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19 March 2011

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Preliminary draft: Not for publication

Abstract

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It is well established that regression analysis on non-stationary time series data may yield spurious results. An earlier response to this problem was to run regression with first difference of variables. But this transformation destroys any long-run information embodied in the levels of variables. According to 'Granger Representation Theorem' (Engle and Granger, 1987) if variables are co-integrated, there exist an error correction mechanism which incorporates long run information in modeling changes in variables. This mechanism employs an additional lag value of the disequilibrium error as an additional variable in modeling changes in variables. It has been argued that ECM performs better for long run forecast than a simple first difference or level regression. This process contributes to the literature in two important ways. Firstly empirical evidence does not exist on the relative merits of ECM arrived at using alternative co-integration techniques. The three popular co-integration procedures considered are the Engle-Granger (1987) two step procedure, the Johansen (1988) multivariate system based technique and the recently developed Autoregressive Distributed Lag based technique of Pesaran et al. (1996, 2001). Secondly, earlier studies on the forecasting performance of the ECM employed macroeconomic data on developed economies i.e. the US and the UK. By employing data form the Asian countries and using absolute version of the purchasing power parity and money demand function this paper compares forecast accuracy of the three alternative error correction models in forecasting the nominal exchange rate and monetary aggregate (M2).

1. Introduction:

The Granger Representation Theorem (Engle and Granger, 1987) enables simultaneous modeling of first difference and the levels of the variables using an error correction mechanism which provides the framework for estimation, forecasting and testing of co-integrated systems. If X_t and Y_t are individually I(1) variables are co-integrated with cointegration vector $(1, -\beta_0, -\beta_1)$ the general form of the ECM can be expressed as

$$A(L)\Delta Y_t = \delta + B(L)\Delta X_t + \alpha\,(Y_{t-1} - \beta_0 - \beta_1 X_{t-1}) + u_t \tag{1}$$

with the lag polynomials

$$A(L) = 1 - a_1 L - a_2 L^2 - \ldots - a_p L^p \,;\, B(L) = b_0 + b_1 L + b_2 L^2 + \ldots + b_q L^q$$

where the lag operator is defined as $L^i Y_t = Y_{t-i}$. In this model the coefficients in the A(L) and B(L) represent the impact of short changes while the long run effects are given by the co-integration vector $(1, -\beta_0, -\beta_1)$ and the α controls the speed of adjustment short run changes towards long run path.

As co-integration and ECM provides a unified framework of molding both long and short run an interesting question for researcher was whether incorporating the long-run restriction in an error correction models yields superiors forecast in comparison with pure first difference models which do not impose co-integration restrictions. On a theoretical ground co-integration is expected to yield better forecast as pointed by Stock (1995, p-1) who asserts that "If variables are co-integrated, their values are linked over the long run, and imposing this information can produce substantial improvements in forecast over long horizons". This assertion is based on theoretical results by Engle and Yoo (1986)

that long horizon forecasts from the co-integrated systems satisfy the co-integration relationship exactly and that the cointegration combination of variables can be forecast with finite long-horizon forecast error variance.

A simulation study by Engle and Yoo (1987) shows that the two step EG ECM provide better forecast compared to unrestricted VAR particularly at longer horizons while the similar simulation study by Chambers(1993) further corroborated this result using a non-linear one-step ECM. Using the same experimental set up as Engle and Yoo, Clements and Hendry (1995) find that over-differencing the system results in inferior forecasting performance. In a simulation study using a four-dimensional VAR(2) Reinsel and Ahn (1992) show that forecast gains from co-integrated system depends on proper specification of the number of unit roots and under specifying the number of unit roots results in poor performance for ten to twenty five steps ahead forecasts whereas over-specification results in inferior short-term forecasts

After the pioneering two-step estimator of the ECM parameters proposed by Engle and Granger (1987) several ECM techniques have been developed. The Engle-Granger technique can identify only a single equilibrium relationship among the variables under study. Johansen (1988) proposed a frame work of estimation and testing of vector error correction model (VECM) based on vector auto regression (VAR) equations. The VECM can be expressed as:

$$\Delta Y_t = \Pi Y_{t-1} + \sum_{j=1}^{p} \Gamma_j Y_{t-j} + u_t \tag{2}$$

The Π is an $m \times m$ matrix containing the long-run parameters. If there are r co-integration vectors then Π can be expressed as a product of tow matrices as $\Pi = \alpha\beta'$ wher both α and β are $m \times r$ matrices. The matrix β contains the coefficients of long-run relationship and the α contains the speed of adjustment parameters which is also interpreted as the weight with which each co-integration vectors appears in a given equation.

