Banks Risk Taking, Financial Innovation and Macroeconomic Risk.

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Abstract

This paper shows how financial innovation, together with the observed changes in the structure of macroeconomic risk in the U.S. economy, can explain the strong growth in primary and secondary credit markets since the 1990s. In the empirical part we document the fall in macroeconomic risk, the financial innovation in the financial markets and the expansion of the prime and secondary credit market. We also show that changes in macroeconomic risk are closely related to the evolution of the prime market. In the theoretical part of the paper we study the interconnection of these different elements in a simple model. The model incorporates heterogeneous banks that seek to maximize the value of their portfolio by investing in safe and risky assets in the prime market for risk. In addition, financial innovation allows them to reduce the risk of their portfolio by investing in credit derivatives in the secondary markets. The CARA-Normal specification of the model permits the generation of closed-form expressions for the demand of risky assets and for the demand of credit derivatives. The results of the model show that financial innovation increases bank appetite for risky investment, credit derivatives acquisition and the portfolio variance. The model also highlights the fact that the strength of its effect on portfolio choices is stronger in environments with low aggregate macroeconomic risk.

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1 Introduction

From the mid 1980's until the current financial crisis the US financial market has been characterized by a big expansion of the prime market for risk (Figure 2). How can such a credit boom be justified? One possible explanation is the rise in global imbalances (e.g., Caballero and Krishnamurthy (2009); Caballero, Farhi and Gourinchas (2008); Obstfeld and Rogoff (2009); Blanchard and Milesi-Ferretti (2009)). Thus the increasing demand for safe asset from the rest of the world, increased the U.S. holding of risky assets. Additional explanations of the consumer credit boom are: the decline in the monetary interest rate (e.g., Schularick Taylor (2009) and Taylor (2007)), the rise in house prices (Attanasio, Blow, Hamilton and Leicester (2005)) and the deregulation on the financial markets (Campbell and Hercowitz (2006)).

Financial innovation was another explanation highlighted in the literature, as a possible explanation of the credit boom. Until the 1970’s, both loans to household and to the business sector were considered illiquid and thus they were held in banks balance sheets until maturity or default. However during the 1970’s the structure of the U.S. financial market began to change substantially. In February 1970, the U.S. Department of Housing and Urban Development created the first credit derivative, the mortgage-backed security (MBS), as an application of the securitization technology in the mortgage market. The first institutions to issue them were the government-owned corporations Ginnie Mae and Freddie Mac. This date signed somehow the date of creation of the modern structured finance because thereafter a lot of other derivatives that applied securitization in all kinds of different sectors were introduced in the market. The most important ones were the interest rate swaps, currency swaps and zero coupon bonds introduced in 1981, the collaterized mortgage obligation (CMO) and the junk bonds in 1983, the asset-backed securities (ABS) in 1985 and finally the collaterized debt obligation (CDO) and the credit default swaps (CDS) that were created in 1995 by JPMorgan. Moreover in the 70’s a lot of investment funds like, the hedge funds, the money market fund and the mutual funds were established and started to grow rapidly. In addition the investment banking industry began to change to a more "transactional" form and a large number of boutique investment banks were established. To conclude this parenthesis, continuous product innovation in the U.S. financial market let to an expansion of the set of credit risk management tools that financial institutions were using and in addition it created a more integrated but complex financial system. The figure (time line) summarize the history of these financial innovations in a time line. The last five years there has been a considerable amount of papers that study the effect of the secondary market instruments, on banks risk taking, liquidity and financial stability. Examples are Marsh and Wagner (2006), Wagner (2008), Instefjord (2004) and Shin (2009).

However an interesting observation arise from the study of the evolution of both prime and the secondary markets for risk and the history of financial innovation. Even though many of these new credit derivative products were available from the 1970’s, it was almost two decades later, in the 1990’s that
both the prime and the secondary market for risk expanded substantially. Hence in this paper we consider a **complementary** explanation for the credit boom: the fall of macroeconomic risk (the aggregate volatility) in combination with the financial innovation. Thus the purpose of this paper is to understand how changes in both the macroeconomic and financial environment have contributed to these expansions.

Why the fall in macroeconomic risk is important? There is now broad consensus among macroeconomists of a widespread and persistent decline in the volatility of real macroeconomic activity after the mid 1980’s. Kim and Nelson (1999) and McConnell and Perez-Quiros (2000) were the first to formally identify structural change in the volatility of U.S. GDP growth, occurring sometime around the first quarter of 1984. Blanchard and Simon (2001), using a different set of econometric tools, also find a large decline in output volatility over the last 20 years. Following this work, Stock and Watson (2002) subject a large number of macroeconomic time series to an exhaustive battery of statistical tests for volatility change. They conclude that the decline in volatility has occurred broadly across sectors of the aggregate economy. It appears in employment growth, consumption growth, inflation and sectoral output growth, as well as in GDP growth. It is large and it is persistent. Reductions in standard deviations are on the order of 60 to 70 percent relative to the 1970s and 1980s. Therefore the fall in macroeconomic risk is important because the drop was large, persistent and indentified in many macro aggregates. As a results two new strands of literature were developed; the macroeconomic literature that investigates the cause of this sustained volatility decline (see Cecchetti, Flores-Lagunes and Krause (2006) for a review of this literature) and a more recent literature that studies the effect of uncertainty on macroeconomic outcomes (e.g, Lattau, Ludvigson and Wachter (2009) that studies the effect of macroeconomic risk on the equity premium and Fogli and Perri (2009) studies how changes in macroeconomic volatility have affected external imbalances). The subject of this paper is related to the second strand of literature. Thus we would like to examine the possible consequences on macroeconomic risk on the expansion of the prime and secondary U.S. credit market.

