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Size and power of tests based on Permanent-Transitory Component Models☆

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ABSTRACT

The literature has recently proposed a new type of tests for the Efficient Market Hypothesis based on Permanent-Transitory Component Models. We compare the power of these statistics with conventional tests based on linear regressions. Simulation results suggest that the former dominate the latter for a wide range of data generating processes. We propose an application to spot and forward interest rates. Empirical results show that the two types of tests can yield conflicting results which can be explained by the size distortions and reduced power which affect the statistics based on linear regressions.

1. Introduction

A large number of studies builds on the idea that the price of financial securities is driven by a common stochastic trend - which can be thought of as the fundamental value - and transient disequilibrium terms. For instance, Campbell and Shiller (1987) emphasize how there is only one non-stationary common driving force which can be interpreted as something exogenous to the system of the term structure.[1] The presence of common stochastic trends in financial securities has been traditionally modelled through the concept of co-integration.[2] This last has become a convenient frame within which tests for the Efficient Market Hypothesis (EMH) can be carried out. For instance, considering forward and spot rates, the EMH is evaluated by estimating linear regressions between levels of the two rates (levels regressions), or between excess forward returns and forward premia (forward-spot regressions), and by testing that the parameter attached to the regressor is equal, respectively, to one and zero (see, e.g., Cuthberson, 1996; Fama & Bliss, 1987). However, a well-known limitation of these approaches is that - being the EMH a joint hypothesis of rational expectation (RE) and constant term premia (TP) - they cannot decompose the relative contribution of the two factors to the invalidation of the hypothesis. Moreover, the presence of serial correlation in the disturbance term of levels regressions may induce estimation bias and invalidate asymptotic inference (see Li & Maddala, 1997).

Recently, an important strand of research has documented the presence of different forms of non-linearities in interest rate movements, and shown that these last can affect the finite sample performances of tests for the EMH.[3] For instance, Clarida, Sarno, Taylor, and Valente (2006), and Bansal and Zhou (2002) use different tests for EMH and document how their outcome depends on the ability of empirical models to properly detect regime shifts in interest rates series, thus suggesting that the presence of these last might be an important source of misspecification. Popular modelling strategies were to enable regime shifts in specific parameters featuring univariate or multivariate models with error correction, as well as in the parameters governing the term premia component or conditional volatility. Regime shifts, in turn, have been traditionally modelled through Markov-switching processes - therefore enabling

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[1] Similarly, in Mussa's (1982) sticky-price model exchange rates are represented as a combination of fundamental and transient disequilibrium terms.

[2] See Granger (1986) for a comprehensive coverage of the topic.

[3] Non-linear dynamics can be induced by factors such as business cycle expansions and contractions, asymmetric transaction costs or infrequent trading.

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for multiple switchings - or single structural breaks (see, e.g. Gray (1996) and Brooks and Rew (2002)).

In the last decade, a number of scholars has modelled co-integration by following an alternative approach based on Permanent-Transitory Component Models (PTCMs). For instance, Iyer (2000) applies PTCMs to spot and forward interest rates whereas Hai, Mark, and Wu (1997) use the same modelling strategy to study the forward discount bias in foreign exchange markets. Recently, Casalin (2013) has proposed a PTCMs representation of spot and forward rates which makes it possible the identification of specific restrictions for the EMH and rational expectations which can be tested by means of standard Likelihood Ratio (LR) statistics. By making use of the moving average representation of spot and forward rates, the author shows that the above statistics are linked to conventional tests based on levels and forward-spot regressions.

This paper aims to advance the understanding of the finite sample properties of the LR statistics based on PTCMs by comparing their power with that of conventional tests based on linear regressions. We carry out the empirical analysis for a large spectrum of data-generating processes (DGPs) featuring normal disturbance terms, volatility clustering, misspecification of term premia, multiple regime shifts, and integrated versus near-integrated series for forward and spot rates. Empirical results suggest that LR tests for the null of EMH present approximately correct size and stronger power than their counterparts based on forward-spot and levels regressions. Moreover, conventional tests based on levels regressions are affected by size distortions which lead to over rejections of the null. All in all, our simulation exercises suggest that LR statistics based on PTCMs perform better than conventional tests based on linear regressions over a wide range of DGPs. The power of the above statistics tend to weaken for DGPs that depart from the benchmark case of normal disturbance terms. More specifically, the presence of near-integrated series as well as misspecified term premia are the two elements with the strongest power reducing effect, whereas both volatility clustering and regime shifts present negligible impacts. We propose an application of the above tests to series for three-month Eurodollar and Sterling Libor spot and forward interest rates. When applied to the two datasets, the tests for EMH agree in rejecting the null at standard significance levels. Similarly, tests for rational expectations consistently reject the null when applied to Sterling series. However, the same tests deliver inconsistent results when applied to Eurodollar series. More specifically, conventional tests based on linear regressions soundly reject the null of rational expectations, whereas statistics based on PTCMs fail to reject the same null at the 10% level. The conflict between the two competing tests can be resolved by recurring to our simulation results which show that, conditional on the data-generating process which characterizes spot and forward series, the former is affected by significant size distortions whereas the latter presents approximately correct size and stronger power.

