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Modeling and monitoring risk acceptability in markets: The case of the credit default swap market

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ABSTRACT

Minimal discounted distorted expectations across a range of stress levels are employed to model risk acceptability in markets. Interactions between discounting and stress levels used in measure changes are accommodated by lowering discount rates for the higher stress levels. Acceptability parameters represent a maximal and minimal discount rate, a maximal stress level and the speed of rate reduction in response to stress. An explicit model relating credit default swap (CDS) prices to default probabilities is formulated with a view to making the default risk market acceptable. Data on CDS prices and default probabilities for the six major US banks obtained from the Risk Management Institute of the National University of Singapore is employed to estimate parameters defining acceptability and the movements in market implied recovery rates. We observe that the financial crisis saw an increase in the maximal discount rate and its spread over the minimal rate along with an increase in the maximal stress level being demanded for acceptability and a stable pattern for the speed of rate adjustment through the period. The maximal rate, rate spread and stress levels have come down but with periods in the interim where they have peaked as they did in the crisis. Recovery rates have oscillated and they did fall substantially but have recovered towards 40 percent near the end of the period.

1. Introduction

It is by now well recognized that all economic events have both a probability of occurring and a forward price for a contract paying a unit of currency if the event occurs. The forward prices are also referred to in the literature as Arrow Debreu or state prices. Both the probability and the forward price of an event are nonnegative numbers. Furthermore forward prices, like probabilities, sum to unity across a set of mutually exclusive and exhaustive events. As a consequence forward prices behave like probabilities but they are differentiated from them. We refer the reader to Aït-Sahalia et al. (2001) for an empirical investigation of the differences between price and probability in the context of risks associated with the S&P 500 index for example. The existence of market observable prices, in this context, is explained in Breeden and Litzenberger (1978), for example.

The forward prices when viewed as probabilities are called by many names, with risk neutral probability being a more popular terminology. Other terms often used are martingale probability or equilibrium pricing measure. The ratio of the two probabilities say physical or real world probability to risk neutral is called a risk premium. When this premium is greater than unity, the excess over unity is an excess return earned as compensation for risk taking. On the other hand when this ratio is less than unity the difference from unity is an insurance premium being paid to protect against the event.

Understanding and modeling risk compensation or insurance premia is an important objective of the study of financial economics. Basically if the compensation is right or the premium correct there is a market transaction that may be conducted and otherwise there is no trade. By observing transaction terms and modeling the link between price and probability, one may indirectly learn about risk compensation and insurance premia.

Furthermore, understanding what risks may be taken or the terms under which they can be undertaken is critical to comprehending the scale and scope of permissible economic activities in modern financial economies. One may note in this regard that excepting some trivial activities, there is always some risk attached to economic activities. There may be models in which risks are hedged but generally this does not transform into reality. We therefore seek to formally model risk acceptability in markets with a view to estimating the parameters of risk acceptability from observable market information.

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Markets trade many events, especially when we consider the markets for options on a variety of underlying risks. Most of the related securities have cash flows taking a multitude of possible values that in some cases may even be unbounded. However, among the relatively simpler contracts, with just two payout values, are Credit Default Swap (CDS) contracts that either payout nothing if there is no default or they payout a fraction of a unit in the event of default. The risk neutral default probability may be inferred from CDS prices.

The physical or real world default probability is harder to come by. However, currently the Risk Management Institute (RMI) of the National University of Singapore implements a forward intensity approach developed by Duan et al. (2012) and publishes default probabilities monthly on their website for some 60,000 firms worldwide. They were also generous to provide us with daily default probabilities for the six major US banks over the period January 2006 to January 2014. One may then attempt to learn about the terms of risk acceptability in markets by modeling the connection between CDS prices and the default probability.

The traditional approach to modeling risk acceptability or the terms at which it is accepted is to invoke the law of one price, model this price and infer the acceptability parameters from an estimation of the associated risk neutral model. An example of such an approach includes, Berndt et al. (2004) that comes closest to the perspective adopted here of transforming default probabilities, as sufficient statistics, to credit default swap prices. They employ the KMV EDF's while we use the PD's from RMI. Their underlying approach is however classical in terms of specifying and estimating a risk neutral measure. Other recent examples are provided by Chen et al. (2008), Siu et al. (2008), Cremers et al. (2008) and Zhang et al. (2009).

The set of risks accepted by the market in such a traditional approach consists of all risks offered at a forward price below the selected risk neutral expectation. This is a very large and generous set of acceptable risks when viewed from a different and more conservative perspective. Acceptable risks have been formally defined in a now pioneering paper by Artzner et al. (1999). The essential idea is to consider as acceptable, a convex cone of random variables that also contains, the obviously acceptable, nonnegative random variables.

