JUMPING BEANS: IMPLICATIONS OF FAT TAILS IN INTERNATIONAL SOYBEAN AND BIOFUELS MARKETS

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Overview

Several recent policies have been promulgated to reduce reliance on fossil fuels in the United States (US) transportation sector, including the Renewable Fuel Standard and the Low Carbon Fuel Standard. Both policies are likely to increase reliance on biofuels, both corn- and soybean-based. Two approaches that have been discussed to accomplish this transition are increasing the amount of ethanol blended into motor vehicle fuels or increasing use of biodiesel or sugarcane-based ethanol. Sugarcane ethanol used in the US is mainly imported from Brazil; biodiesel generally is produced from soybean oil. For many years, the US and Brazil have been the two largest sources of soybean production. Accordingly, the pathway forward for renewable fuels in the US is intertwined with soybean production, both in the US and Brazil, as well as ethanol production, also in the US and Brazil (Stock, 2015).

As the two largest sources of soybean production in the world, any shifts in information regarding production and yield within Brazil or the US are likely to exert important effects on global soybean markets. Moreover, any changes in expectations regarding soybean exports from competing nations, like China, can swiftly reverberate onto soybean prices, with fluctuations influenced by changes in export volumes from major producers. Dramatic weather phenomena, such as hot and dry conditions in critical growing regions, could be a significant contributor to market dynamics, prompting revisions in crop estimates and production forecasts. All these effects have the potential to cause abrupt changes ("jumps") – leading to "fat tails" in the distribution of prices.

Increased production of biofuels will require important large-scale (irreversible) investments in refining and processing, as well as deployment of motor vehicles capable of running on higher concentrations of ethanol (so-called E85 vehicles). These investments are subject to substantial uncertainty, underscoring the importance of characterizing the stochastic nature of soybean and ethanol prices. In this paper we investigate the potential presence of jumps in four spot prices: soybeans, in the US and Brazil, and ethanol produced from soybeans, also in the US and Brazil. We find compelling empirical evidence for the importance of jumps in both markets. The presence of jumps in these markets has important implications for large scale infrastructure investments, as would be necessary to produce ethanol-based motor vehicle fuels, as well as ecological implications associated with deforestation that is likely to accompany any increases in Brazilian soybean production.

Methods

We first describe an extension of the familiar model of a stochastic process that allows for unexpected changes (jumps). This extension leads naturally to an econometric specification, which can be readily combined with time-varying volatility (also known as the generalized autoregressive conditional heteroscedasticity, or GARCH, framework). After incorporating these elements, we characterize the likelihood function that governs the data-generating process; this, in turn, leads directly to an estimation procedure and hypotheses tests regarding the appropriate specification of the stochastic process. We then apply this econometric methodology to the four times series (soybeans and ethanol for each of the US and Brazil). Our data are based on daily observations, for both spot prices. We compare four stochastic data-generating processes: GBM (which we refer to as PD in the pursuant discussion), GBM allowing for a jump diffusion process (which we refer to as JD in the pursuant discussion), GBM allowing for GARCH (which we refer to as GPD in the pursuant discussion), and GBM allowing for both GARCH and a jump diffusion process (which we refer to as GJD in the pursuant discussion).

Based on the results from our empirical analysis, we execute numerical simulations. These simulations are built up from an extension to the conventional model of investment under uncertainty, which generally assumes GBM (Dixit and Pindyck, 1994). In this extension we derive expressions for key investment thresholds in the presence of jumps. The thresholds are based on a parameter that cannot be obtained analytically, and so we use numerical methods to derive values. Armed with this value we determine the critical levels of the underlying stochastic price that would trigger investment for a variety of combinations of values describing the jump (frequency of jump; mean and standard deviation of jump size).

Results

From our econometric analysis we find that each of the four price returns displays clear evidence of fat tails. For all four series estimates of parameters related to both jumps and GARCH processes are important. Moreover, the data strongly suggest that allowing for jumps or time-varying volatility in price returns improved predictive power: in every case, including both jumps and GARCH generates increases in the log-likelihood function that are statistically significant at better than the 1% confidence level.

From our numerical simulations we find that the cutoff price that triggers investment is increased by each of: increases in the probability of a jump, mean size of a jump, and standard deviation of jump size. The implication is that any of these three changes would delay a large-scale investment.

Conclusions

There are many reasons why a better understanding of the stochastic process driving soybean and ethanol prices would be useful. These energy resources can have important microeconomic effects, with commodity price risk having a potentially significant impact on profits in a variety of lines of business. Knowledge of the underlying stochastic behavior of these assets could aid in forecasting spot prices, with attendant reductions in risk exposure. Moreover, decisions to invest in important infrastructure can be improved by an enhanced understanding of the stochastic processes driving the prices of related resource. For example, the accuracy of a decision to significantly expand a refinery to handle ethanol infrastructure, or to process imported soybeans, will almost surely be improved by such enhanced understanding. This is particularly true when the prices of imported soybeans or ethanol are subject to jumps, as our results indicate. For in this case, the underlying distributions of these prices are fat-tailed, which can be particularly important if prices exert a non-linear marginal impact on the agent's profit flow. On the other hand, fat tails in soybean prices can increase the option value of delaying the conversion of a plot of land, so as to facilitate expanded soybean production. This effect could amplify the impact of policies designed to inhibit deforestation, such as requiring the purchase of a permit prior to clearing a forest, or some form of punishment (such as a substantial fine or jail time) for undertaking such land conversion without prior government approval.

The potential for jumps in soybean and ethanol prices is of more than academic interest, as jumps in these prices have implications for investment in biofuel capacity and in the requisite infrastructure needed to accommodate a meaningful increase in the use of vehicles than can capitalize on expanded ethanol supplies (*i.e.*, E85 vehicles).

To the extent that there are jumps in these prices, biofuels producers with excess capacity might be able to cash in on unexpectedly high price returns. But as our simulation results showed, it is also true that jumps in the underlying commodity price induce an option value associated with delaying investment in increased capacity. Similarly, the presence of jumps implies an option value to waiting to add E85 fueling stations or delaying land conversion.

Other benefits accrue from the ability to better frame the underlying stochastic model in an investment under uncertainty framework, which we believe has real potential for evaluating important large-scale infrastructure investments such as refinery expansions or import/export terminals. Because such enhancements to transportation infrastructure may have far-reaching benefits, for example by facilitating gas movements to regions with larger demand, the welfare consequences of these investments may be substantial. The potential for substantial welfare implications of these investments underscores the importance of developing a better understanding of the stochastic process underlying biofuels prices, which in turn highlights the value of developing a more accurate empirical model to describe these prices.

References

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