This approach can accommodate multiple equilibrium relationships in the VECM. Both of these estimation techniques assume that the variables to be modeled are I(1). Recently Pesaran, Shin and Smith (1996) and Pesarn (2001) proposed a techniques based on Autoregressive Distributed Lag (ARDL) model which allows both I(0) and I(1) variables thus potentially avoids pre-test bias. In the literature some studies have compared forecast ability of the ECM resulting from the Engle-Granger and the Johansen VECM technique. However the literature does not provide empirical evidence regarding the forecast accuracy of the ARDL based ECM and its comparison with EG and Johansen techniques. In addition, most of the empirical evidence employing real data in forecast comparison comes from the developed economies. This study provides empirical evidence of forecasting performance of the ECM resulting from the three techniques from Asian countries.

2. The Literature

Hoffman and Rasche (1996) compared the forecast performance of a cointegrated system relative to the forecast performance of a comparable VAR that fails to recognize that the system is characterized by cointegration. They considered cointegrated system composing three vectors, a money demand representation, a Fisher equation, and a risk

premium captured by an interest rate differential. The data were from the US economy. They found that the advantage in imposing co-ingratiation appears only at loner forecast horizon and this is also sensitive to the appropriate data transformation. They considered 8 years out-sample forecast horizon.

Jansen and Wang (2006) investigated the forecasting performance of the Error Correction model arising from the co-integrating relationship between the equity yield on the S&P 500 and the bond yield relative to that of univariate models. They found that the Fed Model improves on the univariate model for longer-horizon forecasts, and the nonlinear vector error correction model performs even better than its linear version. The forecast horizon they considered was 10 years.

Wang and Bessler (2004) employed five US agriculture time series. They used annual data from 1867 to 1966 for model specification and data for 1966 to 2000 were used for out-of sample forecast evaluation. Their results favored ECM for three to four steps ahead forecasts. However the differences in forecast obtained from different models were not statistically significant.

Lin and Tsay (1996) considered both simulated and financial and macroeconomic real data from the UK, Canada, Germany, France and Japan and interest rate data from the US and Taiwan. Their results are contradictory as the simulated data yield better forecast fro the ECM whereas for real data the performance of ECM is mixed. They attribute this contradiction to deficiency in forecast error measure which does not recognize that forecast are tied together in the long-run.

This brief literature review indicates that at best the results on relative merit of imposing co-integration constraint are mixed. If there is some advantage on using ECM it occurs at

longer horizon. An important observation from this review is that very few studies employ data from the less developed economies such as East and South Asian economies. Also no study has yet considered forecasting performance of the newly developed ARDL based co-integration. It has been argued that ARDL has important advantages over the Engle-Granger and Johansen approaches. Firstly it can be applied irrespective of whether underlying repressors are I(0) or I(1). Secondly in simulation studies it performs better than EG and Johansen co-integration test in small samples. Thirdly appropriate modification of the orders of the ARDL model is sufficient to simultaneously correct for residual serial correlation and the problem of endogenous variables.

3. The data and the models

The economic models we considered are the Purchasing Power Parity and the money demand function. The absolute PPP states that exchange rate between two currencies adjust to remove any arbitrage opportunities (buy in a low price market and sell with a profit in a high price market). If PPP holds then in the long run exchange rate equals ratio of prices in the two economies. i.e. the intercept equals zero and slope equals 1 in the equation: $\log(e)_t = \beta_0 + \beta_1 \log(CPI\ Ratio)_t + u_t$ (3)

Secondly we considered demand of real money balances depends positively on transaction volume (output level) and negatively on cost of holding cash i.e. interest rate i.e.

$$\log(M/CPI)_t = \beta_0 + \beta_1 \log(Y)_t + \beta_2 R_t + u_t \qquad (4)$$

Thus the task is to forecast exchange rate (local currency per dollar) and money stock (M2) from the alternative ECM resulting from the three co-integration techniques. The quarterly data (1978Q1-2009Q4) of ten Asian countries are employed namely

1. Korea 2. Singapore 3. Malaysia 4. Indonesia 5. Thailand 6. Philippines 7. Sri Lanka 8. India 9. Pakistan 10. Bangladesh.

Interest rate is measured by discount rate, lending rate or money market rate (whichever is available for full sample period) Output is measured by manufacturing production index which indicate significant seasonality so quarterly dummies are added in estimation. The data comes mostly from IFS. Thai manufacturing production index is obtained from Bank of Thailand. The output data for Sri Lanka are not available so money demand results are not presented for Sri Lanka.

In the empirical analysis possess certain challenges e.g. EG and Johansen require the pre-testing for unit root in the variables and strictly speaking are valid if variables are I(1). However ARDL does not need such pre-testing. Unit root tests on all the series were conducted using ADF, Phillips-Perron and KPSS methods. In some cases EG, Johansen and ARDL co-integration tests could not uncover any co-integration however in most cases the co-integration evidence comes from significance of Error Correction term. The analysis is conducted for all countries despite these limitations.

