Testing for multiple-period predictability between serially dependent time series

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A B S T R A C T
This paper reports the results of a simulation study that considers the finite-sample performances of a range of approaches for testing multiple-period predictability between two potentially serially correlated time series. In many empirically relevant situations, but not all, most of the test statistics considered are significantly oversized. In contrast, both an analytical approach proposed in this paper and a bootstrap are found to have accurate empirical sizes. In a small number of cases, the bootstrap is found to have a superior power. The test procedures considered are applied to an empirical analysis of the predictive power of a Phillips curve model during the 'great moderation' period, which illustrates the practical importance of using test statistics with accurate empirical sizes.

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1. Introduction

Tests of multiple-period-ahead predictability are complicated by the fact that the prediction errors necessarily have a moving average structure, due to the overlap of successive prediction periods. In a theoretically ideal large sample setting, this does not present any problem for applied researchers, since there exist many covariance matrix estimators that are consistent in the presence of this type of autocorrelation. However, for samples of the sort of magnitudes that are encountered most frequently in economics, test statistics constructed using many of the well-known alternative heteroscedasticity and autocorrelation consistent (HAC) covariance estimators may be severely oversized. While this issue has received some attention in the literature (see Ang & Bekaert, 2007; Hodrick, 1992; Kilian, 1999; Nelson & Kim, 1993; Richardson & Smith, 1991; Smith & Yadav, 1996; Wei & Wright, 2009), the context has often been the prediction of asset returns, and so the null model has usually been a martingale difference sequence (MDS). Consequently, while this body of literature has found evidence of significant size distortions when using well-known techniques for dealing with autocorrelation, and has suggested some superior methods, these methods are not usually directly applicable to cases in which the predicted variable is serially correlated under the null, as would be expected for macroeconomic series and many other applications of interest. Previous work that has considered a serially correlated predicted variable includes that of Lütkepohl and Burda (1997), who consider the Wald test in the context of a vector autoregression (VAR); Dufour, Pelletier, and Renault (2006), who use a parametric bootstrap to circumvent the technical difficulties of the Wald test; Pesaran, Pick, and Timmermann (2011), who pool non-overlapping regressions and propose a SURE estimator for a factor-augmented VAR; and Britten-Jones, Neuberger, and Nolte (2011), who propose a transformation to account for the serial correlation induced by the construction of the overlapping dependent variable, and deal with serial correlation in the variable from which it is constructed using the Newey–West estimator.

In this paper, the covariance estimator that was proposed by Hodrick (1992) for the multiple-period prediction
regression of a variable that is an MDS under the null is
generalized to cover cases in which the predicted variable
is serially correlated. A simulation study is then conducted
that compares the small-sample performance of a test for
multiple-period predictability based on this estimator to
those of a selection of other approaches that might be con-
sidered by applied researchers. The simulation study con-
siders a range of prediction horizons, sample sizes, and
degrees of serial correlation in both the predictor and pre-
dicted variables, and the results provide clear guidance for
researchers who are interested in testing multiple-period
predictability.

West (1997) also proposed a generalization of the Hod-
rick (1992) estimator for dealing with regression models
with moving average errors. However, his approach dif-
fers from that proposed in this paper. Furthermore, the
simulation study reported in West’s paper considers only
moving average orders of one and two, which is of lit-
tle interest for applications in which predictions are be-
ning made more than three periods ahead. Other authors
have reported simulation studies that consider longer hori-
zons for test statistics based on different estimators. Sim-
ulation studies by Ang and Bekaert (2007), Britten-Jones
et al. (2011), Dufouf et al. (2006), and Smith and Ya-
dav (1996) found the kernel-based estimators of Andrews
(1991) and Newey and West (1987) to provide test statis-
tics for multiple-period predictability that are significantly
oversized. Smith and Yadav (1996) found that the statis-
tics were still oversized when the prewhitening procedure
of Andrews and Monahan (1992) was used. Similar results
were found for the Hansen and Hodrick (1980) estimator
by Ang and Bekaert (2007) and Smith and Yadav (1996).
In contrast, Dufouf et al. (2006) and Kilian (1999) found that
a bootstrapped statistic may have an accurate empirical size,
and Ang and Bekaert (2007) found a similar result for the

