Credibility Markets for Shock Risk Analysis

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Abstract: A new category of knowledge management systems is proposed which promises to be particularly helpful with regard to shock risks, which (as the current crisis has proved) are otherwise not properly addressed by the risk analysis methods of portfolio management.

1. Introduction

As noted e.g. by [Krugman 2014], global financial crises appear to be increasing in frequency and severity, with one major pattern of such crises being huge international money flows into some markets, which suddenly stop, followed by intense economic pain. Another scary pattern is that of the crisis of the financial sector of 2008, when too many banks were ill-prepared for weathering the effects of the bursting of the real estate price bubble in the USA. A global crisis has resulted even though the bursting of this bubble certainly should not have been a surprise. Clearly, the financial system needs to be made more robust, since it might be tested by much stronger shocks in the future. This observation raises some obvious questions:

- Could these crises have been prevented, and if so, how?
- Will there be further crises of similar (or even greater) magnitude?
- Is it possible for individual banks to take measures that would greatly reduce the bank's vulnerability to such crises?

These questions are closely related: If many banks strongly reduce their vulnerability individually, these actions have the aggregate effect of making the financial system on the whole more resistant to crises. The cause for this aggregate effect of crisis preparedness is that in any financial crisis, the severeness of the crisis is amplified by each additional case of a bank with severe problems.

Nevertheless, proposals which are aimed at preventing or reducing financial crises through this mechanism are likely to fail if implementing the proposal has no immediate business benefits: Otherwise, as long as it is believed that a government bailout is the worst-case scenario, each individual bank has a strong incentive to avoid the costs of implementing the proposal. In order to achieve the desired results, strategies for increasing the robustness of banks against crises must therefore also offer significant business benefits in the absence of any acute crisis.[1]

The present paper proposes "credibility markets" as a method for improving risk analysis in a way which reduces vulnerability to crises while also achieving immediate business benefits. Such a "credibility market" is a knowledge management system that is designed to help an organization develop an accurate picture of risks which are otherwise difficult to estimate quantitatively. The question whether the organization is prepared adequately is also subject to discussion within the "credibility market" system. The knowledge that is accumulated in this system empowers the firm which operates it to not only ensure its own preparedness, but also to credibly market itself as being well-prepared. The key point here is that the claim of being well-prepared will not be a mere unverifiable assertion, but there will be a valid argument (with specific quantitative bounds) in

1 This argument is based on the assumption that in good approximation, the actions of banks are chosen rationally from the set of potential actions that the bank's decision-makers are aware of.

support of the claim. Since the customers of banks have a strong desire to choose a bank with good robustness against crises, this provides an immediate business benefit of successful "credibility market" systems: Banks which have a successful "credibility market" system will have a significant competitive advantage over competitors which don't have such a system.

This "credibility markets" approach to shock risk analysis has the important properties that it can be integrated smoothly into the methods of modern portfolio management, and that it can be expected to achieve stabilization of the financial system without reliance on government regulation.

The present paper is organized as follows: Section 2 proposes definitions for the notion of "credibility markets" and for key terms which are needed for describing this idea. Section 3 explains which risks of shocks are intractable by statistical modeling. The following section 4 explains credibility markets in more detail by discussing how they can help avoid the kind of errors in risk analysis which led to the financial crisis of 2008. The relevance of Bayesian inference and other generalized logics like Dempster-Shafer theory is discussed in section 5. Then section 6 explains how the knowledge which is accumulated in a credibility market can be used in the context of portfolio management. Section 7 provides a more in-depth discussion showing how these "credibility markets" are markets. Section 8 argues that it is possible to implement credibility markets quickly, using only existing general-purpose computer software. The expectation of the important side benefit of credibility markets in the area of stabilization of the financial system is discussed in section 9. Sections 10 and 11 are brief remarks about the strategy for broadening the adoption of credibility markets beyond the early adopters: The development of special-purpose supporting computer software and standardization of credibility markets are important in this context. Finally, there is a brief concluding statement at the end (section 12).

