PSL Quarterly Review, vol. 65 n. 260 (2012), 53-77

The supreme subprime myth: the role of bad loans in the 2007-2009 financial crisis

ALBERTO NICCOLI* and FRANCESCO MARCHIONNE**

1. Introduction

This paper examines losses of financial markets at the end of 2007 due to subprime mortgage loans (henceforth referred to as SMLs) and suggests that they were insufficient to justify the intensity of the 2007-2009 financial crisis. Many papers have supported this assessment (Ackermann, 2008; Wallison, 2009; Fratianni and Marchionne, 2009; Demyanyk and Van Hemert, 2011). It arises from the observation that the subprime market size was very small with respect to the whole financial sector. Differently from previous papers, we quantify the ex-ante potential impact of losses on SMLs at the individual level and not at the market level. The surprising result is that subprime mortgages could have been profitable for lenders also when the 2007 subprime crisis started.

Subprime mortgages were an innovation of the 1990s that gave incentives to lenders to grant loans to people with low income and limited or even bad credit histories (Gramlich, 2007). Similarly to "Alt-A", the term refers to borrowers riskier than the average borrower because of a poor credit history: subprime borrowers typically have a FICO score below 640, whereas it ranges from 640 to 700 for Alt-A borrowers (Gorton, 2009, table 1).[1] Subprime mortgage originations

* Corresponding author, Università Politecnica delle Marche and Mo.Fi.R, Ancona (Italy), email: a.niccoli@univpm.it.
** Università Politecnica delle Marche and Mo.Fi.R, Ancona (Italy), email: f.marchionne@univpm.it.
We thank Michele Fratianni, Andrea Presbitero and Antonino Trapani for their useful comments and suggestions.
[1] FICO is a credit score developed by Fair Isaac & Company (http://www.fico.com/en/Pages/default.aspx): it ranges from 300 to 850 and increases with the chance of loan repayment.

increased from essentially zero in 1994 to $625 billion in 2005 by growing at an average annual rate of 26 percent up to a share of 20 percent of total mortgages (Fratianni and Marchionne, 2009). SMLs often are designed to force refinancing over a period of two to three years (Arestis and Karakitsos, 2010). Given that their initial interest rate is adjusted to a significantly higher rate at a 'reset' date, subprime mortgages give borrowers an incentive to refinance their loans before this date (Gorton, 2009). Despite this so-called teaser rate, independent lenders were particularly active in this market and promoted the creation of 12 million new homeowners (Gramlich, 2007).

The common interpretation of the crisis timeline suggests that SMLs triggered the 2007-2009 financial turmoil. This crisis fits many characteristics of the credit-boom-and-bust-cycle hypothesis (Mitchell, 1913; Fisher, 1933; Minsky, 1977; Kindleberger, 1978), but

> "[…] it also has some unique features, such as the transfer of assets from the balance sheets of banks to the markets, the creation of complex and opaque assets, the failure of rating agencies to properly assess the risk of such assets, and the application of fair value accounting" (Fratianni and Marchionne, 2009, pp. 12-13).

During the last decade, fast-increasing housing prices in the US real estate market provided collateral for low credit rating borrowers to obtain bank loans, in particular subprime mortgages (Calomiris, 2009); the property boom was also encouraged by the US government (Wallison, 2009, p. 3). From 2001 to 2006, positive expectations fed credit standards deterioration (Dell'Ariccia *et al*., 2008).

The originate-to-distribute banking model provided a fertile breeding ground for a credit boom (Keys *et al*., 2010; Demyanyk and Van Hemert, 2011). Banks and specialized intermediaries originated SMLs and sold them to other financial intermediaries that, in turn, packaged these risky loans together with other assets through an iterated process of securitization (Purnanandam, 2010). The distribution of final *sausage* assets to financial markets made it impossible to trace the loan origin, generating information asymmetries between loan originators and final investors (Berndt and Gupta, 2009). When housing prices fell, subprime defaults increased quickly because of the high leverage

(Sherlund, 2008): the share of "seriously delinquent" SMLs surged to 5.2 percent by the third quarter of 2008, with an increase of 62 percent with respect to the first three quarters of 2007 (Mayer *et al*., 2009).

Subprime defaults triggered a Minsky moment, as predicted by the credit-boom-and-bust cycle hypothesis (Minsky, 1977; Whalen, 2008). Unable to realize where bad loans were, investors became more risk-adverse and *sausage* assets turned suddenly into *toxic* assets (Fratianni and Marchionne, 2010a; Marchionne and Niccoli, 2011). Then, financial contagion quickly infected all other markets through liquidity and risk-premium channels (Longstaff, 2010). The final outcome was a massive government intervention in favour of the banking system to avoid the possibility of the credit crunch becoming an economic recession (Fratianni and Marchionne, 2010b). In brief, according to these authors, subprime mortgages played a key role in the financial crisis.

Difficulties in financial markets were exacerbated by opportunistic behaviour from some agents, such as rating agencies and managers (White, 2010a; Wray, 2008).[2] The failure of rating agencies in evaluating new complex products was astonishing (Calomiris, 2007; Fratianni and Marchionne, 2010b). The concern is that rating agencies assessed fraudulently low risk status to agents (banks, financial intermediaries, non-financial companies, etc.), whose more precarious situations were known to them, in order to obtain illegal private benefits (White, 2010b, p. 215). Furthermore, often the balance sheets of financial and non-financial companies were often not reliable. This was not only for tax reasons, but also to trick potential equity buyers and allow managers to take a greater advantage of their compensation in share options through the increase of equity prices. Last but not least, fraudulent behaviour occurred (FBI, 2007; 2008), the most famous being the Ponzi scheme used by Bernard Madoff. Povel *et al*. (2005) show that the emergence of fraud is a natural aftermath of financial crises, not its cause. However, fraud accelerated the reduction of asset market values.

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[2] See also White (2010b) for a historical review of credit rating agencies and Povel *et al*. (2007) for a theoretical model of boom-and-bust with fraud.

