

# Vanishing Signals: Trading Agent Kills Market Information

## EXTENDED ABSTRACT

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### ABSTRACT

We devise a coordination game to explain equilibria in signaling behavior on marketplaces where humans and automatic agents interact. The theoretical outcome of two alternative equilibria—high signaling and low signaling—is confirmed with empirical evidence from a natural experiment using data of a German online social lending marketplace. The experimental condition is the introduction of an optional trading agent to match loan applications to pre-committed offers rather than by a bidding scheme. Signaling behavior is measured by the amount of unverified information provided by market participants in textual descriptions of loan applications, and by the provision of customized pictures to illustrate the credit project. In line with our model, both indicators reveal a substantial drop in signaling after the introduction of the trading agent for loans matched by the agent and conventional loans alike. The results are robust after controlling for third variables, such as changes in the aggregate credit quality and average credit conditions.

### 1. BACKGROUND

The idea of online social lending (also known as peer-to-peer lending) is to provide a marketplace for unsecured personal loans. An electronic platform lists borrowers' loan applications so that individual lenders can review this information and decide in which project they invest. Each lender contributes a small fraction of the financed amount. This distributes the credit risk in loan-specific pools of lenders. As compensation for taking risk, lenders receive interest payments, whereas platforms charge fixed (risk-free) fees [3, 4].

Traditional institutional lending relies on a number of factors including 'hard' and verifiable facts such as requested amount, interest rate, credit rating information and past repayment performance as well as unverifiable 'soft' facts that consider the wider context of a potential transaction [10]. In online social lending, unverifiable information is typically expressed in credit applications that may include

an essay description of the project complemented with a picture and other personal information. The careful evaluation of the application may enable lenders to further differentiate between borrowers and to eventually reduce the risk of loan defaults in the long run. This way, unverified information may reduce the asymmetric information discrepancy between borrowers and lenders [2]. While requesters of funds might *conceal* information that would make them appear less desirable [11], they will also pro-actively *signal* to lenders their credit-worthiness [13]. In credit markets, signaling is more elaborate in comparison to many other financial markets that have stronger forces of data aggregation and price formation [9].

An interesting and so far untackled question arises when automatic trading agents are permitted to the electronic marketplace to improve market efficiency—simultaneously with human traders. As trading agents lack the ability to interpret and base their decision on unverified information, their presence might impact the human market participants willingness to provide soft information, which obviously incurs opportunity costs in terms of effort and—for the case of online social lending—loss of privacy [3].

Coexistence of human traders and trading agents on general marketplaces has previously been studied from the point of view of market efficiency [8, 5], both theoretical and with laboratory experiments [6, 7]. We are not aware of studies focusing on information efficiency and signaling behavior.

### 2. SIGNALING GAME

Table 1 shows the payoff matrix of our proposed signaling game, which is characterized by competition between borrowers with lenders defining the mechanism. The intuition behind it is as follows.

Lenders are uncertain about the credibility of unverified information. Let  $p \in [0, 1]$  be an unobservable true probability of information being credible. Then lenders' risk assessment can be described in two steps. First, an initial assessment of credit quality  $q$  is formed from verified information. Second, it is updated by considering signal  $s$  consisting of unverified information,

$$q' = q + \hat{p} \cdot (\hat{s}_j - \bar{s}), \quad (1)$$

where  $\hat{p}$  is the lenders belief about the credibility of unverified information,  $\hat{s}_j$  is borrower  $j$ 's private assessment of the valence of signal  $s$ , scaled to the unit of  $q$ . Because lenders know that borrowers conceal unfavorable information [11], a rational lender adjusts for this bias by subtracting the average signal valence  $\bar{s} > 0$  on the platform.