2. Definitions

This section proposes a definition for the notion of "credibility markets" and of several other notions which are important for formulating and discussing this idea. The definition has been written to emphasize the workflow aspect which is inherent in all business activities including risk analysis. The motivation for this is the importance of using appropriate procedures and incentives for causing all important information to be taken appropriately in consideration in risk models: Otherwise, working with those risk models is merely "garbage in, garbage out", which has been admitted to be a widespread problem that contributed to the financial crisis of 2008, see [Thibodeau 2008]. (The justification for referring to "credibility markets" as a kind of markets is deferred to section 7.)

Definition 1 (from [Ackoff 1981], where this is given as definition for "system" rather than for "strongly interdependent system")**:** A ***strongly interdependent system*** is a set of two or more elements that satisfies the following three conditions

- The behavior of each element has an effect on the behavior of the whole.
- The behavior of the elements and their effect on the whole are interdependent.
- However subgroups of the elements are formed, all have an effect on the behavior of the whole, but none has an independent effect on it.

Definition 2 (from [Schäl 1996])**:** A ***workflow*** is a unit of work generating products or services which are related to, or result in, customer satisfaction. Each workflow has a main customer, who is served by a supplier, or a co-operative network as being a chain of customers and suppliers, working towards the satisfaction of the main customer.

Definition 3**:** A ***KMS*** **(*knowledge management system*)** a set of elements which includes guidelines for human action, and which in addition may comprise software for general-purpose computers and/or special-purpose IT systems, where all the elements are intended to be used together for the purpose of assisting in workflows which involve formulating and retrieving knowledge.

Definition 4**:** A risk is called a ***shock risk*** if it refers to a rare event which has the property that if it occurs, its amplitude will be large because there is a positive-feedback (i. e. “vicious circle”) mechanism which causes the event's amplitude to increase from a small value to a large value.

In the economics literature, ***shocks*** in this sense are typically described as transitions of some subsystem of the economy from some stable equilibrium to another. Therefore, in the language of equilibria, a shock risk would typically be described as the risk of a transition from a more favorable equilibrium to a less favorable equilibrium. However it is also possible for a shock risk to be a risk of a transition from a stable or semistable equilibrium to what is called a strange attractor in dynamic systems theory, or a risk of transition from a strange attractor to an undesirable stable equilibrium. In addition, even a transition to a more favorable equilibrium could require very painful adjustments so that it needs to be treated as a shock risk.[2] In any case, it is important to define fundamental notions in terms of phenomena which can be observed empirically relatively easily. From this empirical perspective, the above definition is clearly preferable to any definition which is based on considering subsystems of the economy that are dynamic systems with multiple attractors. The benefit is that the decision to consider a possible scenario as a “shock risk” can with this definition be taken independently of any hypotheses of dynamic systems theory.

Definition 5**:** A KMS is said to have the ***internal shock exposure minimization incentives property*** if, when it is applied by a bank, it causes both the bank as a whole and the individual employees of the bank who interact with the KMS to have strong incentives for using the KMS in ways which contribute effectively to minimizing the bank's exposure to shock risks.

Definition 6**:** A KMS is said to have the ***strong shock exposure minimization incentives property*** if it has the internal shock exposure minimization incentives property, and in addition also during times when there is no or resulting crisis, there is a strong business benefit for banks which apply the KMS.

Definition 7**:** A ***credibility market*** is a KMS which has all of the following characteristics:

- The KMS is designed and maintained for a specific purpose of describing a subset of the risks and opportunities inherent in a specific strongly interdependent system, where this description covers all significant shock risks together with the potential effects of these shocks and of measures to reduce vulnerability to these shocks.
- All assertions which are entered into the KMS, the credibility of their underlying assumptions, and the validity of the conclusions which are being drawn are themselves also subject to discussion within the KMS.
- A model of generalized logic (such as Dempster-Shafer theory or one of the models discussed in [Bollow 2014]) is used to assign belief and plausibility scores to the various assertions in the KMS, as well as credibility scores to the contributors to the KMS.
- Contributors are offered an effective incentive or set of incentives for making many contributions of consistently high quality.

2 This might be the case e.g. when a transition occurs from a state of the world in which the USA is the sole economic superpower to a world in which some other region has relatively much greater economic weight than before the crisis. This would be a transition to what is a more desirable equilibrium from the perspective of banks in that region, even though the transition must inevitably be painful.

Conjecture 1 in section 9 asserts that credibility markets have the strong shock exposure minimization incentives property.

