Rational learning about rare-disaster frequencies: A persistent source of asset-price overreaction

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A stock-market collapse such as the one after the 2008 Lehman Brothers default is followed by more pessimistic assessments of the likelihood of future collapses in surveys and by lower price-dividend ratios. This column argues this reaction of expectations and asset prices can be explained by Bayesian decision theory. The key is to appreciate that market participants know little about the drivers of such crashes. They revise their beliefs and learn over time.

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Investors want to understand how asset markets work. Their perceptions of the mechanism determining asset prices are essentially forecasting models with unknown parameters. If they could have full confidence in the model's parameters such as in a casino where unknowns have known probabilities, investment strategies and asset prices would reflect rational expectations.

However, Shiller (1981) and LeRoy and Porter (1981) already demonstrated thirty years ago that actual stock prices 'overreact' relative to the yardstick predictions of a casino-type rational-expectations asset-pricing theory. These findings triggered an enormous literature on the sources of excess volatility in asset prices.

Understanding asset-price overreaction

As noted by Shiller (2005) many contributions to the literature have attributed stock-price overreactions relative to the rational expectations yardstick to bounded rational behaviour by investors. By contrast, we explore whether such price deviations may be due to investors' lack of knowledge about the probability distribution of unknown drivers of asset prices (see Koulovatianos and Wieland 2011). Specifically, we investigate whether rational learning about the unknown frequency of sudden dividend drops can explain the loss of confidence and seemingly excessive decline in asset prices observed after a crash as in 2008.

Recently, economists have started to study the implications of rare disasters for asset pricing. Empirical work such as Barro and Ursua (2009) underscores the limited knowledge available regarding the stochastic nature of such disasters. Sudden sharp declines in dividends might be triggered by bankruptcies of companies in key sectors. But even if we do not know the exact causes, we can try to quantify the implications of limited knowledge on investors' perceptions and stock-price overreactions after such an incident has occurred.

Dividends, stock prices, and survey measures of disaster expectations

Figure 1 serves to illustrate the connection between stock-market crashes, fundamentals, and disaster beliefs. The two vertical dashed lines indicate episodes with massive dividend drops, *ie* the 2000 dot-com bust and the 2008 Lehman Brothers default. The declines in stock dividends (top left panel) and earnings (not shown) coincided with substantial drops in stock prices (top right panel). Yet price declines seem excessive as they imply significant reductions in price-dividend (bottom left panel) and price-earnings ratios (not shown).

Following the bust in fundamentals and prices, the Crash Confidence Index (bottom left panel) indicates that survey participants feared that another crash would be imminent. Technically, this index measures the percentage of respondents stating that the likelihood of a crash in the next semester is less than 10%. Thus, low values indicate low confidence.[1]

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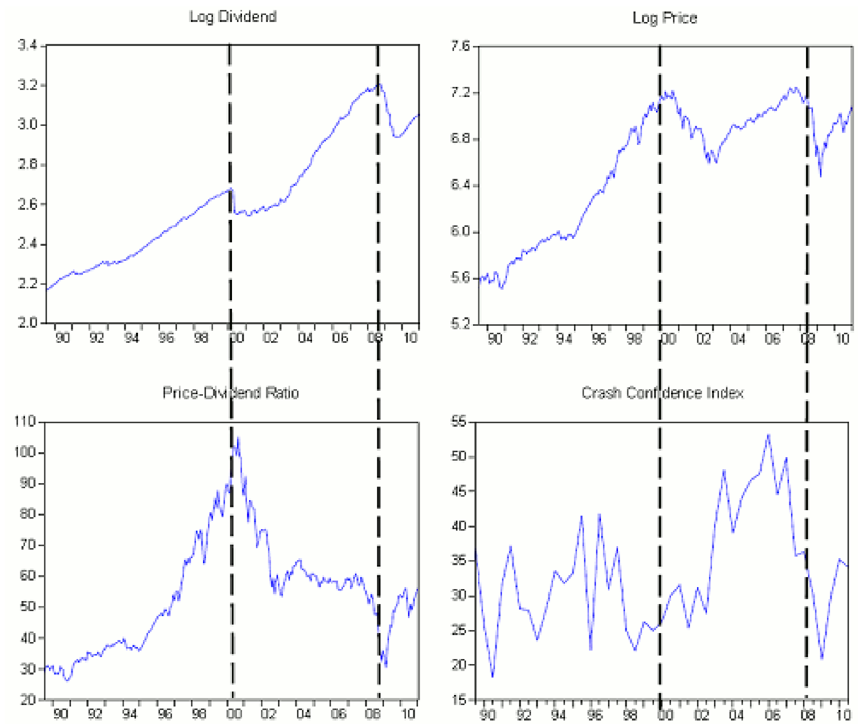
Figure 1. Monthly US stock-market data and Crash Confidence Index 1989–2010