Our main investigation contains two parts. In the first part, we employ the same empirical techniques used in the macroeconomic literature to characterize the decline in volatility of the real GDP growth rate in the U.S. data. In the second part, we investigate behaviour of the financial intermediaries (banks) in a theoretical CAPM model.

The empirical part of this paper follows much of the macroeconomic literature and characterizes the decline in volatility by estimating an AR(1) process for the real GDP growth. The estimation produces evidence of a shift to substantially lower aggregate volatility at the mid of the 1980s. It also examines empirically the correlation of the macroeconomic risk with the prime market for risk. The empirical results show that changes in macroeconomic conditions are closely related to the evolution of the prime market for risk.

The theoretical part of our study puts together these different elements and shows their interconnection in a simple model. The model describes the port-
folio problem of a banker under two different scenarios; (i) without a secondary market for risk ("autarky") and (ii) with a secondary market for risk ("financial innovation"). The bankers are identical except the fact that they face different idiosyncratic payoff shocks. They are modelled as risk averse traders with CARA preferences who seek to maximize the value of their portfolio by investing in safe and risky assets. The payoff of the risky assets depends both on idiosyncratic (regional) risk and aggregate risk and both kinds of risks follow normal distributions. In autarky banks can invest only in their region. Therefore the portfolio that they hold is not fully diversified. In the second scenario the bankers have the opportunity to invest also in some new risky assets, the credit derivatives. The return of the credit derivatives is negatively correlated with the idiosyncratic component of the risky asset. Therefore the credit derivatives are new instruments that the banker could use in order to hedge his idiosyncratic risk. By using the credit derivatives, the banking sector becomes more homogeneous (integrated), given that the regional differences between the different banks decrease. We solve the model and compute the optimal portfolio choices of the banker under the two different scenarios. The CARA-Normal specification of the model permits the generation closed-form expressions for the demand of risky assets and for the demand of credit derivatives. The results of the model show that the presence of the credit derivatives induces banks to invest more in risky assets and on credit derivatives. The portfolio variance of the banks increases because even though credit derivatives help to hedge the idiosyncratic risk, they induce the banks to acquire more risky assets and therefore the total variance increases. The paper also examines empirically how changes in the aggregate risk have affected the key variables of the model. The results show that changes in macroeconomic risk have played a major role in the expansion of both the prime and the secondary markets for risk after the mid 80's. In addition, interesting nonlinear effects arise from different levels of innovation of the banking sector. The more integrated is the banking sector, the more correlated are asset returns with the hedging instruments and the stronger is the effect of macroeconomic changes on risk taking and on risk hedging.

The rest of this paper is organized as follows. In the next section we present empirical results documenting the changes in the volatility of real GDP growth. We then explore their statistical relation with movements in measures of the prime credit market. Section 3 presents a model that incorporates credit derivatives, and evaluates the joint effect of the financial innovation and the decline of aggregate volatility in explaining the expansion of the trading volume of the prime and secondary credit markets during the 1990s. Additional results from a model where the banks face VaR constraints are also presented. Section 4 concludes.
2 Empirical Evidence

In this section we document the changes in aggregate volatility that took place in the 80’s and we provide evidence on how the prime and secondary markets for risk developed thereafter.

Our benchmark measure of the aggregate volatility is the standard deviation of quarterly real GDP growth rate, which is a broadly used measure in the macroeconomic literature. Figure 1 plots real GDP growth rates and its volatility for overlapping 5-year windows where the time indicator represents the last year of the window\(^1\). We follow the pioneer paper in this literature, McConnell and Perez-Quiros (2000), and we compute the volatility of GDP growth by estimating an AR(1) process for quarterly GDP growth data\(^2\). The series is in 2005 chain-weighted dollars and span the period from the first quarter of 1967 to the fourth quarter of 2009. The figure clearly reveals the sharp drop in volatility. After the mid 80’s there is significant decline in aggregate risk. More specifically we estimate that the decrease in the macroeconomic volatility in the subsample (1967Q1:1984Q4) is around 50% compared to the subsample (1985Q1:2009Q4).

\[\text{Figure 1}\]

As we already mentioned, over the last 20 years the US financial market was characterized by an explosion in the size of the prime market for risk, thus the market for households and business loans. Figure 2 displays the time series of total household debt, business sector debt and financial sector debt. It is

\(^1\)The right y axes (blue) indicates the measure for the standard deviation and the left y axes (red) indicates the measure for the GDP growth rate.