According to common interpretation, the occurrence of a Minsky moment, evaluation errors from rating agencies, fraud and panic led to high levels of subprime defaults and triggered the financial crisis. This analysis does not adequately consider the interest rate charged on subprime mortgages. The probability of default (*PD*, henceforth) for SMLs is particularly high, but these loans usually entail fairly high interest rates and a relatively low level of loss given default (*LGD*, henceforth): the former is because they are risky and the latter because they imply a mortgage on the house bought with the loan. The impact of both these two features should be explicitly considered when evaluating the expected rate of return for SMLs. As these loans are reimbursed over long periods (from 25 to 45 years), the borrower pays a high interest rate for many years when they are regularly paying back, whereas the lender is able to get back part of his loan through the sale of the house in case of default.

Estimates of *PD* and *LGD* for SMLs and Alt-A loans are provided by the IMF (2007); see table 1. The *PD* value is high: one customer out of four is going to default in case of the subprime category and one out of 14 in case of Alt-A loans. In particular, the first probability seems to be very high, especially in comparison to the case of short-term bank loans when insolvencies usually equal a few percentage points. This evidence suggests that the ex-ante risk on SMLs and Alt-A loans was well known and consequently their net present value had to be positive to induce investors to keep these assets. In this paper, we test this hypothesis using simulations with ex-ante real data (Marchionne, 2007).

Table 1 – *Estimated values of probability of default (PD) and loss given default (LGD)*

Loan Type	*PD*	*LGD*
Subprime loans	25%	45%
Alt-A loans	7%	35%

Source: IMF (2007, ch. 1, p. 12).

In our research we consider a risk-free loan with an *n*-year maturity and a fixed interest rate r_{RF}, repaid in equal installments at the end of each year. This is compared with a SML or an Alt-A loan with the same maturity and a fixed interest rate r_L whose *PD* and *LGD* values are shown in table 1. We then compute theoretical values of the rate r_L and the rate spread $r_L - r_{PR}$ consistent with the assumption of risk-neutrality and zero operating costs.[3] The results are surprising in that, taking the actual values of interest rates, r'_L, SMLs show a significantly higher net-of-risk rate of return than the risk-free investments. Finally, a robustness analysis shows that r'_L is higher than r_L even when very high values for either *PD* or *LGD* (or a combination of the two) are considered. These findings suggest that SMLs were profitable even during the 2007-2009 financial turmoil and that any key role they played in the financial crisis was very weak.

The bulk of subprime literature uses ex-post data to show the catalyst role of SMLs (e.g. Arestis and Karakitsos, 2010; Demyanyk and Van Hemert, 2011). On the other hand, few papers use ex-ante data: Gorton (2008) focuses on FICO scores and the securitization process; Coleman *et al*. (2008) find that the pre-crisis subprime market is fed not only by housing price increases, but also by economic, political and regulatory environment characteristics; Frame *et al*. (2008) analyze trend and geographical distribution of delinquency and foreclosure rates in the US; Longstaff (2010) examines rating scores and contagion effects and Sherlund (2008) simulates potential trends for subprime mortgage defaults between 2008 and 2010 using data from 2000 to 2007. However, we are not aware of any paper examining interest rates and profitability of SMLs.

In this paper, the simulation approach and its assumptions are described in Section 2 while Section 3 presents results using different values for r_L and in the special case of unredeemable loans. Section 4 is devoted to a robustness analysis where we rerun our exercise under alternative hypotheses. Conclusions are presented in the last section.

[3] Zero operating costs simulate the characteristics of an efficient bank.

2. Methodology

When the financial crisis erupted, SMLs were estimated to be worth about \$1,300 billion and Alt-A loans \$1,000 billion (IMF, 2007). The IMF (2007, ch. 1, p. 13) estimated total losses in the range of \$170 billion to \$200 billion. These loan volumes and losses could not justify the start of the financial crisis (Sanders, 2008).

We use simulations to examine whether interest rates are high enough to cover credit risks. Losses due to defaulting should be compared to additional revenues from customers paying back regularly. We rely on simulations because the estimated *PD* distribution over initial years is not uniform and loans' internal rates of return cannot be determined analytically. Also, we use available information before the crisis erupted and ignore strategic defaults that took place when housing prices collapsed. In fact, people with SMLs had an incentive to default when the price of their home fell below the value of their outstanding mortgage.

In what follows, we consider long-term mortgages with zero operating costs, reimbursed with constant, end-of-period installments and collateralized by the house. We assume an annual fixed interest rate for simplicity and tractability: it is equal to r_L for a risky loan and to r_{PR} for a non-risky loan. The installment amount R for a unitary loan is equal to:

$$R(r_L, n) = \frac{r_L}{[1-(1+r_L)^{-n}]} \tag{1}$$

If the borrower defaults, the lender sells the house; we assume that the probability of default is equal to *PD* and the loss given default *LGD* is equal to a percentage of the residual debt, *RD*. If default takes place at the end of period i, RD_i is computed recursively as follows:

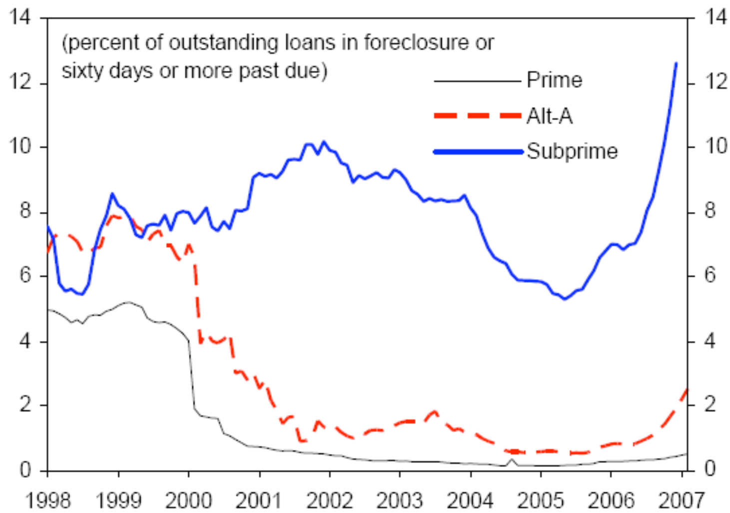
$$RD_i = (1+r_L) * RD_{i-1} - R \tag{2}$$

In Sections 3 and partially 4, we assume that defaults occur in one of the first seven years of the pay-back period because IMF data only allows us to estimate current default distribution over this period; if one installment is not paid, subsequent installments will not be paid either.