The smallest set of acceptable risks will then be just the set of nonnegative random variables and in this case there is clearly no risk being accepted. At the other extreme one has the largest possible cone and this is a half space of random variables. An admissible half space would consist of all random variables thought of as state contingent vectors of cash flows, that make an angle of less than 90 degrees with a given positive random variable. Certainly any two positive random variables have an angle below 90 degrees. Now, the risk neutral probabilities of states are such a particular positive random variable. When the law of one price is invoked, as it is in the traditional risk neutral approach, the set of acceptable risks is given by the half space of all zero cost cash flows making an angle below 90 degrees with the risk neutral probabilities. Such trades are more popularly referred to as positive alpha trades. From the perspective of convex cones of acceptable risks the law of one price delivers the largest possible set of acceptable risks. The law of one price basically evaluates a single risk neutral expectation and if positive the risk is acceptable.

When the set of market acceptable risks is a proper cone smaller than a half space, it is then an intersection of numerous half spaces. The smaller cones of acceptability would require that expectations be positive for a much larger set of test probabilities than just a single risk neutral expectation. As a consequence the law of one price fails and we get a two price economy. The supremum of all test valuations, defining the cone as the intersection of half spaces, form an ask price, at which one may buy from the market. Similarly, the infimum of such test valuations is a bid price at which one may sell to the market. Modeling and monitoring risk acceptability from such a conservative perspective relative to the generous formulation delivered by risk neutral pricing can be critical in the design and formulation of leverage policies embedded in the management of capital requirements covering risk taking in modern financial economies. This paper is an initial attempt at an analytical specification of market acceptable cones of risk taking coupled with a parametric estimation as inferred from the credit default swap market.

Such two price economies have been studied in a one period model, for example, by Carr et al. (2001), Cherny and Madan (2010). A generalization to a discrete time model was developed in Madan and Schoutens (2012b). Continuous time extensions may be found in Eberlein et al. (2014) and Eberlein et al. (2013). Equilibrium models for two price economies are formulated in Madan and Schoutens (2012a) and Madan (2012). In all these papers the bid and ask prices are nonlinear functions of the random cash flows being priced with the bid price being a concave functional while the ask price is a convex functional. The nonlinearity appears via a dependence of the pricing measure being employed on the cash flow being priced. There is no nonlinearity in discounting or time value accounting in these papers.

More recently, however, Madan (2014) studies two price economies from a no arbitrage perspective and demonstrates that bid and ask prices in general incorporate nonlinearity in discounting as well. Furthermore, one would expect some interaction between the discounting and measure change nonlinearities. Essentially the discount rate employed is risk sensitive and a risk free contract just does not exist. Such considerations may potentially be driving financial practice. For example, post the financial crisis of 2008, the financial industry has moved to multicurve principles for time value accounting with the use of risk sensitive discount rates. We cite in this regard Bianchetti and Carlichhi (2012), Mercurio (2010) and Pallavicini and Tarenghi (2010).

These risk sensitive discounting methods are consistent with the nonlinearly discounted nonlinear measure changes associated with two price economies in the presence of no arbitrage as reported in Madan (2014). Here we follow Madan (2014) and apply a model for risk acceptability that incorporates nonlinearity in both discounting and measure changes to construct bid and ask prices for the defaultable pure discount bond. We then follow industry practice and take the mid quote as a candidate for the risk neutral price from which we infer a risk neutral probability, a risk neutral hazard rate, and the implied price for the credit default swap contract. The statistical or real world probability of default is employed in evaluating risk acceptability and constructing the associated bid and ask prices incorporating nonlinearity in both discounting and change of measure with interactions between the two. For two price economies, only the two separate bid and ask prices exist. The mid quote merely serves as a candidate fair proxy for a two way valuation. The output of the model is a credit default swap quote. The credit default swap market provides a rich source of market data to employ in ascertaining movements in risk acceptability that may be occurring in financial economies.

We show that the general model can display CDS quotes increasing concave in the default probability and decreasing convex in the recovery rate. Under the law of one price one has the CDS quote increasing convex in the probability and linear in the recovery rate while if the law of one price prevails for loans then one may get concavity in the probability but the CDS rate is linear in the recovery rate.

The model is estimated on daily data on default probabilities for the six major US banks from RMI coupled with market data on daily credit default swap quotes. We then estimate the parameters of risk acceptability and their variation through the period January