The definition of "credibility markets" does not specify whether in the system, all contributions from the same user will *a priori* have the same weight. This might be an appropriate model for a credibility market in which all assertions should be (in the contributor's judgment at least) of a professional level of high reliability. Alternatively, it might be desirable to give contributors the opportunity to specify how much credibility they are willing to risk on any given assertion, similar to how it can be advantageous to express uncertainty in more informal forms of social interaction, see [Tenney et al 2007]. Such a credibility-staking mechanism might be particularly important for assertions which turn out to be critically relevant for some assessment of risks. After all (as pointed out in [Taleb 2008]): "In some situations, you can be extremely wrong and be fine, in others you can be slightly wrong and explode. If you are leveraged, errors blow you up; if you are not, you can enjoy life." It would be plausible to relate the quantitative credibility stake which is required from credibility market contributors before an assertion is accepted (without flagging it as requiring further examination) to the seriousness of the potential consequences for the firm if a risk assessment which is based on that assertion turns out to be wrong.

3. Risks of shocks are important but intractable by statistical modeling

As pointed out e. g. by [Taleb 2008], there are two categories of variables which differ fundamentally with regard to how they can be modeled by random variables. Taleb calls the set of variables with relatively thin-tailed distributions "Mediocristan" and the set of variables with more heavy-tailed distributions "Extremistan", and characterizes them as follows: "In *Mediocristan*, exceptions occur but don't carry large consequences. Add the heaviest person on the planet to a sample of 1000. The total weight would barely change. In *Extremistan*, exceptions can be everything (they will eventually, in time, represent everything). Add Bill Gates to your sample: the wealth will jump by a factor of >100,000. So, in Mediocristan, large deviations occur but they are not consequential—unlike Extremistan."

Closely related to Taleb's categories are the two fundamental mechanisms through which small-scale phenomena can add up to large effects: In one category of phenomena, large amplitudes are primarily the result of the combined effect of variations of several independent variables, which will sometimes coincidentally take extreme values at the same time.[3] In the other category, large amplitudes result from positive-feedback mechanisms in the case of some relatively rare event.[4]

An example of a positive-feedback mechanism which plays a role in financial crises is the following property of markets with speculative prices: Notable price increases and decreases, as well as notable phases of volatility, all tend to have the effect of increasing these trends when more market participants become aware of the trend.

The key difference between "Mediocristan" and "Extremistan" is not whether positive-feedback mechanisms play a role at all, but whether they are so strong that they can cause exceptional events to grow to being orders of magnitude greater than typical events. If that is the case, it will result in a great likelihood of massive underestimation of risks, if the probability and severity of a risk is estimated by observing the more frequent events with smaller amplitudes (as is done implicitly in many risk management models, including in particular the practical applications

3 The so-called *central limit theorem* of mathematical statistics states that the re-averaged sum of a sufficiently large number of identically distributed independent random variables (with finite mean and variance) will approximately be distributed according to the normal distribution, which is therefore the archetypal "thin-tailed" distribution.

4 These two fundamental mechanisms can also occur in combination with each other. This will typically lead to scaling laws and observably heavy-tailed event distributions, like the distributions of price changes which have been observed in many markets with speculative prices, see e. g. [Mandelbrot 1963], [Sornette 2003].

of the theory of modern portfolio management).

This systematic problem of underestimating risks is most severe in the case of a positive-feedback mechanism which is triggered only by a kind of event which is so rare that it has never occurred since the beginning of the observations, but not that rare that it could be expected to never occur at all. Concerning this category of severe risks, no indication of the existence and magnitude of the risk can be expected to be contained in the available data at all. As pointed out in [Taleb 2007, p. xxv], this danger of underestimating severe risks is further increased by a phenomenon which Taleb calls "platonicity": the human tendency to focus on well-defined idealizations of patterns (which Plato called "forms" and effectively deified) so much that "when these ideas and crisp constructs inhabit our minds, we privilege them over less elegant objects, those with messier and less tractable structures." This can easily lead to a belief that an estimation of risks is somehow scientifically valid and reliable, even where such confidence is totally misplaced since the possibility of crises which come about in an unprecedented way has not been considered at all.

