NBER WORKING PAPER SERIES

BREAKING THE SPELL WITH CREDIT-EASING: SELF-CONFIRMING CREDIT CRISES IN COMPETITIVE SEARCH ECONOMIES

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Working Paper 22006
http://www.nber.org/papers/w22006

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
February 2016

We thank Marco Bassetto, Pierpaolo Battigalli, Fiorella De Fiore, Manolis Galenianos, Stephen Morris, Dirk Niepelt, Thomas Sargent, Harald Uhlig, Tack Yun and participants in seminars and workshops, where previous versions of this work have been presented, for their comments. We thank Mauro Lanati for excellent research assistance. We acknowledge financial support by the Fondation Banque de France and of the ADEMU project, "A Dynamic Economic and Monetary Union" funded by the European Union's Horizon 2020 Program under grant agreement N. 649396. The views expressed in this paper do not necessarily reflect those of Banque de France or European Commission. The views expressed herein are those of the authors and do not necessarily reflect the views of the National Bureau of Economic Research.

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NBER Working Paper No. 22006
February 2016
JEL No. D53,D83,D84,E44,E61,G01,G20,J64

ABSTRACT

We show that credit crises can be Self-Confirming Equilibria (SCE), which provides a new rationale for policy interventions like, for example, the FRB's TALF credit-easing program in 2009. We introduce SCE in competitive credit markets with directed search. These markets are efficient when lenders have correct beliefs about borrowers' reactions to their offers. Nevertheless, credit crises - where high interest rates self-confirm high credit risk - can arise when lenders have correct beliefs only locally around equilibrium outcomes. Policy is needed because competition deters the socially optimal degree of information acquisition via individual experiments at low interest rates. A policy maker with the same beliefs as lenders will find it optimal to implement a targeted subsidy to induce low interest rates and, as a by-product, generate new information for the market. We provide evidence that the 2009 TALF was an example of such Credit Easing policy. We collect new micro-data on the ABS auto loans in the US before and after the policy intervention, and we test, successfully, our theory in this case.

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1 Introduction

Overview. The recent global crisis has been characterized by high uncertainty - not just risk - regarding the state of the economy. This uncertainty showed up in credit markets in the form of perceived counterpart risk, resulting in high lending rates and, in some cases, complete market freezes. As policies of lowering the cost of money seldom translated into a substantial improvement of the credit conditions (the Euro area crisis is an example), policy makers started implementing never-experimented - so called non-conventional - policies of credit-easing. These policies were specifically designed to partly ensure private lenders against the *perceived* counterpart risk in specific and important credit markets under pressure.

However, from a theoretical point of view it is not obvious how to rationalize these interventions. Why is a policy maker, who faces the same uncertainty as the private sector, willing to take risks that the private sector does not want to take? For example, robust decision theory[1] is often applied to address the problem of designing policies in situations of high uncertainty; however, this approach leads to recommendations of prudence, which does not seem to be a characteristic of recent unconventional policies.

Possibly the most relevant risk-taking credit-easing policy has been the Term Asset-Backed Securities Lending Facility (TALF) by which the the Federal Reserve Bank provided ABS buyers with a subsidy contingent on losses, counting on the backing of the US Treasury. The introduction of TALF in the AAA-rated ABS market – completely frozen in late 2008 – coincided with a rapid recovery of transactions. Surprisingly, the recovery occurred without any subsidy actually being dispensed: a proof, in retrospect, that the counterpart risk *perceived* by the private sector in that market was indeed excessive. Should we conclude that in that occasion the Fed was less risk averse, better informed, or just lucky? In sum, which market failure can credit-easing alleviate that other policies cannot?

In this paper we develop a theory of optimal policy in situations of high economic uncertainty, which can encompass policy experiences like the TALF, without being specific to them. We provide three original contributions: first, we develop the theory of self-confirming equilibrium in a competitive environment to characterize credit crises due to excessive perceived counterpart risk; second, we show that in this environment a credit-easing policy of subsidizing lenders' losses can be an *optimal* policy for a monetary (and fiscal) authority sharing the same subjective beliefs as the private sector, and third, we provide new micro-evidence concerning the effect of TALF policy in the US automotive AAA-rated ABS in 2009, which is consistent with our theory.

Competitive SCE. In section 2 we introduce *Self-Confirming Equilibria* (SCE) in a competitive directed search model of the credit market, consisting of a continuum of

[1] See Hansen and Sargent (2014) or Adam and Woodford (2012).

lenders and borrowers. Lenders borrow money from the interbank market, and offer fixed interest rate loans to borrowers, who apply for loans to finance their – possibly risky – projects. The basic mechanism is simple: a borrower can implement a riskless project at a fixed cost, or a risky project without cost. Therefore, the borrower adopts a safe project only when *both* the fixed cost *and* the interest rate offered are sufficiently low. However, lenders do not observe borrowers' costs of adoption. Hence, lenders may overestimate counterpart risk – believing that adoption costs are higher than they actually are – and only offer high interest rate loans. As a result, only risky projects are financed. Thus credit crises can emerge in the form of high-interest-high-risk SCE in which lenders have correct beliefs about equilibrium outcomes, although they may be wrong about the never-observed counterfactual in which low interest rates induce borrowers to adopt safe projects.

Self-Confirming Equilibria, as originally introduced in Game Theory by Fudenberg and Levine (1993), have two distinct properties. First, subjective and objective probability distributions coincide in equilibrium, but may not coincide outside equilibrium; that is, agents may have misspecified beliefs about never-realized states of the economy. Second, agents' actions determine what is observable in equilibrium; that is, individual actions can potentially produce the observables that correct these misperceptions[2].

In Macroeconomics, Sargent (2001) and Primiceri (2006) used the concept of SCE by modeling the learning problem of a major actor who has the power to affect aggregate observables and hence can be trapped in a SCE.[3] In this paper, instead, we characterize a SCE in a directed search and matching competitive environment, where individual (atomistic) agents cannot affect equilibrium outcomes, but can affect what is individually observable within a match.

Our SCE concept is more resilient than the original concept, in game theory (and macro), on two grounds. First, since lenders choose the interest rate (a continuous variable), we require that subjective and objective probability distributions coincide in a neighborhood of the equilibrium, i.e. up to small variations of interest rates (we call it *Strong* SCE). Second, even if lenders were infinitely patient, the subjective *private expected value* of experimenting is negative. In fact, due to the public nature of the market, competition erodes any eventual private benefit of "discovering" that low interest rates induce lower default rates; in other words, in a competitive equilibrium lenders will run at zero profits anyway.[4]

Optimal *Credit-Easing*. In section 3, we study the problem of a Ramsey planner

[2]It should be noticed that in the macro literature sometimes the term SCE is (mis-)used by accounting only for the first feature but not accounting for this second key feature, as for example in Sargent et al. (2009).

[3]In their case, the Fed was taking actions based on a theory of the economy, which was supported by the outcomes determined by the FED policy, but that would had been confuted if the FED had taken different actions.

[4]By contrast, in repeated games, learning rents do not generally disappear, and patient experimentation eventually pays off.

who takes into account the directed search equilibrium constraints, and has neither more information nor less uncertainty than lenders have[5]. As is well known, competitive directed search is efficient, in the sense that the decentralized market fulfills the constrained optimal allocation.[6] This implies that a Ramsey planner – with the same (or more pessimistic) beliefs as lenders – will choose to implement the same allocation achieved by the decentralized market, *unless an instrument that can affect the distribution of matches is available*.[7]

A subsidy to lenders targeting an interest rate (which requires fiscal backing) allows the Ramsey planner to directly affect the payoffs of lenders and borrowers, determining the split of the surplus independently from the distribution of matches. We characterize credit-easing as the optimal policy that takes the form of a fixed subsidy to eventual lenders' losses, financed by lump-sum taxes paid by borrowers. The policy maker can induce different market interest rates by properly adjusting the subsidy (i.e. the policy maker solves an " optimal implementability problem'). In particular, with the subsidy, lenders offer loans at the targeted interest rates. Hence, the subsidy acts as an implicit tax to lenders who offer interest rates different from the targeted interest rate. This implicit tax takes the form of lower matching rates for offers at non-targeted interest rates. Furthermore, the subsidy has the property of restoring the Hosios condition at the targeted interest rate.

We also show that an optimal subsidy can be made contingent on eventual lenders' losses when targeting a sufficiently low interest rate. In the case that no losses realized, no subsidy will actually be given! Thus, at no cost, the policy could both reveal and implement a low-interest-low-risk REE, which will eventually persist even once the policy expires. Of course, if such a low-interest-low-risk REE does not exist (i.e. borrowers do not have low risk projects to finance), then the policy will bear a finite cost. Thus, the *social expected value* of such *experimental* policy is likely to be largely positive even when evaluated with the same subjective beliefs of lenders!

Evidence on the TALF. In section 4, we show that our theory can rationalize recent credit-easing policy interventions, such as the TALF, which has the features of our optimal subsidy. In general, it is difficult to empirically distinguish models of SCE based on incomplete knowledge, from models of multiple REE based on payoff externalities (as in Bebchuk and Goldstein (2011)). To overcome this difficulty, we

[5]Notice that we depart from the literature that studies QE policies, which usually assumes that private banks are subject to incentive or informational constraints, while the Central Bank is not (e.g. Gertler and Karadi (2011) and Correia et al. (2014)).

[6]As we show, any SCE in our environment satisfies the Hosios' efficient matching condition (Moen, 1997), although, as we emphasize, this only ensures local – rather than global – efficiency.

[7]For example, in our model, a central bank conventional policy instrument, such as an interest rate, is not effective because it is typically a " local instrument' and therefore in a locally efficient equilibrium should not be used (unless the economy parameters are just at the margin); furthermore, not being targeted to specific markets, it may not be optimal to use it as a " global instrument' to implement large deviations in all markets. Similarly, a less conventional policy, such as QE liquidity provision to banks, is not effective since more liquidity does not change the pessimistic beliefs of the banks.

collected micro data relative to issuance and riskiness of AAA-rated auto loan ABS before and after the implementation of the TALF. In this market, the likelihood that an auto loan is repaid is not influenced by the likelihood that other auto loans are repaid. Thus, an observed change of regime from high-risk-high-interest to low-risk-low-interest, which we show to be independent from aggregate conditions, can only be attributed to a self-confirming mechanism, as payoff externalities do not exist in this market.

Our unique dataset provides information on the effect of the TALF on the riskness of the underlying retail market of auto loans. Initially, we observe a high-risk-high-interest regime. Our theory would say that, before the TALF, the market was in a risky SCE, where, given the information available to lenders, increasing interest rates was an optimal choice to minimize losses. This is what we find in an econometric analysis of the pre-TALF sample: higher interest rates are associated with smaller losses. Then, the introduction of the TALF made the interest rates on the newly generated Auto ABS, and consequently on the underlying Auto loans, to fall dramatically and stayed low even after the end of the TALF. Our theory would say that this is the effect of learning that sufficiently low interest rates generate smaller losses. This is indeed what we find looking at the post-TALF sample: lower interest rates are associated now with smaller losses. We interpret the information embedded in these two subsamples as capturing the beliefs of Auto companies before and after the TALF, beliefs which were justified by their own experience in the market. We finally run a regression discontinuity analysis that uses the whole dataset and find evidence of a switch in the effect of interest rates on losses, after the introduction of the TALF. This last exercise demonstrates that the riskiness of Auto loans was indeed affected in a non-linear way by interest rates, which in our model is a condition for the emergence of a self-confirming credit crisis.

Other related work. This paper belongs to a broad research agenda on financial market crises and related policy interventions. Examples of causes of the disruption of financial intermediation in literature are: i) tighter incentives, as in Gertler and Karadi (2011) and Correia et al. (2014); ii) pervasive " adverse selection ", as in Chari et al. (2014) and Tirole (2012), or " moral hazard', as in Farhi and Tirole (2012); iii) coordination failures as in Bebchuk and Goldstein (2011) and iv) deterioration of collateral value, as in Gorton and Ordonez (2014). In contrast to existing work, our mechanism specifically relies on uncertainty about out-of-equilibrium states and it applies to models that have a unique rational expectations equilibrium. Furthermore, our policy prescriptions are different from those derived when other credit-freeze mechanisms are in place: we vindicate credit easing as a targeted subsidy policy, but not other conventional (lower interest rates) or unconventional (liquidity provision) policies, which are, in general, ineffective in self-confirming credit crises. Nor do we propose more interventionist policies – such as " direct lending' from the Central Bank – which can be very costly and may not dissipate pessimistic beliefs. Our work also relates to the literature that studies " price discovery', as in Kim et al. (2012), in the context of REE models. Finally, by its modeling, our work also connects to the search and matching literature which builds up on the strategic interaction within a match, as in Guerrieri et al. (2010). Ours is the first to demonstrate the possibility of SCE in competitive directed search models and to show the power, in reestablishing efficiency, of a targeted subsidy policy in the context of a *Self-Confirming Crisis*.

2 Self-Confirming Crises in Competitive Markets

This section introduces Self-Confirming Equilibria in a model of competitive search for credit. Competition strengthens the resilience of this equilibrium concept, in contrast to its original formulation in game theory. We use the model to describe how a deterioration of fundamentals can induce the economy to slide from an efficient equilibrium into a Self-Confirming crisis.

2.1 A simple game of the credit market

We start by describing the credit relationship between a single lender and a single borrower. For the sake of clarity, we introduce a minimal pay-off structure and focus attention on a one-period economy; it will be clear in due course that none of the main insights of the paper hinge on these simplifications.

A borrower

A borrower can obtain liquidity from a lender to invest in a project which requires one unit of investment. A lending contract specifies an interest rate R that the borrower pays to the lender at the end of the period. Given credit conditions characterized by an interest rate R, a borrower chooses the type of the project.

The borrower can invest in one of two types of project, namely a safe (s) or a risky (r) one, which differ in their likelihood of success and implementation costs. Table 1 below summarizes the borrower's payoff for the different kinds of project. Both types have the same conditional per-unit return: in the case of success it is $1+y$ with $y > 0$, whereas it is 1 in the case of failure. Safe projects do not fail, but their implementation requires a fixed per unit cost of k. Risky projects do not have any fixed per-unit additional cost, but they can fail with a probability of $1-\alpha$. Finally, only in the case of success does the borrower need to pay $1+R$ to the lender, otherwise the borrower repays just the capital 1. The two options available to the borrower are characterized by a state $\omega \equiv (\alpha, k)$ belonging to $\Omega \equiv \{[0,1], R_+\}$, which denotes the couple of parameters α and k related to the returns of the risky and the safe options, respectively.

Projects (α, k)	Safe (s)	Risky (r)
Success	cost: $1+R+k$ return: $1+y$ probability: 1	cost: $1+R$ return: $1+y$ probability: α
Failure	cost: 1 return: 1 probability: 0	cost: 1 return: 1 probability: $1-\alpha$

Table 1. Borrower's payoffs.

Formally, a project adoption is an action denoted by ρ that belongs to $\{s, r\}$. For a given ω and R, the optimal adoption policy is then

$$\rho^*(R, \omega) \equiv \underset{\{\rho \in \{s,r\}\}}{\arg\max} \{\pi^b(\rho; R, \omega)\}, \tag{1}$$

with

$$\begin{aligned} \pi^b(r; R, \omega) &\equiv (y-R)\,\alpha, && \text{(2a)} \\ \pi^b(s; R, \omega) &\equiv y-R-k, && \text{(2b)} \end{aligned}$$

where $\pi^b(\rho; R, \omega)$ is the expected net return associated with the project $\{s, r\}$ of a borrower, given an interest rate R and a state ω. The participation of the borrower in the market requires that $R \leqslant y$.

A lender

A lender is an agent that has access to the money market, but who cannot implement projects. A lender borrows money at a rate, δ, and chooses the interest rate R at which she makes a take-it-or-leave-it lending offer to a borrower. The lender observes the choice of the borrower only ex-post, so contracts are restricted to a fixed R.

