ARTICLE IN PRESS

Economic Modelling xxx (2017) 1–21

Contents lists available at ScienceDirect

Economic Modelling

journal homepage: www.elsevier.com/locate/econmod

Testing commodity futures market efficiency under time-varying risk premiums and heteroscedastic prices

Duminda Kuruppuarachchi [a], Hai Lin [b], I.M. Premachandra [c,*]

[a] Department of Decision Sciences, University of Sri Jayewardenepura, Nugegoda 10500, Sri Lanka
[b] School of Economics and Finance, Victoria University of Wellington, Wellington 6140, New Zealand
[c] Department of Accountancy and Finance, University of Otago, 60 Clyde Street, Dunedin 9016, New Zealand

ARTICLE INFO

JEL Classification:
G13
G14
G15

Keywords:
Commodity futures
Market efficiency
Futures risk premium
State-space model
Kalman filter

ABSTRACT

We propose a novel test to measure market efficiency while estimating the time-varying risk premiums of commodity futures, given that the prices are heteroscedastic. The risk premium is estimated using a state-space model with a Kalman filter modified for heteroscedasticity. Using 79 commodity futures traded on 16 exchanges during the period 2000–2014 and a Monte Carlo simulation, we demonstrate that the proposal produces robust results compared with conventional approaches. The global financial crisis has improved the efficiency and affected the trading volumes of commodity futures, but it has had no effect on the average or the volatility of risk premiums.

1. Introduction

Under the joint assumptions of risk neutrality and rationality, a futures market is efficient if the current futures price is an unbiased predictor of the future spot price. The conventional tests for testing this efficient futures market hypothesis (EFMH) such as Bilson (1981) and Baillie and Bollerslev (1989)) assume constant risk premiums and homoscedastic prices i.e., these tests ignore the information contained in the heteroscedasticity of prices and the time-variant risk premiums. Recently, several authors have proposed more powerful futures market efficiency tests by capturing the information contained in the heteroscedasticity of the data. For example, Westerlund and Narayan (2013) proposed a test accounting for the information contained in the heteroscedasticity of futures prices using a WLS (weighted least square) model which is shown to be more powerful than conventional tests that ignore this information. But, their test does not take into account the information on time varying risk premium i.e., risk premium in a market is assumed to be a constant in their test. In this paper, we take one step forward where Westerlund and Narayan (2013) stopped by proposing a more robust futures market efficiency test that accounts for the information contained in both the heteroscedastic prices as well as time-variant risk premiums. The proposed test is used in this paper to investigate the market efficiency of commodity futures.

Even though the conventional market efficiency tests assume constant risk premiums, there is evidence in the literature to show that the risk premiums are in fact time varying. For example, Deaves and Krinsky (1995) document that the risk premiums of commodity futures may be time-variant due to factors such as changes in risk aversion and market volatility, shifts in the balance between long and short hedging demand, and seasonality revealed by the basis (see Fama and French (1987)). This observation demands for a new test for testing the futures market efficiency under time varying risk premiums and heteroscedastic prices. This study fills this gap in the literature by proposing a new market efficiency test. We document that the proposed test is more robust in testing the futures market efficiency as it takes into account the information contained in both the time varying risk premiums and heteroscedastic prices compared with the conventional tests that ignore this information. Another important feature of the proposed test is that it simultaneously estimates the time varying risk premiums of the underlying futures using a state-pace model which uses the Kalman filter that we modified in this paper to accommodate for heteroscedastic spot prices.

Furthermore, theoretically, the proposed test is more appropriate in testing the futures market efficiency compared to the conventional tests due to the fact that the conventional futures market efficiency tests are

* Corresponding author.
E-mail addresses: duminda@sjp.ac.lk (D. Kuruppuarachchi), Hai.lin@vuw.ac.nz (H. Lin), i.premachandra@otago.ac.nz (I.M. Premachandra).

https://doi.org/10.1016/j.econmod.2017.12.005
Received 15 August 2017; Received in revised form 9 December 2017; Accepted 11 December 2017
Available online xxxx

based on the joint assumptions of risk neutrality and rationality (i.e., speculators cannot make excess returns). This joint assumption, commonly referred to as the unbiasedness hypothesis, is derived from an uncovered interest rate parity theory in currency markets (Hansen and Hodrick (1980), Baillie et al. (1983)), and therefore its theoretical appropriateness for testing the efficiency of futures markets has been argued by authors such as Brenner and Kroner (1995).

This paper employs the proposed test to investigate the market efficiency of a comprehensive sample of 79 commodity futures traded on 16 exchanges worldwide during the period 2000–2014. In addition to the empirical evidence, we use a Monte Carlo simulation to demonstrate that by taking into account the information on time-varying risk premiums and conditional heteroscedasticity the proposed test minimizes the potential estimation biases of the conventional approaches documented in Hodrick and Srivastava (1986) and Brenner and Kroner (1995). Thus, the robustness of the proposed test under varying market conditions is well demonstrated in this paper. Our focus on the commodity futures market in this study is due to two reasons. First, the presence of a risk premium is more prominent in commodity futures due to the existence of spot premia and term premia (Szymanowska et al., 2014). As such, commodity futures markets provide an excellent platform for demonstrating the effectiveness of the proposed test. Second, the commodity futures markets have emerged as a popular asset class in many financial institutions since 2000. According to the Futures Industry Association, the volume of commodity futures traded worldwide in 2012 represents 29% of the total futures trading. Moreover, during the period from 2007 to 2016, the number of contracts traded in the agricultural, energy and non-precious metals categories has risen from 1.16 billion to 5.77 billion depicting a remarkable growth in commodity investments. Hence, a proper understanding of the efficiency of commodity futures markets and their risk premiums is vital, as they could impact, for example, the hedging decisions of companies and the investment decisions of financial institutions.