\(^2\)Moreover it is well know in the literature that US GDP has a unit root. Thus its first difference must follow a stationary process (for references see Nelson and Plosser (1982)). Thus we estimate the GDP growth rate with an AR(1) process.

\(^3\)Our results are robust to the use of HP-filtered GDP growth. See also Cecchetti et al. (2006).
obvious that all variables increased considerably after mid 80’s. Especially the increase in household borrowing is remarkable.

To investigate the relationship between the macroeconomic volatility and the prime market for credit we divide our sample in nonoverlapping 5-year windows and we compute the standardized standard deviation of quarterly GDP growth and the standardized values of the inverse of the household, business and financial sector debt. The results are plotted in the figure 3. Figure 3 exhibits a strong correlation between macroeconomic volatility and the volume of each of the prime markets under consideration. During the periods of low-frequency movements in aggregate risk, the prime markets tend to expand and the economy has high levels of debt and the opposite happens when volatility is high. Noteworthy is the correlation between the household sector debt and the aggregate volatility\(^4\).

\(^4\)Suppose \(x\) is the initial data series where \(x = \{\text{household debt, business debt, financial debt}\}\) and \(y = \log(1/x)\). Then the data plotted is \(y = \frac{\max(y)}{x} \cdot \frac{1}{x(y)}\).
In addition to the prime market, the secondary market for risk, thus the credit derivative market, started to develop rapidly as well. The figures below show the trading volume of the credit derivative market and of the securitization market for the US commercial banks. As we can clearly see, even though in the beginning this market had a very small trading volume, thereafter it expanded rapidly.

Therefore except of the changes in the macroeconomic risk, important changes took place also in the financial markets. The figure below shows the timeline where the different financial innovations took place.
One would expect that the banks would immediately explore these new opportunities and invest more in risky assets in order to increase profits. However, the data show that until the beginning of the 90’s, the size of these new markets for risk was relatively modest and banks increased their investment in risky loans only by a conservative amount. Instead, after the 90’s both the prime and the secondary market for risk expanded substantially.

To summarize, in the mid 80’s aggregate volatility declined sharply. Shortly after, in the 90’s, we observed an explosion in the size of the prime and secondary markets for risk. Our hypothesis is that the decrease in aggregate volatility caused the credit boom in the prime market for credit and consequently increased demand for credit in the prime market let to a boom also in the secondary market as well. In the rest of the paper we will put together these elements and study how they might be interconnected.

3 The model

The model presents a two period, one good economy. There is a continuum of regions indexed by $i$, where $i \in [0,1]$. In each region is located a risk adverse banker with constant coefficient of absolute risk aversion (CARA), $\Gamma$. There are two kinds of assets in the economy: risky and riskless. The risky asset promises a return $R = R^i + R^a$ where $R^i$ is the idiosyncratic (regional) component and $R^a$ is the aggregate one. Both $R^i$ and $R^a$ are normally distributed where $R^i \sim N[E(R_i), Var(R_i)]$ and $R^a \sim N[E(R_a), Var(R_a)]$ at time 1. The idiosyncratic component is identically and independently distributed across regions and uncorrelated to the aggregate component. Thus
R \sim N[E(R), Var(R)] = N[(E(R_i) + E(R_a)), (Var(R_i) + Var(R_a))]. The riskless asset offers a sure return of \( R^f \). In order banks to have incentive to take risk, we assume that in expectation the return of the risky asset is higher than the safe asset, \( E(R) > R^f \). Each banker possesses some initial wealth \( W_0 \). We assume that the initial wealth is high enough in order to make sure that the bankers are never capital constrained. Investment decisions take place in the first period and in the second period uncertainty is realized and consumption occurs.

In this model we study two different scenarios of the economy: in autarky and in financial innovation. When the economy is in autarky, the bankers are modelled as investors that choose an optimal portfolio by investing in safe and in risky regional assets. They can invest only in their region. Therefore by construction the portfolio that they hold is not fully diversified. Under the financial innovation scenario, we introduce in the basic model a new risky asset, the credit derivatives. The credit derivative promises a return \( R^{CD} \) where \( R^{CD} \sim N[E(R^{CD}), Var(R^{CD})] \). For simplicity we assume that the expected return of the credit derivative is equal to the risk free rate, thus \( E(R^{CD}) = R^f \).

In addition, the return of the credit derivative is negatively correlated with the idiosyncratic component of the risky asset. Therefore the credit derivatives are new instruments that the banker can use in order to hedge his idiosyncratic risk, without gaining any extra return. The use of the credit derivatives decreases to regional differences between the different banks therefore the banking sector becomes more integrated.