Excluding a case considered in Section 4, customers who pay regularly during the first seven years will continue to do so thereafter. Let PD_i be the ex-ante probability of default for the i^{th} installment; if default occurs, the bank obtains a share (*1-LGD*) of RD_i, with a loss of $LGD*RD_i$. Kiff and Mills (2007, p. 10) report that "[…] there can be a long lag from when a default is registered to when MBS and CDO principal payments are impacted, because the foreclosure process can take up to 18 months to complete." Hence, we assume that 18 months elapse between the time of default and the recovery of money by the bank. We consider a longer delay in Section 4.

Let $PD = \sum_{i=1}^{7} PD_i$ and consider *PD* = 25% for SMLs, and *PD* = 7% for Alt-A loans according to IMF (2007, ch. 1, p. 7) estimates; similarly, *LGD* = 45% for SMLs and *LGD* = 35% for Alt-A. As shown in figure 1, our *PD* values are very high in comparison to the *PD* in the decade 1998-2007. The upward bias on losses works against our hypothesis.

Figure 1 – *Defaults and foreclosures of variable rate loans*



Source: Kiff and Mills (2007, figure 5, p. 8), based on data by Citigroup.

The temporal default distribution is similar for *PD* = 25% and *PD* = 7%; it comes again from IMF (2007, ch. 1, fig. 6) for loans granted from 2000 to 2006. For the year 2000, 2001, …, 2006, we have delinquency loan data occurring respectively in the first seven, six, …, one years; see figure 2. Since we assume that total defaults are equal to 25% of granted loans, we disregard defaults beyond the 7th year.[4] This is because defaults, and losses to the bank, peter out in the first seven years with *PD* = 25% (or 7%). It follows that the spread between r_L and r_{PR} for a risk-neutral efficient bank would become smaller when defaults are distributed over the whole payback period and total *PD* = 25%, because the bank would, on average, receive installments for a longer period. The assumption of no later defaults shifts the *PD* distribution to the left, thus lowering the net present value on these loans. Again, we have adopted an assumption working against our hypothesis.

According to figure 2, the timing of defaults is very homogenous over the 2000-2006 period. They are equal to 0 when the loan is granted, but rapidly increase over the following two years, decrease quickly in the third year, and then more slowly after that.

We use the monthly data of figure 2 to derive an overtime default distribution consistent with the *PD* estimated by IMF. We apply the *PD* variation over the last available 12 months of loans originated in a given year to the *PD* of SMLs originated in the following year; then we adjust the default distribution rescaling PD_i so that the total *PD* = 25%. In practice, to extend the 2006 default distribution beyond the first 12 months, we use the proportional *PD* rate from 12 to 24 months of loans originated in 2005. By iterating this operation, we extend the estimated result to subsequent years. Then, as the total *PD* is larger than the IMF estimate, we rescale PD_i so as to be consistent with IMF data. Figure 3 shows the incidence of PD_i with i = 0, 1, 2, …, 7 obtained using this procedure. Blue markers are relevant when *PD* = 25% (SMLs), red ones when *PD* = 7% (Alt-A).

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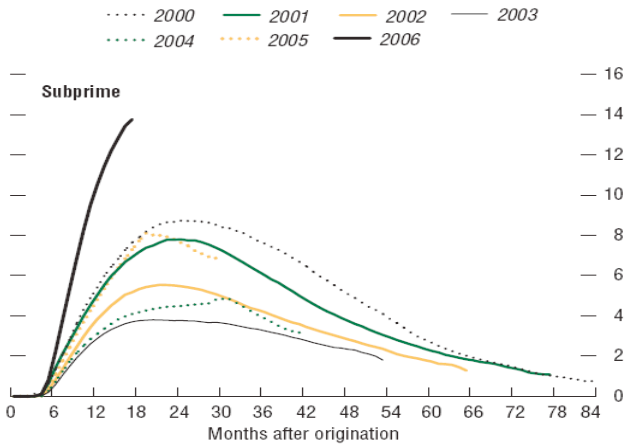
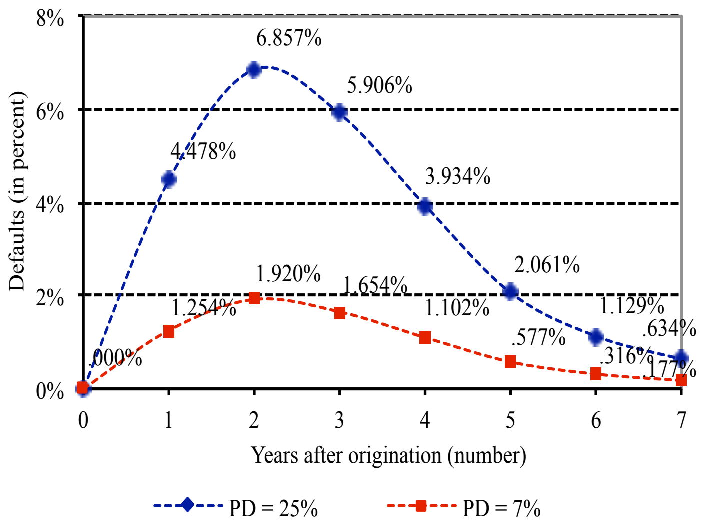
[4] See Section 4 for defaults beyond the 7th year.

Figure 2 – *Temporal default distribution by months after loan origination (in percent of original balance)*



Source: IMF (2007, ch. 1, p. 7, figure 1.6), based on data by Merrill Lynch and Intex.

Figure 3 – *Overtime default distribution by year after loan origination (PD = 25% or 7%)*



Source: Elaboration on data by IMF (2007).