This study contributes to the strand of literature on testing market efficiency in several ways. First, we propose a new test for testing market efficiency in the presence of a time-varying risk premium and conditional heteroscedasticity of spot prices. We document that the power of the proposed efficiency test is improved due to the underlying assumptions and hence more accurate and informative investment decisions could be made by the investors. Second, we perform a comprehensive analysis of the market efficiency of 79 commodity futures traded globally during the period 2000–2014. Empirical results show that the market efficiency and the size of the risk premium vary significantly not only across individual commodities but also among major market sectors. Our findings based on such a large sample of commodities will help the policy makers to clearly understand how the commodity market behaves and how the macroeconomic changes affect the market. Third, we investigate the impact of the global financial crisis (GFC) in 2008 on commodity futures market efficiency and its risk premiums. We find that, apart from short-term deviations during the crisis period, the GFC has not made any significant permanent impact on the market efficiency and risk premiums of commodity futures. Fourth, using a Monte Carlo simulation, we demonstrate that the proposed test produces superior and robust results under varying market conditions compared with the conventional approaches with restrictions on the risk premiums.

The rest of the paper is organized as follows. Section 2 discusses conventional market efficiency tests and introduces the proposed market efficiency test. Section 2 examines the market efficiency and risk premiums of 79 commodities using the proposed test. In Section 3, the proposed test is compared with conventional approaches empirically to demonstrate the effect of time-varying risk premiums and heteroscedasticity assumptions on the market efficiency tests. Section 4 is devoted to a simulation study where we numerically investigate the sensitivity of the risk premium and heteroscedasticity assumptions on the performance of the proposed test compared with the conventional tests under varying market conditions. Section 5 concludes the paper.

2. Testing futures market efficiency

Under the assumption of risk neutrality, the conventional market efficiency tests assume that the current futures price is an unbiased predictor of the future spot price at maturity; that is, these tests are based on the relationship in (1) which does not have a risk premium component.

$$E_\delta[S(t_i)] = F\left(t_i^\delta\right) \tag{1}$$

Here, $F(t_i^\delta)$ is the futures price of contract i $(i = 1, 2, 3, \ldots, N)$ of a commodity on δ days prior to the maturity day (t_i), while $S(t_i)$ is the spot price of the underlying commodity at maturity. $N$is the number of futures contracts (or number of maturity cycles) of the commodity during the sample period. $E_\delta[S(t_i)]$ is the market expectation of $S(t_i)$ δ days prior to the maturity of a contract, conditional on the information set at time t_i^δ.

Consistent with our motivation in this study, Hodrick and Srivastava (1986) theoretically argue that the relationship in equation (1) does not hold when the stochastic behaviour of spot and futures prices is considered, suggesting the incorporation of a risk premium component in (1). The authors also document that the rejection of the unbiasedness hypothesis does not necessitate a rejection of market efficiency due to the fact that the risk premium can cause the futures prices to deviate from the expected future spot prices. Furthermore, in reality, market participants are not necessarily risk neutral and hence markets do have a risk premium. These findings imply that a continuous form equilibrium relationship between the expected future spot price and the current futures price, as in equation (2), should hold. That is, the phenomenon, known as the rational expectation model (see Hull (2008), p. 119) illustrated in (2), must hold for an efficient futures market in the presence of a risk premium.

$$E_\delta[S(t_i)] = F\left(t_i^\delta\right)e^{\pi\left(t_i^\delta\right)} \tag{2}$$

Here, $\pi(t_i^\delta)$ is the $\delta-$day risk premium for a contract i at time t_i^δ that is sufficiently large enough to yield a competitive expected return to holding inventory. Our proposed efficiency test is based on the rational expectation model in (2) instead of (1), which allows the risk premium, $\pi(t_i^\delta)$, to vary across successive term structures.

2.1. Conventional futures market efficiency tests

The conventional tests of futures market efficiency briefly mentioned in Section 1 test the expectation relationship in equation (1) commonly referred to as the unbiasedness hypothesis under the risk neural assumption. One class of such conventional tests assumes a constant risk premium. For instance, Bilson (1981) introduces a test of futures (forward) market efficiency using a change-regression model such that $s(t_i) - s(t_i^\delta) = \beta_0 + \beta_1[f(t_i^\delta) - s(t_i^\delta)] + \varepsilon_\delta(t_i)$. Here, $f(t_i^\delta)$ and $s(t_i^\delta)$ are the log of futures $(F(t_i^\delta))$ and spot $(S(t_i^\delta))$ prices, respectively, at time t_i^δ, and $s(t_i)$ is the log of spot price on the maturity day, t_i. The unbiasedness hypothesis is implied by testing for the joint hypothesis, $\beta_0 = 0$, $\beta_1 = 1$, and non-existence of serial correlation in $\varepsilon_\delta(t_i)$. Since then, the same model has been used in the market efficiency literature, such as Hodrick and Srivastava (1986), Barnhart and Szakmary (1991), Serletis (1991), Switzer and El-Khoury (2007) and many others. Most of these studies find evidence against the unbiasedness hypothesis and also result in negative estimates for β_1 in most cases. Brenner and Kroner (1995) provide theoretical evidence for observing such negative values for β_1 by using the cointegration theory of Engle and Granger (1987).

Another class of market efficiency tests that has become popular in the literature argues that if the future spot and current futures prices have a stochastic trend, then a necessary condition for the unbiasedness hypothesis to hold is to have a cointegration relationship between $s(t_i)$ and $f(t_i^\delta)$ with a cointegrating vector (1, −1). Thus, the cointegrating regression, $s(t_i) = \beta_0 + \beta_1 f(t_i^\delta) + \varepsilon_\delta(t_i)$, should satisfy the joint restriction,