations of the model and the proof.

Proposition 1 *Both the debt level B and the risk premium $r - \tau$ increase when the capital requirement decreases (i.e. Δ decreases inducing more risk-shifting)*

$$\frac{\partial B}{\partial \Delta} < 0 \ \textit{and} \ \frac{\partial (r-\tau)}{\partial \Delta} < 0$$

The proposition states that increasing capital per unit of the risky asset decreases both the volume of debt of intermediaries, and the credit risk premium, $r - \tau$. As a consequence, a decrease in capital per unit of the risky asset increases risk premia. This result is due to two main effects. First, the overall general equilibrium effect of a decrease in Δ is an increase in the intermediaries' debt level, as financial intermediaries put down less of their own capital, and have thus a greater incentive to increase their exposure to risk by issuing debt.

Second, when households observe changes in Δ, the effect of risk-shifting on asset prices is somewhat moderated by the response of the risk premium, $r - \tau$. Investors realize that intermediaries are taking more risk, and that the residual value of the assets in case of default decreases. They hence request a larger default risk premium $r-\tau$ to compensate for the increased cost of default. This version of the model is therefore incompatible with the stylized facts of the sub-prime cycle. As showed by Figure 1, indeed, banks have been able to borrow at lower risk premia during the five years leading up to the crisis, in spite of increasing their exposure to US housing assets.

To summarize, if the risk per unit of capital pledged by financial intermediaries—which could be due, for instance, to a larger scale of off-balance sheet activities—can account for an increase in their debt level, it cannot explain the path of the risk premia between 2000 and 2007. We therefore assert that risk-shifting, *per se*, is not sufficient to replicate the stylized fact of the *subprime crisis*. Before the crisis, banks and financial intermediaries have in fact benefited from extremely favorable funding conditions, a feature which cannot arise in the presence of known changes to capital requirements.

In order to prove this proposition, we now derive the program of the households and the market equilibria.

5.1 Households

It has been assumed that the households do not observe the amount of risky asset X_R and the risk of this asset, π, but they know the regulatory requirement Δ. One can first show that households can deduce both X_R and π from asset prices and from the value of Δ. Indeed, they can deduce the amount of risk π from the price level (20). Then, they can deduce the amount of aggregate exposure to risk from the amount of regulatory capital and with their knowledge of the coefficient Δ, $K = \Delta P X_R$. Finally, they can infer the amount of safe asset X_S from the balance sheet constraint of the intermediary. To summarize, households can deduce the structure of the asset side of intermediaries and the aggregate risk from the regulatory constraint and from the structure of financial intermediaries' liabilities.

Households anticipate correctly that, in the bad state of the world, the intermediaries' default implies that they get the residual value of the bank's portfolio. With probability π their return per unit invested is r, and with probability $(1-\pi)$ it is $r_S X_S / B$. The no-arbitrage condition for household can be written as

$$\pi r + (1-\pi)\frac{r_S X_S}{B} = \tau \tag{22}$$

5.2 Market clearing

Note that since $\pi \in]0,1[$ and $X_S < B$, the no-arbitrage condition (22) implies $r > \tau$. The return on the safe asset X_S for the intermediaries is then strictly higher than the return on the storage asset, and intermediaries therefore never invest in storage.

Equality (22) can be written as

$$B(r) = \frac{(1-\pi)\, r X_S}{\tau - \pi r} \tag{23}$$

We can substitute K, X_S and P by their equilibrium values given by equations (20) and (21) to obtain an expression $B(r)$:

$$B(r) = \frac{(1-\Delta)\, R}{\frac{\Delta}{\beta\pi} + r(1-\Delta)} X_R + f'^{-1}(r)$$

Using this expression in the equality (22), together with the expression for X_S given by (21), one obtains an equation in which r is the only unknown. The solution to this equation gives the equilibrium level of the interest rate.

In this economy, changes in Δ have two effects:

1. a direct effect, through the intermediaries' incentives to take risk,

2. an indirect one, through the evolution of the interest rate r, as households require a higher return when Δ declines.