The expected net return of a loan depends on the interest rate R, the cost of money δ, and the choice of the borrower ρ. In particular, the latter determines the probability that the project will succeed and hence a loan can be repaid. In particular, if the lender offers a contract at an interest R and the borrower chooses $\rho^*(R, \omega)$ the expected net return will be

$$\pi^l(R; \rho^*(R, \omega), \delta), \tag{3}$$

with

$$\pi^l(R; r, \delta) \equiv \alpha R - \delta, \tag{4a}$$
$$\pi^l(R; s, \delta) \equiv R - \delta. \tag{4b}$$

Implicitly we assume that the money market is a secured market; on the contrary in the credit market liability is limited, as only the project income is pledgeable. Therefore, the lender bears the cost of an eventual failure on the part of the borrower.

Modeling counterpart risk

The surplus generated by a credit relationship, i.e. the sum of agents' payoffs, is independent of the level of the interest rate R. In the case of a *risky project* the sum of the interim surplus is $\alpha y - \delta$ whereas in the case of the *safe project* it is $y - k - \delta$. Therefore as soon as $y - k/(1-\alpha)$ becomes positive, the surplus generated by adopting the safe project is larger.

However, the borrower has no interest in adopting the safe option when offered a too-high interest rate. Specifically, for a given R, the borrower will choose to implement a safe project if and only if $\alpha(y - R) \leqslant y - k - R$ or

$$R \leqslant \bar{R} \equiv y - \frac{k}{1-\alpha}.$$

Whenever $\bar{R}$ is negative – which occurs when $k > (1-\alpha)y$, that is, the fixed cost associated with the safe project is sufficiently high – borrowers will never adopt the safe technology no matter what interest rate R, is offered at.

Therefore $\bar{R}$ is an important parameter in the choice of the lender. The lender needs to understand the extent to which a lower R can induce the borrower to implement a safe project, which is not subject to default risk[8]; $\bar{R}$ represents the highest interest rate compatible with safe project adoption.

Nevertheless, computing $\bar{R}$ requires knowing the payoff structure of the borrower, i.e. the values y, k, and α. Whereas it is natural that an agent observes her own payoffs, it is less obvious that she can directly observe all the underlying incentives of other players. This is the key idea motivating the formulation of a Self-Confirming equilibrium, which in our case takes the following form:

Assumption (A): *A lender does not know the payoff structure of a borrower, but can observe project adoption ex-post.*

As a consequence, the lender is a-priori uncertain about the actual behavior of the borrower. Such uncertainty generates counterpart risk in the lending contract as the borrower's choice ρ affects the returns of the lender.

[8]We refer to default risk as: the risk that interest rates are not repaid by the borrower at the end of the contract.

In particular, we can think of the set of available project as a random variable $\tilde{\omega}$ which is distributed on Ω according to an *objective* density function $\phi(\tilde{\omega})$.[9] Our simple specification implies $\phi(\tilde{\omega})$ is degenerate with mass one on a particular value ω. We can then denote by $\beta(\tilde{\omega})$ the *subjective* density function of a lender, describing her beliefs about the probability that a borrower has access to a set of choices characterized by $\omega \in \Omega$. In particular, for a given R and δ, $E^{\beta}\left[\pi^{l}(R; \rho^{*}(R, \tilde{\omega}), \delta)\right]$ denotes the expected lender's profit evaluated with the probability distribution induced by β, where

$$E^{\beta}\left[(\cdot)\right] \equiv \int_{\Omega} (\cdot)\beta\left(\tilde{\omega}\right) d\tilde{\omega}, \tag{5}$$

is a subjective expectation operator. Note that we allow for subjective density function $\beta(\tilde{\omega})$ to possibly - but not necessarily - differ from the objective density function, $\phi(\tilde{\omega})$. Nevertheless, we assume that $\text{supp}(\phi(\tilde{\omega})) \in \text{supp}(\beta(\tilde{\omega}))$ and, moreover, lenders' beliefs comply with Bayesian updating.

More generally we will maintain the notation $\phi(\tilde{\omega})$ or simply ϕ in the rest of the paper, whenever the analysis is not restricted to the specific pay-off specification that we have described above. Finally, without loss of generality, and to keep notation compact, we assume $E^{\beta}[E^{\phi}[(\cdot)]] = E^{\beta}[(\cdot)]$, that is, the subjective expectation of the objective mean is the subjective unconditional mean. This is nothing else than a *consistency condition* for beliefs to be rationally formed, it ensures that the subjective probability distribution is believed the best estimate of the objective probability distribution.[10]

Fragility to patient experimentation in non-competitive environments

The simple setting just introduced can be used to briefly discuss the game-theory notion of self-confirming equilibrium and help to illuminate one of its limitations.[11] To do so, let us assume for a moment that a lender could only choose between two interest rates, namely R_h and R_l, such that $R_h > \bar{R} > R_l$ and $R_h\alpha < R_l$.

If the lender knows the payoff structure of the borrower, she would understand that the dominant strategy is to offer R_l, anticipating that the borrower has an interest in implementing the safe project. Nevertheless, under the assumption (A), a lender can well entertain beliefs about $\bar{R}$, namely $\bar{R}^e$, such that $R_h > R_l > \bar{R}^e$. In this case a lender will never offer R_l.

A Self-Confirming equilibrium is one in which the lender offers R_h and the borrower implements risky projects. In this situation, even ex-post the lender will not observe the counterfactual in which the borrower adopts a safe project in response to an offer R_l (i.e. that indeed $R_h > \bar{R} > R_l$). Therefore, the equilibrium itself does

[9]We use a tilde to denote a random variable, $\tilde{x}$, in contrast to one of its particular realizations, x.

[10]In any case, a relaxation of this assumption is innocuous to the following analysis, although would force us to keep track of the double expectation.

[11]For a formal and exhaustive discussion refer to Fudenberg and Levine (1998).

not produce any observables that can confute lenders' beliefs, i.e. lenders' beliefs are self-confirmed. In a Self-Confirming equilibrium the strategy of the lender is not a violation of Bayesian rationality in any respect, neither ex-ante nor ex-post.

Of course, one can wonder to what extent such an equilibrium is robust in the context of a repeated game. After any repetition, the lender will observe (or infer) either the value of α if the last project of the borrower was risky, or otherwise k. Therefore, the lender could play R_l to assess the reaction of the borrower and then exploit this piece of information for future repetitions: i.e. the lender can experiment. The choice to experiment involves a trade-off. On the one hand, a one-period deviation from the believed best action R_h generates an expected opportunity cost. On the other hand, if the lender discovers unexploited opportunities, the information yields a rent for future repetition of the game, whose value can potentially be unbounded. Thus, a lender who is patient enough and can secure the eventual gains of the experimentation will always choose to play the perceived lottery by offering R_l, at least once. In a dynamic context a Self-Confirming equilibrium is fated to break down when the lender gives high value to future payoffs, and can secure rents from experiments. In this sense, the game-theory formulation of the Self-Confirming equilibrium (Fudenberg and Levine, 1993) is fragile to patient experimentation.[12]

This kind of fragility is common to applications of the Self-Confirming equilibrium in Macroeconomics that hinge on the learning friction of a major actor who is large enough to influence observables (Sargent, 2001; Primiceri, 2006).[13] Deviations from the typical large player framework appear problematic, given the difficulty in defining settings in which atomistic agents can still retain the power to affect what they observe. In the following, we will overcome this difficulty. We will provide a static characterization of Self-Confirming equilibrium in competitive environments. We will then argue that competition makes Self-Confirming equilibria robust to patient experimentation, so that the main insights from the static model naturally extend to dynamic frameworks.

2.2 From games to competitive markets

Below, we present a competitive search and matching environment where credit relationships are formed randomly. We characterize Self-Confirming equilibria within this environment. We consider the class of linear economies characterized by the generic payoff functions $\pi^b(\rho; R, \tilde{\omega})$ and $\pi^l(R; \rho, \tilde{\omega})$ with $\pi^b_R = -\pi^l_R$, for a given ρ and a generic distribution $\phi(\tilde{\omega})$.

We focus on a static economy and then discuss how the insights naturally extend into a dynamic version. In contrast to non-competitive economies, even if lenders

[12]It should be noticed that the game-theory literature has developed conditions to overcome this limitation of SCE. For a recent study see Battigalli et al. (2015).

[13]Such a major actor is typically a policy maker that, implementing policies based on a misspecified theory, prevents available data from revealing the misspecification.

are infinitely patient, competition dries out the private incentives of experimentation, exactly as in a models of investment in R&D where discoveries are public goods.

Matching in the credit market

Atomistic lenders and borrowers match to form a credit relationship in the context of a competitive direct search framework, as intoduced by Moen (1997) along the simplified variant described by Shi (2006). We normalize the mass of borrowers to one, whereas we allow free entry on the side of lenders.

Each lender can send an application for funds replying to an offer of credit posted by a borrower. The search is *directed*, meaning that at a certain interest rate R there is a subset of applications $a(R)$ and offers $o(R)$ looking for a match at that specific R. The per-period flow of new lender-borrower matches in a submarket R is determined by a standard Cobb Douglas matching function

$$x(a(R), o(R)) = Aa(R)^{\gamma} o(R)^{1-\gamma} \tag{6}$$

with $\gamma \in (0, 1)$. This assumption, which is standard in the literature, ensures a constant elasticity of matches to the fraction of vacancies and applicants, for each submarket R.[14] The probability that an application for a loan at interest rate R is accepted is $p(R) = x(a(R), o(R))/a(R)$ and the probability that a loan offered at R is finally contracted is $q(R) = x(a(R), o(R))/o(R)$. Once the match is formed, the lender lends one unit to the borrower at rate R. We will say that a submarket is active if there is at least a contract posted.

Borrowers send applications once lenders have posted their offers. A borrower sends an application to one posted contract R among the set of posted contracts H to maximize

$$J(R) \equiv p(R)\, E^{\phi}[\pi^{b}(\rho^{*}(R))], \tag{7}$$

where $\pi^{b}(\rho^{*}(R))$ stays for $\pi^{b}(\rho^{*}(R); R, \tilde{\omega})$, and

$$\rho^{*}(R) \equiv \arg\max_{\rho \in \{s,r\}} \{E^{\phi}[\pi^{b}(\rho; R, \tilde{\omega})]\} \tag{8}$$

with $E^{\phi}[(\cdot)]$ being analogous to (5). In (7)-(8) we assume that borrowers apply for credit and invest without knowing the realization of their individual state ω, which ensures $p(R)$ being independent of $\tilde{\omega}$. The competitive behavior of borrowers implies that the mass of applicants to a submarket $R' \in H$, namely $a(R')$ increases (resp. decreases), whenever $J(R') > J(R'')$ for each $R'' \in H$ (resp. $J(R') < J(R'')$ for at least a $R'' \in H$). Competition among borrowers implies that $J(R)$ is equalized across the

[14] In particular, the ratio $\theta(R) = a(R)/o(R)$ denotes the tightness of the submarket R. The tightness is a ratio representing the number of borrowers looking for a credit line *per-unit of vacancies*. Notice that the tightness is independent of the absolute number of vacancies open in a certain market.

posted contracts, i.e. more profitable contracts are associated with lower probabilities of matching.

Lenders are first movers in the search: they choose whether or not to pay an entry cost c and, once in the market, at which interest rate R they post a contract. A posted R is a solution to **the lender's problem**:

$$\max_R E^{\beta}[q\left(R\right) E^{\beta}[\pi^l\left(R;\rho^*(R)\right)] - c], \tag{9}$$

subject to

$$p\left(R\right) E^{\phi}[\pi^b\left(\rho^*(R)\right)] = \bar{J}, \tag{10}$$

and

$$q\left(R\right) = A^{\frac{1}{1-\gamma}} p\left(R\right)^{-\frac{\gamma}{1-\gamma}}, \tag{11}$$

where $\bar{J}$ is an arbitrary constant[15] and $\pi^l\left(R;\rho^*(R)\right)$ replaces $\pi^l\left(R;\rho^*(R),\delta\right)$. Note that (11) is a direct implication of (6). The constraints (10) and (11) make sure that the individual lender takes the probability of matching in a submarket as given. Such probabilities are evaluated according to the subjective probability distribution $\beta(\tilde{\omega})$. Lenders cannot individually affect the distribution of offers and applications, and in particular, the expected utility granted to borrowers. Thus, the competitive behavior of borrowers implies that (10) holds, which together with (11), defines $q(R)$.

On the side of the lenders, free entry guarantees competition, so that the mass of lenders posting a contract in the submarket R, namely $o(R)$, increases (resp. decreases) whenever $E^{\beta}[V(R)] > 0$ (resp. $E^{\beta}[V(R)] < 0$), where

$$V(R) \equiv q\left(R\right) E^{\beta}[\pi^l\left(R;\rho^*(R)\right)] - c, \tag{12}$$

is the value of posting a vacancy. Competition among lenders implies $max_R E^{\beta}[V(R)] = 0$, i.e. at the equilibrium lenders run at zero profits.

Notice that, in order to solve (9), a lender needs to anticipate the reaction of the borrower $\rho^*\left(R,\tilde{\omega}\right)$ to an offer R, to determine both the probability $q(R)$ that an offer R is accepted and the default risk associated with it. Hence a lender bears the risk associated with the probability that a contract is not filled and the uncertainty, or possible misperception, concerning the payoff incentives of lenders.

Equilibria: SSCE and REE

We present the definition of Strong Self-Confirming Equilibrium (SSCE) and we contrast it to the notion of Self-Confirming Equilibrium (SCE) and the one of Rational Expectation Equilibrium (REE).

Definition 1 (SSCE). *Given an objective density function $\phi(\omega)$, a Strong Self-Confirming*

[15] Here, we emphasize that the lender does not need to know the equilibrium value of $J(R)$, but just that she cannot affect it.

equilibrium (SSCE) is a set of posted contracts H^* *and beliefs* $\beta(\omega)$ *such that:*

sc1) for each R^**, the maximizing value for the borrower* $J(R^*) = \bar{J}$*;*

sc2) each R^* *solves the lender's problem (9)-(11);*

sc3) there is an open neighborhood of R^**, namely* $\mathfrak{I}(R^*)$*, such that for any* $R \in \mathfrak{I}(R^*)$ *it is*

$$E^{\beta}[V(R)] = E^{\phi}[V(R)], \tag{13}$$

that is, borrowers correctly anticipate lenders' reactions only locally around the realized equilibrium contracts.

The third condition (sc3) restricts lenders' beliefs $\beta(\tilde{\omega})$, regarding borrowers' actions, to be correct in a neighborhood of an equilibrium R^*. This is a stronger restriction on beliefs than the one usually assumed within the notion of Self-Confirming Equilibrium (SCE), which instead does not contemplate any belief restriction out of equilibrium. In fact, at a SCE, condition (sc3) holds punctually for any R^* rather than for any $R \in \mathfrak{I}(R^*)$.

Crucially, the definition of SSCE does not require lenders to have correct beliefs about non-realized out-of-equilibrium behavior. This leaves open the possibility that, in a SSCE, better contracts outside of the neighborhood of the equilibrium could be wrongly believed by lenders to be strictly dominated by existing ones. In particular, lenders may misperceive the actions the borrowers would take – and the resulting risks – when offered lower interest rates. Since such contracts will not be posted, then in equilibrium there do not exist counterfactual realizations that can confute wrong beliefs, neither ex-ante nor ex-post.

A REE is a stronger notion than a SSCE requiring that no agent holds wrong out-of-equilibrium beliefs. In the present model this is equivalent to impose that lenders' beliefs about borrowers' payoffs are correct. In such a case the equilibrium contract is the one which objectively yields the highest reward with respect to every possible feasible contract.

Definition 2 (REE)**.** *A rational expectation equilibrium (REE) is a Self-Confirming equilibrium such that, at any* $R \in \mathfrak{R}$*, (13) holds that is, lenders correctly anticipates borrowers' reactions for any possible contract.*

A REE obtains from a tightening of condition (sc3) in the definition of a SSCE. This implies that every $R^* \in H^*$ is such that lenders can exactly forecast the out-of-equilibrium value of posting a credit line, as they can correctly anticipate borrowers' responses. Therefore, posting in the submarket R^* is a globally dominant strategy both from an objective and a subjective point of view.

Equilibrium Characterization

We now provide a characterization of an equilibrium. We develop a non-marginal technique that can be generally used to identify the equilibrium of search and matching economies with non convex payoff structures, and potentially multiple local maxima. As we will show, the Hosios condition obtains from a linear local approximation of the global criterion.