Table 1: Borrower  $i$ 's payoff in the signaling game

Borrower $i$	Other borrowers	
	S: signal	N: no signal
	$\hat{p} \lesssim 1$	$\hat{p} \gtrsim 0$
S: signal	$u(s - \bar{s}) - \gamma(s)$	$-\gamma(s)$
N: no signal	$u(\bar{s})$	0

Borrowers decide whether to signal, and if so how, by utility maximization. Signaling imposes direct (short-term) costs, such as the effort to draft a verbose description or to take a picture, and indirect (longer-term) costs in the form of privacy losses [1]. Let  $\gamma(s) > 0$  be a cost function for a given signal  $s$ . Further, let  $u(s)$  be a utility function that maps the marginal lender's credit quality assessment to borrowers' costs and benefits, e.g., in terms of credit conditions. Function  $u$  is monotonically increasing and normalized to the valence of a neutral signal, i. e.,  $u(0) = 0$ . The borrowers' optimization problem is,

$$\max_s \hat{p} \cdot u(s - \bar{s}) - \gamma(s). \quad (2)$$

Only if this term is positive, a borrower decides to signal, i. e., to voluntarily provide unverified information.

Since  $p$  is not observable, lenders can form a belief  $\hat{p}$  of  $p$  by observing the signaling behavior of other loans on the platform. This connects the actions of competing borrowers and leads to a matrix of expected payoffs (Tab. 1). The table is simplified to pure corner strategies.

As  $-\gamma(s) < 0$  and  $u(\bar{s}) < 0$ , and due to symmetry, it is evident that (N, N) is a Nash equilibrium. Another Nash equilibrium exists at (S, S) if  $u(s - \bar{s}) > 0$  and  $u(s - \bar{s}) - \gamma(s) > u(\bar{s})$  from the borrower's point of view. On average, this is very likely to hold as borrowers choose  $s$  according to Eq. (2): each borrower picks the information that she considers to be most helpful in getting favorable credit conditions.

Without detailing the parameter choices and functional forms further, this mechanism shows that signaling in online social lending can be governed by a coordination game. In practice, the game will be less stylized, and will exhibit a tipping point  $p^*$  which separates the two equilibria. In this case, the focal point that decides which equilibrium is reached, is determined by the relative position of the initial estimate  $\hat{p}$  to  $p^*$ . For example, the user interface design for personal profiles of typical online social lending websites and the framing as a human-to-human lending platform may serve as focal points for a high degree of information revelation. In contrast, the introduction of the artificial agent is a strong driver for the reduction of signaling efforts. If the game is initialized at  $\hat{p} > p^*$ , then (S, S) is reached and stabilized until an exogenous shock moves  $\hat{p}$  below  $p^*$ . Our empirical question is whether the dilution of human-matched by machine-matched loans can prompt the vanishing signals market equilibrium.

We are agnostic about deciding which equilibrium yields a higher payoff to the players. The choice between these equilibria is an empirical question [12]. In the following, we interpret empirical data that supports this formalization as a coordination game.

Table 2: Activities on the *Smava.de* marketplace before (Apr–Jun '09) and after (Aug–Oct '09) the introduction of the automatic loan placement

Signaling	Before	After	
		all	old <sup>1)</sup>
Median length of description	456	271	332
Provision of custom picture (%)	25.5	11.3	15.3

<sup>1)</sup>loans using the old take-it-or-leave-it mechanism

### 3. DATA

*Smava.de* is the largest online social lending platform in Germany handling a total of €46 million allocated to about 5900 loans (as of March 2011). Borrowers place loan applications including amount, interest rate, maturity along with verified demographic information (age, occupation, state of residence) and a credit grade. These applications serve as take-it-or-leave-it offers for lenders, who decide if and how much they contribute to financing each pending loan. Loan applications are settled when they are fully funded or after two weeks. Borrowers may complement their loan application by unverified information, such as textual descriptions, motivation statements, or custom pictures. We use this voluntary provision of information as indicator for signaling.

*Smava.de* introduced an automatic loan placement agent in July 2009. This agent assists borrowers in finding the right interest rate such that a loan application would immediately be approved. To do this, the new agent reinterprets the parameterization of the lenders' trading agents—all controlled by the platform—as an order book, and replaces the take-it-or-leave-it mechanism by a matching mechanism.

After July 15th, 2009 both mechanisms coexist. This forms a unique natural experiment to study not only the influence of trading agents on signaling in the part of the market served by the agents, but also on the rest of the loans which continue to use the old mechanism.