Finally, the increase in the risky asset price will be moderated because r increases.

We can now derive the results of proposition 1. The algebra, which is not insightful, is gathered in Appendix.

6 Solution with capital requirement uncertainty

We now assume that the amount of capital pledged by financial intermediaries is not observed by households. Considering the possibility that capital requirement is either high or low, with the relevant probabilities given in (3), households infer from asset prices their best estimate of the aggregate risk π, and charge a risk premium accordingly. We show that in this case debt can be high and credit risk premia low, because households deduce a low value of the aggregate risk from the price of the asset. Moreover, we derive the effect of the level of the riskless interest rate on households' inference about this risk.

We characterize the inference on the part of households for each state. We use the upperscript *up* for values conditional on the fact that capital is high $\Delta = \Delta^{up}$, and the upperscript *low* for values conditional on the low level of capital, $\Delta = \Delta^{low}$.

First, the price of the risky asset is still given by equation (20), because it results from a no-arbitrage condition for intermediaries, who know the real value π and the real Δ. Households deduct π^{up} and π^{low} from their observations of the price P and of the real interest rate r, and from their belief about Δ. The following equation must hold:

$$\frac{\beta\pi R}{\Delta + r\beta\pi\left(1-\Delta\right)} = \frac{\beta\pi^{up} R}{\Delta^{up} + r\beta\pi^{up}\left(1-\Delta^{up}\right)} = \frac{\beta\pi^{low} R}{\Delta^{low} + r\beta\pi^{low}\left(1-\Delta^{low}\right)} \tag{24}$$

Note that we denote Δ (without upperscript) as the level of capital requirement effectively imposed on financial intermediaries. We deduce the following inference for households

$$\pi^{up} = \frac{\pi}{\frac{\Delta}{\Delta^{up}}\left(1 - r\beta\pi\right) + r\beta\pi} \tag{25}$$

$$\pi^{low} = \frac{\pi}{\frac{\Delta}{\Delta^{low}}(1 - r\beta\pi) + r\beta\pi} \tag{26}$$

These equations characterise the inference on the part of households on the level of aggregate risk consistent with the anticipated regulatory constraint. In case nature chooses $\Delta = \Delta^{low}$, $\pi^{low} = \pi$ and, since $r\beta\pi < 1$ in the equilibrium under consideration, $\pi^{up} > \pi$. The households' inference on π is biased upward when households overestimate the extent of regulatory constraint: the higher the ratio $\Delta^{up}/\ \Delta$, the higher π^{up}, and the higher the belief about the probability of the good state of nature for the risky asset. Symmetrically, if nature chooses $\Delta = \Delta^{up}$, $\pi^{low} < \pi$ for most parameter values.

Second, households form their inference about the residual value of their portfolio, $\frac{rX_S}{B}$, in the following way. First, from the observation of the level of regulatory capital of the banks, K, and from their belief about Δ, households assume that the level of investment in the risky asset is:

$$X_R^{up} = K/(\Delta^{up}P) \text{ and } X_R^{low} = K/(\Delta^{low}P)$$

From the balance sheet constraint of banks given by equality (6), households form the following expectation of the amount of safe asset

$$X_S^{up} = B + K - P\frac{\Delta}{\Delta^{up}}X_R \text{ and } X_s^{low} = B + K - P\frac{\Delta}{\Delta^{low}}X_R \tag{27}$$

Note the in the previous equalities, X_R denotes the true level of the risky asset in the balance sheet of financial intermediaries.

Third, the no-arbitrage condition for households must now be written according to the expectations of households. As they anticipate that the regulatory constraint will be high with probability p^{up} and low with probability p^{low}, they adjust their portfolio so that:

$$p^{up}\left(\pi^{up}r + (1 - \pi^{up})\frac{rX_S^{up}}{B}\right) + p^{low}\left(\pi^{low}r + \left(1 - \pi^{low}\right)\frac{rX_S^{low}}{B}\right) = \tau \tag{28}$$

Using equations (25 and 26) in order to substitute for π^{up} and π^{low}, the expressions for X_S^{up} and X_S^{low} given by (21), the value of B implied by the balance sheet constraint of the intermediary, and the fact that $r_S = r$, we obtain an equation for the equilibrium interest rate r which depends only on known parameters and functional forms.