Plugging constraints into the objective[16] we can derive the condition for an equilibrium contract as:

$$R^* = \arg\max \left(A^{\frac{1}{1-\gamma}} \bar{J}^{-\frac{\gamma}{1-\gamma}} E^{\beta}[\pi^b\left(\rho^*(R)\right)]^{\frac{\gamma}{1-\gamma}} E^{\beta}[\pi^l\left(R;\rho^*(R)\right)] - c] \right),$$

so that, after defining

$$\mu(R) \equiv E^{\beta}[\pi^b\left(\rho^*(R)\right)]^{\frac{\gamma}{1-\gamma}} E^{\beta}[\pi^l\left(R;\rho^*(R)\right)], \tag{14}$$

we have the following lemma as a direct consequence.

Lemma 1. *Consider two contracts posted respectively at* R_1 *and* R_2*. From the point of view of a single atomistic lender*

$$E^{\beta}\left[V\left(R_1\right)\right] \geqslant E^{\beta}\left[V\left(R_2\right)\right] \Leftrightarrow \mu\left(R_1\right) \geqslant \mu\left(R_2\right), \tag{15}$$

for any profile of contracts offered by other lenders.

Note that the evaluation of R does not depend on $\bar{J}$, i.e. it does not depend on the level of utility granted to the other side of the market, which a single lender cannot affect. However, lenders partly internalize the welfare of borrowers, as contracts that provides better conditions for borrowers are more likely to be signed. In particular, with $\gamma = 0$, when all the surplus is extracted by lenders, (15) becomes $E^{\beta}\left[\pi^l(R_1;\rho^*(R_1))\right] \geqslant E^{\beta}\left[\pi^l(R_2;\rho^*(R_2))\right]$ that is, at the equilibrium only the interim payoff of lenders is maximized, as borrowers will always earn zero. With $\gamma = 1$ on the other hand, when the whole surplus is extracted by borrowers, (15) becomes $E^{\beta}\left[\pi^b(\rho^*(R_1))\right] \geqslant E^{\beta}\left[\pi^b(\rho^*(R_2))\right]$ that is, only the interim payoff of borrowers is maximized as lenders will always earn nothing.

Let us introduce here a definition of local maxima of μ evaluated by the system of beliefs β and ϕ, respectively.

Definition 3. *A contract* R' *is a* β*-local maximum for the lender if there exists a neighborhood of* R'*, namely* $\mathcal{I}(R')$*, such that*

$$\mu(R') = \sup_{R \in \mathcal{I}(R')} \mu(R), \tag{16}$$

[16] Remember, to simplify the notation, we are looking at the case $E^{\beta}[E^{\phi}[\cdot]] = E^{\beta}[\cdot]$, which avoids the necessity of keeping track of the double expectation.

with $\mathcal{M}^{\beta}$ denoting the set of β-local maxima. An interior β-local maximum is a contract R *such that*

$$\mu(R)\left(\frac{\gamma}{1-\gamma}\frac{1}{E^{\beta}[\pi^{b}(\rho^{*}(R))]}-\frac{1}{E^{\beta}[\pi^{l}(R;\rho^{*}(R))]}\right)=0, \tag{17}$$

with $\hat{\mathcal{M}}^{\beta} \subseteq \mathcal{M}^{\beta}$ denoting the set of interior β-local maxima. The corresponding sets of local ϕ-maxima, namely $\hat{\mathcal{M}}^{\phi}$ and $\mathcal{M}^{\phi}$, obtain for $\beta = \phi$.

The definition above allows a simple characterization of the equilibria as follows.

Lemma 2. *For a given $\phi(\tilde{\omega})$ and $\beta(\tilde{\omega})$, a set of contracts H^{*} is a SSCE but not a REE if any $R^{*} \in H^{*}$ is such that: i) $R^{*} = \sup \mathcal{M}^{\beta}$, ii) $R^{*} \in \mathcal{M}^{\phi}$ but $R^{*} \neq \sup \mathcal{M}^{\phi}$; whereas it is a REE if any $R^{*} \in H^{*}$ is such that: $R^{*} = \sup \mathcal{M}^{\beta} = \sup \mathcal{M}^{\phi}$.*

The requirement $R^{*} \in \mathcal{M}^{\phi}$ is a direct consequence of having $\beta = \phi$ locally around the equilibrium. Of course, (17) is satisfied locally by any interior SSCE (or REE), i.e. an equilibrium where neither incentive-compatibility nor participation constraints are binding. In such a case we can obtain a marginal condition on the elasticity of the $\mu(R)$ function which identifies the local maximum. The criterion (17) reduces to the famous Hosios (1990) condition, that is, R^{*} is such that $\pi^{b} = \gamma(\pi^{b} + \pi^{l})$ and $\pi^{l} = (1-\gamma)(\pi^{b} + \pi^{l})$.

Robustness to Patient Experimentation

In contrast to the non-competitive versions of the self-confirming equilibrium, our characterization is robust to experimentation by highly patient agents. To sketch our argument we shall extend our static economy to an infinite horizon economy where each period is a repetition of our one-period version. A SSCE in this environment is a sequence of static SSCE. The only key difference is that now beliefs are updated dynamically in light of the equilibrium realizations of the period before. Of course, given that lenders' beliefs are correct at the equilibrium, what a lender will observe along the equilibrium path is of no help in refining their beliefs.

We ask ourselves whether, when the competitive economy is on a SSCE, a patient lender, who is aware of her ignorance, has any incentive to experiment with lower interest rates. The answer is "no" and follows as a consequence of two very general points.

First, any individual deviation from the equilibrium is perceived to be costly. This is of course true by definition of any equilibrium. Notice that, in this respect, the restriction to a one-period contract is innocuous we could extend the model to include richer contract specifications, without altering the conclusion that on a SSCE each lender perceives that deviating entails a loss (big or small does not matter) with respect to the status quo.

Second, all the information generated by the market is public, i.e. there are no informational rents. This condition is a pre-requisite for a decentralized economy to achieve a competitive outcome. The implication is that the outcome of any eventual deviation from the equilibrium will be observed by all competitors and used to update beliefs. This argument does not require specification as to which information is produced or observed, but only that *if* a deviation produces information which is sufficiently informative for a single lender to update beliefs, then all lenders will update beliefs in the same way. As a result, the zero-profit condition will necessarily hold after any individual deviation, whatever the outcome may be.

In the end, competition dries out lenders' profits so that they always expect to earn zero profits at *any* equilibrium: there are no informational rents that the individual lender could eventually exploit in this environment. Individual gains are only possible out of equilibrium. Nevertheless, deviations from an equilibrium, are, by definition, expected to yield negative profits. Therefore, the typical fragility of self-confirming equilibrium to patient experimentation in non-competitive environments does not apply in competitive ones. For this reason, the insights of our simple static formulation are no less general that the ones we could obtain in any dynamic extension of the model.

2.3 Self-Confirming credit crises

We use now our simple specification – with pay-offs (2) and (4), and a given ω – to describe how an economy can slide into a Self-Confirming crisis.

The first step to compute equilibria is to work out the set $\mathcal{M}^{\phi}$ to which a SSCE belongs. We can use (17) to compute the interior local maximum relative to safe and risky project choice, respectively. Next, we check whether such contracts are within the bounds imposed by incentive-compatibility and participation constraints. Note that, conditional on a particular project choice, the problems are nicely concave, so that a unique maximum typically arises.

Proposition 1. *For a given ω, the set of ϕ-local maxima is $\mathcal{M}^{\phi} = \{R_s^*, R_r^*\}$ where $R_s^* = \min(\bar{R}, \hat{R}_s)$ with*

$$\hat{R}_s = (1-\gamma)(y-k) + \gamma\delta, \tag{18}$$

provided that $R_s^* > \delta$, and $R_r^* = \min(y, \hat{R}_r)$ with

$$\hat{R}_r = (1-\gamma)y + \frac{\gamma}{\alpha}\delta \tag{19}$$

and it exists if $R_r^* > \bar{R}$.

Proof. Postponed to Appendix A.1 ∎

$\hat{R}_s$ and $\hat{R}_r$ represent interior local maxima, namely the contracts which locally maximize lenders' profits when no constraints are binding; converely R_s^* and R_r^* account for the possibility that constraints do bind. In particular, $R_r^* > R_s^*$, that is, ceteris paribus, risky projects imply higher interest rates. Nevertheless, the expected profit of both a borrower and a lender can be higher when a risky project is implemented depending on parameters (for example, when $\alpha = 1$).

Let us now characterize the set of REE, i.e. $\sup \mathcal{M}^{\phi}$.

Proposition 2 (REE). *For a given ω, there exists a threshold value $\hat{\alpha}(k)$ which is decreasing in k and belongs to $(\underline{\alpha}(k), \overline{\alpha}(k))$, where*

$$\underline{\alpha}(k) = \frac{y - \hat{R}_s - k}{y - \hat{R}_s} \quad \textit{and} \quad \overline{\alpha}(k) = \frac{y - \delta - k}{y - \delta},$$

such that:

(i) if $\alpha < \hat{\alpha}(k)$ then $\sup \mathcal{M}^{\phi} = \{R_s^*\}$,

(ii) if $\alpha > \hat{\alpha}(k)$ then $\sup \mathcal{M}^{\phi} = \{R_r^*\}$,

(iii) only for $\alpha = \hat{\alpha}(k)$ then $\sup \mathcal{M}^{\phi} = \{R_r^*, R_s^*\}$.

Proof. Postponed to Appendix A.2 ∎

The proposition establishes that for a sufficiently high level of riskiness ($\alpha < \hat{\alpha}$) the safe equilibrium is the unique REE, otherwise the risky equilibrium is the unique REE. The threshold $\hat{\alpha}$ is the only value of α where two REE exist in this model. This threshold lies in $(\underline{\alpha}, \overline{\alpha})$ that is, the interval for which $R^s \geqslant \bar{R} \geqslant \delta$.

We state now the existence of a unique equilibrium contract which is SSCE but not REE.

Proposition 3. *For a given ω, only R_r^* can be SSCE without being REE. In particular, for $R_r^* \in \mathcal{M}^{\phi}$ it is $\sup \mathcal{M}^{\beta} = \{R_r^*\}$ without being $\sup \mathcal{M}^{\phi} = \{R_r^*\}$ provided that : $\alpha < \hat{\alpha}$ and $E^{\beta}[k]$ is sufficiently high so that $E^{\beta}[\hat{\alpha}(k)] < E^{\beta}[\alpha] = \alpha$.*

Proof. Postponed to Appendix A.3 ∎

The two conditions for the existence of a risky SSCE that is not a REE are intuitive. First, the safe equilibrium must be globally a strictly dominant contract when evaluated with the objective distribution. Second, lenders must believe that it is sufficiently unlikely that borrowers will adopt the safe project if they lower the interest rate i.e. they expect to be in a risky REE. A sufficiently high level of k is, for example, $\mathbb{E}^{\beta}[k] > (1-\alpha)r$.

There are two features of a SSCE that are worth noticing. First, the model has the important feature of generating a unique determinate SSCE that is not a REE, characterized by having excessive credit tightening and risk taking. Hence, missbeliefs can only sustain credit crises. Second, the beliefs that sustain a Self-Confirming crisis should satisfy a threshold condition, which is compatible with belief heterogeneity. Moreover, considering risk aversion or ambiguity would expand the set of beliefs that sustain a Self-Confirming crisis.

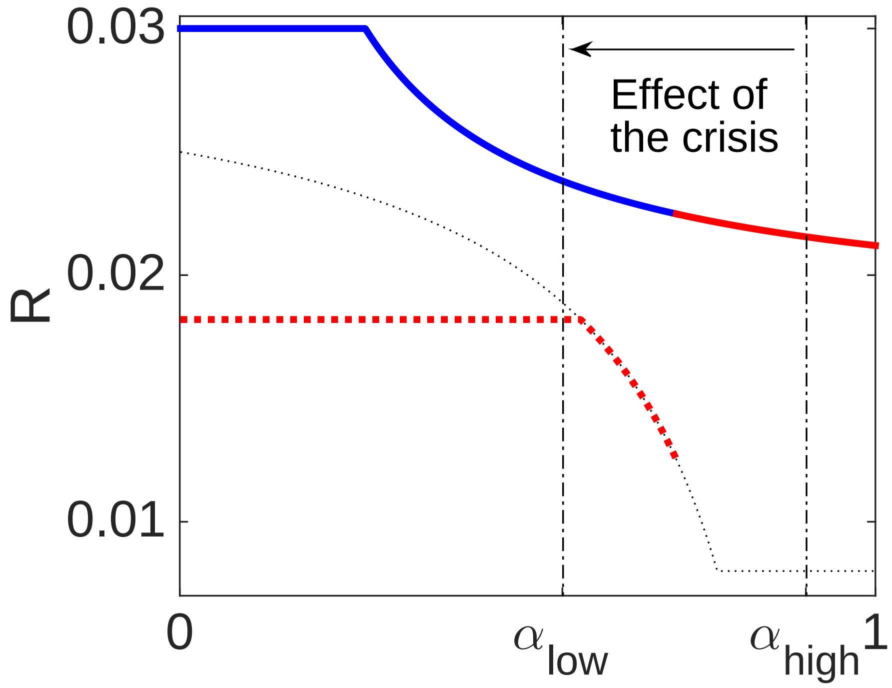

Figure 1: Weaker fundamentals create room for a Self-Confirming crisis.

Figure 1 illustrates our findings in the space (α, R). Our baseline configuration is $r = 0.03, \delta = 0.008, k = 0.005, \gamma = 0.4, c = 0.001, A = 0.1$. The feasible range of equilibrium interest rates compatible with the adoption of a safe (resp. risky) technology is the region below (resp. above) the dotted thin curve representing the adoption frontier of borrowers. For any α, R_r and R_s are denoted by the upper and lower thick lines. In particular, the red solid line denotes the unique REE for a given $\alpha > \hat{\alpha}$. For $\alpha < \hat{\alpha}$ the unique SSCE which is not REE is plotted in solid blue. The dotted red line represents the REE safe equilibrium for $\alpha < \hat{\alpha}$.

We are ready now to describe how a transition from a REE period to a Self-Confirming crisis can happen. We can think about a credit crisis as determined by an exogenous fall in α. When the risk is low ($\alpha_{high} = 0.9$) then the unique REE is the risky equilibrium where borrowers only adopt risky projects which, in fact, are not very risky. This is optimal. When risk increases up to a sufficiently high level ($\alpha_{low} = 0.55$), rational expectation would predict that the lenders switch to the low interest rate regime. In the logic of Self-Confirming equilibria, whether or not the "jump", occurs at the right point crucially depends on lenders' expectations about the counterfactual reaction of borrowers. In particular, the actual borrowers' reaction to low interest rates could not materialize as long as lenders keep posting high interest rates. Therefore, the trap is self-confirming, as high interest rates, justified by perceived counterpart risk, induce risky choices by borrowers.

Figure 2 illustrates the individual maximization problem corresponding to the sit-

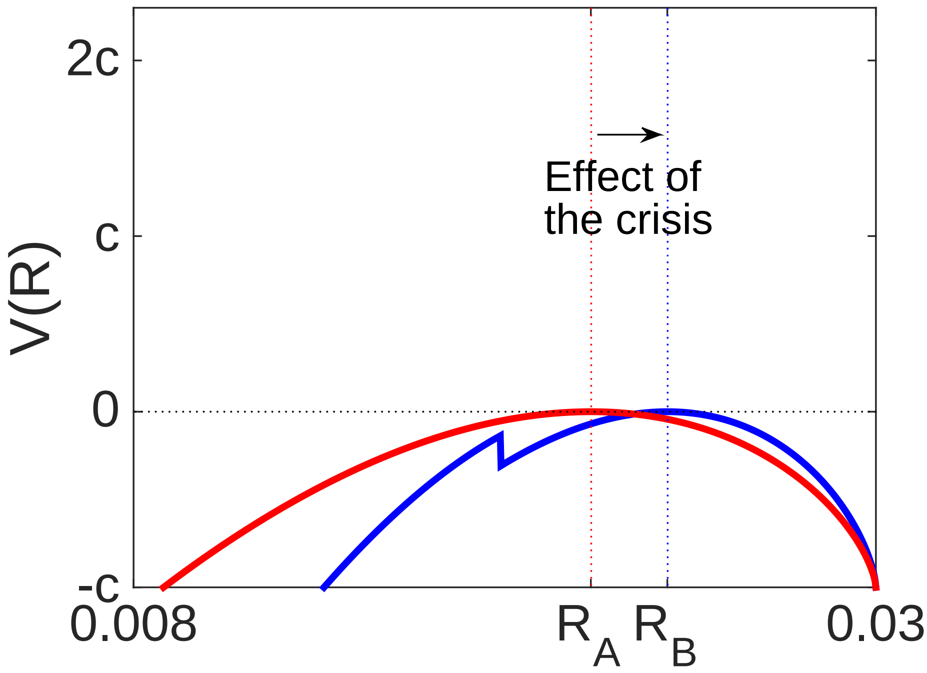

Figure 2: In a Self-Confirming crises, an increase in risk implies higher interest rates.