### 3.1 Autarky

Each banker invests his initial wealth \( W_0 \) in a portfolio comprising of both riskless and risky assets \((y^f, y)\). Thus the time-zero budget constraint is \( W_0 \geq y^f + y \). Bankers wealth at time-one is \( W_1 \geq y^f R^f + y R \). The bankers maximize the expected utility subject to the budget constraint by choosing the optimal asset holdings. The problem of the banker \( i \) is formulated as

\[
\begin{align*}
\text{Max}_{y, y^f} & \quad E\left[U(W^B)\right] \\
\text{s.t.} & \quad W_1 = y R + y^f R^f
\end{align*}
\]

**Lemma 1 (Optimal Portfolio)** The optimal portfolio of risky assets for the banker has the mean-variance form:

\[
y^{*, \text{Autarky}} = \frac{E(R) - R^f}{\Gamma(Var(R_i) + Var(R_a))}
\]

\(^5\)We suppress the \( i \) notation because even though the bankers face different regional risk, the setting of their optimization problem is the same.
The demand for risk is positively related to the excess return and negatively related to risk aversion and the idiosyncratic and aggregate risk.

Proof. See Appendix.

3.2 Financial Innovation

The problem of the banker in this scenario consists of choosing a triplet \((y^f, y, d)\) that maximizes his expected utility. \(y^f\) and \(y\) is the amount of safe and risky assets that he acquires in the first period and \(d\) is the amount of credit derivatives.

Thus the banker’s problem is

\[
\begin{align*}
\text{Max}_{y^f, y, d} E[u(W_1)] &= E[-e^{-\Gamma W_1}] = -e^{-\Gamma E(W_1) + (\Gamma^2/2) Var(W_1)} \\
\text{s.t.} \quad W_1 &= Ry + dR^c + y^f R^f \\
\end{align*}
\]

Definition 2 An equilibrium allocation in the economy is given by a triplet of risky investment, safe asset and credit derivative \([y^*, (y^f)^*, d^*]\) such that every banker \(i\), for each \(i \in [0, 1]\), solves his optimization problem.

Lemma 3 (Optimal Portfolio) The optimal portfolio of risky assets and credit derivatives for the banker has the form:

\[
\begin{align*}
\nonumber d^* &= -\rho y \frac{\text{Var}(R^i)}{\text{Var}(R^c)} \quad (1a) \\
\nonumber y_{CD}^* &= \frac{E(R) - R^f}{\Gamma[\text{Var}(R^n) + (1 - \rho^2)\text{Var}(R^i)]} \quad (1b) \\
\end{align*}
\]

where \(\rho (-1 \leq \rho < 0)\) is the correlation coefficient between the credit derivative and the idiosyncratic component of the risky asset. The smaller is \(\rho\), the higher is the degree of correlation between the risky asset and the credit derivative and therefore the bigger the hedging opportunities for the banker. In this paper, \(\rho\) represents the degree of financial innovation of the banking sector.

Proof. See Appendix.

3.2.1 Comparative Statics

Proposition 4 An increase in the degree of financial innovation of the banking sector (decrease in \(\rho\)) increases the demand for risk in both the prime and the secondary market for risk.

Proof. Directly from \((1a)\) and \((1b)\) we have\(^6\)

\[
\begin{align*}
\frac{\partial y}{\partial \rho} &= \frac{2 (E(R) - R^f) \rho \text{Var}(R^i)}{(\Gamma[\text{Var}(R^n) + (1 - \rho^2)\text{Var}(R^i)])^2} < 0 \quad (2a) \\
\frac{\partial d}{\partial \rho} &= -\frac{\text{Var}(R^i)}{\text{Var}(R^c)} \left( y + \rho \frac{\partial y}{\partial \rho} \right) < 0. \quad (2b) \\
\end{align*}
\]

\(^6\)Keep in mind that \((-1 < \rho < 0)\).
An increase in the degree of financial innovation offers the possibility to the banks to better hedge their idiosyncratic risk. As a result banks face less total risk in their investment and therefore they acquire more risky assets than in autarky. The effect of financial innovation on the demand for credit derivatives is both direct and indirect. An increase in the degree of financial innovation directly increases the demand for credit derivatives because they automatically become more efficient instruments for risk hedging. In addition the demand of credit derivatives increases even more as a result of the extra demand for risk assets in the prime market.

Next, we study the effect of financial innovation on banks stability, where banks stability is expressed as the portfolio variance of the bank.

**Proposition 5** An increase in the degree of financial innovation (a decrease in \(\rho\)), reduces bank stability.

**Proof.** Differentiating the portfolio variance with respect to \(\rho\) we get

\[
\frac{\partial \text{Var}(W_1)}{\partial \rho} = \frac{2\rho (E(R) - R_f)^2 \text{Var}(R^c)}{[\text{Var}(R^a) + (1 - \rho^2)\text{Var}(R^i)]^2} < 0.
\]

See the Appendix for the derivation of the portfolio variance. ■

Proposition 5, shows that in a financially integrated banks face a higher portfolio variance. The economic intuition behind this result is that, even though banks can better hedge their idiosyncratic risk compared to autarky, their portfolio variance increases because their risk appetite increases as well. By acquiring more risky assets, except of idiosyncratic risk, which can be hedge with credit derivatives, banks also get more aggregate risk that cannot be diversified. Therefore in the end, banks become riskier and less stable than in autarky.