In order to focus on the interesting case, we assume that the binding regulatory constraint (which, within this framework, is chosen by nature) is Δ^{low}. This may capture, for instance, the possibility of increasing effective leverage through securitization.

In this case, when $p^{low} = 1$ one obtains the outcome of the previous section, in which agents know the true regulatory constraint. We study below the cases where $p^{low} < 1$.

6.1 An extreme case

In order to get insights into the economic mechanisms in the model, we consider the simplest case in which households associate a probability $p^{up} = 1$ to a capital requirement regime which amounts to a form of narrow banking. Within this regime all the investment in the risky asset is funded by financial intermediaries' own capital, hence $\Delta^{up} = 1$. This case is only used here in order to show the main effects at work in the model, which is solved in the next section in a more general, though only numerical, case. In this case, households anticipate that $X_S^{up} = B$ from the budget constraint of banks. As a consequence, they expect that the residual value of banks' portfolio fully covers the debt of the banks. Using (28) one finds that the equilibrium interest rate is

$$r = \tau$$

Since households expect that all the risk is borne out by banks, the return on the portfolio liquidation is the same as the return on the safe asset. Hence households charge no premium on banks. The risk perception error $(E(\pi) - \pi)$ is :

$$E(\pi) = p^{up}\pi^{up} + p^{low}\pi^{low}$$

$$E(\pi) = \pi^{up} = \frac{\pi}{\Delta + (1-\Delta)\,\beta\tau\pi} > \pi$$

The price of the risky asset can be written simply as

$$P = \frac{\beta\pi R}{\Delta + (1-\Delta)\,\beta\tau\pi}$$

This extreme example also illustrates the role of the level of interest rates. Lower interest rates ($\tau \downarrow$) lead to an increase in P, the price of the risky asset, and to a larger risk perception error ($E(\pi) - \pi$). Households infer from the rise in P that aggregate risk has declined (i.e.$E(\pi) \uparrow$). Indeed, households underestimate the impact of a decrease in the riskless rate τ on the price of the risky asset, because they underestimate the incentives to take risk. Households do not require premia in order to be compensated for the default risk, and the price of the risky asset increases. In what follows, we study the more general case.

6.2 Model simulations for the general case

This section studies the general case in which households form expectations about the level of capital requirement. Unfortunately, it is not insightful to derive an analytical expression for the endogenous variables. We thus illustrate the main conclusions of the model with a simple calibration exercise. We show how the perception of risk $E(\pi)$ and the risk premium paid by intermediaries $r - \tau$ are affected by the riskless interest rate τ.

We take the following numerical values $\beta = 0.96$, $R = 1, \eta = 0.9$ and $X_R = 1$. We also set $\pi = 0.8$ and $\Delta^{low} = \Delta = 0.04$ and $\Delta^{up} = 0.07$. For these parameter values, the three conditions on the parameters (1), (2) and (19) are always satisfied for the range of parameters considered.

In order to observe the impact of the riskless interest rate, we construct the average (unconditional) expectation about the average risk:

$$E(\pi) = p^{up}\pi^{up} + p^{low}\pi^{low}$$

$E(\pi)$ is the expected probability that the risky investment succeeds and that the financial intermediary does not default. Since we assume that nature draws $\Delta = \Delta^{low}$, we have $\pi^{low} = \pi$. Hence, the difference between $E(\pi)$ and π stems from the deviation of π^{up} from π.

Fig. 6 shows the value of $E(\pi)$ as a function of τ for $p^{up} = 0.4$; $p^{up} = 0.5$ and $p^{up} = 0.6$.[14] Recall that the true value of the risk is $\pi = 0.8$. Households underestimate the extent of aggregate risk ($E(\pi) > 0.8$) because putting a positive probability on having a high capital requirement implies that higher asset prices can be due to a higher probability of success of the risky asset.