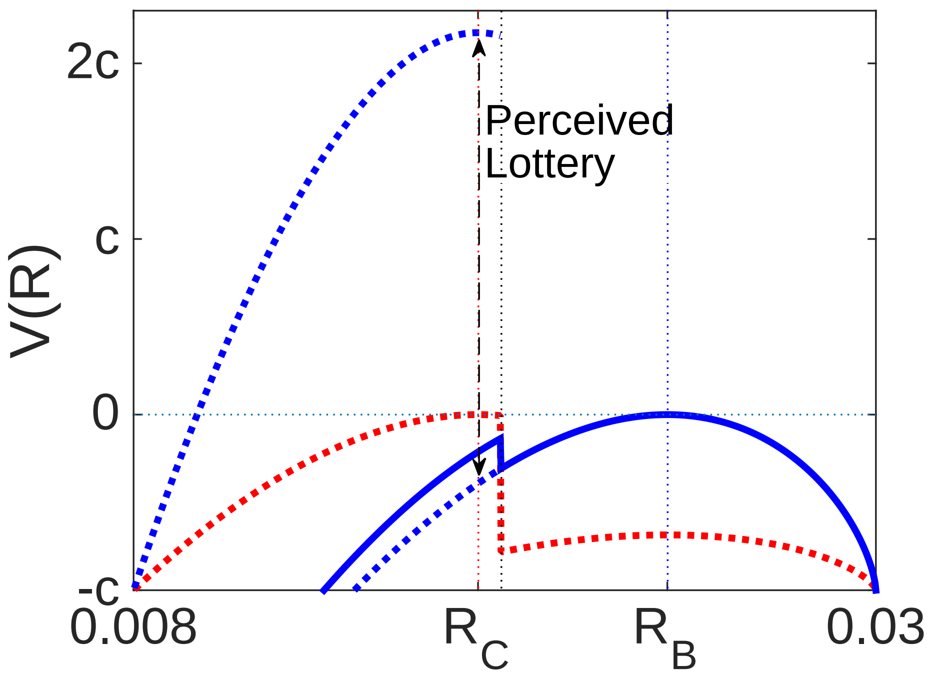

Figure 3: At a Strong Self-Confirming Equilibrium, a lender perceives a out-of-equilibrium lottery with negative expected value.

uation plotted in previous figure. On the x-axis we represent R, i.e. the individual choice of a lender. On the y-axis we measure the expected pay-off of the individual lender $\mathbb{E}^{\beta}[V(R)]$ *when all the other lenders post at the equilibrium* R. Thus, the figure shows the individual incentive to deviate from an equilibrium prescription. When risk is low ($\alpha = \alpha_{low}$ as in figure 1) the maximization problem of the lender is represented by the convex solid red curve, whose maximum at R_A yields zero, as implied by the zero profit condition. After an exogenous increase in risk ($\alpha = \alpha_{high}$ as in figure 1) the maximization problem becomes the solid blue line. The new curve peaks at $R_B > R_A$, accounting for bigger risk premia factored into interest rates. Moreover, a discontinuity arises for a sufficiently low interest rate, as a result of the uncertainty of a lender about the counterfactual reaction of a borrower. In particular, in this example, we consider the case $\beta(k = 0.005) = 0.07$, whereas the probability that the state is $\beta(k = 0.015) = 0.93$ where, notice $0.015 > r(1 - \alpha)$ that is, $k = 0.015$ is too high to induce a safe adoption for any feasible level of R.

Figure 3 illustrates the perceived lottery of the lender. The lower dotted blue line denotes the lender's payoff in the case $k = 0.015$, whereas the higher dotted blue line represents the case $k = 0.007$. In the latter, an *individual* deviation from R_B to R_C, with all other lenders posting at R_B, would yield a large profit. Nevertheless, this possibility is believed with too small a probability to induce an individual deviation. This is a necessary condition for R_B to be an equilibrium. Hence, a set of misspecified beliefs can sustain a SSCE that is not a REE when, as in our example, an existing globally optimal state for the lender is not believed to be sufficiently likely. Such misbelief cannot even be confuted ex-post because, given that only high interest rates are offered, no borrower adopts the safe option in equilibrium.

The maximization problem of a lender when all other lenders post at the unique REE interest rate R_C (unique conditionally to $\alpha = 0.55$ and $k = 0.007$) is represented by the dotted red curve in figure 3. The local and global maximum is at R_C and yields zero profits. This is useful to illustrate how competition dries out private incentives of experimentation in a dynamic extension of the model. Suppose for a moment that (despite pessimism) a lender discovers that posting R_C grants profits i.e. $k = 0.007$ is known with certainty now. This outcome will be observed by other competitors who in turn will choose to post R_C, fulfilling the zero-profit condition anyway.

Finally, figure 4 plots the equilibrium social welfare, measured in terms of cost-per-vacancy c, as a function α. Colors and traits are used to distinguish the REE from the other SSCE, as in figure 1. Note that since lenders run at zero expected profits, the social welfare coincides with the expected profits of borrowers. Social welfare is increasing in α (and so decreasing in R_r) when the economy is on a risky equilibrium, whereas it is insensitive to risk at a REE where borrowers adopt safe projects.[17] The effect of a Self-Confirming crisis triggered by an increase in fundamental risk is a

[17]Social welfare is decreasing in α when $\alpha \in (\underline{\alpha}, \bar{\alpha})$ i.e. the safe equilibrium arises as a corner solution.

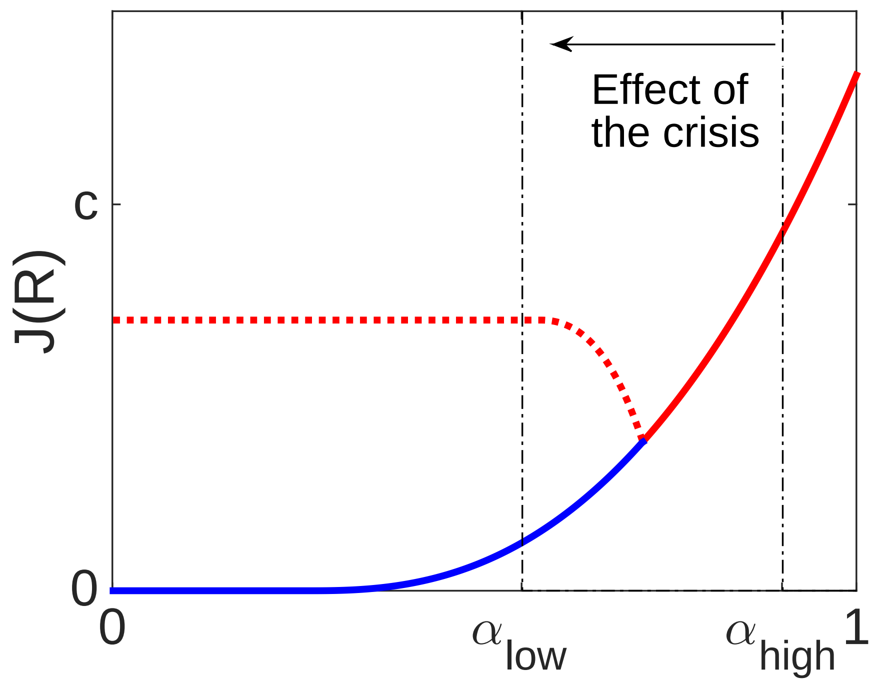

Figure 4: Social welfare in a self-confirming crisis.

dramatic decrease of social welfare. The drop would have been much lower in the REE instead. How would a policy maker, who shares the same beliefs as lenders act in a Self-Confirming crisis?

3 Credit Easing as an optimal policy

In this section, we demonstrate how a targeted subsidy from the central bank to the private lenders, financed by borrowers, can be a powerful tool for breaking a socially inefficient equilibrium. Under fairly general conditions, we show that if the objective of the CB is to maximize *ex-ante* social welfare, this is equivalent to maximize the *interim* total surplus of a match between a borrower and a lender when an optimal subsidy is implemented. Moreover, the CB will implement the policy whenever it assigns positive probability to the existence of a REE associated with strictly higher *ex-ante* surplus.

On the other hand, the lenders' private evaluation of the policy does not align with the social evaluation. The subsidy moves the whole distribution of matches and, therefore, lenders will always expect to earn zero profit.

3.1 Welfare evaluation of *laissez-faire* economies

Let us first analyze the problem of a benevolent social planner who maximizes social welfare, by choosing R as a policy instrument, subject to the directed search competitive restrictions, and in particular, the free entry lender's expected zero profit condition, which means that the planner maximizes $J(R)$. Importantly, we will provide the planner with the same subjective beliefs of the lenders, and no fiscal capacity, i.e. without power to operate transfers between lenders and borrowers. We will call this a *laissez-faire* economy, i.e. one in which a planner has no other instrument than R to affect the terms of trade.

The problem of a planner *without* fiscal capacity is:

$$\max_{R} E^{\beta}[p\,(R)\,E^{\phi}[\pi^{b}\,(\rho^{*}(R))]], \tag{20}$$

subject to

$$c = q\,(R)\,E^{\beta}[\pi^{l}\,(R;\rho^{*}(R))]$$

and

$$p\,(R) = A^{\frac{1}{\gamma}} q\,(R)^{-\frac{1-\gamma}{\gamma}};$$

i.e, the social planner maximizes social welfare taking the zero profit condition and the market tightness as a constraint. Notice that in (20) the subjective beliefs are those of the planner. Here we assume that they share the same beliefs, β, but in general there may be different.

As before, by plugging constraints into the objective[18] we can derive the constrained first-best contract as

$$R^{\star} = \arg\max\left(A^{\frac{1}{\gamma}} c^{-\frac{1-\gamma}{\gamma}} E^{\beta}[\pi^{l}\,(R;\rho^{*}(R))]^{\frac{1-\gamma}{\gamma}} E^{\beta}[\pi^{b}\,(\rho^{*}(R))]\right),$$

so that after defining

$$\bar{\mu}(R) \equiv E^{\beta}[\pi^{l}(R;\rho^{*}(R))]^{\frac{1-\gamma}{\gamma}} E^{\beta}[\pi^{b}(\rho^{*}(R))], \tag{21}$$

we have a criterion to rank the welfare generated by different contracts. From here onward, we will use a $\star$ to denote a policy outcome, as opposed to $*$ denoting a market outcome.

Lemma 3. *Consider two alternative laissez-faire economies trading at interest rates R_1 and R_2, respectively. From a the point of view of a planner:*

$$E^{\beta}\,[J\,(R_1)] \geqslant E^{\beta}\,[J\,(R_2)] \Leftrightarrow \bar{\mu}\,(R_1) \geqslant \bar{\mu}\,(R_2)\,, \tag{22}$$

for any profile of contracts offered by other lenders.

[18] Remember, to simplify the notation, we are looking at the case $E^{\beta}[E^{\phi}[\cdot]] = E^{\beta}[\cdot]$, which avoids the necessity of keeping track of the double expectation.

Comparing (22) and (15) we can easily see that the two criteria are maximized for the same equilibrium contract, i.e. $R^* = R^\star$. We therefore obtain the following proposition, which is a version of the wellknown result on the efficiency of the directed search competitive equilibrium:

Proposition 4. *In a laissez-faire economy where lenders and the planner have the same subjective beliefs, the competitive allocation is a solution to the planner's problem.*

The proposition states that in an economy in which the social planner has no other instrument than R to alter the terms of trade, the socially preferred allocation coincides with the one determined by the decentralized market. It reproduces the standard result on the constrained efficiency of directed search equilibria, except that in our context it is a local equilibrium result when the planner and the competitive agents (private lenders) share the same subjective beliefs.

3.2 Welfare evaluation with a subsidy as policy instrument

In this subsection we will introduce the possibility that the social planner can use linear transfers between borrowers and lenders, when she shares the same beliefs as lenders. The availability of a fiscal instrument introduces the possibility of compensating for the hold-up problem produced by pessimism on safe project adoption, and therefore of implementing the competitive equilibrium that maximizes social welfare.

Optimal subsidy

We construct a structure of transfers that have two desirable features:

i) the transfer that an agent - a lender or a borrower - *expects* in a match is independent of her individual action;

ii) the subsidy is financed by a tax on the fraction of matched borrowers.

To satisfy condition i), we consider a subsidy to lenders $d(R, \rho^*(R))$ contingent on general equilibrium objects, namely the equilibrium interest rate R and the equilibrium project choice $\rho^*(R)$, which are observable ex-post.[19] To satisfy condition ii), we require that the subsidy is paid by borrowers within a match. The optimal subsidy $d^\star(R, \rho^*(R))$ for a given R is the subsidy that maximizes social welfare when R is the equilibrium contract. **The problem of a planner *with* fiscal capacity** is:

$$\max_{R,d(\cdot)} E^{\beta}[p\,(R)\,E^{\phi}[\pi^{b}(\rho^*(R)) - d(R, \rho^*(R))]], \tag{23}$$

subject to

$$c = q(R)E^{\beta}[\pi^{l}(R; \rho^*(R)) + d(R, \rho^*(R))],$$

[19] In particular, the fraction of defaults across the population reveals the equilibrium project choice.

and

$$p(R) = A^{\frac{1}{\gamma}} q(R)^{-\frac{1-\gamma}{\gamma}},$$

where d denotes a subsidy to lenders financed by taxing borrowers, such that in expectation the individual choice of project is correct. Plugging constraints into the objective[20] we can derive the optimal *average* subsidy for a given R as:

$$d^{\star}(R) = \underset{d(\cdot)}{\arg\max} \left(A^{\frac{1}{\gamma}} c^{-\frac{1-\gamma}{\gamma}} \left(E^{\beta}[\pi^{l}(R;\rho^{*}(R))] + d(R) \right)^{\frac{1-\gamma}{\gamma}} \left(E^{\beta}[\pi^{b}(\rho^{*}(R))] - d(R) \right) \right),$$

where $d(R) \equiv E^{\beta}[d(R,\rho^{*}(R))]$. Hence, after defining

$$\mu^{\star}(R) \equiv \left(E^{\beta}[\pi^{l}(R;\rho^{*}(R))] + d^{\star}(R) \right)^{\frac{1-\gamma}{\gamma}} \left(E^{\beta}[\pi^{b}(\rho^{*}(R))] - d^{\star}(R) \right), \tag{24}$$

we have a criterion to rank the welfare generated by different contracts provided the authority implements the optimal subsidy. In the case of linear economies (i.e. when $\pi^{l}_{R} = -\pi^{b}_{R}$) the optimal subsidy $d^{\star}$ targeting a contract R satisfies the first-order condition:

$$\frac{1-\gamma}{\gamma} \frac{1}{E^{\beta}[\pi^{l}(R;\rho^{*}(R))] + d^{\star}(R)} + \frac{1}{E^{\beta}[\pi^{b}(\rho^{*}(R))] - d^{\star}(R)} = 0. \tag{25}$$

Therefore, the optimal *average* subsidy targeting an interest rate R satisfies:

$$d^{\star}(R) = (1-\gamma)E^{\beta}[\pi^{b}(\rho^{*}(R))] - \gamma E^{\beta}[\pi^{l}(R;\rho^{*}(R))]. \tag{26}$$

Notice that the optimal subsidy implies a split of the total expected interim surplus determined by the relative elasticities of the matching function to the mass of applicants and offers:

$$\begin{aligned} E^{\beta}[\pi^{b}(\rho^{*}(R))] - d^{\star}(R) &= \gamma E^{\beta}[\mathcal{S}(R,\rho^{*}(R))], & (27)\\ E^{\beta}[\pi^{l}(R;\rho^{*}(R))] + d^{\star}(R) &= (1-\gamma)E^{\beta}[\mathcal{S}(R,\rho^{*}(R))]. & (28) \end{aligned}$$

where $\mathcal{S}(R,\rho^{*}(R)) \equiv \pi^{b}(\rho^{*}(R)) + \pi^{l}(R;\rho^{*}(R))$ is the total interim surplus generated by the project choice of the borrower as an optimal reaction to an offer R. Finally, plugging (26) back into (24) gives

$$\mu^{\star}(R) = \gamma(1-\gamma)^{\frac{1-\gamma}{\gamma}} E^{\beta}[\mathcal{S}(R,\rho^{*}(R))]^{\frac{1}{\gamma}},$$

which, reduces the social evaluation to a simple total expected surplus criterion, given by $\log(\mu^{\star}(R))$. As a consequence, we have the following:

[20]Remember, to simplify the notation, we are looking at the case $E^{\beta}[E^{\Phi}[\cdot]] = E^{\beta}[\cdot]$, which avoids the necessity of keeping track of the double expectation.