The rest of the paper is organized as follows. Section 2 sets out the baseline relationship on which tests based on PTCMs are built, and it highlights the link between these last and conventional tests based on linear regressions. Section 3 illustrates the design of the simulation experiments. Section 4 compares size and power of tests based on PTCMs with their counterparts based on linear regressions. Section 5 checks the robustness of the above results when spot and forward rates evolve as stationary highly persistent processes. Section 6 proposes an application of the above tests to actual data. Section 7 concludes the paper.

2. Tests based on linear regressions and PTCMs

Defining $S_m(t)$ the m-period spot rate and $F_i^{i+m}(t)$ the m-period futures rate, i.e. the rate at trade date t prevailing between periods $(t+i)$ and $(t+i+m)$, we can specify the baseline relationships for spot and forward rates as follows:

$$F_i^{i+m}(t) = E_t[S_m(t+i)] + \varpi + \gamma(t) \tag{1}$$

$$S_m(t+i) = E_t[S_m(t+i)] + e_{S_m}(t+i) \tag{2}$$

where $E_t[S_m(t+i)]$ denotes the expected spot rate at time t, ϖ and $\gamma(t)$ denote the constant and time-varying component of the term premium and $e_{S_m}(t+i)$ is a random forecast error orthogonal to the information set available at time t.[4] Conventional tests based on linear regressions can be constructed by estimating the following two relationships:

$$F_i^{i+m}(t) - S_m(t+i) = \alpha_0 + \beta_0\left[F_i^{i+m}(t) - S_m(t)\right] + e(t+i) \tag{3}$$

$$F_i^{i+m}(t) = \alpha_1 + \beta_1 S_m(t+i) + \xi(t+i) \tag{4}$$

where the validity of the EMH implies $\beta_0 = 0$ and $\beta_1 = 1$. The above restrictions are tested through the statistics $t_0 = \hat{\beta}_0/se\left(\hat{\beta}_0\right)$ and $t_1 = \left(\hat{\beta}_1 - 1\right)/se\left(\hat{\beta}_1\right)$.

Tests based on PTCMs exploit Stock and Watson's (1993) observation that co-integrated variables can be expressed as a linear combination of I(1) common stochastic trends and I(0) components. By applying this result to spot and forward rates, it becomes possible to write:

$$F_i^{i+m}(t) = \mu_{F_i^{i+m}}(t) + x_{F_i^{i+m}}(t), \qquad \mu_{F_i^{i+m}}(t) = \mu_{F_i^{i+m}}(t-1) + \epsilon_{F_i^{i+m}}(t) \tag{5}$$

$$E_t[S_m(t+i)] = \mu_{S_m}(t), \qquad \mu_{S_m}(t) = \mu_{S_m}(t-1) + \epsilon_{S_m}(t) \tag{6}$$

where $\mu_{F_i^{i+m}}(t)$ and $\mu_{S_m}(t)$ are random walk processes, $\epsilon_{F_i^{i+m}}(t)$ and $\epsilon_{S_m}(t)$ are independently distributed white noise disturbances and $x_{F_i^{i+m}}(t)$ is a transient deviation from the stochastic trend.[5] By using Eqs. (2) and (6) to specify the observable spot rate at time $(t+i)$ and assuming co-integration, spot and forward rates can be specified as follows:

$$F_i^{i+m}(t) = k_{2,1}\cdot\mu^*(t) + x_{F_i^{i+m}}(t) \tag{7}$$

$$S_m(t+i) = \mu^*(t) + e_{S_m}(t+i) \tag{8}$$

$$\mu^*(t) = \mu^*(t-1) + \epsilon(t) \tag{9}$$

where $k_{2,1}$ is a constant parameter, $\epsilon(t) \sim \text{iid } N\left(0,\sigma_\mu^2\right)$ and $e_{S_m}(t+i) \sim \text{iid } N\left(0,\sigma_S^2\right)$. Eqs. (7)–(9) are the PTCMs representation of spot and forward rates. This last shows that the two rates are driven by the same stochastic trend $\mu^*(t)$, a stationary "*omnibus*" term modelled by $x_{F_i^{i+m}}(t)$, and a forecast error $e_{S_m}(t+i)$ which encompasses all the residual forces which affect the two rates.

The rational expectations leg of the EMH is modelled through the parameter $k_{2,1}$. More specifically, when $k_{2,1}$ equals 1, then expectations are formed "correctly", i.e. the forward rate at time t will match, in conditional expectations, the future spot rate. In this case, any difference between the two rates is driven by a term premium plus a

[4] For series of spot and forward rates in stock, foreign exchange and commodity markets m is set equal to 1, whereas for series in bond markets $m \geq 1$.

[5] In line with Stock and Watson (1993), no restrictions are imposed on the stochastic properties of $x_{F_i^{i+m}}(t)$ beyond being ARMA stationary.