We downloaded all  $N = 931$  loan applications listed on *Smava.de* between April and October 2009—excluding July. This sample has been split into contrast groups consisting of 380 loan applications before and 551 applications after the intervention. This constitutes our *independent* variable. We measure our *dependent* variable, signaling, by two proxies. First, we measure the length in characters of all unverified descriptions of a loan application. The second indicator is the binary fact whether or not borrowers illustrate their loan application by uploading custom pictures. Moreover, we collected a number of *control* variables which might interact with the hypothesized relationship.

### 4. MAIN RESULTS

Table 2 shows our main results. Both indicators of signaling, length of description and provision of custom picture, show a substantial decline after the intervention. Interestingly, this is not limited to the immediate loans (where the effect is most pronounced because the agents do not evaluate unverified signals). So the presence of agent-matched deals spills over and changes the signaling conventions of the *entire* platform in the expected direction.

Superficially, these numbers already tell a story. But the evidence for this interpretation can be further solidified. Market expansion, borrower-friendly conditions, and other

**Table 3: Regression results: Effect of presence and use of trading agent on signaling while controlling for credit volume, conditions, and quality (OLS fit)**

Terms	DV: Length of description ( $\log_2$ )		
	Model 1	Model 2	Model 3
Amount [log]	0.2***	0.4***	0.3***
Interest rate [%-pts]	-0.1*	-0.2***	-0.2***
Trading agent present		-1.1***	-0.9***
Trading agent used			-0.5**
Category fixed effects	yes	yes	yes
Credit grade fixed eff.	yes	yes	yes
Adjusted $R^2$ [%]	3.7	13.2	14.0

Sig. levels: \*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$ ;  $N = 931$

effects could interact with each other and lead to spurious results in the aggregated numbers. To isolate the effect of the introduction of a trading agent on signaling from other shifts in the market conditions, a series of multivariate regression models has been estimated. Table 3 reports the estimated coefficients for a stepwise inclusion of terms along with statistical significance tests. The default Model 1 identifies a highly significant positive correlation between the length of description and the amount (both in logs): borrowers who ask for more money are willing to explain their project better. We also find a significant negative correlation between interest rate and length of description suggesting that borrowers who are less verbose are penalized *ceteris paribus* with (slightly) worse credit conditions. All predictors in Model 1 explain less than 4% of the variance of the dependent variable. This is because the hidden heterogeneity—the regime change—is not reflected in the specification. Models 2 and 3 include a term for the presence of the trading agent, which adds another 10%-pts of explained variance. The coefficient is negative—indicating vanishing signals—and highly significant. This supports our hypothesis with strong evidence on the micro-level and after controlling for third variables. The effect of the intervention can be further decomposed on the individual loan level to isolate contributions from the mere presence of a trading agent and the fact that the trading agent was actually used to settle a particular loan. This is realized in Model 3. Interestingly, the platform-wide effect is responsible for the lion’s share in the decline of signaling whereas the actual use of the trading agent is of subordinate importance. We interpret this as support for a switch in the equilibrium situation stimulated by the option to use the new mechanism. The second indicator of signaling intensity is the provision of a custom picture. This is a binary indicator, and we use logistic regression analysis to regress the predictors of Tab. 3 on the log odds ratio for the provision of a custom picture. The resulting coefficients, not reported in this abstract, support the same conclusion, although slightly less pronounced.

As to the limitations, recall that natural experiments with a single intervention date suffer from the difficulty of excluding unobserved third variables as causes. Therefore they do not permit causal inference. Although, we controlled for observable factors and linear time trends, we might have missed non-linear dynamics of growth or overlapping interventions. Likewise, the fact that vanishing signals have been

observed as predicted by our formal signaling game model does not imply that the model is true.

We intentionally avoid conjectures about efficiency or welfare aspects of signaling regimes. Reliable empirical statements on market efficiency and long-term costs or benefits of signaling in this marketplace depend of the availability of actual default rates. These cannot be observed before the 3–5 year maturity of the outstanding loans has been reached.

## 5. SUMMARY

To the best of our knowledge, this work is the first attempt to study the effect of automatic trading on signaling behavior in marketplaces where humans and computers interact. We have devised a stylized model to explain signaling of unverified information as a coordination game with two equilibria for high, and respectively low signaling. A natural experiment in the context of online social lending, an information-rich market, enabled us to test our model empirically and study the effects of the introduction of an optional trading agent on signaling equilibria.

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