Lemma 4. *Consider two alternative subsidized economies trading at interest rate* R_1 *with subsidy* $s^\star(R_1)$ *and* R_2 *with* $s^\star(R_2)$*, respectively. From a the point of view of a planner:*

$$E^\beta\left[J\left(R_1, d^\star(R_1)\right)\right] \geqslant E^\beta\left[J\left(R_2, d^\star(R_2)\right)\right] \Leftrightarrow E^\beta[\mathcal{S}(R_1, \rho^*(R_1))] \geqslant E^\beta \mathcal{S}(R_2, \rho^*(R_2))]. \tag{29}$$

In general the criteria (22) and (29) do not necessarily coincide. The reason is that, without the subsidy, the interest rate R determines at the same time both: i) the incentives of the borrower in the project choice, and ii) the incentive of the lender to post an offer, which depends on the split of the expected surplus. The presence of the subsidy makes disentangling these two dimensions possible. In particular, the optimal subsidy achieves an efficient share of the (subjectively expected interim) surplus for a given R, so that now R can be targeted to induce lenders to select the type of project which maximizes the surplus.

(Ramsey) Implementability

Since the criteria (22) and (29) may not coincide, there will be situations in which the planner would like to implement the subsidy and change the decentralized allocation in order to achieve a higher *expected* welfare. Moreover, in the case of a SSCE that is not REE, the policy constitutes a social experiment, as it is based on subjective beliefs β, which can be misspecified. In such a case the policy has the effect of producing evidence that can correct beliefs and clear uncertainty. A temporary policy intervention could be necessary to break the spell of misbeliefs about counterpart risk.

As we have seen, the design of the optimal subsidy is an exercise in optimal implementation. As a result, the authority can induce whatever equilibrium contract she prefers by means of the subsidy. To see this, suppose the authority targets a certain $R^\star$ and implements the subsidy $d^\star(R^\star)$. The private evaluation criterion in the case of a subsidy becomes:

$$\mu(R, d^\star(R)) \equiv \left(E^\beta[\pi^b\left(\rho^*(R)\right)] - d^\star(R)\right)^{\frac{\gamma}{1-\gamma}} \left(E^\beta[\pi^l\left(R; \rho^*(R)\right)] + d^\star(R)\right) \tag{30}$$

where $\mu(R, 0)$ is nothing else than (14). It is clear that:

$$\mu(R, d^\star(R)) = \mu^\star(R)^{\frac{\gamma}{1-\gamma}}. \tag{31}$$

Following our notation for local equilibria, let us denote by $\mathcal{M}^\beta_{d^\star(R)}$ (resp. $\hat{\mathcal{M}}^\beta_{d^\star(R)}$) the local (resp. interior) maxima of the function $\mu(R, d^\star(R^\star))$. Therefore, the first order condition of $\mu(R, d^\star(R))$ with respect to R (the analogous to (17)), satisfies

$$\frac{\gamma}{1-\gamma}\frac{1}{E^\beta[\pi^b\left(\rho^*(R)\right)] - d^\star(R^\star)} - \frac{1}{E^\beta[\pi^l\left(R; \rho^*(R)\right)] + d^\star(R^\star)} = 0, \tag{32}$$

exactly at $R^\star$ because of (26). The conditions (27), (28) and (32) makes clear that the optimal subsidy restores optimality *locally* at *any* targeted contract in the sense of the Hosios (1990) condition. We have just demonstrated that the following proposition holds.

Proposition 5. *Suppose the authority targets a contract* $R^\star$ *fixing a targeted subsidy* $d^\star(R^\star)$*, then the lenders' best reply to this policy is to offer:*

$$R^\star = \sup \mathcal{M}^{\beta}_{d^\star(R^\star)} = \sup \hat{\mathcal{M}}^{\beta}_{d^\star(R^\star)}.$$

We have shown that, in the case of linear economies, for the decentralized market to sustain a certain $R^\star$ it is sufficient that the authority commits to $d^\star(R^\star)$. Let us now clarify under what conditions the authority will decide to implement a subsidy.

Corollary. *Consider a decentralized SSCE equilibrium* $R^* \in \mathcal{M}^{\phi}$ *delivering an expected total surplus* $\mathcal{S}(R^*, \rho^*(R^*))$*. The authority will implement a contingent subsidy* $d^\star(R^\star)$ *targeting a contract* $R^\star$ *whenever* $E^{\beta}[\mathcal{S}(R^\star, \rho^*(R^\star))] \geqslant E^{\beta}[\mathcal{S}(R^*, \rho^*(R^*))]$.

Furthermore, by the definition of SSCE, $E^{\beta}[\mathcal{S}(R^*, \rho^*(R^*))] = E^{\phi}[\mathcal{S}(R^*, \rho^*(R^*))]$. In sum, the authority will implement the subsidy no matter how small the subjective probability that total surplus could improve is. The implementation of the subsidy is, in general, *ex-ante* the right decision for the authority, irrespective of what agents can eventually learn after exploring new submarkets (notably, that the status quo was not a REE). Although the CB in principle has the power to unveil the true state by experimenting on few matches, she finds it to be worth implementing the policy on the whole distribution to maximize the expected benefit across the population. On the other hand, the fact that all the distribution of posted contracts moves after the subsidy, leaves the lenders at zero expected profits in any case, that is, the private and social values of experimentation diverge.

Credit Easing as a self-financed social experiment

To gain more intuition on how the use of an *optimal subsidy* works, it is useful to go back to our baseline economy with pay-offs (2) and (4), and a given ω. There, a large enough interest rate, for example R' such that $R' > y - k/(1-\alpha)$, will induce borrowers to always choose the risky project. In this case, the surplus is $\mathcal{S}(R', \alpha) = \alpha y - \delta$, whereas the matching yields a surplus of $\mathcal{S}(R'', k) = y - k - \delta$ in the case where the borrowers are offered a positive R'' such that $R'' < y - k/(1-\alpha)$. Notice that whenever such a positive R'' exists we also have $\mathcal{S}(R'', k) > \mathcal{S}(R', \alpha)$. Therefore,

$$k < (1-\alpha)y \tag{33}$$

identifies the condition for which a planner, with the same beliefs as lenders, would like to target an interest rate satisfying $0 < R < y - k/(1-\alpha)$, if the decentralized equilibrium does not belong to this range.

In the case of figure 5, we considered an example where lenders believe $k = k^L = 0.005$ with probability $p^L = 0.07$ and $k = k^H = 0.015$, with probability $p^H = 1 - p^L$. Therefore, p^L is also the probability that $\mathcal{S}(R, k) = y - k - \delta$ at any $R < y - k/(1-\alpha)$. In particular, for any positive $R < y - k/(1-\alpha)$, the following inequality

$$E^{\beta}[\mathcal{S}(R, k)] > E^{\beta}[\mathcal{S}(R, \alpha)], \tag{34}$$

holds. This implies that the authority would like to implement a contingent subsidy at any $R < y - k/(1-\alpha)$. Let us focus on the case where the authority targets a contract $R^{\star} = R_C = R_s^*$ (note that $R_C < y - k/(1-\alpha)$), which is the best contract conditional to the realization of the good state k^L (as shown in Figure 5). In particular, the optimal targeted subsidy is

$$d^{\star}(R_C) \;=\; p^L d^{\star}(R_C, s) + p^H d^{\star}(R_C, r),$$

and given that $d^{\star}(R_s^*, s) = 0$ then we finally have

$$d^{\star}(R_C) \;=\; p^H\left((1-\gamma)\alpha(y - R_C) - \gamma(\alpha R_C - \delta)\right).$$

The subsidy satisfies (32), so that lenders - *all of them* - strictly prefer to post offers at R_C. This is illustrated by the curved green line in figure 5, which represents the expected payoff when the the subsidy $d^{\star}(R_C)$ is implemented. The peak of the green line is exactly at R_C, where the zero profit condition is satisfied. Notice that in this case lenders reply to the *credit easing* policy by offering loans at the interest rate R_C and, at such low interest, borrowers choose the safe technology. As a result, the effect of implementing a subsidy to the lenders at the cost of taxing borrowers results in no effective transfer in equilibrium, but in an implicit tax outside equilibrium. Lenders with beliefs β, as described, perceive that they are being taxed at R_B. In practice, once R_C is being offered, borrowers prefer the new choice to the old R_B, i.e. the effect is through a sharp decrease of $q(R_B)$. Therefore, a policy of subsidization of lenders at the expense of borrowers results in an implicit tax to lenders if they do not offer the planner's desired equilibrium interest rate.

Finally, let us now demonstrate how a credit easing intervention can be self-financed in the context of our example. Condition ii) requires that the subsidy to lenders is financed by a tax to matched borrowers. Nevertheless, in the case of a risky project adoption, matched borrowers could fail and not have pledgeable income to finance the policy. To ensure that the policy is self-financing, we shall consider individual-specific taxes on borrowers $d^b(R, \rho^*(R), i)$ where R and $\rho^*(R)$ are still general equilibrium objects, whereas $i \in \{c, f\}$ denotes the state of the project of the borrower being either a success (c) or a failure (f). The realization of the state i, it should be noted, is not under the control of a borrower, so that condition i) is still

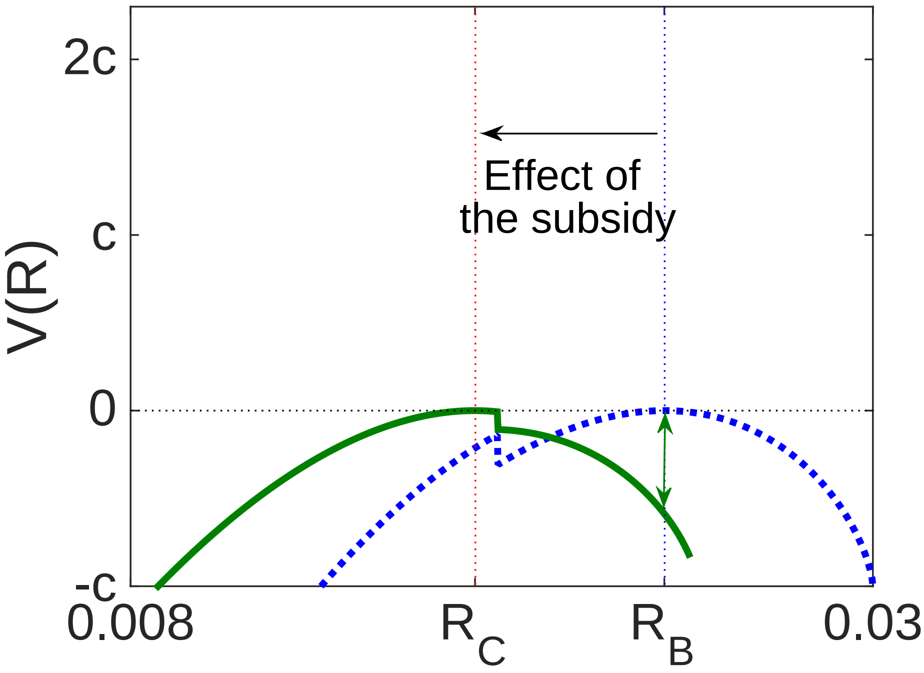

Figure 5: The effect of the optimal subsidy.

satisfied for the borrower. Self-financing, in our example, implies:

$$d^b(R_C, r, c) = \alpha^{-1} d(R_C, r) \quad \text{and} \quad d^b(R_C, r, f) = 0,$$

so that $\alpha d^b(R_C, r, c) + (1-\alpha) d^b(R_C, r, f) = d(R_C, r)$. This structure of contingent transfers ensures that at any equilibrium R the government can finance the subsidy to lenders relying on the same pleadgeable income on which private contracts also rely. In practice, in equilibrium each matched borrower finances *in expectation* a matched lender. Moreover, note that $y - R_C \geqslant d^{\star}(R_C, \alpha)$ always holds. In particular, in case k^H realizes, matched borrowers with successful projects still have pleadgeable resources to pay the tax. This makes sure that the fiscal plan can be self-financed in any possible state of the world, and, it also implies borrowers still have incentives to participate in the market despite the tax.

4 The case of TALF in the Automotive ABS market

The objective of this section is to provide evidence in support of the self-confirming mechanism implied by our theory, which cannot be explained by alternative mechanisms of self-fulfilling liquidity traps. To this aim, we collect and analyze micro-data on the effect of the 2009 TALF - the most significant (and controversial) US credit-easing intervention - on the evolution of riskiness and market value of the underlying securities.

A brief history of the TALF

> This facility [TALF] will provide three-year term loans to investors against AAA-rated securities backed by recently originated consumer and small-business loans. *Unlike our other lending programs, this facility combines Federal Reserve liquidity with capital provided by the Treasury, which allows it to accept some credit risk*... If the program works as planned, it should lead to lower rates and greater availability of consumer and small business credit. (Ben Bernanke, January 13, 2009)[21].

Asset Backed Securities (ABS) are assets through which private companies liquidate credit that they have with their customers. The value of an ABS is the value of claims over future receivables originated from an underlying pool of credit contracts. ABS cover important sectors of the US economy such as home equity, automotive, students loans, credit cards, to quote the principal four.

In the second half of 2007 the ABS market experienced a sudden contraction after a constant increase in volume since early 2000 (see figure 6).[22] The crash was mostly driven by lower-than-expected returns in the housing markets, which depressed the value of subprime home equities. The dramatic increase in perceived risk and the lack of confidence in rating agencies resulted in an abrupt freeze of the AAA-rated ABS segment, whose interest-rate rose at exceptionally high levels reflecting unusually high risk premiums (see figure 7). Private liquidity collapsed rapidly, and investors directed available resources to quality assets like Treasury bills, which almost doubled their daily volume of trade from 40 to 80 USD billion during 2008-2009.

Within this context, the Fed stepped in with the launch of the Term Asset Backed Securities Lending Facility (TALF) which supplied about 71 billion of non-recourse loans at lower interest rates, to any U.S. company which could provide highly rated (AAA and AAA-) collateral. The TALF was set in such a way that, if the ABS given as collateral fell sharply in value, an investor could put the collateral that secured its TALF loan back into the hands of the Fed, losing only a collateral haircut of 15%. Thus, TALF constitutes a subsidy contingent on credit losses on the underlying ABS security, eventually financed by the US Treasury. This intervention was made primarily to sustain the credit market in a period of high perceived counterpart risk. More precisely, the Fed acted as a borrower of last resort, taking the risk of experimenting with contractual conditions which were perceived as too risky by the private sector.

Despite malign prophecies welcoming the birth of the programs, on 30 September 2010, the Fed announced that more than 60% of the TALF loans had been repaid

[21] "The Crisis and the Policy Response", the Stamp Lecture, London School of Economics; the emphasis is ours.