In Section 3.1 we take into account loans with payback periods from 25 to 40 years granted by a risk-neutral efficient bank. The rate r_L may be split into two parts: r_{PR}, the rate for risk-free customers, and $(r_L - r_{PR})$, the insurance premium. With risk neutrality and zero operating costs, r_L is obtained by solving the following equation:

$$\sum_{i=1}^{n}\left[(1-\sum_{j=1}^{i}PD_j)*\frac{R(r_L,n)}{(1+r_{PR})^i}+\frac{PD_i*(1-LDG)*RD_{i-1}*(1+r_L)}{(1+r_{PR})^{i+1,5}}\right]=1 \qquad (3)$$

The essence of the equation is simple: positive cash flows are discounted at time 0 with the risk-free rate, r_{PR}. The first term in square brackets in equation (3) refers to the value of the installments paid by borrowers at time *i*. The second term refers to the value obtained by the bank from the sale of the house of a defaulting customer: the residual debt *RD* at time $i - 1$ is multiplied by $(1 + r_L)$ to obtain RD_i, and is discounted for $(i + 1.5)$ years at the r_{PR} rate, on the assumption that the house is sold 18 months after default. In the first term, $(1-\sum_{j=1}^{i}PD_j)$ is the probability of a customer regularly paying the instalment at time *i* and in the second term, the recovered amount is multiplied by PD_i for a customer defaulting at time *i*. We find critical values for r_L using a numerical optimization procedure.

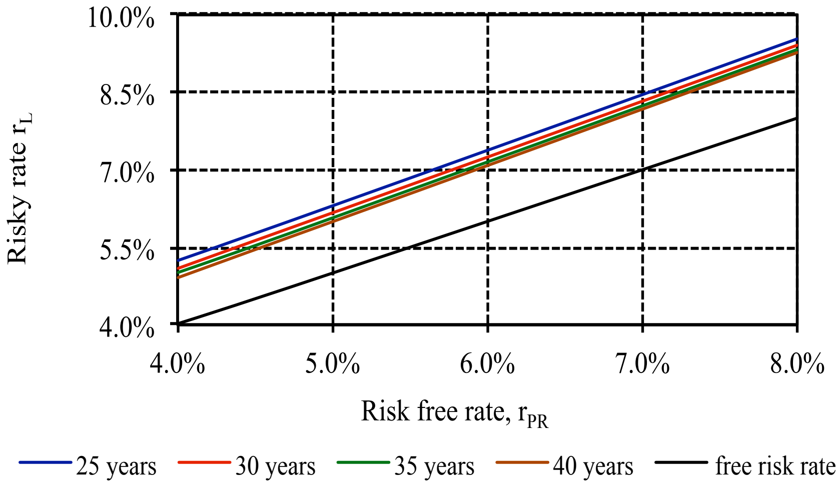
3. Results

3.1. Equivalent interest rates under different loan conditions

Consider constant installment loans of unit size with a *n*-year maturity where $n = 25, 30, 35$ or 40. The risk-free interest rate r_{PR} falls in the 4%-8% interval. Two different cases are considered with reference to the moment of default. In the first, default happens just after the loan has been granted; this case is considered together with an infinite maturity (see Section 3.2). The second assumes that defaults are spread over a seven-year period as in Section 2.

Figure 4 shows that if $r_{PR} = 4\%$, r_L falls in the interval 4.91%-5.23% in order to cover the insurance premium for different maturities under the hypothesis that *PD* = 25% and *LGD* = 45%. The actual value of the insurance premium decreases with the loan repayment period: the upper value is relevant for 25-year loans, the lower values for 40-year ones. When $r_{PR} = 8\%$, the corresponding values for r_L are equal to 9.53% and 9.27% respectively. Insurance premiums increase with r_{PR} and decline with loan maturity; see figure 5. In any case they are fairly small, being a little more or less than 1.2%.

Figure 4 – *Equivalent rates of subprime and risk-free loans (PD = 25% and LGD = 45%)*

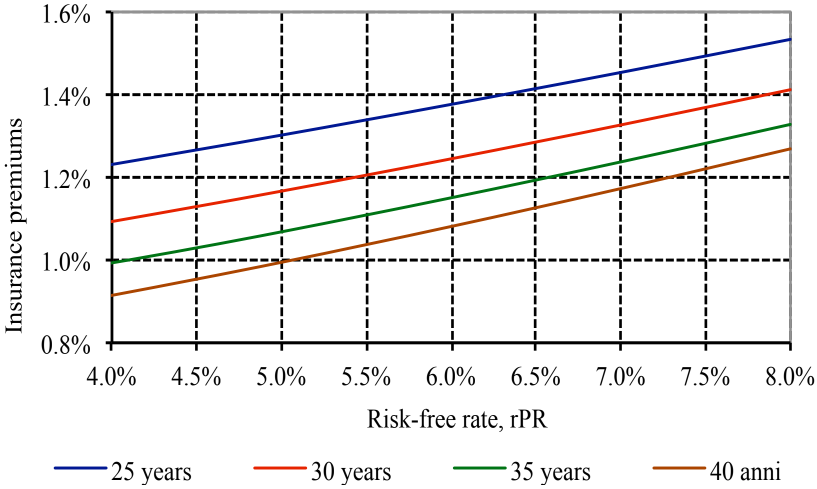


Note: Simulations assume a risk-neutral bank and zero operating costs.

Figure 6 shows interest rates for Alt-A loans: lines for different loan maturities almost completely overlap. Only the insurance premium values, represented in figure 7, show some differences on the basis of loan maturity; yet, these differences are very small indeed, as they fall within the 17.5-30.6 basis point interval.[5]

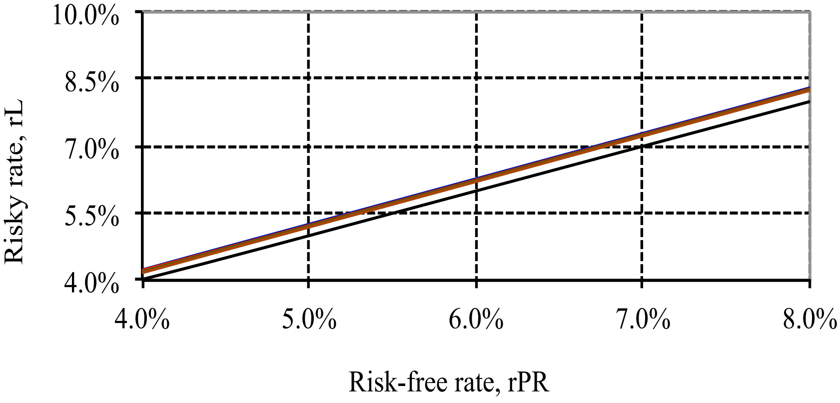
[5] Again, they increase with the risk-free rate and decrease with the loan maturity.