This ***platonicity fallacy*** is particularly likely to occur with respect to crises of the global financial system: Hopefully, after a crisis, politicians, regulators and banks will have learned enough from the mistakes that were made so that a repetition of the exact same set of mistakes can be avoided – as long as the mechanism that caused that crisis is remembered and understood to be of a kind that is potentially relevant to the current situation.

Certainly, preventive measures to avoid the risk of a total collapse of the financial system should be taken without allowing each possible type of crisis to happen once!

If the mechanism of a potential systemic collapse is sufficiently well-understood in advance, it may be possible to structure key contracts in the system so that this mode of collapse can be avoided, see for example the theory of bank runs of [Diamond/Dybvig 1983] or the theory of systemic liquidity crises of [Cao/Illing 2008]. Unfortunately, this kind of theory is typically developed only after the problem has occurred at least once. Therefore it would not be wise to assume that now that these theories are available, implementing their recommendations will be sufficient for stabilizing the financial system: Today's world of finance is much more complex than any model which describes just the traditional banking business.

Furthermore, as more detailed knowledge becomes available about the mechanisms which have caused crises in the past, widespread awareness of this information may also have destabilizing effects. The reason for this is that new patters of behavior can result from this new knowledge, which could cause the financial system to become unstable in a new way. Consider for example the observation of [Sornette 2003] that the major stock market crashes of the past have been preceded by observable log-periodicity in price patterns.[5] As soon as a significant proportion of market participants becomes aware of these facts, and acquires the analytical tools to detect this log-periodicity, a severe market crash could result even from a random occurrence of a price pattern which resembles log-periodicity: If sufficiently many market participants consider a crash likely, and they consequently all try to sell off their more risky positions at the same time, the near-inevitable result is that the concerned market crashes and/or becomes illiquid.

One clear example of a type of shock risk which cannot be prevented by measures that are based on economic theories of market mechanisms is shocks which result from unprecedented economic events triggered e. g. by climate change or decreasing production capacity for crude oil. An example of a less certain but more immediate risk is that the great trust which economic agents have in the U.S. Dollar might become unstable (e.g. if due to some news it appears that the U.S. current account deficit can no longer be sustained.) It is certainly a nontrivial problem to identify the full set of plausible potential shock risks that need to be analyzed in view of goals like stabilizing the financial system, or even just organizing the assets of just a single bank so that it

5 Sornette also gives a plausible and detailed model of stock markets which explains these patterns.

would not be affected in an unacceptably severe way by any plausible crisis of the financial system.

The following section provides another perspective on the risk of such critical shocks, and it will discuss how credibility markets can help to model such risks in an appropriate way.

4. How credibility markets avoid the fattened turkey fallacy

The ***fattened turkey fallacy*** is the belief that when it is known that a property has been observed to be true for an increasing number of days, that knowledge alone suffices to have increasing confidence in the hypothesis that the property will also be true the next day. The name which is here assigned to this well-known fallacy is based on the metaphor of e. g. [Taleb 2008] in which a turkey is fed for 1000 days and "every day confirms to its statistical department that the human race cares about its welfare 'with increased statistical significance'". On the 1001st day, the turkey is slaughtered.

The fallacy comes from making the implicit assumption that whether the property holds on any given day can be modeled by independent random variables for each day. In the case of the fattened turkey, this implicit assumption is evidently false because the turkey can be slaughtered only once.

All economic phenomena which fit the pattern of a price bubble, and more generally all phenomena in the economy which cannot continue indefinitely (this includes for example the expectation of continued exponential growth of the economy) are temptations to underestimate the risk of financial shocks by means of some variant of the above-described fallacy.[6]

Credibility markets allow such risk modeling errors to be pointed out in an effective manner (i. e., in a way that will lead to a corresponding correction of risk models and estimations) before the errors result in catastrophic consequences. In addition, the credibility market provides the necessary incentives for causing this to happen, provided that enough people with knowledge of the relevant markets (which the credibility market is supposed to model) participate in the credibility market.

Typically, severe modeling errors can be revealed in several possible ways, including the following types of criticisms which are possible for most severe modeling errors:

- Showing that the model has impossible or implausible long-term consequences, such as e. g. an implication that certain price bubbles cannot burst.
- Describing a particular economic mechanism which is plausible and which would cause the model to be invalid.