[22] New issuances of consumer ABS plunged from $50 billion per quarter of new originations in 2007 to only $4 in the last quarter of 2008.

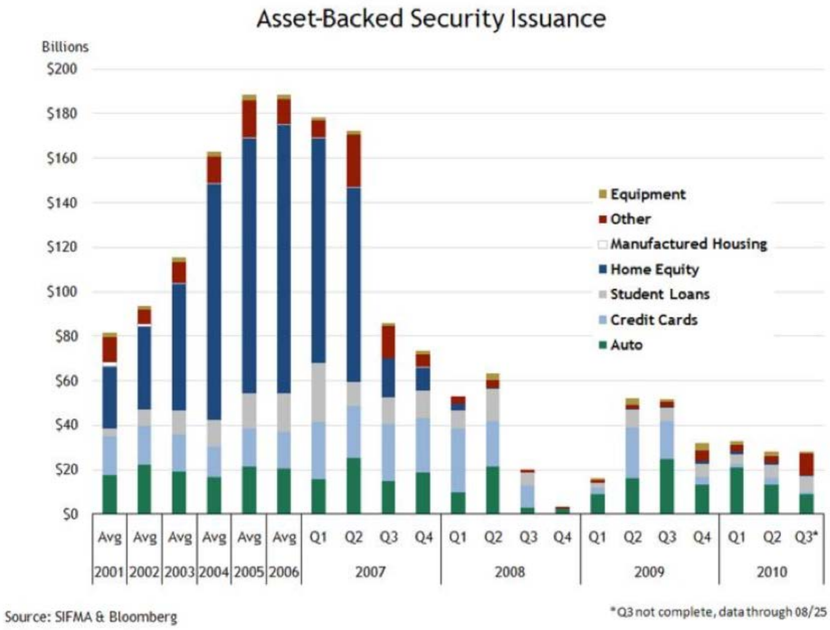

Figure 6: Amounts issued in the US ABS market for different categories.

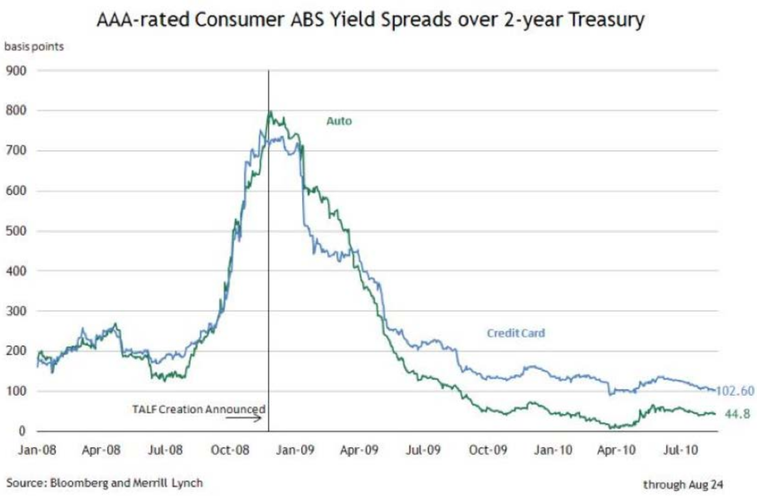

Figure 7: Interest rate spreads in the AAA-rated Auto and Credit Card ABS market.

in full, with interest, ahead of their legal maturity dates. In other words, the more favorable conditions offered by the Fed, instead of triggering an adverse selection process, were the prelude to a remarkable business performance. The NYFed, which was in charge of the operations, finally announced that "as of May 2011, there has not been a single credit loss. Also, as of May 2011, TALF loans have earned billions in interest income for the US taxpayer".[23]

How can our theory explain the effect of TALF?

The aim of this section is to demonstrate that our theory can be used to rationalize the TALF intervention and its success. We already saw that the TALF intervention increased the value of ABS, providing insurance against perceived counterpart risk. In particular, by providing a non-recourse loan at very low interest rates against the 85% of the value of an AAA-rated ABS, the Fed was offering an implicit subsidy contingent on the loss on the ABS being higher than 15% of its market value. However, this fact alone does not imply yet the key mechanism of our theory, which relates to the effect of the TALF on the underlying market for the ABS security. In particular, our theory would predict that:

1. during the crises, losses and interest rates were both rising;
2. the introduction of TALF translated into a decrease of the interest rates applied by financing companies to their customers;
3. after TALF, loans became less risky than that which could have been predicted by using all information available in the market before TALF intervention;
4. after TALF interest rates remained low as a consequence of firms learning that low interest rates generate low losses.

In other words, through the lens of our theory, the crisis of the ABS market is the result of an increase in the underlying riskness of the economy that triggered an increase in interest rates and an increase in losses, evolving in a spiral of self-confirming pessimism. In such a context the TALF insured companies against the perceived counterpart risk, companies stopped charging risk premia and competition mechanically drove their interest rates down. This way, the policy maker produced the counterfactual which eventually corrected firms' misbeliefs: lower interest rates actually yielded lower rather than higher losses. As a consequence, the TALF subsidy was never implemented, although the recovery was permanent.

Of course, at the same time there was a general recovery in the US economy. Therefore, to test our theory we need to isolate the effect of TALF from other business cycle externalities. In particular, to argue that our mechanism is in play, we need to

[23]Source: http://www.newyorkfed.org/education/talf101.html

exclude the possibility that the recovery of the market could be explained by models of multiple REE, as per the one of Bebchuk and Goldstein (2011), based on liquidity externalities.[24] We designed the following empirical strategy to overcome all these difficulties.

4.1 The ABS automotive market

Why look at the Automotive Market?

First of all, let us explain why the automotive market constitutes an excellent case for our analysis. The automotive ABS is the second most significant category of ABS, after credit card, in terms of amount supported by the TALF, about 3 million US$. We choose to look at this market because the peculiar characteristics of the underlying contracts make our analysis particularly informative. Below, there is a list of the advantages that this market offers for the purposes of our research inquiry, in contrast to the most obvious alternative, namely the credit card market.

- **There are no cross-customer externalities.** It is hard to argue that, in the Auto loans market, lower interest rates to new customers may affect the likelihood of repayment of old customers, which may by contrast happen for credit cards (even controlling for the business cycle). Importantly, the absence of this characteristic rules out potential explanations that requires multiple REEs.

- **The contract is only based on a fixed interest rate.** In an automotive loan contract there is no particular structure of delay fees or renegotiation procedure, which conversely may differentiate across credit card contracts.

- **We can control for the duration and amount of the loan.** In an automotive loan contract, once the amount of the loan and the interest rate is fixed, monthly payments will follow according to a pre-determined schedule. By contrast, with a credit card loan the amount of the loan depends on the current propensity to consume, and the debt can in principle be indefinitely rolled-over.

- **We can control for the collateral.** Automotive loan contracts are secured loans; the collateral is typically the car which originated the debt. Credit cards are typically unsecured credit.

- **We can control for the wealth of customers.** The company issuing the automotive loan is typically the same company which is selling the car. Thus, the company is an indicator of the wealth of the customer (i.e. the one who buys a BMW is typically richer than the one who buys a Honda), which is simply not the case with credit card companies (almost everyone can have a Visa).

[24] Notice that the evidence on liquidity effects of the TALF at the single security level have proven very small. On this subject see, for example, Ashcraft et al. (2011), Ashcraft et al. (2012) and Campbell et al. (2011).

Taking advantage of all these useful features comes at the mild cost of stretching the interpretation of our simple payoff structure a little. In the case of the automotive market, a project must be interpreted as a car, so that the project return is a flow of utility given by possession of a car. The fixed cost k meanwhile shall be interpreted as the effort (in terms of portfolio management) needed to avoid a stochastic liquidity shock which, when it hits, forces the agent to miss her payment and, as a consequence of the delinquency, to lose the car. In the end, this interpretation is not crucial. Our payoff structure aims to simply reproduce a demand for credit whose quality (i.e. probability of repayment) increases as the agreed interest rate decreases.

Dataset on Automotive AAA-rated ABS

We collected data on Asset Backed Securities (ABS) in the US automotive sector for 9 different issuers in the automotive sector who appear in the balance sheet of the New York Fed as being accepted as part of the Term Asset-Backed Securities Loan Facility (TALF) program starting in March 2009. In particular, we collected all the available free, online information on Trusts issued from 2007 to 2012, a time span which includes the introduction of TALF[25].

Company (i) →	**BMW**	**Carmax**	**Ford**	**Harley**	**Honda**	**Hyundai**	**Nissan Lease**	**Nissan Owner**	**World Omni**
Year of issuance									
2007	2007-1	2007-1 2007-2 2007-3	2007-A 2007-B	2007-1 2007-2 2007-3	2007-1 2007-2 2007-3	2007-A	2007-A	2007-A 2007-B	2007-A 2007-B
2008		2008-1 2008-A 2008-2	2008-B 2008-B 2008-C	2008-1	2008-1 2008-2	2008-A	2008-A	2008-A 2008-B 2008-C	2008-A 2008-B
2009	**2009-1**	**2009-1** **2009-A** 2009-2	**2009-A** **2009-B** **2009-C** **2009-D** 2009-E	**2009-1** **2009-2** 2009-3 2009-4	**2009-2** **2009-3**	**2009-A**	**2009-A** 2009-B	2009-1 **2009-A**	**2009-A**
2010	2010-1	2010-1 2010-2 2010-3	2010-A 2010-B	2010-1	2010-1 2010-2 2010-3	2010-A 2010-B	2010-A 2010-B	2010-A	2010-A
2011	2011-1	2011-1 2011-2 2011-3	2011-A 2011-B	2011-1 2011-2	2011-1 2011-2	2011-A 2011-B 2011-C	2011-A 2011-B	2011-A 2011-B	2011-A 2011-B
2012	2012-1	2012-1 2012-2 2012-3 2012-3	2012-A 2012-B 2012-C 2012-D	2012-1		2012-A 2012-B 2012-C	2012-A 2012-B	2012-A 2012-B	2012-A 2012-B

Table 1: List of tranches for every issuing company (in **bold** the Trusts' eligible collateral under the Federal Reserve Bank's Term Asset-Backed Securities Loan Facility (TALF)).

Table 1 reports the tranches sorted by issuer for which we have found information. All the issuing entities listed above have benefited from the TALF programme imple-

[25]Every year each of these companies delivers into the market a variable number of Trusts (or tranches). For instance, World Omni in 2008 extended loans in two tranches (2008-A, 2008-B), while the same company extended only one tranche in 2009 (2009-A).

mented by the Federal Reserve (those reported in **bold** in Table 1). The number of tranches that have been eligible varies by issuer. The program started in March 2009; however, the loans covered by TALF have been extended by each issuer at different points in time within the year 2009.[26] The sum of the amounts of the loans mentioned above represents around 46,5% of all ABS-Auto covered by TALF.

The dataset[27] includes information on the following three dimensions:[28]

1. Principal amounts in US dollars. For each of the trust we report the total value of the the credit pool gathered by the asset. Moreover, we have the breakdown for different "Classes" (or Asset Backed Notes) of riskiness, going from the more secure A1, to the riskiest, C. Only the Asset Backed Notes A1, A2, A3 and A4 are the ones classified as AAA by rating agencies (i.e. they are above the minimal level of FICO points credit scores to get the AAA label), hence, the ABS itself to be rated AAA must be almost entirely (but not exclusively) composed by A-rated Asset Backed Notes. The evolution of the total principal amounts in our sample is plotted in figure 8 where a different solid line denotes a different A-rated Asset Backed Notes. Note the collapse of issuance at the end of 2008 and the following recovery in 2009 during the TALF period. Contrast this with the course of the dashed green line, which denotes the total value (y-axis on the left) of minimal risk loan issued by US banks in the same period (source: ST. Louis FRED dataset). The contrast highlights the fact that the recovery in the automotive market during the TALF intervention coincides with the deepest depression of the safest credit market in the US economy.

2. Interest Rates. Each tranche for each company is characterized by an average fixed interest rate for each category where the underlying pool of credit has been signed.[29] The evolution of the weighted average of the interest rate spreads – i.e. interest rate minus 1-month Libor – fixed at the time of the issuance is plotted in figure 9. A different solid line denotes a different A-rated Asset Backed Notes. Note the sharp increase of interest rates at the end of 2008 and the following decrease in 2009 during the TALF period. Contrast this with the evolution of the dotted green dashed, which denotes the interest rate on minimal risk loan issued by US banks in the same period (source: ST. Louis FRED dataset). From the comparison we note that the decrease of interest rates in the automotive market during the TALF intervention is in stark contrast with a permanent increase in interest rates in the safest credit

[26]For instance, for BMW Vehicle Lease Trust 2009-1 the prospectus was made in May 2009, while the correspondent prospectus for Hyundai Auto Receivables Trust 2009 A is September 2009.

[27]The data have been collected one piece of information at a time from prospectuses publicly available online. The major source utilized is *https://www.bamsec.com/companies/6189/208* where the majority of observations are available. The other sources are the issuers' websites which sometimes contain Trust prospectuses. Official TALF transaction data are available at: http://www.federalreserve.gov/newsevents/reform_talf.htm#data

[28]Further details on the composition of the dataset, the sources and the procedure through which the data were collected are presented in Appendix B.1.

[29]Few Trusts included a fraction of credit subject to variable interest rates. See Appendix B.1 for an explanation on how we treat these cases.

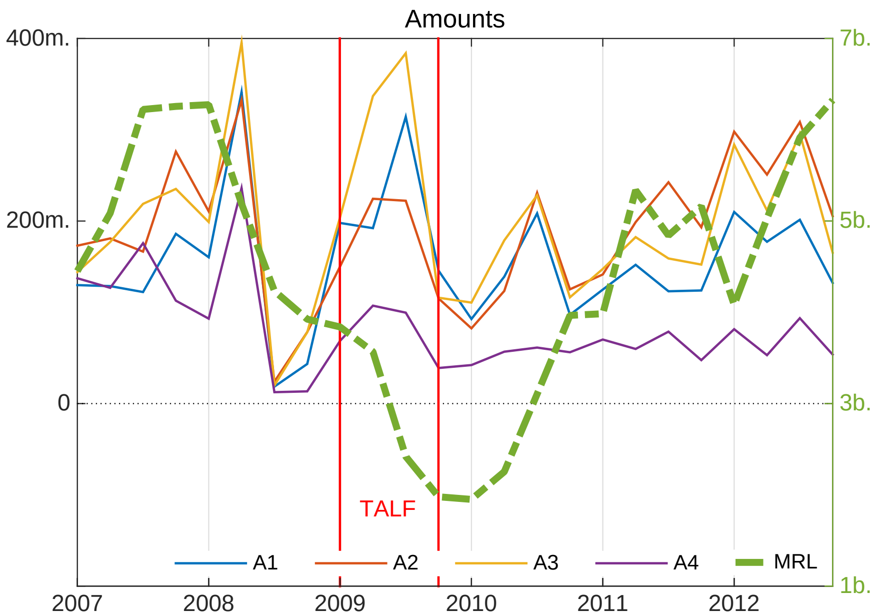

Figure 8: Total quarterly principal amounts issued in our sample for different categories of riskiness; the dotted line denotes the total amount of minimal risk loans agreed during the same period by US banks (3-quarter rolling window; scale on the right axis).

market in the US economy at the beginning of 2009.

3. Losses with respect to the original pool balance. On the 15th day of each month following the date of issuance, the tranche yields the payment received from the pool of contractors of the originating loans. This amount constitutes the coupon of the tranche.[30] Thus, the investor in the ABS bears the default risk on the underlying loan contracts. For each tranche, we collected the series of cumulative losses on this receivables as a percentage of the original pool balance, which is published ex-post by the company issuing the ABS. For this series, we do not have the different breakdown across Asset Backed Notes.

For each tranche, the first difference of these series gives the per-month flow of losses. In figure 10, each point represents the average per month loss relative to a specific tranche identified by a company and a time of issuance (on the x-axis). Note that the TALF period coincides with a drastic drop in average losses for each company. After TALF, losses never again reached the pre-crisis level. The figure also plots, with a dotted green line, the evolution of credit losses reported by all US banks in the same period (source: FRED st. Louis Fed). One can notice that while losses diminished in this market, US banks were experiencing a rapid increase in delinquencies.