**Proposition 6** The effect of financial innovation on banks risk taking is stronger, the lower is the aggregate risk.

**Proof.** We differentiate the results of Proposition 1, (2a) and (2b), with respect to \(\text{Var}(R^a)\) and we get

\[
\frac{\partial \left(\frac{\partial \rho}{\partial \text{Var}(R^i)}\right)}{\partial \text{Var}(R^a)} = -\frac{4 (E(R) - R_f) \rho \text{Var}(R^c)}{(1 - \rho^2)\text{Var}(R^i)} > 0
\]

\[
\frac{\partial \left(\frac{\partial \rho}{\partial \text{Var}(R^a)}\right)}{\partial \text{Var}(R^a)} = -\frac{\text{Var}(R^c)}{\text{Var}(R^{cd})} \left(\frac{\partial \rho}{\partial \text{Var}(R^a)} + \rho \frac{\partial \left(\frac{\partial \rho}{\partial \text{Var}(R^a)}\right)}{\partial \text{Var}(R^a)}\right) < 0.
\]

Proposition 6 highlights the importance of the macroeconomic risk, for the effect of financial innovation on banks risk taking. Next we also present a
graphical demonstration of how these nonlinear effects manifest themselves in the context of real changes in macroeconomic risk. Thus, we characterize the behaviour of the equilibrium banks’ demand for risky investment and credit derivatives, by plotting the model’s solution for these quantities and by feeding the model the historical values of $\text{Var}(R^a)$ estimated in the first section\textsuperscript{7}.

Figure 5 displays the time series of the demand for risky assets. The data are quarterly and span the period from the first quarter of 1967 to the fourth quarter of 2009. We have computed the demand for risk for different degrees of financial innovation, thus for different values of $\rho$. As we can see from the picture, for all levels of financial innovation, the demand for risk increases substantially after the mid 1980’s. This demonstrates that the decrease in aggregate volatility has a big impact on bank risk taking. In addition, it is clear that the fall in aggregate risk adds important nonlinear effects, which become stronger and stronger as the degree of financial innovation increases. Before the 1980’s, the presence of credit derivatives adds not much in risk acquisition, instead in the period after that, we can see that the degree of financial innovation plays a key role in banks risk taking.

\textsuperscript{7}The calibrated values for the coefficient of risk aversion, the return of the risky asset and the return of the risk free asset are 1, 20 and 1 respectively.
Figure 6 displays the demand for credit derivatives. Again it’s obvious that the changes in macroeconomic conditions in the 1980’s have significantly affected the expansion of the secondary markets for risk, as the credit derivative market. For this specific calibration of the model, on average the demand for credit derivatives in the case of partial financial innovation ($\rho = -0.7$) is two times bigger after the 1980’s than the period before it. Instead in the case of total financial innovation is more than three times bigger.

Figure 7

In addition we study also the portfolio variance in order to gain some insight on how the stability of banking sector has changed through time. Figure 7
displays the portfolio variance of the bank. As Proposition 1 shows, the presence of credit derivatives increases in the end the portfolio variance. Even though on one hand banks have the possibility to hedge the idiosyncratic risk by investing in credit derivatives, on the other hand they acquire more risky assets which contain also non diversifiable aggregate risk and thus in the end the portfolio variance increases.

We would like to stress that our concern in this paper is not to match the short to medium term movement in the trade volume of the prime and secondary markets for risk. Instead, we are interested to show in a very simple model how the aggregate risk might have effected banks decisions for risk acquisition, not only explicitly but also implicitly through its effect of the financial innovation. Nevertheless we believe that a precise quantitative assessment would be a very interesting exercise to pursue. However a much richer model framework is needed for such kind of exercise and thus we leave this for future research.

4 Value-at-Risk Constraints

In this section we extend the basic model in order to study how financial innovation and the changes in macroeconomic conditions affect banks decisions in a regulated banking sector. The regulatory structure that we adopt is in the spirit of the 1996 Amendment and the Basel-II proposal that limits the amount of risk that banks are allowed to take. Therefore, in addition to the budget constraint the bankers face also a Value-at-Risk Constraint (VaR). We model the VaR constraint as in Danielsson and Zingard (2003) where the VaR is expressed as

\[ P\left(\frac{E(W_1) - W_1}{V aR} \leq \bar{p}\right) \]  

Equation (2) states that there is a very small probability that the negative difference between realized and expected portfolio wealth is larger than the VaR regulatory lower bound. In Danielsson and Zingard (2003) the authors show that inequality (2) is equivalent to

\[ Var(W_1) \leq \bar{\nu} \]  

Thus the VaR constraint can be expressed as an exogenous upper bound \( \bar{\nu} \) on the portfolio variance.