Here is an example of how a credibility market would very likely have led to an early discovery of the modeling error which led to the subprime mortgage crisis of 2007: Everyone who was familiar with the market for home mortgages in the USA must have realized that in view of the widespread use of variable rate mortgages, any significant increase of the prime interest rate (on which the variable rate mortgages were keyed) from its extremely low value would result in a dramatic increase in the rate of defaults and foreclosures. However this knowledge was not communicated effectively to the risk analysts who were responsible for the risk models that attempt to describe the corresponding aggregate risks. Credibility markets would have provided the means and the incentives for communication of this essential knowledge. Furthermore, since within each credibility market, the conclusions which result from risk models are also part of the set of

6 Using increasingly sophisticated methods of mathematical statistics does not automatically decrease this risk of delusion. For example, the popular method in quantitative risk management for estimating the tail thickness of risk distributions is based on the Pickands–Balkema–de Haan theorem (see [Pickands 1975], [Balkema / de Haan 1974]) which relies on the assumption that the sequence of values under consideration can be modeled by independent random variables. This assumption is clearly invalid if (just like in the situation with the stuffed turkey) a phenomenon cannot continue indefinitely without leading to some kind of collapse.

assertions which can be criticized, risk analysts would have had a strong incentive to quickly make use of the knowledge about a previously unconsidered risk mechanism, and update their models and conclusions accordingly, in order to minimize their personal risk that neglecting to consider this risk mechanism could hurt their personal credibility ratings in the credibility market.

5. Bayesian inference and Dempster-Shafer theory of belief functions

Probability theory has been called “the logic of science” [Jaynes 2003], and in fact Bayesian inference (which is the most widely known framework for the mathematically rigorous application of probability theory as a form of logic) provides powerful quantitative tools for reasoning in some kinds of situations. Specifically, Bayesian inference requires a strongly-trusted model of the system under consideration that allows to specify a so-called ***prior***, a probability measure which assigns *prior probabilities* to the possible outcomes. For example, the prior probability for each of the results of a standard dice throw is 1/6 for reasons of symmetry. If such a prior is given, the theory of Bayesian inference describes how to calculate *posterior probabilities* from whatever empiric evidence is available, which in the case of a dice throw might be the output of a machine which attempts to determine the result of the dice throw, together with what is known about the machine's error rate.

In the case of shock risks however no reasonable method exists for assigning such prior probabilities. This makes it necessary to base credibility markets on a form of generalized logic which does not require a prior. The most broadly endorsed generalized logic of this kind is the Dempster-Shafer theory of belief functions, for which a nice collection of “classical” papers has been published in [Yager/Liu 2008].

The fundamental idea of the Dempster-Shafer theory of belief functions and related theories of generalized logic is to replace the role of the probabilities with two functions which can be interpreted as providing a lower and an upper bound for the intuitive idea of probability. These two functions, which are called “lower probability” or “belief” and “upper probability” or “plausibility”, respectively, are functions from the power set 2^A to the interval [0,1], where A is the set of possible answers to the question or questions under consideration.[7]

Actually, one of these functions is redundant, since the belief in an assertion and the plausibility of its negation always add up to one. Therefore, in mathematical discussions of these generalized logics, the theory is typically presented as a theory of “belief functions” and the plausibility function is defined in terms of the belief function.

An initial state of total ignorance of not only the specific values of the variables under consideration but also of the probability distributions in appropriate models for these variables as random variables is expressed by a belief function which assigns zero as the belief value for all subsets of A besides A itself, which implies that the plausibility is one for all these subsets: Total ignorance means that *a priori,* nothing is believed and therefore all possibilities are considered plausible. Evidence in favor of some hypotheses results in increasing the corresponding belief function values. Evidence against some hypotheses is evidence in favor of the negation of those hypotheses. It therefore increases belief in the negated hypotheses, which implies a decrease of the plausibility function values for those hypotheses against which evidence has been contributed to the credibility market.