The comparison of the automotive market in our sample with the evolution of macro benchmarks - such as the ones represented by dotted lines in each picture - is suggestive of the specific effect of the introduction of the TALF in the ABS markets. At a first glance, we can distinguish between two periods: a pre-TALF period where interest rate differentials increase, volumes suddenly fall and losses are high, and a post-TALF where interest rates fall and stay low, volumes recover and losses decrease. This evolution is consistent with our interpretation that TALF was effective in providing the opportunity to learn that lower interest rates were associated with lower, rather than higher, losses: a conterfactual never previously observed in that market!

In what follows, we are going to elucidate this statement by means of an econometric analysis that will allow us to distinguish between cyclical and market components of losses.

4.2 Econometric analysis

We run two econometric exercises in order to distinguish between local and global knowledge. By global knowledge we mean the best available knowledge when using all the information in our dataset, accounting for all possible non-linearities present in the data; this captures the objective probability distribution ϕ in our theory. By local knowledge we mean the best knowledge that firms could had at the time of the introduction of the TALF, compared with what they learned after the introduction

[30] Each Trust provides for about 3 or 4 years of payments.

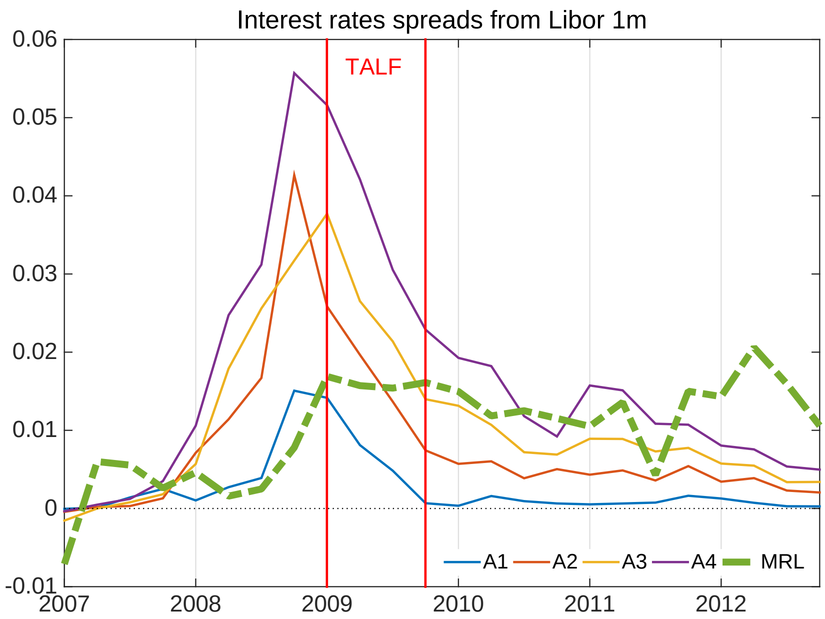

Figure 9: Quarterly weighted average (each company is weighted by its relative issued amount) of interest rate differentials from one-month Libor for different categories of riskiness; the dotted line denotes the interest rate differential from the one-month Libor on minimal risk loans agreed during the same period by US banks.

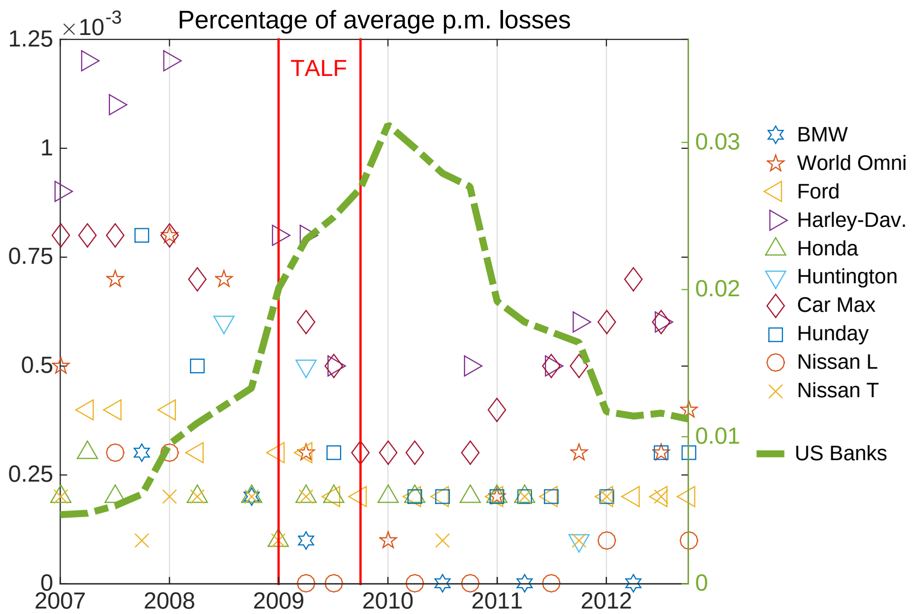

Figure 10: Average monthly loss for each tranche in the sample plotted in its quarter of issuance; the dotted line denotes losses experienced by US banks in the same period by US banks (scale on the right axis).

of the TALF, considering pre- and post-TALF as two isolated regimes and neglecting non-linearities as in a first order approximation; this captures the subjective probability distribution β in our theory, around a neighborhood of the equilibrium. We show that i) the outcome produced by the TALF contradicts what could have been predicted extrapolating from all the information available before TALF, and ii) what companies could learn from the two partial subsamples is consistent with what can be learned using all the information ex-post available in this market.

Assessing local knowledge

We run two regressions on two different subsamples of our dataset, with a similar number of observations. The first sample - Sample I - consists of all the data available before 25 March 2009, which is the date of implementation of TALF. The second, Sample II, consists of all the data relative to tranches issued after 25 March 2009 for the following two years, i.e. until 1 April 2011.

On each sample we run the following linear regressions:

$$\begin{aligned} Y_{i,t,T} = \beta_0 + \beta_1 X_{i,T} + \beta_2 Val_{i,T} + \beta_3 Lib_T + S_i + \\ + \beta_4 Lib_t + \beta_5 u_t + \beta_6 Inf_t + \beta_7 Gdp_t + \beta_8 Vix_t + \epsilon_{i,t,T} \end{aligned}$$

where $Y_{i,t,T}$ denotes the first differences in monthly cumulative losses (with respect to initial pool balance) occurring at time t relative to the tranche issued by company i at time T; $X_{i,T}$ stands for the differential of the average interest rate relative to the tranche (i, T) with the correspondent one-month Libor value at time T; $Val_{i,T}$ is the amount issued, which is relative to the tranche (i, T), valued in current US dollars. S_i are company fixed-effects that control for all the time-invariant unobserved company characteristics. Finally, a set of covariates that control for the business cycle are included: u_t is the US monthly unemployment rate; Vix_t is the monthly VIX index; Lib_t is the one-month Libor at time t; Lib_T is the one-month Libor at the time of the issuance of the relative tranche T; Inf_t is the monthly US inflation rate; Gdp_t is the monthly US national GDP growth rate.

The regression aims at capturing the linear relation between interest spreads, which is a choice variable of the financing companies, and resulting losses, controlling for a number of tranche-specific factors, and business-cycle variables. This specification does not capture eventual non-linearities in our micro-data or in business-cycle series, as if we were looking at local information produced by first-order perturbations around an equilibrium.[31]

Sample I provides information on the evolution of losses that one could have

[31] Note that the truncation of the samples reduces the eventual misspecification. In fact, restricting the estimation range to values closer to the cutoff point is the basis of the local linear regression approach proposed by Hahn et al. (2001) which provides a reliable solution for the presence of non-linearities of the model.

expected as a consequence of lower interest rates at the time of the introduction of the TALF. As Table 2 shows, the estimated coefficient is significant and negative, i.e. lower interest rates were expected to generate higher losses. This finding would explain the tendency of firms to increase interest rates along the diverging paths documented in figure 9. Based on these beliefs, the mechanical decrease in interest rates due to TALF would be expected to generate higher losses for the policy maker.

Sample II is informative about the *actual* impact that the large decrease in interest rates induced by the TALF had on losses. The relevant coefficient is now significant and positive, meaning that lower interest rates were yielding lower, rather than higher, losses. This result explains why there was no need to actually implement the TALF subsidy. This result also explains the tendency of firms to further decrease interest rates even after the TALF expired, as figure 9 illustrates.

In addition, the variables we included to control for the business cycle have all the ex-

Local Linear Regressions (dependent variable $Y_{i,t,T}$)

Variable		Coef	se
Sample I: Pre-TALF issuances, payments until March 2009			
$X_{i,T}$		$\boxed{-0.0237^{**}}$	(0.0075)
$Val_{i,T}$		2.07^{-14}	(2.59^{-14})
Lib_t		-0.0113^{**}	(0.0041)
Lib_T		-0.0043	(0.0057)
u_t		-0.00001	(0.00001)
Inf_t		0.0020	(0.0014)
Gdp_t		-0.0039^{*}	(0.0020)
Vix_t		0.00001^{***}	(2.59^{-06})
R^2	0.5445		
Obs.	536		
Sample II: Post-TALF issuances, payments until April 2011			
$X_{i,T}$		$\boxed{0.0200^{**}}$	(0.0072)
$Val_{i,T}$		-1.11^{-14}	(4.25^{-14})
Lib_t		-0.0520	(0.0441)
Lib_T		-0.0100^{***}	(0.0029)
u_t		0.0001^{***}	(0.00004)
Inf_t		-0.0010	(0.056)
Gdp_t		0.014	(0.0033)
Vix_t		-0.00001^{**}	(5.48^{-06})
R^2	0.5378		
Obs.	589		

Standard errors clustered by issuing company. The model includes a constant and issuing company fixed effects.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 2: Effect of interest rates on cumulative losses controlling for business cycle variables.

pected signs when significant. In particular, note that the policy variable Libor always impacts on losses with a negative sign, in line with several studies that identified the risky channel of monetary policy. In Sample I, a decrease in the policy rate increases losses on simultaneous payments. While in Sample II, this effect vanishes, although the Libor component of the tranche-specific interest rate now exhibits a statistically significant negative coefficient. In fact, in Sample II Libor does not change much, as it is constrained by the zero lower bound; unemployment, on the other hand becomes significant, as if it was a proxy for a fictitious shadow policy rate.

Assessing global knowledge

Our second econometric exercise is designed to capture the point of view of an external observer that wants to ex-post assess how the introduction of the TALF affected the impact of the interest spread on the losses. We still run a linear regression using the whole dataset, but now we introduce time-fixed effects, instead of business-cycle series, in order to capture *any* potential non-linearity in time affecting all companies and all tranches. Our specification is the following:

$$Y_{i,t,T} = \beta_0 + \beta_1 D + \beta_2 X_{i,T} + \beta_3 D X_{i,T} + \beta_4 Val_{i,T} + S_i + S_t + S_p + \epsilon_{i,t,T},$$

where we introduce new variables: D, S_t and S_p. D denotes a dummy which is 1 when the payment belongs to a tranche issued during or after the TALF period, and 0 otherwise. Thus, β_3 measures the differential effect of spreads on losses that the introduction of the TALF generated in the newly issued trust. S_t introduces a fixed effect for each date, in such a way as to capture all common factors acting on the same date; among them there are the business-cycle effects that we included before. Finally, S_p includes a fixed effect for the number of the payment which is intended to control for a non-linear deterministic trend that monthly losses can have when dependent on the number of the payment (e.g. when on average the fourth payment yields more losses than the tenth). Evidence of a strong non-linear trend in losses is provided in appendix B.3.

Global Linear Regressions (dependent variable $Y_{i,t,T}$)

Variable		Coef	se
D		-0.0003^{**}	(0.0001)
$X_{i,T}$		-0.0042^{***}	(0.001)
$D * X_{i,T}$		0.0108^{***}	(0.003)
$Val_{i,T}$		2.19^{-14}	(3.06^{-14})
R^2	0.6560		
Obs.	4169		

Standard errors clustered by issuing company. The model includes a constant, issuing company fixed effects, time fixed effect and payment number fixed effects.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 3: Effect of interest rates on cumulative losses controlling for time-fixed effects.

The results in table 3 confirm the findings of the local linear regressions. The impact of the spread on the losses - namely $X_{i,T}$ - is negative and statistically significant. Nevertheless, the differential effect of the same conditional on the TALF being implemented is positive and statistically significant. Moreover, the latter is larger than the former in absolute terms, and, therefore, the overall effect of spread on losses is positive during and after the introduction of the TALF. This finding confirms that what companies could learn from partial subsamples is indeed what can be estimated using all the information ex-post available in this market.

5 Conclusions

This paper presents a new approach to monetary policy in situations of high economic uncertainty, where private agents and policy makers may misperceive – and possibly underestimate – the actual strength of the economy. By developing and applying the concept of Self-Confirming Equilibrium to a competitive financial market we can characterize a, previously non-captured, form of credit crisis and, more importantly, we show that *Credit Easing* can be the optimal policy response, breaking the credit freeze. While we present a new theory, the paper also emphasizes that the FRB TALF experience in 2009 can be seen as a frontrunner example, which we empirically investigate in order to validate our theory.

A Appendix: Proofs

A.1 Proposition 1

Proof. To find $\hat{R}_s$ and $\hat{R}_r$ we just apply (17) with (1) and (3). Hence, $\hat{R}_s$ and $\hat{R}_r$ result after imposing incentive-compatibility and participation constraints and noting that the two interiors solve well-defined convex problems (so the closer to the interior the higher the payoff). Note that, at the risky equilibrium, lenders' participation constraint $\alpha R_r^* - \delta \geqslant 0$ is always satisfied whenever borrowers' participation constraint $y - R_r^* \geqslant 0$ is too: in fact $y \geqslant R_r^*$ implies $y \geqslant \delta/\alpha$ which in turn yields $R_r^* \geqslant \delta/\alpha$. ∎

A.2 Proposition 2

Proof. The two values $\underline{\alpha}(k)$ and $\bar{\alpha}(k)$ correspond respectively to $\bar{R} = \hat{R}_s$ and $\bar{R} = \delta$.

For $\alpha < \underline{\alpha}(k)$ we have

$$\mu(R_r^*) = \pi^b(R_r^*; \alpha, \omega)^{\frac{\gamma}{1-\gamma}} \pi^l(R_r^*; \alpha, \omega) < \mu(\hat{R}_s) = \pi^b(\hat{R}_s; k, \omega)^{\frac{\gamma}{1-\gamma}} \pi^l(\hat{R}_s; k, \omega),$$

that is,

$$\gamma^{\frac{\gamma}{1-\gamma}}(1-\gamma) \max\left\{(\alpha y - \delta)^{\frac{\gamma}{1-\gamma}}, 0\right\} < \gamma^{\frac{\gamma}{1-\gamma}}(1-\gamma)(y-k-\delta)^{\frac{\gamma}{1-\gamma}},$$

whenever $\bar{R} > 0$ which is true for $\alpha < \underline{\alpha}(k)$. We conclude that whenever $R_s^* = \hat{R}_s$ thenR_s^* is a REE.

For $\alpha > \bar{\alpha}(k)$, contracts that induce the safe adoption require a R lower than the cost of money δ, which violates the participation constraint of the lender; therefore R_r^* will be the unique REE for $\alpha > \bar{\alpha}(k)$.