We considered quarterly data from 1978Q1 to 2009Q4. For model specification and estimation we employ data from 1978Q1 to 1994Q4 and the forecast evaluation is conducted from the period 2005Q1 and 2009Q4. We employ Mean Absolute Percentage Error (MAPE) to evaluate the forecast accuracy. This measure eliminates the effect of

scaling of variables so that forecast error from countries is comparable MAPE is given

by: $MAPE = 100 \times \dfrac{1}{H} \sum_{t=1}^{H} | \dfrac{Y_t - \hat{Y}_t}{Y_t} |$

Where Y_t and $\hat{Y}_t$ represent actual and forecast respectively.

5. Results and Discussion

The following tables (Table 1 and Table 2) present the comparison of forecast accuracy based on MAPE. The best ECM model in each case is highlighted. Generally the ARDL appears to yield lower forecast errors followed by Johansen technique. This is the case for money stock forecast (Table 2) where potentially more than one co-integration vectors are possible. For Bangladesh the EG ECM yields the best forecast for the two variables. For Malaysia Johansen technique appears to be superior. For India and Singapore the ARDL technique results in the lowest forecast error. The results for other countries are mixed for the two variables.

Table 1: MAPE of exchange rate forecast for five year forecast horizon

COUNTRIES	Engle Granger	Johansen	ARDL
Bangladesh	3.058	3.552	5.887
India	14.063	15.265	5.187
Indonesia	62.365	40.818	13.938
Korea	17.628	13.969	14.598
Malaysia	33.750	15.943	33.735
Pakistan	7.325	9.600	6.697
Philippines	37.53	41.039	27.723
Singapore	8.69	12.195	8.427
Sri Lanka	20.563	17.023	17.366
Thailand	16.730	14.752	16.227

Notes: Schwarz criteria selects lag 1 as optimal for Engle-Granger method for all ten countries. Regression of ECM model with this optimal lags indicate that error correction term is insignificant only in Sri Lanka.

For VECM estimation using Johansen technique optimal lags are obtained by choosing lags based on AIC criteria and then determined using AIC then insignificant lags were removed using joint F-test. Same number of lags for each variable was employed in this case. Trace and Max tests did not provide evidence of cointegration in some cases but subsequent analysis by VECM models indicate that loading coefficients

was insignificant only in Indonesia. In other cases loading coefficient was significant with negative sign in at least one VECM equation.

Optimal lags using Schwarz criteria for ARDL is 1 for all countries. With optimal lags ECT term is insignificant only in Indonesia.

Table 2: MAPE of M2 forecast for five year forecast horizon

COUNTRIES	Engle Granger	Johansen	ARDL
Bangladesh	4.178	12.584	5.835
India	14.532	11.425	8.047
Indonesia	10.601	9.334	11.839
Korea	22.725	19.906	10.982
Malaysia	8.374	5.811	6.747
Pakistan	5.074	7.560	6.321
Philippines	19.403	4.951	7.629
Singapore	2.204	2.225	2.056
Thailand	35.399	15.1536	6.166

Notes: Optimal lags for Engle-Granger test are 1 for all counties. In some countries Engle-Granger ADF test did not uncover co-integration but subsequent in ECM model error correction term is insignificant only in Korea, Malaysia and Pakistan.

Optimal lags for Johansen vary over different countries using same lags for each variable. Trace and Max statistics do not indicate co-integration but in VECM models the loading coefficients was insignificant only in Indonesia.

Optimal lags using Schwarz criteria using ARDL method are four for Korea, Philippines, Pakistan and Bangladesh; three for Singapore and one for India, Malaysia, Thailand. With optimal lags error correction term is insignificant only in Malaysia and Pakistan

Manufacturing production for Sri Lanka is not available so money demand estimation is not possible.

6. Conclusion

It is well known that regression analysis on non-stationary time series data may be spurious (non-sense) if the underlying variables are not co-integrated. Error correction models provide a convenient solution for estimation, testing and forecasting. However there are now different co-integration estimation and testing techniques have been developed. In this paper we have compared the forecast accuracy of three popular error correction models that are derived from the Engle-Granger, Johansen and the ARDL techniques. The results indicate that in general the ECM based on both the ARDL and Johansen techniques outperform the Engle-Granger technique. The ARDL ECM results

in the best performance in about 48% of the cases whereas the Johansen's ECM yields the best performance in about 36% cases. The ARDL technique appears to be superior even in cases where more than one co-integration relationships are possible i.e. money demand model which involve three variables in the system. The average MAPE for exchange rate forecast across ten countries is 15%, 18.4% and 22.5% for the ARDL, Johansen and the EG techniques respectively. The average MAPE for M2 forecasts are 7.3%, 9.9% and 13.6% for the ARDL, Johansen and the EG techniques respectively. Thus our analysis provides evidence in favor of the ARDL based ECM. Also it will be interesting to compare forecast of ECM from alternative techniques which do not impose cointegration e.g. ARIMA and VAR techniques. This is reserved for future research.

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