In a credibility market, the various assertions about evidence and about relationships between the assertions (such as the assertion that some economic theory rules out a certain hypothesis, or that a certain risk modeling methodology must be wrong because it implies that it is extremely

7 The set A is assumed to be finite. This is not a restriction for the practical application in credibility markets, because at any given time, only a finite number of assertions will have been proposed in the credibility market.

unlikely for price bubbles to burst) are trusted only with a weight proportional to the credibility rating of the contributor of these assertions. There may be a feature allowing contributors to further modify the weight of their assertions by specifying a "credibility stake", a positive factor less or equal to one, which modifies not only the weight of the assertion in the credibility market but also how the results regarding that assertion will reflect on the contributor's credibility score.

For a more in-depth discussion of mathematical models of credibility see [Bollow 2014].

6. Integration with portfolio management methods

The goal of this section is to justify the claim which was made in the introduction that the "credibility markets" approach to shock risk analysis can be integrated smoothly into the methods of modern portfolio management. For definiteness, this argument is presented in the context of the model of the groundbreaking paper [Markowitz 1952]. The same method applies in the context of the models which are in practical use today in quantitative equity investment management as described in [Chincarini/Kim 2006].

Let (as in [Markowitz 1952]) R_i denote a random variable describing the returns of the *i*'th of the securities under consideration (from which the portfolio can be selected). Furthermore, let S denote a random variable with values in the set {0,1} which will be interpreted as follows: If $S=0,$ no shock occurs, and if $S=1,$ a shock occurs. In this framework, there is no notion of "several independent shocks occurring at the same time". If credibility market analysis shows that the possibility of several independent shock factors affecting the economy at the same time needs to be considered, in order to correctly model possible situations such as for example "a severe hurricane affecting oil facilities occurs shortly after it is realized that already in the absence of wars, hurricanes, etc., the worldwide production capacity for crude oil is no longer sufficient for allowing the populations of the industrial nations to continue with their current lifestyles", that possibility of a "double shock" is to be treated as just one of the possible shocks under consideration.

What needs to be shown is that the results of any method for estimating the expectation values and covariances for the R_i under the assumption that no shocks occur (in mathematical notation $E(R_i|S=0)$ and $Cov(R_i,R_j|S=0)$ respectively) can be combined with credibility market based estimates of the probability of shocks and of these expectation values and covariances under the assumption that a shock occurs, to obtain correct estimates of $E(R_i)$ and $Cov(R_i,R_j)$.

This is however trivial by means of applying the law of iterated expectations

$$E(X)=E(E(X|Y))$$

with $Y=S$ and first with $X=R_i$ and then with $X=(R_i-E(R_i))(R_j-E(R_j))$.

7. Justification for referring to credibility markets as "markets"

The fundamental benefit of markets is that in a market economy, differentiation through pricing between economic goods (which can be substitutes for each other) provides important incentives both to consumers and to providers of these goods:

- An incentive for consumers of goods to use scarce resources efficiently.
- An incentive for producers of goods to meet the actual desires of the consumers.

In the communist, planned economies of Eastern Europe, the experiment has been tried for several decades to run an economy without allowing prices to be at an appropriate level for having this function of providing appropriate incentives to both producers and consumers. Even though these countries tried very hard to economically outperform the capitalistic countries, they failed to even keep up with the "West". Considering this empiric evidence, it is natural to ask the question how "market economy" style incentive mechanisms can be used to direct not only the production and consumption of material goods and services, but also the production and consumption of knowledge. The key feature in the markets for material goods and services is that the market price allows essential information (about how highly different goods are valued relative to each other) to travel from consumers to producers of the goods. One major difficulty in any attempt to apply market mechanisms to knowledge is that although knowledge can be communicated and it has value, the recipients of the knowledge in such a trade will in general not be able to assess how valuable this knowledge will be to them without receiving the knowledge first.

It follows that knowledge cannot be traded for money without the price depending much more on the seller's credibility than on the actual utility of the item of knowledge under consideration. The price which the recipient is willing to pay for some knowledge is therefore not a good indicator of the value of the knowledge. This suggests that for knowledge, the key element in the information flow to the producer (which is provided by an efficient market) is the effect on the knowledge producer's credibility (provided that it is assured that this effect on the credibility is a trustworthy measure of the value of the contributions), which is precisely the incentives effect that credibility markets aim to provide to their contributors. Therefore, what corresponds in the area of knowledge to a market in which physical goods are traded for money is a kind of market in which knowledge contributions are traded for credibility. Hence the name "credibility market".