In fact, higher asset prices are due to an increased leveraged on the part of financial intermediaries. *Ex ante*, households assign a positive probability to the state of nature in which $\Delta = \Delta^{up}$. The expectation of such a state leads them to require a risk premium on B which turns out to be insufficient when nature chooses instead $\Delta = \Delta^{low}$. As shown in Fig. 6, the greater the households' prior that the capital requirement is high, the larger the error in the perception of risk.

The model thus shows how uncertainty about financial intermediaries' risk incentives may induce investors to believe that the extent of financial risk in the economy has declined, leading them to lend to financial intermediaries at relatively small risk premia (see Fig. 1). In this case, lenders look "optimistic" compared to banks. The model can thus be seen as a first step to endogenize market sentiment, which is introduced exogenously in Shleifer and Vishny (2010) for instance.

An alternative explanation for the low level of risk premia is that investors expected to

[14] In the trivial case in which p^{up}=0, note that $E(\pi) = \pi$ irrespective of the value of τ.

be bailed out collectively by governments and central banks. Farhi and Tirole (2009) propose a model in which financial institutions coordinate their exposure to risks in order to increase systemic risk, and therefore the likelihood that public authorities will bail out all financial intermediaries. Whereas their model explores the issue of risk-shifting from investors to taxpayers, we focus instead on the shifting of risk from banks to bondholders. We see our model as complementary to theirs. It is important to stress, though, that the increase in credit spreads for US commercial banks in 2007 (see Fig. 1) suggests that at least some investors feared that the US commercial banks might not be ultimately bailed out. The capital loss on a portfolio of US commercial banks bonds associated to these decrease in spreads is all but negligible.

6.3 A model of the risk-taking channel of monetary policy

The second result generated by the model is that the underestimation of credit risk, $E(\pi) - \pi$, decreases, and the risk premia, $r - \tau$, increases with τ, the level of the risk-free interest rate. This is showed, for our calibrated example, in Fig. 6 and Fig. 7. The intuition for these effects has been identified in the previous section: households do not fully assess the marginal effects of changes in τ (which is the floor for r) on the incentive to take risk, and therefore on the asset price P. Within our framework, the impact of the interest rate on asset prices is magnified by risk-shifting. The capital requirements curb this effect, but their strength is overestimated, leading households to incorrectly infer that part of the increase in asset prices is due to a reduction in aggregate risk. This overestimation is larger when interest rates are low, because the valuation of our assets is non-linear. An incorrect prior for Δ has a larger effect on the price of the risky asset P at lower levels of interest rates. The higher response of P translates, through (24), into a higher risk perception error[15].

[15] The model therefore provides an explanation for two complementary aspects of "the risk taking channel of monetary policy" defined by Borio and Zhu (2008) as : "the impact of changes in policy rates on either risk

The predictions of the model for risk perception are actually consistent with the empirical results produced by Altumbas, Gambacorta and Marquez (2009). They found that the Expected Default Frequencies, and other market-based measures of bank's risks as perceived by financial market participants, react positively to changes in interest rates: a lower interest rate leads investors to perceive banks as less risky. Turning to banks' risk-taking, which may be interpreted as banks exploiting their ability to borrow cheaply from financial markets, a number of recent studies, including Jimenez *et al.* (2008), Ioannidou, Ongena and Peydro (2008), and Ciccarelli, Maddaloni and Peydro (2009) show that credit standards are correlated to the level of interest rates. Lower interest rates therefore imply lower credit standards, including for customers who are perceived as presenting a higher credit risk.

It is important to stress, however, that the model bears results for the imapct of the level of interest rates on risk perception and risk-taking irrespective of the source of variation in interest rates. The interest rate in the model is real, and can therefore be influenced by several factors. During the decade leading up to the crisis, several explanations had been put forth in order to explain the low level of nominal and real interest rates. According to Taylor and Williams (2007), US monetary policy had been overly accommodative. Bernanke (2010), however, stressed instead that China's excess savings had played a major role in keeping the long end of the US yield curve at comparatively low levels. Either of these factors may in turn have been amplified by the phenomenon of "search for yields", as emphasized by Rajan (2006). We don't take a stand on these alternative possible drivers of the level of the interest rates, and only stress that the endogenous mechanism described in our model would hold for either of them.

perceptions or risk-tolerance and hence on the degree of risk in the portfolios, on the pricing of assets, and on the price and non-price terms of the extension of funding".