4.1 Autarky

In autarky the banker maximizes his portfolio value subject to his budget constraint and to the VaR constraint. Thus the problem of the banker is

\[ \begin{align*}
& \text{Max}_{x,y} \ E^x [ U(W^f) ] = -e^{-\Gamma E(W_1) + \frac{1}{2} \bar{\nu}^2 Var(W_1)} \\
& \text{s.t.} \quad W_1 = yR + y^f R^f \quad \text{(the budget constraint)} \\
& \quad Var(W_1) \leq \bar{\nu} \quad \text{(the VaR constraint)}
\end{align*} \]
In order to study the effect of the VaR constraint on bankers portfolio decisions, we concentrate our attention only on the corner solutions of this problem. Hence in the case that the VaR constraint is binding. When the VaR constraint is not binding, the solution to the bankers problem is equivalent to equation (1).

**Lemma 7** *(Optimal Portfolio)* The optimal portfolio of risky assets for the VaR constrained banker has the mean-variance form

\[
y_{\text{Autarky}}^* = \frac{E(R) - R^f}{(\Gamma + \phi)\text{Var}(R)}
\]

where \( \phi = \frac{2\lambda}{\Gamma e^{-\frac{1}{2}E(W_1)}} \) is the Lagrange multiplier of the VaR constraint. \( \lambda \) is equal bigger than 0 and otherwise \( \phi = 0 \). Thus when the bankers hit the VaR lower bound, their risk aversion increases from \( \Gamma \) to \( \Gamma + \phi \). The sum of the degree of risk aversion, \( \Gamma \), with the Langrange multiplier, \( \phi \), is known also as the effective risk aversion.

### 4.2 Financial Innovation

In this subsection we study how a regulated bank by VaR constraints reacts to increasing hedging opportunities. In order to do so, we solve the portfolio problem of the bank when the bank has access to the credit derivative market and in addition to the budget constraint it also faces a VaR constraint. Hence the problem of the bank in this case is

\[
\begin{align*}
\text{Max}_{y, y^f, d} E[u(W_1)] &= E[-e^{-\Gamma W_1}] = -e^{-\Gamma E(W_1) + (\Gamma^2/2)\text{Var}(W_1)} \\
\text{s.t.} \quad W_1 &= (R - R^f)y + (R^{cd} - R^f)d + W_0R^f \\
\text{Var}(W_1) &\leq \bar{\nu} \quad \text{(the VaR constraint)}
\end{align*}
\]

As in the Autarky case, we concentrate only on the corner solutions of the problem.

**Proposition 8** An increase in the degree of financial innovation (a decrease in \( \rho \)), increases the effective risk aversion of the banks.

**Proof.** In the equilibrium \( \text{Var}(W_1) = y^2\text{Var}(R) = \bar{\nu} \).

By solving the problem of the bankers, stated above, we get that

\[
y = \frac{E(R) - R^f}{(\Gamma + \phi)\text{Var}(R)}
\]

Therefore \( \phi = \frac{E(R) - R^f}{\sqrt{\bar{\nu}\text{Var}(R^2) + (1 - \rho^2)\text{Var}(R')}} - \Gamma \) and

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\*We assume throughout the paper that \( E(R) > R^f \).
\[ \frac{\partial \phi}{\partial \rho} = \left( \frac{\mathbb{E} \left[ \text{Var}(R^c) + (1 - \rho^2) \text{Var}(R^i) \right]}{\text{Var}(R^c) + (1 - \rho^2) \text{Var}(R^i)} \right)^{\frac{1}{2}} \rho \text{Var}(R^i) < 0. \]

Proposition 7 states that the financial institutions that are VaR constrained, in the presence of increasing hedging opportunities, do not acquire as much risk as they would like because of an increase in the effective risk aversion. Thus the presence of VaR constraint moderates the effect of financial innovation on risk taking. Figure (8) presents how the effective degree of risk aversion of VaR constrained intermediaries might have changed through time as a result of changes in macroeconomic risk and financial innovation. Consistent with Proposition 7, Figure 8 shows that intermediaries that operated in a more financially integrated banking sector, faced higher degrees of effective risk aversion. In addition the effective risk aversion has increased through time because of the changes in the macroeconomic factors.

![Risk Aversion with VaR Constraints](image)

**Figure 8**

### 5 Conclusion

From the beginning of the 90’s until 2006, the US financial market was characterized by a substantial expansion of banks investment on risky loans and a rapid development of the secondary market for risk. In this paper we studied theoretically and empirically, how the financial innovation in the banking system in combination with changes in aggregate risk observed in the mid 80’s, have contributed to banks risk taking. The first part of the paper presents how the aggregate risk and the prime and secondary market for credit have changed in time. It also examines empirically the correlation of the macroeconomic risk with the prime market for risk. The aggregate macro risk is measured as the standard deviation of the real GDP growth rate. Instead the trading volume of the prime market is measured at the total borrowing of the household, the
business and the financial sector. The empirical results show that changes in macroeconomic conditions are closely related to the evolution of the prime market for risk. In the second part of the paper we built a simple static model where bankers are modelled as risk averse traders who choose their optimal portfolio by investing in risky and safe assets. The returns of the risky assets depends both on idiosyncratic and on aggregate risk. We computed optimal portfolio choices in autarky and in a financially integrated banking sector where banks can also acquire credit derivatives, instruments that hedge their idiosyncratic risk. The results of the model show that the presence of the credit derivatives makes banks to invest more on risky assets compared to the autarky. In addition the financial instability of the banking sector increases.