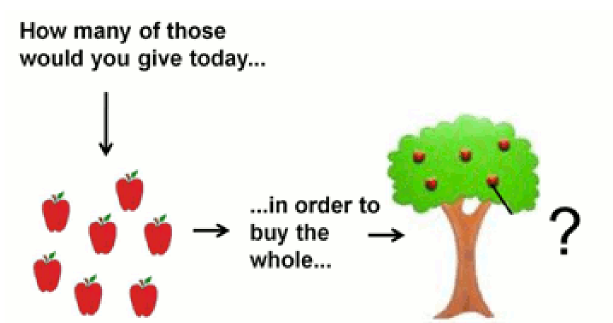


Source: Datastream (TOTMKUS) and Shiller et al (1996).

Dividends and prices: The simplest connection

A vehicle enabling a clear connection between fundamentals and investors' beliefs is the Lucas-fruit-tree framework (Lucas 1978). This asset-pricing model uses the metaphor of a tree to describe a unit of the stock-market portfolio, and the market-dividend index as the random quantity of fruit produced each season. The fundamental question addressed by the model is illustrated in Figure 2. If we anticipate a tree to be very productive, we can spare a lot of fruit in order to buy it. So, a slight change in expectations about future prospects of dividend yields can have a profound effect on asset prices.

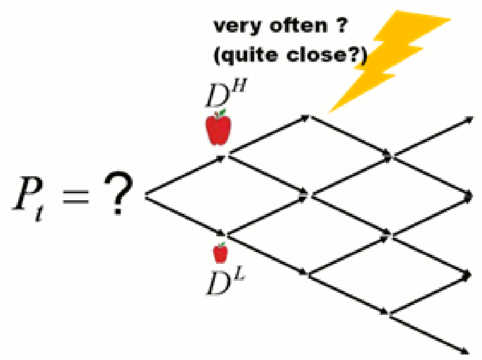
Figure 2. The Lucas-tree pricing question



The tree metaphor also reminds of the textbook uncertainty tree. Dividend data are fairly well-described by a stochastic process that combines a random walk with a jump (Poisson) process. Figure 3 depicts the resulting dividend (fruit) evolution. The upper branches of the tree are occasionally hit by disasters that destroy growth prospects and depress stock (tree) prices.

We add limited confidence and learning about the parameters driving the frequency of disasters to the model. The lack of econometric confidence about the frequency of disasters implies a confidence interval within which econometric perceptions may swing from optimism to pessimism depending on collected histories of disaster data. Figure 3 depicts how this lack of confidence is embodied into the fundamental asset-pricing question. At times of pessimism, there is a perception that the frequency of disasters is high. Thus, disasters are perceived as possibly imminent. Such beliefs can have a profound effect on asset prices, because they prune growth possibilities of valuable goods in the short and medium run.

Figure 3. The econometrician's question



What (rational) Bayesian learning about rare disasters brings to the table

In Koulovatianos and Wieland (2011) we propose a statistical formulation of rational Bayesian learning which delivers the following key implications:

(i) After a dividend bust, Bayes' rule induces a drop towards more pessimistic beliefs (that is a perception of a greater frequency of disasters), followed by a slow recovery towards more optimism if no new dividend busts occur.