7 Concluding Remarks : Can the model explain the build up of financial fragility?

In this paper we have showed, first, that the combination of risk-shifting and fuzzy capital requirement can explain a puzzling fact of the sub-prime crisis, i.e. that banks could increase their exposure to risk without having to pay higher risk premia on their debt.

In a situation of uncertainty with respect to regulatory constraints, the increase in the observed asset prices can be interpreted as a lower aggregate risk in the economy while, in fact, asset prices are driven by greater risk-taking on the part of financial intermediaries. We also showed that this model gives rise to a risk-taking channel of monetary policy: the influence of the level of the interest rate on risk perception on the part of some agents and exposure to risk on the part of others.

Our result resonates with the popular notion that financial markets participants can form wrong inference on risks. In particular, when the effectiveness of capital requirements is not observable by agents, the signal extracted from market prices is contaminated by noise coming from excessive risk-taking behavior. In our model, market forces, by themselves, are not able to lead the economy to the optimum allocation of capital, because risk incentives are not correctly understood.

We see two obvious extensions to our model. First, it is possible to endogenize the expectations of households within a dynamic setting in which households learn about the relevant parameters. Although the results of our models would still hold even if the priors of the households were far enough from the true parameters, the resulting dynamics might generate interesting patterns. Second, it would be interesting to study the political economy aspects associated with the assessment of risk within such an economy. Sellers of the assets have an incentive to underestimate the extent of economic risk, or to generate complexity in order to increase the cost of signal extraction. This should be anticipated by households, who would then look for other sources of information. For instance, we understand the current discussion about rating agencies as part of the political economy debate on the management of risk expectations in economies where intermediaries play an important role.