Figure 5 – *Insurance premiums of subprime and risk-free loans (PD = 25% and LGD = 45%)*



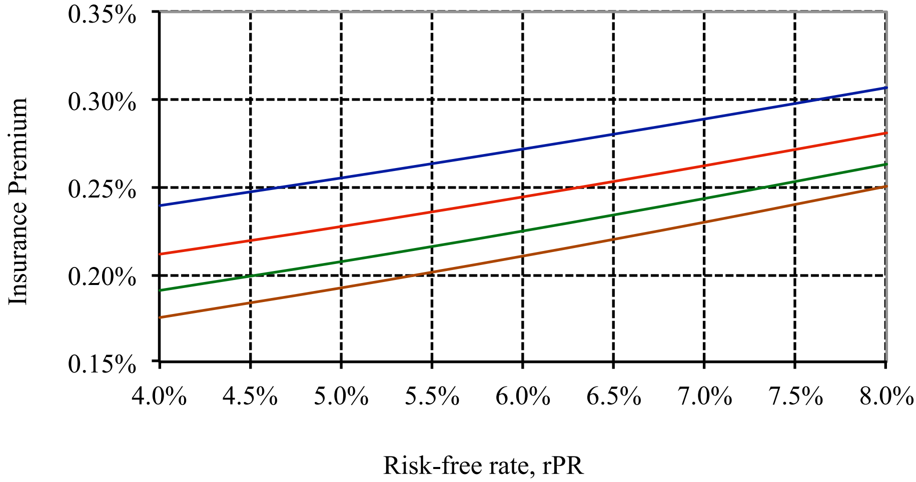
Note: Simulations assume a risk-neutral bank and zero operating costs.

Figure 6 – *Equivalent rates of Alt-A and risk-free loans (PD = 7% and LGD = 35%)*



Note: Simulations assume a risk-neutral bank and zero operating costs.

Figure 7 – *Insurance premiums of Alt-A and risk-free loans (PD = 7% and LGD = 35%)*



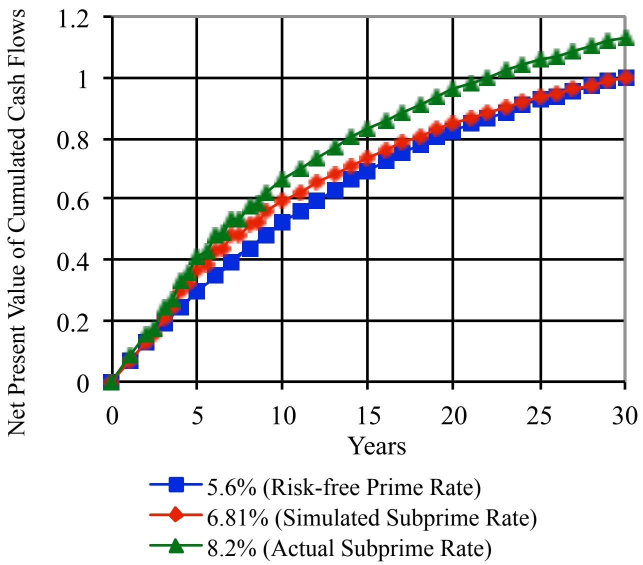
Note: Simulations assume a risk-neutral bank and zero operating costs.

A key result of this paper is that small insurance premiums support high probabilities of default and losses in case of default. The explanation is related to the relatively long periods over which installments are paid back. When the loan is regularly reimbursed, the spread $r_L - r_{PR}$ applies to time horizons ranging from 25 to 40 years. Small spreads consequently are large enough to cover very large risks of default, and/or very large losses in case of default.

The subprime crisis erupted in the US in August 2007. From January 2005 to June 2007, interest rates for 30-year SMLs with a fixed interest rate were on average 8.2% (Mayer *et al.*, 2009, table 2, panel D); the interest rate of similar prime mortgages over the same period was 5.6%. Assuming the default distribution of figure 3, *PD* = 25% and *LGD* = 45%, the 2.6% spread (i.e. 8.2%-5.6%) can be split: 1.2% to cover default risk for a risk-neutral efficient bank and 1.4% as additional profit. The inference is that subprime loans were very profitable until 2007.

Figure 8 shows the cumulated present value of instalments for three different borrowers at time 0: the risk-neutral bank charges the prime rate r_{PR} = 5.6% to the first risk-free customer (blue), the simulated subprime rate r_L = 6.81% to the higher risk customer (red), and the actual subprime rate r'_L = 8.2% to another higher risk customer (green). Each loan is a fixed rate 30-year unitary loan. All lines start from zero: the first two reach the value of 1 after 30 years, while the third reaches a value of 1.13 because this loan (green) is more profitable than the other two. For the two higher risk loans, the bank receives money also at time i = 2.5, 3.5,…, 8.5, selling the collateral of borrowers that have defaulted at time 1, 2,…,7 respectively. The duration of the risk-free loan (11.59 years) is longer than those of the higher risk loans granted at the simulated 6.81% and the actual 8.2% subprime rate (10.43 and 10.51 years respectively).

