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**Discussion Paper**

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## **Black Swans, Dragon Kings, and Bayesian Risk Management**

*Armin Haas, Mathias Onischka, and Markus Fucik*

### **Abstract**

In the past decades, risk management in the financial community has been dominated by data-intensive statistical methods which rely on short historical time series to estimate future risk. Many observers consider this approach as a contributor to the current financial crisis, as a long period of low volatility gave rise to an illusion of control from the perspectives of both regulators and the regulated. The crucial question is whether there is an alternative. There are voices which claim that there is no reliable way to detect bubbles, and that crashes can be modeled as exogenous ‘black swans’. Others claim that ‘dragon kings’, or crashes which result from endogenous dynamics, can be understood and therefore be predicted, at least in principle. The authors suggest that the concept of ‘Bayesian risk management’ may efficiently mobilize the knowledge, comprehension, and experience of experts in order to understand what happens in financial markets.

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## 1 Introduction

As in the 30s, an enormous and devastating financial and economic crisis is rocking conventional economic wisdom. According to a perspective widely held in the economic community, there is no way to detect speculative bubbles in financial markets. Moreover, it is said that big hits in financial markets, i.e. large scale decreases of asset values that put severe stress on financial institution, are *Black Swans*, a notion coined by Nicholas Taleb (Taleb, 2007), meaning rare events that most people cannot imagine, or refrain from considering, before they happen.

Even before the current crisis hit, these views had been challenged. Didier Sornette, among others, claims that big hits in financial markets, although infrequent, are in no way Black Swans but can be analysed before they happen. This would be due to the fact that they are resulting from endogenous dynamics, which can be understood and therefore be predicted, at least in principle (Sornette, 2009). He coined the notion *Dragon Kings* for endogenously brought about financial crises.

For the practical management of risks, it makes a crucial difference whether one assumes that big hits are Black Swans or Dragon Kings. Basically, this is deeply interwoven with whether one believes in the efficiency of financial markets. If they believe in efficient financial markets, authorities cannot do more than enforce the rule of the law for keeping fraud and misbehaviour in check. By definition, all available information is reflected in the market prices, and scholars or authorities do not have superior knowledge.

We think that there is ample evidence from economic history that the assumption that financial markets are efficient is wrong. We agree with Haldane (2009) who uses the notion of a *Golden Decade* for the time span between October 1998 and June 2007. The U.K., among many other nations, had seen a decade of extraordinary economic stability in historic terms. This decade, however, had given rise of a *control illusion*, the idea that financial actors can control financial risks in a way that makes big hits obsolete, or, to put it mildly, *very unlikely*. We claim that the main responsibility for this disaster myopia can be attributed to the *frequentist weltanschauung* that prevailed – and continues to prevail – in contemporary risk management.

According to the frequentist risk paradigm, it is a reasonable operation to build expectations on the basis of looking back on data series of the past years and to derive respective risk measures (Onischka and Fucik, 2009). To us, this resembles navigating by focussing on a ship's wake. If markets really would be efficient, they would have relied on what we know from economic history and would not have focussed on just some recent years of extraordinary stability. If there had been no alternative to what happened, we would not criticise this approach. There is, however, an alternative paradigm: *Bayesian Risk Management* (BRM).

In this short paper, we want to suggest using Bayesian Risk Management as a concept for managing risks in general, and financial risks in particular. Since we primarily focus on the scope and limits of Bayesian Risk Management as a new approach in dealing with uncertainty, details of its tools and elements will not be issued in this short paper. For such details see Fucik (2010).

## 2 Bayesian Belief Systems

Bayesian Risk Management (BRM) draws on the Bayesian notion of probability. For frequentists, probability is an *objective* measure, independent from any observer. It is attached to the *object* under consideration (e.g. a dice, an electron, a financial asset). For a subjectivist Bayesian, in contrast, probability is a *subjective* measure, indicating the *uncertainty* of an analyst or, even more radically defined, her *willingness to bet*.<sup>1</sup> In contrast to the conventional frequentist perspective, for subjectivist Bayesians probability is not a feature of an object under scrutiny, but of the scrutinizer. Building on this understanding, we have coined the notion of *knowledge-based probabilities*. With this notion, we want to highlight that the judgment of an analyst can reasonably only rest on his understanding of the world in general, and of the subject under consideration in particular. In practice there are no “objective measurement” of risks, since there is no measurement without theory, as physicists tell us. And which theory an analyst adopts is at her discretion, which should be informed by her judgment.