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8 Figures

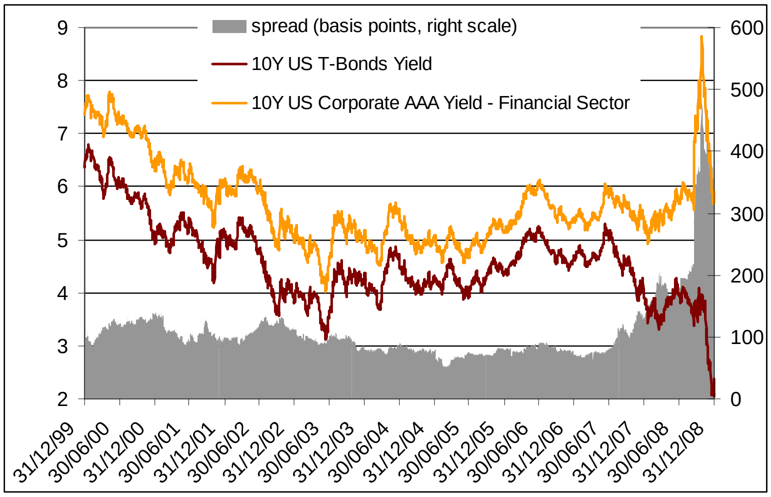

Fig 1: Spread between 10Y US T-Bonds and 10Y Bonds of US AAA Financial Companies

Source: Bloomberg

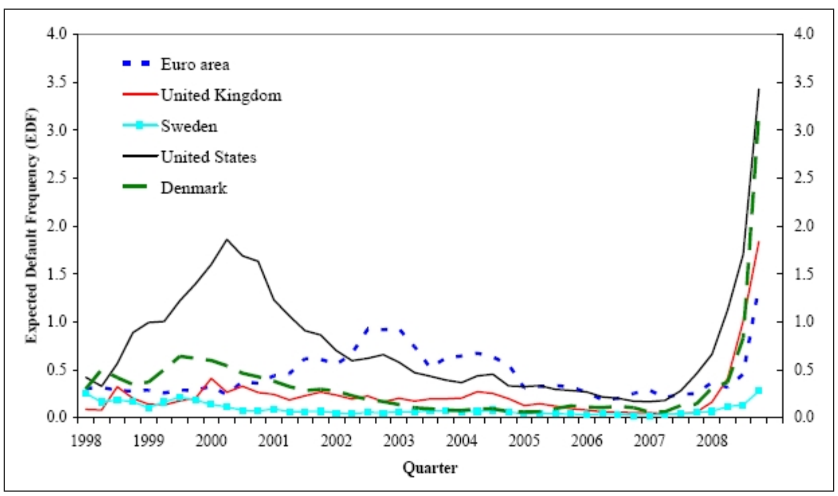

Fig 2: Expected Default Frequency of banks, over a 1-year horizon,

averages by country and groups of countries

Source: Moody's KMV, from Altunbas and al. (2009)