Figure 8 – *Net Present Value of Cumulated Cash Flows at time 0*

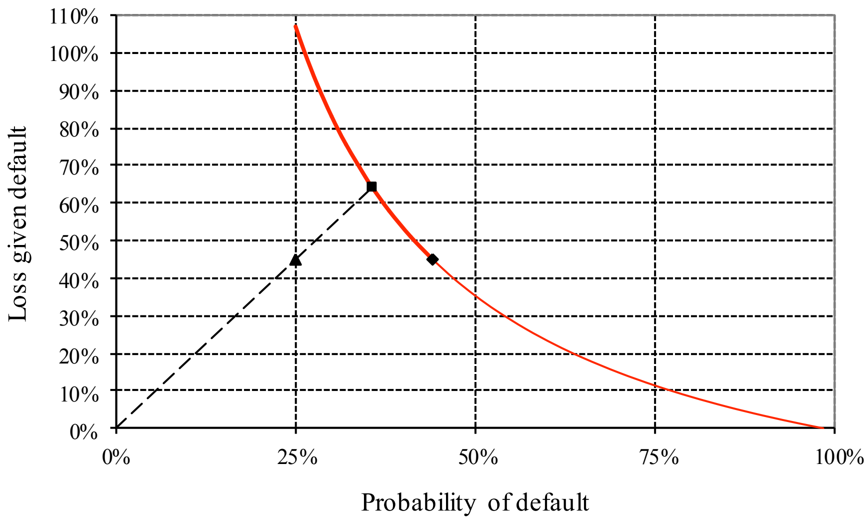


Note: Simulations assume zero operating costs. The blue and red lines refer to risk-neutral bank whereas the green line to a risk-averse one.

As the actual subprime rate includes a risk premium, the number of years needed to fully recover a unitary loan by a risk-neutral bank is also considered: with a maturity of 22 years, the duration reduces to 8.49 years. In brief, SMLs at the actual 8.2% rate guarantee earlier cash flows, a relevant advantage in a Minsky framework.[6]

It is also possible to find combinations of *PD* and *LGD* consistent with loan rates equal to 5.6% and 8.2%, charged by a risk-neutral bank. Defaults occur only during the first seven years, but *PD* varies; for each value, the corresponding *LGD* is computed assuming that the bank is indifferent between the two interest rates.

Figure 9 – *PD and LGD consistent with* $r_L = 8.2\%$, $r_{PR} = 5.6\%$ *and* $n = 30$



Note: Simulations assume a risk-neutral bank and zero operating costs.

[6] For example, 40 percent of the loan's net present value is repaid after 7 years by a risk-free borrower (blue) and only after 5 years by the higher risk customer (green).

The red line in figure 9 displays combinations of *PD* and *LGD* consistent with $r'_L - r_{PR}$ = 2.6%. The curve has a significant, positive second derivative: it starts from a value larger than 100% for the *LGD* when *PD* = 25%, and reduces to *PD* = 98.34% when *LGD* = 0. When we consider larger values for both variables than those considered by the IMF (2007, ch. 1, p. 12) such as the triangular marker, we move along the thicker part of the red line: the 2.6% spread is large enough to take care of *LGD* = 107% when *PD* = 25%, or *LGD* = 64% when *PD* = 36%, or *PD* = 44% when *LGD* = 45%.

The subprime crisis was caused by the number of unexpected defaults coupled with falling housing prices. The former turned ex-ante bank profits into ex-post losses: "[…] sophisticated risk management models based on historical data can be misleading […] because […] markets can change dramatically and […] also […] the most sophisticated models can be taken by surprise" (Sanders, 2008). Note that the SMLs profitability by origination time depends also upon future defaults and housing prices.

Finally, we use simulated rates and spreads for a risk-neutral efficient bank granting SMLs and Alt-A loans to present an additional interpretation for effective rates and spreads (figures 4 to 7). According to Mayer *et al*. (2009, table 2, panel D), the average Alt-A rate from January 2005 to June 2007 is equal to 6.86%, implying a spread equal to 1.26%. The average SMLs rate and spread are 8.2% and 2.6% respectively. We use this information to examine the assumptions of a risk-neutral bank and zero operating costs.

When r_{RF} = 5.6%, simulated spreads are equal to 1.213% for SMLs in figure 5 and 0.237% for Alt-A in figure 7. We assume that banks apply a mark-up to simulated spreads to determine actual spreads (Niccoli, 1979, ch. 1; Niccoli, 2011, pp. 135-146). In particular, we adopt the following linear function for the mark-up:

$$r'_L - r_{PR} = (1+q)[\alpha + (r_L - r_{PR})] \qquad \textit{with} \quad L = \text{SMLs, Alt-A} \tag{4}$$

where $r'_L - r_{PR}$ and $r_L - r_{PR}$ are respectively the actual spread for a real bank and the simulated spread for a risk-neutral efficient bank; *L* is equal to SMLs or Alt-A loans. Using data on these variables, we can solve the 2x2 equation system deriving from equation (4): $1 + q = 1.373$ and $\alpha = 0.68\%$. The results are interesting. The mark-up coefficient is consistent with the range of values reported by Martins *et al*. (1996) and α, a proxy for additional operating costs, is reasonably much lower than 1%. The profitability of risky loans ($r'_L - r_L - \alpha$) remains positive (0.71%) suggesting that SMLs were profitable for banks even after taking into account operating costs.

3.2. Unredeemable loans

In order to better understand why small spreads cover the insurance premium against defaults in long maturity mortgages, we consider the British consol. It is an unredeemable loan in which, at the end of each year, the lender receives an interest rate r_L in perpetuity for a unitary loan at time 0. In addition, we also consider the cases where either the borrower is always solvent, or defaults just after receiving the loan.[7]