Of course, there must be some kind of financial or other incentive for achieving a high credibility score. This incentive will normally be provided by the firm which operates the credibility market.

As suggested at the end of section 2, the balancing of the interests between the buyer of a knowledge contribution (typically the firm which operates the credibility market) and the seller of the contribution can plausibly lead to a kind of price. This price is however not in terms of money, but in units of a credibility stake. Credibility market contributors don't receive money through the credibility market, although their employment might be subject to the condition of making significant contributions to the credibility market and maintaining a high credibility score.

8. Practicing credibility markets using existing general-purpose software tools

The basic mechanics of credibility markets are simple enough that no special-purpose software tools are immediately needed for being able to put the principles in practice. Rather, it will be possible to ask potential contributors for contributions of relevant knowledge, compile the results while keeping track of sources, and iterate the process of requesting further comments. After a few iterations it will make sense to start computing belief function values and credibility scores, and it will be useful to automate this task by means of a little program, but it is important to keep things flexible in the initial stages, so that the logical and social dynamics of how new contributions can reference existing assertions in the credibility market is not constrained by assumptions in the user interfaces of software tools which would necessarily be developed without any significant previous experience with credibility markets.

9. Stabilization of the financial system

When the financial system as a whole is considered, key questions to consider include the following:

- Who has the information which is necessary for regulating the system?
- How and where can this information be effectively communicated, without relying on patterns of communication which involve severe moral hazards?

It appears likely that the Conant-Ashby theorem [Conant/Ashby 1970], which asserts that under very general conditions, *every good regulator of a system must be (or contain) a model of that system,* should be applicable to the financial system. Now using the insights of [Brammertz et. al. 2009] it is in fact plausibly possible for a government agency tasked with "regulating" the financial system to fulfill the condition of containing a model of the financial system, at least to the extent of recording all financial contracts where at least one party is above a certain threshold of importance for the financial system, and subject to that government's jurisdiction.

Even when all this data is collected in a centralized location, the challenge of knowing what are the right questions to ask in analyzing it remains daunting; this could legitimately be the topic of a credibility market operated by the regulator.

Alternatively, the information processing work of modeling the financial system in its entirety (which according to the Conant-Ashby theorem cannot be avoided if good regulation is desired) could be conducted in a decentralized manner by the banks themselves.[8] When stability and reliability of the overall financial system is seen as the primary goal, such decentralized modeling could be seen as highly desirable redundancy.

The key question is whether the modeling system has sufficiently strong incentives properties that banks and their individual employees will actually use the modeling system in such a way that the desirable stabilizing effect is achieved.

The following conjectures summarize the hope that this will be the case for credibility markets:

Conjecture 1: C*redibility markets* (see definition 7 in section 2) have the *strong shock exposure minimization incentives property* (see definition 6 in section 2).

Conjecture 2: When it becomes publicly known how a KMS (see definition 3 in section 2) can be operated so that it has the *strong shock exposure minimization incentives property,* that knowledge will be applied with the effect of stabilizing the financial system, in the sense that then no conceivable shock risk would have the effect of leading to a collapse of the basic functions of the banking system.

Any attempt to fully validate the above conjectures by means of theoretical efforts must necessarily remain inconclusive, because we can never be sure that all possible mechanisms of instability have been considered. In particular, a key observation in Minsky's theory of systemic instability (see [Minsky 1975], [Minsky 1986]) is that there will always be innovative financial firms whose innovations have the effect of increasing systemic risks. The strength of the credibility markets approach is that instead of attempting to address this innovative force by means of some kind of rules (which can likely be "innovated around"), credibility markets address the problem of potential destabilization by creating economic incentives for stabilizing action, so that it can be expected that the systemic problems will at least be attacked in real time with the full force of human ingenuity and innovativeness.