The analysis in this paper is an initial, preliminary attempt to study the effect of financial and macroeconomic changes on banks risk taking. However much more needs to be done. For example, the assumptions of CARA utility and normally distributed returns are very handy for obtaining closed form solutions but this works against the accuracy of the quantitative results. Therefore the next step would be to extend the basic model to a more general framework in order to pursue a more careful quantitative evaluation. From the macroeconomic point of view, another limitation of this model is the partial equilibrium analyses. It would be very interesting to study how prices respond to the interaction of macroeconomic changes and the availability of new hedging instruments (like the credit derivatives). Finally, even though this paper gives an explanation why so much risk was accumulated in the financial markets in the last 20 years, it doesn’t explain why all this turned out to the big financial crises that we observed the last years. However we believe that the present model can be extended in order to allow the analysis of this phenomenon. The way to continue is to substitute the assumption of full rationality with some learning process. The intuition is the following: the agents will operate in an environment where they don’t have full information about the state of the economy. By living for a long period in a world with very low volatility (the Great Moderation), they will tend to underestimate the true risk and believe that the world has passed to a new permanent state with high idiosyncratic risk but very low aggregate one. Moreover the presence of credit derivatives will give them the ability to better hedge the idiosyncratic risk and therefore to engage even more in risky investments, creating like this an investment bubble. The bubble will burst as soon as a negative shock will hit the economy and agent will readjust their beliefs. We leave these extensions open for future research.
References


6 Appendix

Proof of Lemma 1

The bankers have CARA preferences with a coefficient of absolute risk aversion $\Gamma$. Thus their utility is $U(W_1) = -e^{-\Gamma W_1}$ where $W_1 = y^f R^f + y R = (W_0 - y) R^f + y R$ is wealth at time one. Given that the payoff $R \sim N[E(R), Var(R)]$, the conditional expected utility of the banker can be expressed as

$$E[U(W)] = -e^{-\Gamma E(W_1)} + \frac{1}{2} \Gamma^2 Var(W_1)$$

where $E(W_1)$ is the mean and $Var(W_1)$ is the variance of the portfolio.

Thus the problem of the banker is

$$\text{Max } y E^x[U(W^B)] \text{ s.t } W_1 = yR + (W_0 - y) R^f$$

The FOCs with respect to $y$

$$y = \frac{E(R) - R^f}{\Gamma Var(R)}$$

Proof of Lemma 2

The wealth of the banker at time $t = 1$ is the sum of the payoffs of the safe and risky assets, and the value of the credit derivatives. Thus $W_1 = (R - R^f)y + (R^{cd} - R^f)d + W_0 R^f$. The portfolio mean and variance in this case are $E(W_1) = y[E(R) - R^f] + d[E(R^{cd}) - R^f] + W_0 R^f$ and $Var(W_1) = y^2 Var(R) + d^2 Var(R^{cd}) + 2yd Cov(R, R^{cd}) = y^2 Var(R) + d^2 Var(R^{cd}) + 2yd Cov(R^a, R^{cd}) = y^2 Var(R) + d^2 Var(R^{cd}) + 2yd \sqrt{Var(R)} \sqrt{Var(R^{cd})}$

Thus the banker’s problem is

$$\text{Max } y, d, E[u(W_1)] \text{ s.t } W_1 = (R - R^f)y + (R^{cd} - R^f)d + W_0 R^f$$

The FOCs with respect to $y$

$$y = \frac{E(R) - R^f}{\Gamma [Var(R) + Var(R^{cd})]}$$

The FOCs with respect to $d$

$$\{\Gamma [E(R^{cd}) - R^f] - \Gamma^2 [d Var(R^{cd}) + y \sqrt{Var(R^a)} \sqrt{Var(R^{cd})}]\} = 0$$
\[ d = \frac{E(R^{cd}) - R^f - y\rho \sqrt{\text{Var}(R)\text{Var}(R^{cd})}}{\text{Var}(R^{cd})} \]

Given the assumption that \( E(R^{cd}) - R^f = 0 \)

\[ d(y) = -\rho y \frac{\sqrt{\text{Var}(R)}}{\sqrt{\text{Var}(R^{cd})}} \]

The demand for credit derivatives depends positively on the demand for risky assets. By combining the first order conditions for \( y \) and \( d \) we get the demand for risky assets.

