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Rethinking cointegration and the expectation hypothesis of the term structure

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ABSTRACT

Empirical investigations of the expectations hypothesis of the term structure often test the stationarity on the yield spread. We show that as the term difference increases this stationarity breaks down even under the most favorable assumption with regard to the risk premium. As a result, these cointegration tests are inappropriate. We conduct Monte Carlo simulations and provide empirical evidences that the frequency with which the data fail to reject no cointegration increases as the term difference increases. This finding remains robust after we account for a proxy for risk premium, asymmetries, and employ a new augmented error correction model that allows for time-varying error correction terms.

1. Introduction

In this paper, we raise doubts that cointegration tests are an appropriate test of the expectations hypothesis (EH) of the term structure, even if the term risk premium is constant. Hall et al. (1992) showed that the EH implied that the term yield spread is the sum of stationary series, and so is itself a stationary series. If yields are integrated of order one I(1), then cointegration between long and short term rates is a testable implication of the EH. We show that although stationarity holds for finite term differences, the yield spread converges to a non-stationary process as the term difference goes to infinity even under the most favorable circumstances.

This result makes the evaluation of the EH using cointegration tests or tests that impose a stationary restriction on the yield spread problematic when the term difference is large. In particular, as the term difference increases, the EH implies that it will be increasingly more difficult to find evidence of cointegration between long and short term rates. This result provides an explanation of earlier work that often found cointegration for shorter term differences, but not for longer term differences, see, for example, Hall et al. (1992), Campbell and Shiller (1991), Anderson (1997), Tzavalis and Wickens (1997), and Sarno and Thornton (2003).

The empirical failure of the EH for longer term differences is troubling for a number of reasons.[1] Perhaps most importantly, the traditional transmission mechanism of monetary policy relies upon the effect of a change in short term rates flowing to spending through its effect on long term rates. Moreover, the connection between expectations and long term yields is an essential element of forward guidance.[2] If this mechanism is incorrect or unreliable, the use and effectiveness of monetary policy must be reconsidered. However, we do not claim to rehabilitate the EH as a reliable link between long and short term rates. Indeed, we find that at the one year term difference the failure to reject no cointegration rates are relatively high. Instead, we argue that care must be taken in interpreting these negative results since they are, in principle, consistent with the EH.

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[1] Understanding the term structure is also important in portfolio analysis and in forecasting. See, for example, Ang et al. (2006) and Campbell and Viceira (2005).

[2] See, for example, Blinder et al. (2008) or Ben Bernanke's 2012 Jackson Hole speech.

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The key empirical question is when does the term difference, m, become sufficiently large for the data to be unable to distinguish between a stationary and non-stationary process. We address this question directly through Monte Carlo simulations in which the data are generated according to the weakest form of the EH, but without the risk premium. The simulations clarify the important elements that determine length of the term spread at which nonstationarity appears.

We next test the prediction that it will be increasingly more difficult to find evidence of cointegration between long and short term rates as the term difference increases. We test for cointegration using standard linear test and threshold tests, and also by estimating the speed of adjustment coefficient in an error correction model. If the speed of adjustment parameter is not significantly different than zero, the model fails to provide support for cointegration. The results of these empirical exercises support the conclusion that the link between the long term and short term rates weakens rather rapidly as the term difference in maturity rises.

Finally we relax the strong assumption that the risk premium is constant, and assume that it may be non-stationary. In this case, the term spread is not necessarily stationary even for finite m. Nevertheless, stationarity is still possible, if the risk premium and interest rates are cointegrated. However, there is no longer the presumption that the cointegrating vector of yields will be $(1, -1)$. We examine this question with traditional tools, and propose an error correction model that allows the term spread to be the appropriate error in one regime, and a more general error term to be appropriate in the other regime. We continue to find evidence that an increase in the term difference makes it less likely to find support for cointegration.[3]

The contribution of this paper is mainly statistical—we try to reconcile previous seemingly unfavorable empirical findings with the EH theory, and our findings suggest that statistical tools other than cointegration tests are needed for purposes of testing the EH. The only "economics" contribution is that we prove that the EH indicates increasingly weak link between long and short term interest rates as the term difference rises. Nevertheless, this result has strong implications on the monetary policy and financial management. Readers may keep this in mind when evaluating the significance of this work.

2. Expectation hypothesis

In this section, we establish and discuss our key theoretical finding which we refer to as the Limiting Proposition. We begin with a well-known implication of the EH.[4] Formally, let $i_{s,t}$ be the continuously compounded yield to maturity of an s-period pure discount bond at time t. The weakest form of the EH can be written as

$$i_{m,t} - i_{1,t} = \frac{1}{m}\left[\sum_{s=1}^{m-1}\sum_{j=1}^{s} E_t \Delta i_{1,t+j}\right] + r_{m,t}, \tag{1}$$

where E_t denotes the expectation conditional on the information at time t, and $r_{m,t}$ represents the risk premium on an m-period bond at time t.[5]

Eq. (1) embodies a strong prediction. If yields are integrated of order one, and the risk premium is stationary, then the term spread should be stationary; or, equivalently, the m-period yield and the one-period yield should be cointegrated with the cointegrating vector $(1, -1)$. This strong prediction has received at best mixed results in the empirical literature.[6]

It may fail, broadly speaking, for two reasons. First, the risk premium may vary over time, involve important non-linearities, or be itself non-stationary. Engle et al. (1987) and Clarida et al. (2006) address this case by allowing for a more general risk premium. The second possibility, which has not, to our knowledge, been discussed in literature, arises from the double summation in Eq. (1). This double summation implies that as m becomes large the spread, $i_{m,t} - i_{1,t}$, behaves like an integrated or nonstationary process. In a single summation of stationary terms, the law of large number implies that multiplying the sum by $\frac{1}{m}$ yields stationarity. However, in the double summations $\frac{1}{m}$ does not decay to zero with sufficient speed, the necessary scalar for stationarity is instead $\frac{1}{m^{3/2}}$, and the spread becomes non-stationary when m goes to infinity.

To see more easily the role of the double summation, first consider the single summation of m constant terms

$$\frac{1}{m}\sum_{s=1}^{m} c = c, \tag{2}$$

which is finite, meaning that the scalar $1/m$ works. Next consider the double summation with the same scalar

$$\frac{1}{m}\sum_{s=1}^{m-1}\sum_{j=1}^{s} c = \frac{1}{m}[c + (c + c) + \cdots (c + c + \cdots + c)] \tag{3}$$

$$= \frac{c}{m}[1 + 2 + \cdots + (m-1)] \tag{4}$$

$$= \frac{m(m-1)c}{2m}. \tag{5}$$

[3] Our work here follows the work of Enders and Siklos (2001), and Clarida et al. (2006).

[4] EH has multiple implications. For instance, Shiller (1979) and Campbell and Shiller (1991) test EH from a non-cointegration perspective.

[5] Please see Eqs. (1), (2), (3) and (4) in Hall et al. (1992) for detailed derivation. Basically, the Fisher–Hicks formulae state that the long term yield is the average of forward rates, and the forward rate is related to the expected future short term rate. For a particularly clear explanation see the discussion in Clarida et al. (2006).

[6] For some positive evidence for relatively short term differences, see Clarida et al. (2006). For negative evidence on the non-stationarity of yields and the EH, see Sarno et al. (2007).