The opinion of an individual about an issue can be described by a set of hypotheses and variables, and the respective probabilities that are attached to them. We denote this set together with the respective probabilities *Bayesian Belief System*. Decision makers first come up with *a priori* probabilities. Then they observe outcomes and use them for *updating* the probabilities, i.e. deriving *a posteriori* probabilities from their *a priori*s and their observations.

## 3 The Three Pillars of BRM

The BRM core concept comes in two varieties, depending on the kind of information a decision maker has access to. *Hardcore BRM* applies when sufficient data are available so that Bayesian updating in the strict mathematical sense can be applied. This is the approach of Bayesian statistics, and of Bayesian decision theory when

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<sup>1</sup> There also is an objectivist Bayesian community that uses the elegance of Bayesian techniques but prefers to stick to an objectivist definition of probability. Rachev et al. (2008), for example, pursues along the objectivist line of Bayesian thinking. For more details cf. Fucik (2010).

inference is made using Bayes' rule, for example in Bayesian influence diagrams and belief networks.

When a decision maker has no sufficient data for performing an updating in the strict mathematical sense, she must resort to a more general, informal way of constructing and updating her belief system. Bayesian updating and learning in *Softcore BRM* means that a decision maker adjusts the probabilities she holds so that the changed probabilities reflect what she has learned from observing the world. Many economists, for example, had to update their beliefs in the possibility of large-scale financial crises, or in the soundness of the risk analyses of rating agencies.

More generally speaking, our notion of Softcore BRM is about identifying, structuring, and quantifying risks based on a risk analyst's understanding of the subject under consideration.

There is no Hardcore BRM without Softcore BRM. Every Bayesian Belief System is set up and chosen by human expertise. Models are just a specific instance of belief systems. Whenever a modeller chooses one model over another he applies his judgment.

Alongside the Softcore and Hardcore varieties, the third pillar of our BRM concept is *Bayesian Due Diligence*. We suggest Bayesian Due Diligence for keeping arbitrariness in check and critically reflect daily management procedures. Bayesian Due Diligence asks not only for including the most recent quantitative data concerning a subject under consideration, but also for an up-to-date qualitative understanding of the system the decision maker operates in.

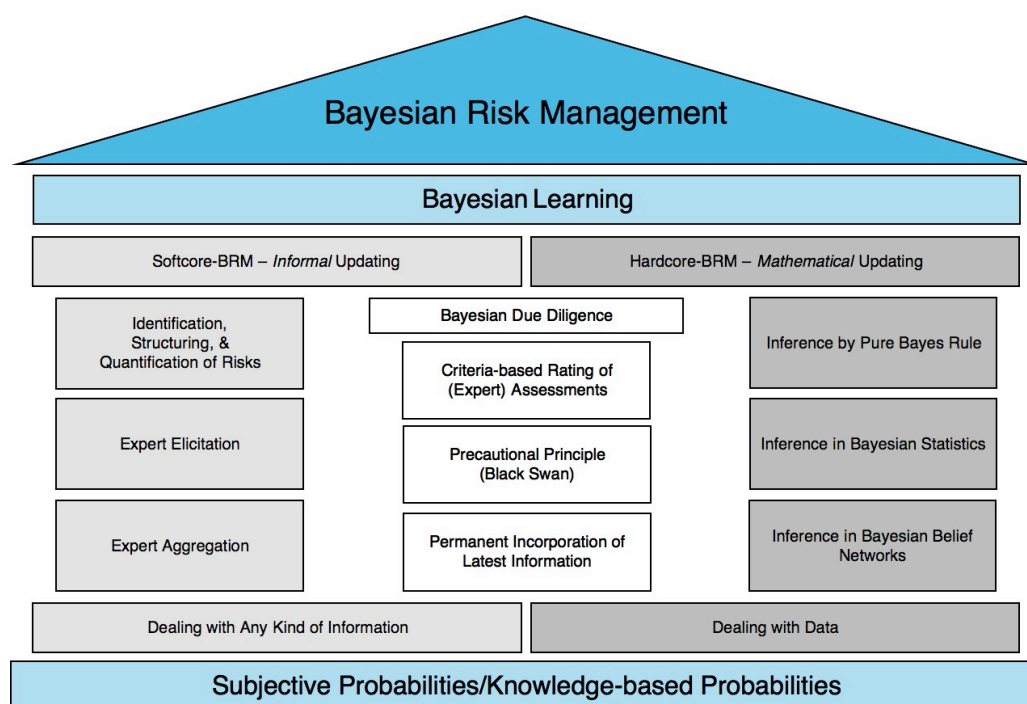
A further means to keep arbitrariness in check is to take other experts' opinion into consideration and critically reflect group effects and correlations of opinions. Identifying the dependence structure of experts and their expertise and of how their opinions correlate are key measures for addressing groupthink.