\[ y^* = \frac{E(R) - R^f}{\Gamma \text{Var}(R^a) + (1 - \rho^2)\text{Var}(R^i)} \]

**Derivation of the Portfolio Variance**

\[ \text{Var}(W_1) = y^2 \text{Var}(R) + y^2 \text{Var}(R^{cd}) + 2y\rho \sqrt{\text{Var}(R)\text{Var}(R^{cd})} \]

\[ = y^2 \text{Var}(R) + \rho^2 y^2 \frac{\text{Var}(R^i)}{\text{Var}(R^{cd})} \text{Var}(R^{cd}) - 2\rho^2 y^2 \frac{\sqrt{\text{Var}(R)\text{Var}(R^{cd})}}{\sqrt{\text{Var}(R)}} \sqrt{\text{Var}(R^i)\text{Var}(R^{cd})} \]

\[ = y^2 \text{Var}(R) + \rho^2 y^2 \text{Var}(R^i) - 2\rho^2 y^2 \text{Var}(R^i) \]

\[ = y^2 \text{Var}(R^a) + (1 - \rho^2)\text{Var}(R^i) \]

\[ = \left( \frac{E(R) - R^f}{\Gamma \text{Var}(R^a) + (1 - \rho^2)\text{Var}(R^i)} \right)^2 \left[ \text{Var}(R^a) + (1 - \rho^2)\text{Var}(R^i) \right] \]

\[ = \left( \frac{E(R) - R^f}{\Gamma \text{Var}(R^a) + (1 - \rho^2)\text{Var}(R^i)} \right)^2 \left[ \text{Var}(R^a) + (1 - \rho^2)\text{Var}(R^i) \right]^{-1} \]

\[ = \frac{(E(R) - R^f)^2}{\Gamma^2 \text{Var}(R^a) + (1 - \rho^2)\text{Var}(R^i)} \]

**Proof of Lemma 3**

The bankers have CARA preferences with a coefficient of absolute risk aversion \( \Gamma \). Thus their utility is \( U(W_1) = -e^{-\Gamma W_1} \) where \( W_1 = y^d R + y R = (W_0 - y^d) R + y R \) is wealth at time one. Given that the payoff \( R \sim N[E(R),\text{Var}(R)] \), the conditional expected utility of the banker can be expressed as

\[ E[U(W)] = -e^{-\Gamma E(W_1) + \frac{1}{2} \Gamma^2 \text{Var}(W_1)} \]

where \( E(W_1) \) is the mean and \( \text{Var}(W_1) \) is the variance of the portfolio.

\[ E(W_1) = [E(R) - R^f]y + W_0 R^f \] and \( \text{Var}(W_1) = y^2 \text{Var}(R) \).

Thus the problem of the banker is

\[ \text{Max}_{y} E^z[U(W^B)] = -e^{-\Gamma E(W_1) + \frac{1}{2} \Gamma^2 \text{Var}(W_1)} \]

\[ \text{s.t. } W_1 = y R + (W_0 - y) R^f \] the budget constraint

\[ y^2 \text{Var}(R) \leq \bar{\nu} \] the VAR constraint

FOCs

\[ \{\Gamma[E(R) - R^f] - \Gamma^2 y \text{Var}(R)\} e^{-\Gamma E(W_1) + (\Gamma^2/2) \text{Var}(W_1)} - 2\lambda y \text{Var}(R) = 0 \]
\[ y = \frac{\Gamma[E(R) - R^f]e^{-\frac{1}{2}E(W_1) + \frac{\phi}{2}Var(W_1)}}{\Gamma Var(R) e^{-\frac{1}{2}E(W_1) + \frac{\phi}{2}Var(W_1) + 2\lambda Var(R)}} \]

\[ = \frac{Var(R)}{(1+\phi)Var(R)} \left( \Gamma' \right) \]

\[ where \quad \phi = \frac{2\lambda}{\Gamma - \frac{1}{2}E(W_1) + \frac{\phi}{2}Var(W_1)} \]

\[ y^* = \frac{E(R) - R^f}{(1+\phi)Var(R)} \]

7 Data Appendix

The sources and description of each data series that we use is listed below.

**GDP** is the quarterly gross domestic product, measured in 2005-chained dollars. The source is the National Economic Accounts of the Bureau of Economic Analysis (BEA).

**US financial liabilities**, includes historical data on total household borrowing, total business borrowing and total borrowing of the domestic financial sector. The data are quarterly and seasonally adjusted annual rates. The source is the Flow of Funds Accounts of the United States of the United States.

**Credit derivatives**, includes historical data on credit derivatives bought and sold from commercial banks in the US. This series is an aggregation of different off-balance sheet derivatives like Credit Default Swaps, Return Swaps and other credit derivative instruments. The data are quarterly and bankspecific. The source of the data is the Federal Bank of Chicago. The Federal Reserve data are from FR Y-9C reports led by the banks.

**Securities (MBS, ABS, CDO)**, are U.S. Private-Label Securitization Issuances. The data are yearly and the data source is the IMF.