Therefore, ultimately, the assertions of these conjectures can only be justified on the basis of

8 As is clear from examples like regional banks or otherwise strongly specialized banks, not every bank can be expected to have knowledge of all markets which need to be modeled in any reasonable model of the financial system in its entirety. However, when banks model the potential shock risks of the markets in which they participate, and publish quantitative bounds on how such shocks could potentially affect them and the financial products that they offer to their business partners, that suffices for allowing their business partners to also determine upper bounds on their exposure to these shock risks. Therefore, in the aggregate, credibility markets can fulfill the requirements of the Conant-Ashby theorem, even if no single credibility market models the entire financial system.

practical experiments in which the attempt to implement these ideas is made, and in which the specific cause-effect relationships of the above conjectures can be verified. It is important to note that these conjectures are in a form which allows to develop specific assertions about the relevant incentives, and to subject these hypotheses to severe empiric testing in the sense of [Mayo 1996]. For these reasons, the promises of credibility markets are, in principle at least, in a reasonable sense empirically verifiable. By contrast, the fattened turkey fallacy (see section 4) and the platonicity fallacy (see section 3) are characterized by trust in stability assumptions which are fundamentally impossible to subject to such severe testing[9], due to the lack of any specific, testable assertions about stabilizing mechanisms (i.e. cause-effect mechanisms which can result in long-term stability even in spite of systemic mechanisms and exogenic shocks that would otherwise result in instability.)

What can be argued theoretically is that the present proposal will not fail due to the typical failure modes of "stupidity of users" and "personal greed of decision-makers": As outlined in the introduction, the incentive for banks to implement a credibility market rests to a large extent on its marketing benefit: The knowledge which is accumulated in the credibility market system empowers the bank to make valid arguments, with specific quantitative bounds, in support of the claim of being well-prepared for weathering the shocks (and potential crises) that customers and potential customers are concerned about. The existing legal requirements for such statements (and legal sanctions for making risk related statements without proper factual basis) give decision-makers a strong incentive to be truthful in reporting the results of credibility market analysis, and to be diligent in ensuring that sufficiently many intelligent people with the required knowledge participate in the credibility market. Finally, credibility markets can be expected to be robust with regard to stupid participants (as long as they are not in the majority) and with regard to occasional stupid assertions from otherwise intelligent participants. This robustness can be expected because of the method of inviting criticism and computing belief and plausibility scores for each assertion, with the contributions of each participant being weighed according to that participant's credibility score.

10. In a second stage: Development and/or adaptation of specific software tools

When the credibility market idea has proven its usefulness, naturally it will appear desirable to eliminate needlessly repetitive error-prone human tasks, so that for most contributions to the credibility market, it will be possible for the contributors to handle the process of making their contributions entirely themselves. This automatization is necessary for allowing credibility markets to scale to support a large number of participants.

11. In a third stage: International standardization

When the idea of credibility markets starts to spread beyond a relatively small community of early adopters who know each other, it will be important to pursue standardization as an international (i. e. ISO/IEC) standard. The reason for this is that the market benefit for banks which apply credibility markets will be reduced if some banks attempt to apply the idea but do so incorrectly. Examples of potential errors in implementing credibility markets include insufficient incentives for stating and defending uncomfortable truths, failing to arrange for sufficiently many contributors with first-hand knowledge of the relevant topic area, or applying generalized logic in a way which is

9 This question whether an assertion can be subjected to severe testing in the sense of [Mayo 1996] can be considered a refinement of the falsifiability criterion [Popper 1959] for distinguishing between science and pseudoscience. Such a refinement is fundamentally important in the present context, since the falsifiability criterion is clearly not helpful for identifying potentially valuable hypotheses about financial system stability: Practically all assertions about this topic are in principle falsifiable, but the falsification event is a crisis which we must try to prevent.

mathematically wrong. With proper standardization, credibility markets can be certified to conform to the standard, so that the trustworthiness of conclusions from the credibility market process can be established. This requires that the certification procedure must be sufficiently strict that any errors in credibility market implementation (which make the results untrustworthy) will be found during the certification process.

The long-term benefit for banks which are pioneers of credibility markets is that they are seen as leaders rather than as followers in the effort to correct the problems which have caused the trust in banks to be damaged so badly. This trust is after all the most important form of capital of a bank.

12. Conclusion

In this paper, an idea has been presented for a new type of knowledge management system which promises to be able to make an important contribution to risk analysis, especially with regard to shock risks which have proven to be important and potentially disastrous for the entire financial sector. The author is currently looking for opportunities to put these ideas into practice, in order to validate and refine them from practical experience.

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