The simulation study reported in this paper extends this
literature in several ways. Firstly, in contrast to the studies
by Ang and Bekaert (2007) and Smith and Yadav (1996),
this study considers serial correlation in the predicted vari-
able, and, in contrast to Britten-Jones et al. (2011) and
Dufouf et al. (2006), a range of different strengths of this
correlation are considered. Like Smith and Yadav (1996), I
consider different strengths of the serial correlation in the
predictor variable. Secondly, the present study considers a
wider range of prediction horizons and sample sizes than
has been considered in previous studies. Thirdly, this study
considers nine different alternative test procedures, in con-
trast to the studies by Ang and Bekaert (2007), Dufouf et al.
(2006) and Smith and Yadav (1996), which consider seven,
three and two, respectively. As a consequence, it provides a
comparison of a wide range of test statistics within a single
study design.

The remainder of this paper is structured as follows. In
Section 2, the generalization of the Hodrick (1992) covari-
ance estimator is derived, and compared to the alternative
generalization due to West (1997). In Section 3, the Monte
Carlo simulations are presented. Section 4 presents a brief
application of all of the test procedures considered to the
question of whether an expectations-augmented Phillips
curve model was able to predict inflation over horizons of
four to 12 quarters during the ‘great moderation’ period be-
tween the 1980s and the start of the financial crisis in 2008.
Section 5 provides some concluding comments.

2. The estimator and test statistic

Suppose that we wish to test the null hypothesis that a
vector \( w_t \) does not predict the change in a scalar variable
\( y_t \) over \( h \) time periods. Let \( y_t^{(1)} = y_{t+1} - y_t \) be an observ-
able variable. The change in \( y_t \) over \( h \) time periods is then
\( y_t^{(h)} = \sum_{k=0}^{h-1} y_{t+k}^{(1)} \). It is assumed that, under the null hy-
thesis, \( y_t^{(1)} \) may be approximated well by a stable, finite-
derived autoregression

\[
y_t^{(1)} = \beta_0 + \sum_{j=1}^{p} \beta_j y_{t-j}^{(1)} + \varepsilon_{t+1}, \quad t = p + 1, \ldots, T - 1. (1)
\]

The technical assumptions for what follows are that (under
the null hypothesis) \( E(\varepsilon_{t+1} | \mathcal{F}_t) = 0 \), where \( \mathcal{F}_t =
\sigma(\varepsilon_t, w_t, \varepsilon_{t-1}, w_{t-1}, \ldots) \); that the fourth moments
of \( \varepsilon_t \) and \( w_t \) are finite; and that the characteristic roots
of Eq. (1) lie outside the unit circle. Autoregressions are used widely
in applied prediction problems, often quite successfully.
Nonetheless, not all economic variables can be represented
adequately by an autoregression. The working assumption
made in this paper is that a stable, finite-order autore-
gression approximates the process of interest sufficiently
well to provide errors that, at most, differ from an MDS
only negligibly. Standard statistical tools exist for estima-
ting the order and assessing the fit of an autoregression,
and these should be applied prior to the application of the
procedures proposed in this paper.

What follows may be understood more easily by first
considering a simple special case. Set the order \( p \) in
Eq. (1) to one, set \( \beta_0 = 0 \), and set the prediction horizon \( h \)
to two. Since \( y_t^{(2)} = y_t^{(1)} + y_t^{(1)} \), it is simple to show that

\[
y_t^{(2)} = \beta y_{t-1}^{(1)} + \eta_t, \quad \text{where } \eta_t = (\beta + 1)\varepsilon_{t+1} + \varepsilon_{t+2} + b = \beta(1 + \beta).
\]

Let \( \hat{b} \) be the OLS estimator of \( b \). Then

\[
T(\hat{b} - b)^2 = S_T \left\{ \frac{1}{T} \sum_{t=2}^{T-2} y_{t-1}^{(1)} \right\}.
\]

and the estimation of the variance of \( \hat{b} \) requires the con-
struction of an estimator of \( E(S_T) \). This task is the main
topic of the present paper. Popular approaches include
the kernel-based estimators of Andrews (1991), Andrews
and Monahan (1992) and Newey and West (1987). The new
approach proposed here is related to, but distinct from, the
approach taken by West (1997). Let

\[
g_t = \varepsilon_{t+1}((\beta + 1)y_{t-1}^{(1)} + y_{t-2}^{(1)})
\]
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