A decision maker should also make sure that he applies the precautionary principle, possibly by using risk cushions for designing some leeway into his system.

Fig. 1 gives a visual sketch of our BRM concept, highlighting our three pillars of BRM, and Bayesian learning and knowledge-based probabilities as overarching principle and foundation.

## 4 Black Swans, Dragon Kings, and Bayesian Risk Management

BRM is no crystal ball and no truth-telling machine. It is a concept that comes with a set of tools for making uncertainties explicit. Moreover, its tools help



**Figure 1:** Bayesian Risk Management

mobilise, structure and make explicit expertise and judgment. We think it is crucial that experts acknowledge that their expertise and judgment are basically subjective, and must be so. This is unavoidable because economies in general, and financial markets in particular are complex dynamic systems that offer a plenitude of different explanations. Thinking to have identified a specific causation chain as the *one-and-only* causation chain for us is a perfect example of a narrative fallacy.<sup>2</sup>

In our perspective, expert judgments must necessarily be subjective. This is in remarkable contrast to the strive for objectivity, which is still dominating risk management. Brunnermeier et al. (2010), for example, state that

“Unless we are able to measure risk objectively, quantitatively, and regularly, it is impossible to determine the appropriate trade-off between such risk and its rewards and, from a policy and social welfare perspective, how best to contain it.”

<sup>2</sup> For narrative fallacies cf. Taleb (2007) and Menashe and Shamash (2005). Besides the narrative fallacy, Taleb identifies two other fallacies, the *ludic fallacy* when people erroneously assume that unstructured real life randomness resembles structured randomness typically found in games, and the *statistical regress fallacy* that the structure of probability can be derived from data. Taleb subsumes these three fallacies under the notion of the *Platonic fallacy*.

As we typically must assess risks while being confronted with many differing expert judgments, we suggest striving for concepts and tools that can reasonably and practically deal with a plenitude of necessarily subjective expert judgments, some complementing and some challenging each other. Our BRM concept, which is one specific example of such an approach, is able to deal with plurality, i.e. the simultaneous existence of controversial perspectives and explanations. For us, they are just instances of different Bayesian Belief Systems.

BRM as we suggest it nicely complements Taleb's Black Swan concept and Sornette's Dragon Kings. Minding for Black Swans is part of our Bayesian Due Diligence approach. Moreover, with our concept and toolkit we are able to address both Taleb's *Platonic fallacy* and this *triplet of opacity*.<sup>3</sup> Concerning Dragon Kings, we can widen the area of application for this concept. Sornette uses the quantitative approach of frequentist statistics for identifying Dragon Kings. Our concept transcends his notion and allows using qualitative knowledge for detecting Dragon Kings.

For demonstrating what we have in mind with our approach, we want to give the example of dealing with *network externalities*.<sup>4</sup> Network externalities occur when, due to contagion effects and spillovers, hits to single knots in the financial network spread and can amplify with the risk of driving the whole network into instability. As Malevergne and Sornette (2005) argue, financial markets usually operate in a smooth mode with rather stable co-variances in asset yields. Sometimes, however, they switch to an exceptional mode in which the formerly stable co-variances break down and an unprecedented dynamics prevails. If this is indeed the case, this phenomenon must be taken into account when financial risk managers calculate risk measures, or when authorities strive for safeguarding the stability of the financial sector. Risk management procedures that focus only on the recent past are misleading in this context. Value at risk measures or stress tests, for example, that only use data generated in the standard mode of financial market operations are striking examples of harmfully misleading procedures. In times like the golden decade, they signal much lower risks than should and could actually be expected. The frequentist statistical knowledge from the ordinary mode of financial market operations is no basis for inferring catastrophes to come. In contrast, using Bayesian inference that takes into account *all* available information, including the reasoning of stylised facts from financial crises history, and the multi-modality of financial market dynamics, is a basis for inferring catastrophes to come. The power of Bayesian inference should therefore be mobilised for the future regulation of

<sup>3</sup> Taleb's triplet of opacity comprises i) the illusion of understanding current events; ii) a retrospective reframing of historical events; iii) overestimating factual information combined with overvaluing intellectual elites.

<sup>4</sup> Cf. Brunnermeier et al. (2009), Morris and Shin (2008); Haldane (2009) has put their contributions concerning network externalities lucidly into context.

financial markets as well as the identification of systemic risks by supervisory authorities.

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