For $\alpha \in (\underline{\alpha}(k), \bar{\alpha}(k))$ we have that $R_s^* = \bar{R}$. The relevant equation for $R_s^* = \bar{R}$ to be unique REE is

$$\mu(R_r^*) = \pi^b(R_r^*; \alpha, \omega)^{\frac{\gamma}{1-\gamma}} \pi^l(R_r^*; \alpha, \omega) < \mu(\bar{R}|\rho = k) = \pi^b(\bar{R}; k, \omega)^{\frac{\gamma}{1-\gamma}} \pi^l(\bar{R}; k, \omega),$$

that is,

$$\gamma^{\frac{\gamma}{1-\gamma}}(1-\gamma) \max\left\{(\alpha y - \delta)^{\frac{\gamma}{1-\gamma}}, 0\right\} < \left(\left(y - \frac{k}{1-\alpha} - \delta\right)\left(\frac{\alpha k}{1-\alpha}\right)^{\frac{\gamma}{1-\gamma}}\right).$$

On the one hand, $\mu(R_r^*)$ is always monotonically increasing in α. On the other hand, $\mu(\bar{R})$ is always monotonically decreasing in α, given that:

$$\frac{\partial\left(\left(y - \frac{k}{1-\alpha} - \delta\right)\left(\frac{\alpha k}{1-\alpha}\right)^{\frac{\gamma}{1-\gamma}}\right)}{\partial \alpha} = \frac{(1-\alpha)\gamma(y-k-\delta) - 2k\alpha}{\alpha(1-\alpha)^2(1-\gamma)}\left(\frac{\alpha k}{1-\alpha}\right)^{\frac{\gamma}{1-\gamma}} < 0,$$

holds for $\alpha \in (\underline{\alpha}, \bar{\alpha})$.[32] Hence, we can conclude that

$$\left(y - \frac{k}{1-\alpha} - \delta\right)\left(\frac{\alpha k}{1-\alpha}\right)^{\frac{\gamma}{1-\gamma}} = \gamma^{\frac{\gamma}{1-\gamma}}(1-\gamma)\max\left\{(\alpha y - \delta)^{\frac{\gamma}{1-\gamma}}, 0\right\},$$

defines a threshold $\hat{\alpha}(k)$, such that for $\alpha < \hat{\alpha}(k)$ $R_s^* = \bar{R}$ is the unique REE, whereas for $\alpha > \hat{\alpha}(k)$, R_r^* is the unique REE. The hedge case $\alpha = \hat{\alpha}(k)$ is the only one where two REE exist. To conclude, note that

$$\frac{\partial\left(\left(y - \frac{k}{1-\alpha} - \delta\right)\left(\frac{\alpha k}{1-\alpha}\right)^{\frac{\gamma}{1-\gamma}}\right)}{\partial k} = \frac{(1-\alpha)\gamma(y-\delta) - k}{k(1-\alpha)(1-\gamma)}\left(\frac{\alpha k}{1-\alpha}\right)^{\frac{\gamma}{1-\gamma}} < 0$$

holds for $\alpha \in (\underline{\alpha}(k), \bar{\alpha}(k))$.[33] This implies that $\hat{\alpha}(k)$ has to be decreasing in k. ∎

A.3 Proposition 3

Proof. Suppose lenders play R_r^* and that $\alpha < \hat{\alpha}(k)$. By definition of SSCE their expectations about $\rho^*(R_r^*, \omega)$ are correct at the equilibrium, which imply that lenders know α but can have misspecified beliefs about k. In particular, for a $E[k]$ sufficiently high, such that $\hat{\alpha}(E[k])$ is sufficiently low (by proposition A.2), we can have $\alpha > \hat{\alpha}(E[k])$ that implies that lenders wrongly believe that R_r^* is the unique REE (i.e. the global maxima when evaluated by β).

On the other hand, R_s^* cannot be SSCE without being REE. Suppose such an equilibrium exists, then it would arise as a corner solution posted at the frontier $\bar{R}$ because it turns out that interior solutions $\hat{R}_s$ are always REE (i.e. the global maxima when evaluated by ϕ). Nevertheless, by definition of a SSCE, agents would have correct beliefs for marginal deviations from the equilibrium that, at the frontier, are indeed sufficient to induce safe project adoption. Therefore at a SSCE posted along the frontier $\bar{R}$, agents would know the actual α. Hence lenders can correctly forecast $\rho(R, \omega)$ at any R, and so they cannot sustain a safe SSCE that is not a REE. A contradiction arises. ∎

B Appendix: Data

B.1 Data on ABS in the Automotive Industry

The data collected are information on Asset Backed Securities (ABS) in the US automotive sector. The data include information on: Cumulative Losses with respect to the original Pool Balance, Interest Rates, Principal Amounts in US dollars. The information is collected for 9 issuers in the automotive sector, namely: BMW Vehicle Lease

[32] Note that $\alpha k/(1-\alpha(k))$ in increasing in α and $k\underline{\alpha}/(1-\underline{\alpha}) = \gamma(y-k-\delta)$.

[33] Note that $k/(1-\alpha)$ in increasing in α and $k/(1-\underline{\alpha}(k)) = \gamma(y-\delta) + (1-\gamma)k$.

Trust, CarMax Auto Owner Trust, Ford credit Auto Owner Trust, Harley-Davidson Motorcycle Trust, Honda Auto Receivables Owner Trust, Hyundai Auto Receivables Trust, Nissan Lease Trust, Nissan Auto Receivables Owner Trust, World Omni Auto Receivables Trust.

Every year each of these companies delivers onto the market a variable number of Trusts (or tranches). For instance, World Omni in 2008 extended loans in two tranches (2008-A, 2008-B), while the same company extended only one tranche in 2009 (2009-A). As far as our analysis is concerned, we collected all the free available online information on Trusts issued from 2007 till 2012, a time span which includes when Term Asset-Backed Securities Loan Facility (TALF) was introduced. Table 1 reports the tranches sorted by issuer for which we've found information. Each of these Trusts issued loans of different "Class" (or Asset Backed Notes): A1, A2, A3, A4, B and C. Obviously, the Principal Amount of these loans differ by Class, and each Class is also characterized by a different degree of risk (interest rate). It goes from the more secure loan with the lowest interest rate (A1) progressively to the riskier categories (A2, A3 and so on). The Trust will pay interest and principal on the notes on the 15th day of each month (or the next business day).

All the issuing entities listed in **bold** in Table 1 was eligible for the TALF program. The number of tranches that were eligible varies by issuer. The program started in March 2009; however, the loans covered by TALF have been extended by each issuer at different points in time within year 2009. The tranches covered by TALF programme that are included in the database are sufficiently representative of the whole sample of Asset Backed Securities covered by TALF in the US automotive sector, since the sum of the loan amounts mentioned above represents around 46,5% of all ABS covered by TALF (calculations are our own, reference "TERM ASSET-BACKED SECURITIES LOAN FACILITY DATA" from FED). The data have been collected one piece of information at a time from prospectuses publicly available online. The major source utilized is *https://www.bamsec.com/companies/6189/208* where the majority of observations are available. The other sources are the issuers' websites which sometimes contain the Trusts' prospectuses.

Concerning the controls for the business cycle, the data were collected from several sources: the monthly US Inflation is calculated as $(\mathrm{CPI_t} - \mathrm{CPI_{t-1}})/\mathrm{CPI_{t-1}}$ and the US Consumer Price Index (all items) are taken from OECD (MEI); The US Civilian Unemployment rate not seasonally adjusted comes from the US Bureau of Labor Statistics; the CBOE Volatility Index (VIX) along with the one-month Libor correspondent to the 15th day of each month are from the St. Louis FED data. Lastly, the monthly GDP Index used to calculate the GDP growth rate is from *Monthly GDP Index - Macroeconomic Advisers*.

B.2 Construction of the variables for the Empirical analysis

Cumulative Losses with respect to the original Pool Balance. The cumulative net losses for each issuing entity and for every tranche refer to the total pool which includes all risk classes. Therefore, data on losses are not available at disaggregated class level. The losses are reported monthly and the time span of monthly losses varies depending on the date Trusts are issued and the number of payments expected.

Interest Rates. Interest rates vary within Trusts according to the Class being considered. For some Asset Backed Notes the loans are issued as a combination of fixed and floating components of interest rates. For instance, in the case of Ford credit Auto Owner Trust 2007-A the Class A2 is divided into the ’a’ and ’b’ components, where the ’a’ component extends loans with a fixed interest rate of 5,42% and the ’b’ component has the floating rate of one-month Libor + 0,01%. In those cases we calculate the weighted average of class A2, where the weights are the principal amounts in US dollars for each component and the floating component is substituted by the corresponding FED one-month Libor at the time when the prospectus was made (source: *http://www.fedprimerate.com/libor.htm*). Following this particular example, the weighted interest rate for the A2 Class of Ford credit Auto Owner Trust 2007-A whose prospectus was made in June 2007, equals $((5,42 * 300) + (5,33 * 287.596))/(300 + 287.596)$ where the one-month Libor in June 2007 equals 5,32%.

The dataset contains both the weighted average of interest rates expressed in levels, as well as the differentials with respect to the corresponding one-month Libor at the time when the prospectus was made. The latter is utilized as the variable of interest in our empirical analysis. It is calculated as follows: within each tranche we first obtain the differential of the interest rates of every class with respect to the corresponding one-month Libor at the time when the prospectus was made. Then we calculate the inter-Class global weighted average of these differentials using Principal amounts as weights.

As an example we use World Omni Auto Receivables Trust 2009-A where for the Classes A1,A2,A3 and A4 the calculated interest rate differentials are 1,17%, 2,43%, 2,88% and 4,67%, respectively, while the corresponding principal amounts in US million dollars are 163, 192, 248 and 147, respectively. Table ?? gives an example of the structure of the data and how the information on Principal Amounts and Interest Rates are presented for each tranche in all prospectuses. The resulting weighted average of interest rate differentials for each Trust is $((1,17\% * 163m.) + (2,43\% * 192m.) + (2,88\% * 248m.) + (4,67\% * 147m.))/(163m. + 192m. + 248m. + 147m.)$.

Principal Amounts in US dollars. Principal Amounts vary within Trusts according to the Class being considered. In our empirical exercise, it stands for a control; it is included as the sum of the Amounts within each Trust of all Asset Backed Notes. In the previous example for World Omni Auto Receivables Trust 2009-A, it enters the model as $(163m. + 192m. + 248m. + 147m.) = 750m.$

Asset Backed Notes 2009-A	Class A1 Notes	Class A2 Notes	Class A3 Notes	Class A4 Notes
Principal Amount	163m.	192m.	248m.	147m.
Interest Rate	1.62%	2.88%	3.33%	5.12%
Payment Dates	Monthly	Monthly	Monthly	Monthly
Initial Payment Date	May 15,2009	May 15,2009	May 15,2009	May 15,2009
Final Scheduled Payment Date	April 15,2010	October 17,2011	May 15,2013	May 15,2014

Table 4: World Omni Auto Receivables Trust 2009-A (04-2009; 1m. libor at 0.45)

B.3 Non-linear trend in monthly losses

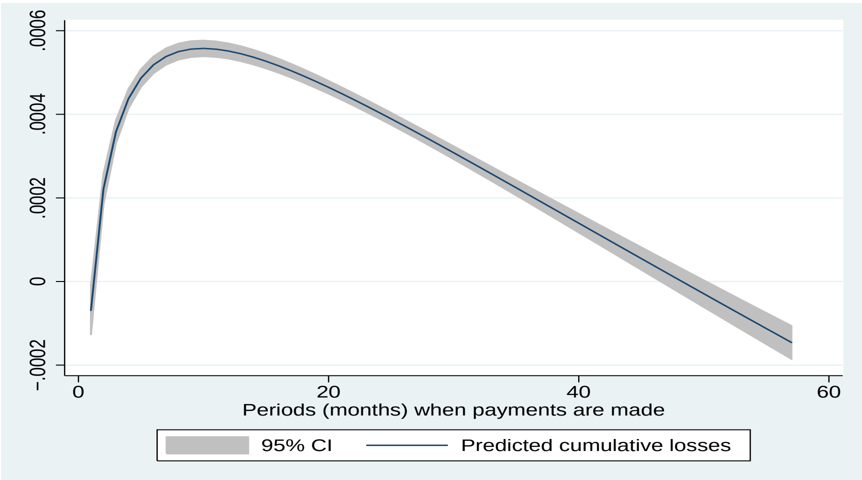

Figure 11: Predicted mean of ABS monthly cumulative losses over time: the y axis has the first differences of cumulative losses with respect to initial pool balance for each tranche $q(t)$, the x axis reports the time span of ABS repayments

There is a common pattern that emerges for each tranche in the evolution of monthly losses over time, which tends to peak around the 15th-20th month and then progressively dies away as time goes by. This means that losses concentrate in the first half of the life of each trend, whereas late losses can be even positive due to the recovery of earlier delinquencies. The pattern is well illustrated in Figure 11 which shows the predicted mean of monthly cumulative losses of ABS over time within a 95% confidence interval. The resulting decreasing trend over time is determined by clients' debt repayments of past instalments (reduction of delinquencies) which contributes to the flattening of the curve.

References

Adam, K. and M. Woodford (2012): "Robustly optimal monetary policy in a micro-founded New Keynesian model," *Journal of Monetary Economics*, 59, 468–487.

Ashcraft, A., N. Garleanu, and L. H. Pedersen (2011): "Two Monetary Tools: Interest Rates and Haircuts," in *NBER Macroeconomics Annual 2010, Volume 25*, National Bureau of Economic Research, Inc, NBER Chapters, 143–180.

Ashcraft, A. B., A. M. Malz, and Z. Pozsar (2012): "The Federal ReserveâĂŹs Term Asset-Backed Securities Loan Facility," *Economic Policy Review*, 29–66.

Battigalli, P., S. Cerreia-Vioglio, F. Maccheroni, and M. Marinacci (2015): "Self-Confirming Equilibrium and Model Uncertainty," *American Economic Review*, 105, 646–77.

Bebchuk, L. A. and I. Goldstein (2011): "Self-fulfilling Credit Market Freezes," *Review of Financial Studies*, 24, 3519–3555.

Campbell, S., D. Covitz, W. Nelson, and K. Pence (2011): "Securitization markets and central banking: An evaluation of the term asset-backed securities loan facility," *Journal of Monetary Economics*, 58, 518–531.

Chari, V., A. Shourideh, and A. Zetlin-Jones (2014): "Reputation and Persistence of Adverse Selection in Secondary Loan Markets," *American Economic Review*, 104, 4027–70.

Correia, I., F. De Fiore, P. Teles, and O. Tristani (2014): "Credit Spreads and Credit Policies," *C.E.P.R. Discussion Papers*.

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

Fudenberg, D. and D. K. Levine (1993): "Self-Confirming Equilibrium," *Econometrica*, 61, 523–45.

——— (1998): *The Theory of Learning in Games*, vol. 1 of *MIT Press Books*, The MIT Press.

Gertler, M. and P. Karadi (2011): "A model of unconventional monetary policy," *Journal of Monetary Economics*, 58, 17–34.

Gorton, G. and G. Ordonez (2014): "Collateral Crises," *American Economic Review*, 104, 343–78.

Guerrieri, V., R. Shimer, and R. Wright (2010): "Adverse Selection in Competitive Search Equilibrium," *Econometrica*, 78, 1823–1862.

Hahn, J., P. Todd, and W. V. D. Klaauw (2001): "Identification and Estimation of Treatment Effects with a Regression-Discontinuity Design," *Econometrica*, **69**, 201–209.

Hansen, L. P. and T. J. Sargent (2014): *Uncertainty within Economic Models*, no. 9028 in World Scientific Books, World Scientific Publishing Co. Pte. Ltd.

Hosios, A. J. (1990): "On the Efficiency of Matching and Related Models of Search and Unemployment," *Review of Economic Studies*, 57, 279–98.

Kim, K., B. Lester, and B. Camargo (2012): "Subsidizing Price Discovery," *Society for Economic Dynamics 2012 Meeting Papers*, 338.

Moen, E. R. (1997): "Competitive Search Equilibrium," *Journal of Political Economy*, 105, 385–411.

Primiceri, G. (2006): "Why Inflation Rose and Fell: Policymakers' Beliefs and US Postwar Stabilization Policy," *Quaterly Journal of Economics*, 121, 867–901.

Sargent, T., N. Williams, and T. Zha (2009): "The Conquest of South American Inflation," *Journal of Political Economy*, 117, 211–256.

Sargent, T. J. (2001): "The Conquest of American Inflation," *Princeton University Press*.

Shi, S. (2006): "Search Theory; Current Perspectives," Working Papers tecipa-273, University of Toronto, Department of Economics.

Tirole, J. (2012): "Overcoming Adverse Selection: How Public Intervention Can Restore Market Functioning," *American Economic Review*, 102, 29–59.