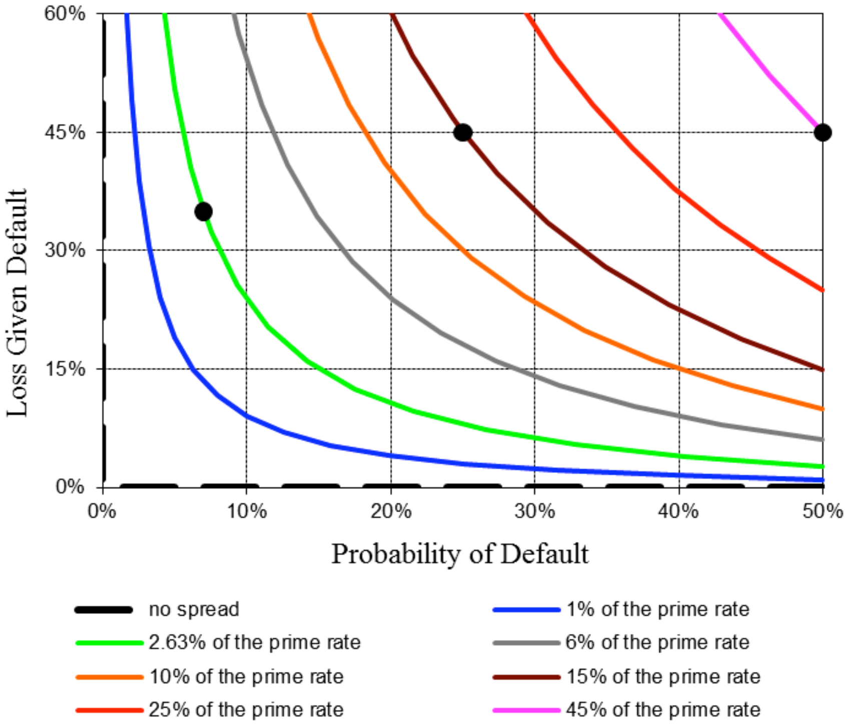
Consequently, the insurance premium of unredeemable loans is equal to *PD*LGD*, and the spread $r_L - r_{PR}$ has to be large enough to cover this loss. The present value at time 0 of a permanent flow of payments, once a year, of the amount $r_L - r_{PR}$, with the discount rate r_{PR}, is equal to $(r_L - r_{PR})/r_{PR}$. This flow occurs with a probability equal to $1 - PD$. So, in case of risk-neutrality and zero operating costs, r_L and r_{PR} are equivalent if:

$$(1 - PD)\left(\frac{r_L - r_{PR}}{r_{PR}}\right) = PD * LGD \qquad (5)$$

According to equation (5), the spread $r_L - r_{PR}$ expressed in proportion to the risk-free rate r_{PR}, is equal to the expected loss *PD*LGD* in proportion to the probability of a regular payment *1-PD*.

[7] In this case, the loss is higher than when default occurs at time *i* because its value discounted at time 0 is smaller, i.e. $LGD > LGD/(1 + r_{PR})^i$. For simplicity, we do not take into account the 18 months interval between default and the recovery time of money for the bank.

Figure 10 – *Spread as a percent of the risk-free rate (prime rate)*



Note: Simulations assume a risk-neutral bank and zero operating costs.

Figure 10 represents different values for the spread of equation (5). When $r_L - r_{PR} = 0$ either $PD = 0$ or $LGD = 0$ (the line lying on the x and y axes). In effect, loans do not constitute a risk to the lenders when they are repaid in full or, in the case of default, when the collateral covers the amount outstanding. Each of the other curves refers to a specific value for the spread in proportion to the prime rate: the greater the value, the higher are *PD* and *LGD*.

The green line has been plotted for a spread equal to 2.63% of the prime rate. A black marker identifies Alt-A loans: it implies 11-21 basis points when r_{PR} falls in the 4%-8% interval. The spread is irrelevant. The second marker belongs to the brown curve. It corresponds to *PD* = 25% and *LGD* = 45%. In this case, a relatively low spread equal to 60-120 basis points is sufficient to cover defaults in case of risk-neutrality, zero operating costs and prime rates falling in the 4%-8% range. The third marker, in the violet line, corresponds to *LGD* = 45% and *PD* = 50% and indicates that one out of two loans is defaulted. The 4%-8% range for the prime rate corresponds to a spread equal to 180-360 basis points: these spreads are large, but not uncommon in the SMLs market. In conclusion, we again obtain our key result: small spreads are able to accommodate large risks.[8]

4. Robustness analysis

Results are similar even under more stringent assumptions. To be more precise, we run five robustness exercises: each of them removes a specific hypothesis of the benchmark framework exploring riskier cases for lenders.

The first exercise explores the case of a higher total probability of default. It increases to 37.5%: the value for each year is equal to 1.5 times our benchmark values: *LGD* = 45%. In the second exercise, the higher risk derives from *LGD*: as in the benchmark case, *PD* = 25%, whereas *LGD* increases to 67.5%, i.e. 1.5 times our benchmark value. The third exercise combines an increase of *PD* and *LGD* to examine their joint effect. Both *PD* and *LGD* increase to 1.25 times benchmark values, to 31.25% and 56.25% respectively. The fourth exercise removes the implicit assumption of zero default rates from the 8th year to maturity. On the basis of a constant flow of defaults from the seventh year on, i.e. $PD(t>7) = PD(t=7)$, the total probability of default increase from 25% to 39.57%; *LGD* remains equal to 45%.[9] In the fifth exercise, we increase

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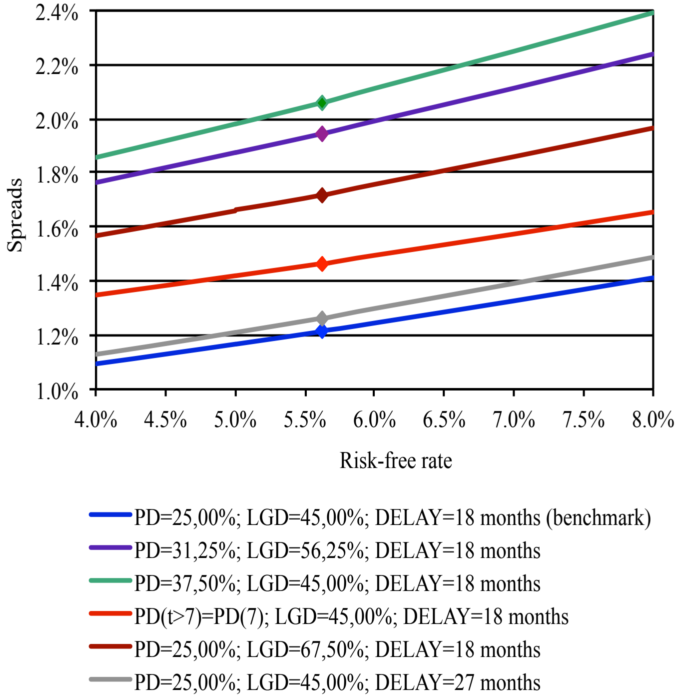
[8] These results are broadly consistent with the rising expected PD in 2009 and 2010 for fixed interest rate SMLs presented in Sherlund (2008, table 8, *baseline*, FRM).