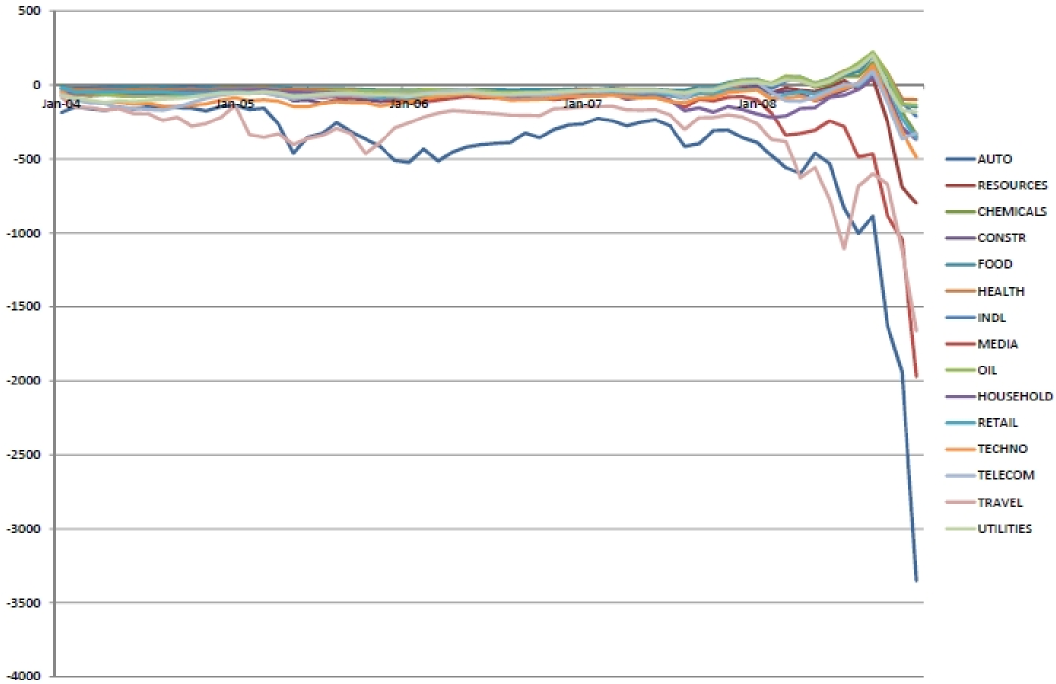

Figure 3 : Difference between CDS premia on US banks and CDS premia

on US non financial economic sectors

Source: Datastream/CMA

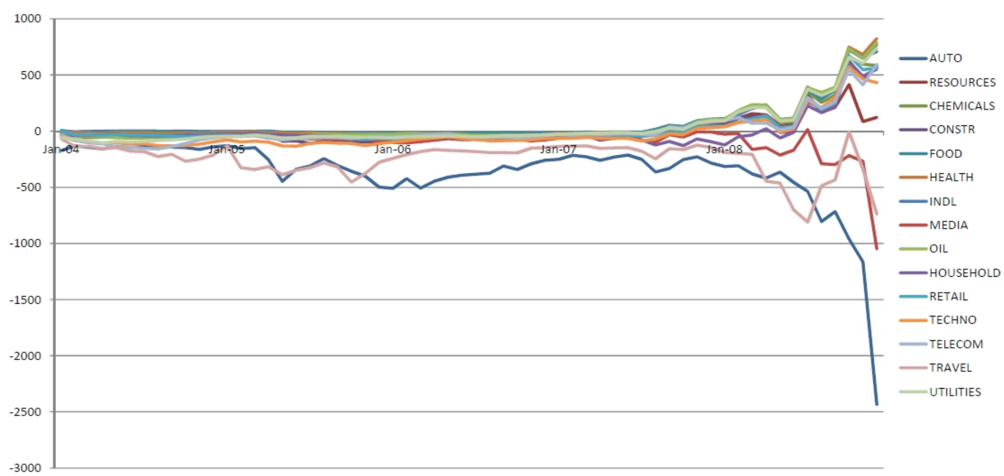

Figure 4 : Difference between CDS premia on US financial institutions and CDS premia

on US non financial economic sectors

Source: Datastream/CMA

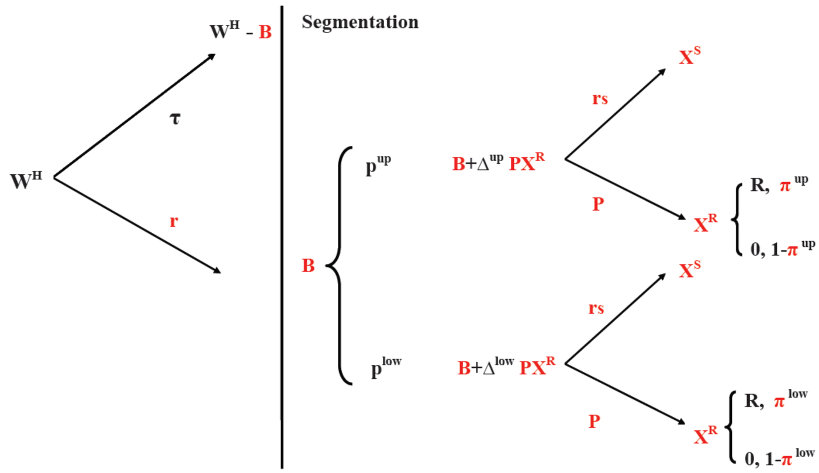

Fig 5 : Summary of the structure of the model

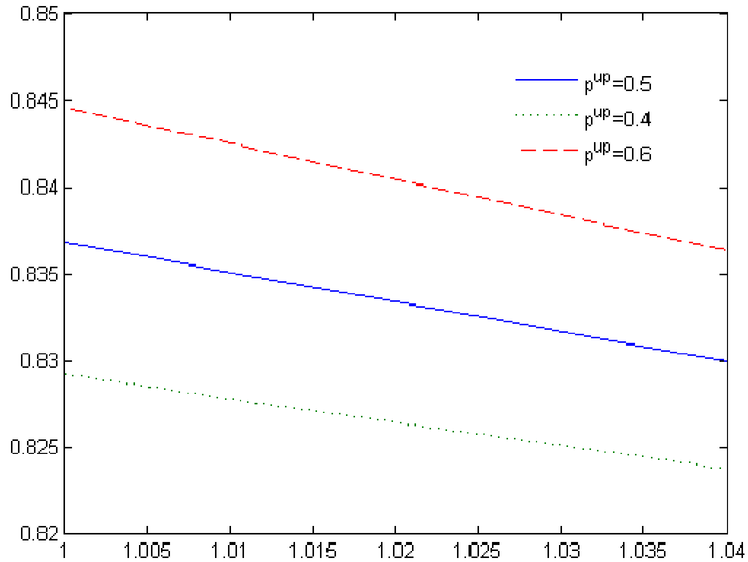

Fig 6 : Expected probability of success $E(\pi)$ (y-axis) as a function of τ (x-axis)

