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What explains the orange juice puzzle: Sentiment, smart money, or fundamentals? ☆

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ABSTRACT

In the famous “orange juice puzzle,” a large amount of inexplicable price volatility arises in frozen concentrated orange juice (FCOJ) futures contracts. Temperature is considered the most important fundamental factor in this market, but its explanatory power is low and limited, so are those of various consumer and stock market sentiment measures that reflect the noise traders’ opinions. In contrast, shifts in a survey-based index called the Consensus Bullish Sentiment Index (CBSI), which reflect the overall opinions of professional investors, provide the largest explanatory power among all measures. Further analysis reveals that bullish shifts in the CBSI are followed by higher FCOJ returns but lower conditional volatility, thus supporting the notion that the index reflects the smart money effect.

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1. Introduction

Whether asset prices are affected by factors other than fundamentals has been an enduring debate in empirical asset pricing tests. Such tests, as well as tests of the efficient market hypothesis, almost always suffer from a joint hypothesis problem, because identifying “abnormal” price movements requires a specification of a proper equilibrium law of motion (i.e., an asset pricing model; Fama, 1991). This is why Roll’s (1984) study of the frozen concentrated orange juice (FCOJ) futures market is

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so notable: The demand for orange juice is stable throughout the year, so exogenous supply shocks (for which weather is the most fundamental source) are the major determinant of FCOJ prices. There is no need to rely on a specific asset pricing model to detect abnormal price movements, so it avoids the joint hypothesis problem.

A unique feature of the FCOJ futures market is that most oranges are grown in a small area around Orlando, Florida; during Roll's (1984) sample period, up to 95% of the oranges were grown there. The weather, and especially the temperature, in this region is thus a primary determinant of supply and FCOJ futures prices. Yet surprisingly, Roll shows that weather explains only a very small fraction of observed variability in FCOJ returns; the adjusted *R*-square is only about 2%. Information about other fundamental factors, such as substitute product prices, general demand, export demand, and production costs, also does not provide significant incremental explanatory power, so Roll (1984, p. 879) concludes that there is a puzzle in the FCOJ market, marked by "a large amount of inexplicable price volatility." Ross (2005, pp. 51–52) cites this example and its "lack of explanatory power [as] one of the great puzzles of neoclassical finance." We refer to it as the "orange juice puzzle."

Roll's (1984) finding represents oft-cited evidence to support behavioral finance views that assert asset prices can be affected by factors other than asset fundamentals (e.g., Shleifer, 2000; Hirshleifer, 2001; Daniel et al., 2002). (Boudoukh et al., 2007; hereafter BRSW), however, argue that researchers have misinterpreted the data, because they ignore the state dependence inherent in the structural relationship between FCOJ returns and their fundamentals.

Specifically, BRSW (2007) argue that a dramatic change in temperature represents a supply shock only if the temperature is around or below freezing, rather than when it is far above 32 °F. There also exists a nonlinear relationship between FCOJ returns and temperature, because a drop in temperature below freezing causes greater damage to orange production. After taking into account the non-linearity problem, BRSW find that temperature explains almost half of the FCOJ return variability around freezing temperatures, in support of the view that fundamental information is important for determining the FCOJ prices.

But this contribution neither implies that the orange juice puzzle is fully resolved, nor does it suggest that the FCOJ market is efficient. Two phenomena are worth noting. First, empirical evidence shows that the price variation in winter accounts for only about half of the total return variation (e.g., Table 1 in BRSW (2007)). In 1983–2014, the proportion of return variation in winter dropped to about 30%, with a slightly downward trend (see Fig. 1). If supply shocks caused by freezes are the sole determinant of FCOJ prices, there should not be much price variation in non-winter seasons or when the temperature is well above 32 °F. Clearly then, it is important to investigate the sources of return variation that are not due to extreme weather.

Second, there appears to be some evidence of price reversals that may have been driven by investors' overreaction. Ross (2005, p. 52), for example, points out that adjusting the forecast downward when the closing price is higher than the opening price that day, or upward when the market return is negative, actually improves the forecast. Our finding also indicates that the autocorrelation coefficient of weekly FCOJ returns is positive from lag 1, but becomes negative from lag 2 to lag 4. The serial correlation pattern is similar to that reported in French and Roll (1986), who document that the average autocorrelation of daily stock returns is positive from lag 1, but is negative from lag 2 to lag 12 [see Table 3 in French and Roll (1986)]; French and Roll attribute the serial correlation pattern to trading noise (i.e., mispricing).

The evidence indicates that fundamentals alone do not suffice to explain the orange juice puzzle, thus calling for the quest for other factors such as the behavioral ones that may help explain the FCOJ return variation. A natural way to tackle this question, in our view, is to investigate the behavior of the participants in the FCOJ market. Several studies have shown that asset prices may be driven apart from their fundamental values by investors' self-serving behaviors. For instance, Campbell and Kyle (1993) propose a model in which "smart-money" investors, who are informed of the asset's fundamental value, are willing to absorb noise traders' orders, and hence take a loss in the short run, for earning the long-run profit. The asset price in equilibrium thereby is not perfectly adhered to the fundamental because of the demand and supply created by such an interaction between smart money and noise traders.

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