[9] The Public Securities Association assumes a constant flow of default from the tenth year on (Sherlund, 2008, p. 6 and figure 5, p. 31).

the time interval between default and recovery of money by 50%, from 18 to 27 months.

Figure 11 – *Robustness analysis: spreads under alternative assumptions for PD and LGD*



Note: Simulations assume a risk-neutral bank and zero operating costs.

Figure 11 summarizes the results from the above exercises. The lower line refers to our benchmark assumptions, that is *PD* = 25% and *LGD* = 45%. Markers show spreads when r_{RF} = 5.6%: they are all lower than 2.1%, i.e. smaller than the actual spread of 2.6%. This result suggests that SMLs remain profitable even when *PD* and/or *LGD* are significantly higher than IMF estimates. When we repeat the five exercises including positive operating costs, the 2.6% spread is more than sufficient to cover these costs in three out of five cases, almost sufficient (by 2-3 basis points) when *LGD* = 67.5% and insufficient (by 14 basis points) only when *PD* = 37.5%. We also reran the same robustness exercises for Alt-A loans. The real spread of 1.26% is always profitable, even when positive operating costs are included.[10]

In brief, we conducted ten robustness exercises in addition to the benchmark exercise for both SMLs and Alt-A loans: 20 out of 22 simulations corroborate our hypothesis, one provides an uncertain result and one is negative, but by a marginal amount. SMLs and Alt-A loans constituted an ex-ante profitable business for risk-neutral efficient banks. This was also the case for risk-averse banks (with or without operating costs) until the panic spread in financial markets when the crisis erupted. The implication is that SMLs could not have triggered the financial crisis nor justify its intensity.

There are four alternative explanations for the 2007-2009 financial crisis. The first assumes that agents are irrational and have herding behaviours: manias and panics result in financial crises (Kindleberger, 1978). The second is that agents defaulted strategically when property values became lower than the residual debt, triggering a vicious circle of housing price reductions and strategic defaults. Figure 12 from Sanders (2008, p. 261) shows that the increase in delinquency rates (a proxy for defaults) was driven by the fall of housing prices in Nevada, an important SMLs and Alt-A origination State, particularly from February 2006 onwards.

The third explanation is based on asymmetric information in securitized mortgages between borrowers and investors. Frictions in the subprime securitization process generated strong asymmetric information between the initial subprime borrower and the final lender (Ashcraft and Schuermann, 2008): unable to identify good and bad SMLs, the lender's optimal response to SMLs defaults is to increase the interest rate applied to all borrowers, thus increasing defaults and leading to a market crash.

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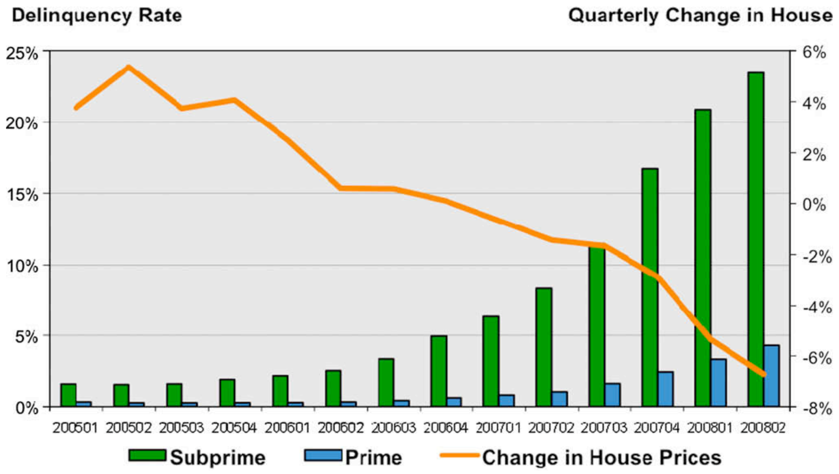
[10] Results are not reported for brevity.

Figure 12 – *Quarterly change in housing price and subprime delinquency rates by year, Nevada*



Source: Sanders (2008, p. 261).

Lastly, the crisis may have been triggered by a collapse in trust due to the increasing number and size of financial transactions. Arcand *et al*. (2011) shows that too much finance has negative effects on economic performance and Marchionne and Niccoli (2011) suggest that an excess of financial deepening negatively affects social capital by reducing cooperation among individuals. As trust is the key ingredient in all transactions, a reduction in social capital leads to lower economic development.

In brief, SMLs could not have triggered the financial crisis: its cause is related to herding behaviour, borrowers' strategic defaults, frictions in the securitization process, and in particular, an excess of finance negatively affecting people's trust.

5. Concluding remarks

A common interpretation of the 2007-2009 financial crisis is that subprime mortgages played a key role in triggering a Minsky moment during a credit-boom-and-bust cycle. This hypothesis relies on the evidence that the subprime market is small with respect to the whole financial sector. In this paper, we analyze subprime mortgages using ex-ante data at the loan level.

Our strategy relies on simulations applying a numerical optimization procedure to determine internal rate of return of subprime mortgages and then to calculate an insurance premium over risk-free rate. We run this exercise under alternative assumptions biased against our hypothesis and we obtain similar results: ex-ante, interest rates of subprime mortgages were high enough to cover expected probabilities of default and any losses in case of default.

The conclusions to be drawn from this are quite simple: subprime loans were not a bad business for risk-neutral efficient lenders because of the high interest rates paid by regular borrowers and the long maturity of subprime mortgage loans. These factors allow the lender to cover actual losses, making the net present value of subprime mortgage loans positive.

It seems very difficult to identify subprime mortgages as the main cause of the financial crisis: at most they may have been a modest catalyst, but our results suggest clearly that the fundamental cause of the 2007-2009 financial crisis is to be found elsewhere.

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