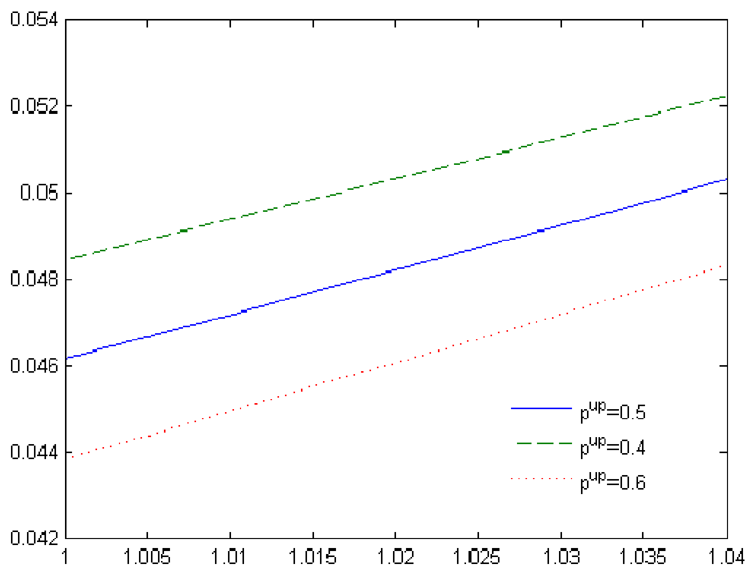

Fig 7 : Interest rate margin $r - \tau$ (y-axis) as a function of τ (x-axis)

9 Appendix

A Proof of $\frac{\partial(r-\tau)}{\partial\Delta} < 0$

Recall that:

$$B = (1-\Delta)PX_R + X_S = \frac{(1-\Delta)\,R}{\frac{\Delta}{\beta\pi} + r\,(1-\Delta)}X_R + f'^{-1}\,(r) \tag{29}$$

and

$$\tau = \pi r + \frac{1-\pi}{B} r f'^{-1}\,(r) \tag{30}$$

Let us define: $\Theta = \frac{\Delta}{1-\Delta}$. Then from (29)

$$B = \frac{R}{\frac{1}{\beta\pi}\Theta + r}X_R + f'^{-1}\,(r)$$

and (30)

$$\begin{aligned} \tau &= r\left(\pi + (1-\pi)\,\frac{f'^{-1}\,(r)}{\frac{R}{\frac{1}{\beta\pi}\Theta + r}X_R + f'^{-1}\,(r)}\right) \\ &\Rightarrow \quad \Theta = \beta\pi\left(\frac{R\,(\tau - \pi r)}{1-\frac{\tau}{r}} r^{\frac{1}{\eta}-1} X_R - r\right) \end{aligned}$$

The last equality defines a function $\Theta\,(r)$, which gives the value of Θ (and hence Δ) necessary in order to obtain an equilibrium interest rate r. We prove that $\Theta\,(r)$ is decreasing, and hence that the function $r\,(\Theta)$ is decreasing. Diffentiating $\Theta\,(r)$, a sufficient condition to obtain $\Theta'\,(r) < 0$ is

$$\left(\frac{1}{\eta} - 1\right)\left(\frac{\tau}{r} - \pi\right) < \pi + \frac{\tau}{r}\frac{\tau/r - \pi}{1 - \tau/r}$$

Define $x \equiv \tau/r$. In the equilibrium under consideration $\pi < x < 1$. After some algebra, one finds that a sufficient condition is

$$\eta > 1 - \pi$$

The condition is satisfied for instance for $\eta > 1/2$ and $\pi > 1/2$. In this case, r is decreasing with Δ. CQFD

B Proof of $\frac{\partial B}{\partial \Delta} < 0$

From equality (22), one finds

$$B = \frac{1-\pi}{\tau - \pi r} r^{1-\frac{1}{\eta}}$$

After some algebra, a sufficient condition for B to increase with r is

$$\eta > 1 - \pi$$

If the previous condition is fufilled one finds that $\frac{\partial B}{\partial r} > 0$ and $\frac{\partial (r-\tau)}{\partial \Delta} < 0$. As a consequence, $\frac{\partial B}{\partial \Delta} < 0$.

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