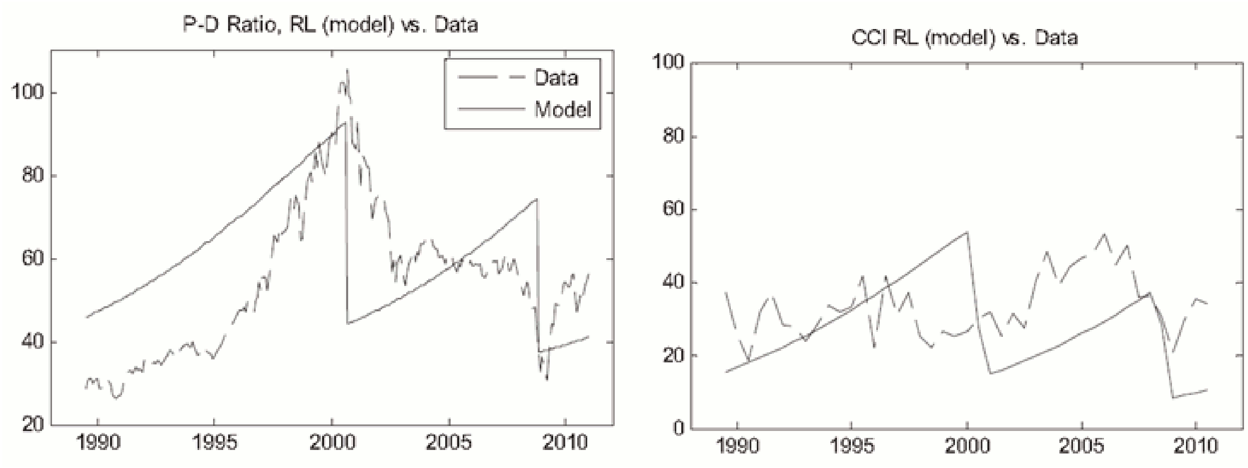
(ii) Uncertainty about the frequency of busts remains even in the limit. Thus, Bayesian investors will never be 100% confident about this important parameter.

In this framework, rational expectations are never fully approached. As a result, Bayesian investors swing between optimism and pessimism as they collect data on the occurrence or the non-occurrence of disasters. This finding is particularly useful when bringing the model to the data. Only the degree of optimism or pessimism in beliefs needs to be measured, but not the extent of any transition towards permanently rational expectations. This measurement can be accomplished using surveys such as the Crash Confidence Index. Since beliefs affect discount factors of future payoffs (see Cochrane 2011), such measures may be used to quantify stock-price overreaction in the context of an asset-pricing model.

How to connect Bayesian learning about the frequency of dividend busts in an asset-pricing model, with data on dividend busts, price-dividend ratios and survey measures of confidence such as the Crash Confidence Index is illustrated by the simulation shown in Figure 4. Here, the 2000 dot-com bust and the 2008 Lehman Brothers default are the only two exogenous disaster-shock realisations plugged into the asset-pricing model of Koulovatianos and Wieland (2011).

Figure 4. Ability of asset-pricing model under rational learning (RL) to explain the range of excess volatility of prices (Price-Dividend ratio fluctuations) and fluctuations in expectations of an imminent stock-market crash (survey-based

Crash Confidence Index).



A key question is whether one can set model parameters and prior beliefs in the beginning of the sample period such that: (i) the model explains excess volatility in asset prices, as captured by the range of fluctuations of the price-dividend ratio (left panel), and (ii) the model delivers a range of belief fluctuations consistent with measures such as the Crash Confidence Index (right panel).

Figure 4 indicates that our model, which offers closed-form solutions for asset prices and disaster beliefs, is capable of providing a rationality-based explanation for asset-price overreaction. This simple numerical experiment shows that the study of rational learning about the frequency of dividend jumps together with available survey measures is a promising ingredient for applied stock-market pricing models, as well as approaches to other economic questions involving asset pricing.

The potential role of disaster expectations in macroeconomic analysis

During turmoil periods with elevated disaster pessimism, investors will not take extrapolation of past GDP trends for granted and may question whether an economy's structural productive sectors are about to survive or to fail (*eg* banks, industry sectors, etc). Understanding the impact of disaster expectations on asset prices and economic performance can help in quantifying the effectiveness of policy in such periods.

For example, revisiting the 2009 fiscal-stimulus debate through the lens of an asset-pricing model with disaster beliefs and learning may shift the focus of the debate away from government spending multipliers to more useful strategies for restoring investor confidence in key production sectors.[2]

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[1] The Crash Confidence Index has been produced using a survey questionnaire described in Shiller et al. (1996). The index is the percentage of survey respondents who stated that the probability of a stock-market crash occurring within the following semester is less than 10%. This survey data can be downloaded from here.

[2] For an overview of this debate see, for example, Cogan and Taylor (2010).

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