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# The Samuelson hypothesis in futures markets: An analysis using intraday data

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**Abstract**

This paper considers the Samuelson hypothesis, which argues that the futures price volatility increases as the futures contract approaches its expiration. Utilizing intraday data from 20 futures markets in six futures exchanges, we find strong support for the Samuelson hypothesis in agricultural futures. However, the Samuelson hypothesis does not hold for other futures contracts. We also provide supporting evidence that the 'negative covariance' hypothesis is the key factor for the empirical support of the Samuelson hypothesis. In addition, our findings remain largely unaltered even after we control for seasonality and liquidity effects.


*JEL classification:* C22; G13; G15; Q14

*Keywords:* Commodity futures; Realized volatility; Samuelson hypothesis; Time to maturity

## 1. Introduction

This study investigates the futures price volatility as a function of the futures contract's time to maturity. Specifically, we examine the Samuelson hypothesis (Samuelson, 1965), which proposes that the futures price volatility increases as the futures contract approaches its expiration. Drawing on the concept of realized volatility, introduced by Andersen and Bollerslev (1998), we test the Samuelson hypothesis using intraday data, rather than using daily data as the current literature does.

In the past four decades, many researchers have investigated the time pattern of the futures price volatility.[1] Much of this interest arises from the importance of the relation between time to maturity and the futures price volatility. First, as Board and Sutcliffe (1990) argue, this relation is important to margin setting. The desired margin is positively related to the futures contract price volatility. Therefore, if the futures price volatility increases as the futures contract approaches maturity, as suggested by the Samuelson hypothesis, the cash balances held by traders to cover for margin calls should also be increased as the maturity date approaches.

Second, the relation between volatility and time to maturity also has implications for hedging strategies. Depending on whether this relation is positive or negative, hedgers should choose futures contracts with either a short or long time to maturity, such that the price volatility is minimized. When the Samuelson hypothesis holds, traders might consider switching to contracts further away from expiration day; otherwise, they will face higher volatility and require a higher risk premium.

Finally, since the volatility of the underlying asset is an important input for pricing options, the relation between maturity and volatility should be considered when pricing options on futures. Higher volatility of the underlying asset provides greater potential gains for option buyers. As a

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[1] See Rutledge (1976), Anderson (1985), Milonas (1986), Grammatikos and Saunders (1986), Khoury and Yourougou (1993), Galloway and Kolb (1996), Bessembinder et al. (1996) and Allen and Cruickshank (2000), among others.

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result, evidence supporting the Samuelson hypothesis will suggest a rise in the price of options on futures such that option sellers are compensated for the risks they face.

The current study contributes to the current literature in the following ways. First, we test the Samuelson hypothesis using intraday data for 20 markets in six futures exchanges during the period of 1996–2003. While previous studies measure the futures price volatility using daily futures closing prices, we examine the Samuelson hypothesis using daily realized volatility calculated as the sum of squared intraday returns (Andersen and Bollerslev, 1998). According to Andersen and Bollerslev (1998), although the daily squared return is an unbiased measure of daily volatility, it is also a noisy estimator. Daily squared returns are unable to capture intraday price fluctuations, which can be substantial. In contrast, realized volatility, which is calculated using intraday returns, provides a better, more robust estimate of the actual price volatility.[2]

Second, for testing the Samuelson hypothesis, we utilize a non-parametric test – the Jonckheere–Terpstra test (JT test) as well as regression-based tests. The non-parametric JT test was developed by Jonckheere (1954) and Terpstra (1952) for the purpose of testing ordered differences among classes. Given that testing the Samuelson hypothesis involves testing the order of volatility among different futures with different times to maturity, the JT test is well suited for this purpose. In addition, we also investigate the Samuelson hypothesis based on linear regression with realized volatility and the conditional volatility, as provided by the GARCH (1, 1) model.

Consistent with the existing literature, we find support for the Samuelson hypothesis in agricultural futures. Evidence supporting the Samuelson hypothesis in all agricultural futures is robust, even after we control for the effects of seasonality and liquidity. In contrast, support for the Samuelson hypothesis is not documented in any of the financial, metals and energy futures. Our findings support the argument of Bessembinder et al. (1996) that the Samuelson hypothesis is more likely to hold in markets that exhibit a negative covariance between changes in spot prices and changes in net carry costs. We also provide supportive evidence for the role of the information flow in explaining the futures price volatility, as suggested by the 'state variable' hypothesis of Anderson and Danthine (1983). However, similar to Bessembinder et al. (1996), we do not find the information flow to be the key condition for the empirical support of the Samuelson hypothesis. Evidence in support of the Samuelson hypothesis remains largely unaltered even after allowing for the information flow in our regressions. Finally, we highlight the economic significance of our empirical findings on the Samuelson hypothesis.

The rest of the paper is organized as follows. Section 2 reviews the literature. Section 3 outlines the data used in this study. Section 4 presents the results and discussion while Section 5 concludes the paper.

## 2. Literature review

Samuelson (1965) developed a theoretical basis for the relation between the futures price volatility and time to maturity. Often referred to in the literature as the 'Samuelson hypothesis' or the 'maturity effect', this hypothesis postulates that the volatility of futures prices should increase as the futures contract approaches expiration. Various empirical studies have tested the Samuelson hypothesis and the results are often mixed. In general, the Samuelson hypothesis is more often supported in agricultural futures than in other futures markets.

Milonas (1986), Galloway and Kolb (1996) and Bessembinder et al. (1996) find evidence supporting the Samuelson hypothesis for agricultural futures traded on the US market. Non-US evidence is presented in Khoury and Yourougou (1993), who find support for the hypothesis in their study of six Canadian agricultural commodities. Similarly, Allen and Cruickshank (2000) also document supportive evidence for the Samuelson hypothesis in the majority of commodity futures traded in the Sydney Futures Exchange, LIFFE, and the Singapore Derivatives Exchange.

Evidence of the maturity effect in financial futures is much weaker than in agricultural futures. Grammatikos and Saunders (1986) fail to find supportive evidence for the maturity effect in any of the five currency futures in their study. Galloway and Kolb (1996) find support for this effect in only one of the financial commodity futures during the period 1969–1992. Similarly, Chen et al. (1999) document that the futures price volatility of the Nikkei-225 index futures actually decreases as the expiry date approaches. Barnhill et al. (1987) conduct one of the few studies that are able to provide some support for the maturity effect in financial futures (the US Treasury Bond futures).

A recent extension of the Samuelson hypothesis is found in Bessembinder et al. (1996). The authors suggest that the key condition for the empirical support of the Samuelson hypothesis is the negative co-variation ('negative covariance' hypothesis hereafter) between spot price changes and changes in net carry costs.[3] Since the negative covariance between changes in net carry costs and changes in spot prices is likely to hold for markets trading real assets, but not for those trading financial assets, Bessembinder et al. (1996) predict that the Samuelson hypothesis is more

[2] Andersen and Bollerslev (1998) document that for the two exchange rates DM–$ and ¥–$, measuring (daily) volatility with daily returns results in the measurement errors from the latent volatility of 1.138 and 0.842, respectively. In contrast, utilizing the sum of five-minute returns to measure daily volatility reduces the measurement errors to 0.004 and 0.003, respectively.

[3] Bessembinder et al. (1996) refer to this relation as 'futures term structure'.