Levels, differences and ECMs – Principles for Improved Econometric Forecasting Appendix

Table A1 Sources for pairwise comparison of estimating different vector autoregression models

Strategies *(number of cointegrating vectors found or assumed)*	Authors, year and number of series
Unrestricted *vs* restricted lag order (1 vs 1a)	Bessler & Babula 1987 (1,3), Fanchon & Wendell 1992 (0,3,*), Funke 1990 (0,5), Kaylen 1988 (2,1), Kling & Bessler 1985 (1,3;0,5;2,1) , Liu et al. 1994 (0,3), Park 1990 (1,3)
Variables in levels *vs* differenced (1 vs 2)	
(No CV)	Lin & Tsay 1996 (0,4), Robertson & Tallman 2001 (0,3), Zapata & Garcia, 1990 (0,1)
(1 CV)	Ansotegui & Esteban (1,0), Clements & Hendry 1995 (1,1), Joutz et al. 1995 (3,1), Lin & Tsay 1996 (0,1), Metin & Muradoglu 2000 (1,0), Sarantis & Stewart 1995 (0,3)
(2 CV)	Lin & Tsay 1996 (0,1)
(3 CV)	Hoffman & Rasche 1996 (1,5) [same for variables expressed in levels or in differences], Lin & Tsay 1996 (1,0)
VAR in levels vs ECM from theory (1 vs 3)	
(1 CV)	Metin & Muradoglu 2000 (0,1), Romilly et al. 2001 (1,1), Sarantis & Stewart 1995 (0,3)
Unrestricted VAR in levels vs Pretest (1 vs 4b)	
(No CV)	Lin & Tsay 1996 (1,1,2*), Zapata & Garcia 1990 (1,0)
(1 CV)	Ansotegui & Esteban (1,0), Bessler & Fuller 1993 (12,0), Bradley & Lumpkin 1992 (0,1), Brown et al. 1997 (0,1), Clements & Hendry 1995 (0,2), Fanchon & Wendell 1990 (2,1,*), Joutz et al. 1995 (3,1), Lin & Tsay 1996 (0,1)
(2 CV)	Lin & Tsay 1996 (0,1), Shoesmith 1995 (1,5)
(3 CV)	Hall et al. 1992 (0,4), Hoffman & Rasche 1996 (2,4), Lin & Tsay 1996 (1,0)
Restricted VAR in levels vs Pretest (1a vs 4b)	
(1 CV)	Fanchon & Wendell 1990 (3,0,*), Madden et al. 2002 (3,3)
VAR in differences vs ECM from theory (2 vs 3)	
(1 CV)	Copeland & Wang 2000 (1,0), Metin & Muradoglu 2000 (0,1), Sarantis & Stewart 1995 (1,2), Tse 1995 (0,1)
(2 CV)	Eitrheim et al. 1999 (12,31),
VAR in differences vs Pretest (2 vs 4b)	
(No CV)	LeSage 1990a (0,1), LeSage 1990b (4,0), Lin & Tsay 1996 (3,1), Zapata & Garcia, 1990 (1,0)
(1 CV)	Ansotegui & Esteban (0,1), Bessler & Covey 1991 (1,0), Clements & Hendry 1995 (0,1,*), Joutz et al. 1995 (1,3), LeSage 1990a (1,1), LeSage 1990b (1,3), Lin & Tsay 1996 (0,1), Löf & Franses 2001 (2,1), Shoesmith 1992 (2,0;0,2;1,1;0,2), Tegene & Kuchler 1994 (0,3),
(2 CV)	Lin & Tsay 1996 (0,1)
(3 CV)	Hoffman & Rasche 1996 (5,1), Lin & Tsay 1996 (1,0)

Sources for cell entries shown below using the following layout: Author year (number of series where first method was better, number of series where second method was better). Semicolon separates different VAR models in the same study. Out-of-sample forecast RMSE, lead times not specified, mostly one step ahead. * indicates that the methods were equally accurate for one series, 2* indicates for two series, etc.

Appendix Table A2: Out-of-sample forecast accuracy results from empirical studies

		Forecast error increases with horizon	
		Without limit	**To a ceiling**
ECM vs VAR is			
Always better	Improving	Lin Tsay (0) 5-exch rates, (0) 5-indust prod, (1) 5-imports, (2) 5-exports; Shoemaker95 (2) gnp; Wang Bessler (3) hog price	Sarantis Stewart (1) DM, (1) FF
	Worsening		
	No pattern	Clements Hendry (1) velocity, (1) cost; Hoffman Rasche (3) money	Brown et al (1); Shoemaker95 (2) Tbill
Always worse	Improving		Joutz (1) residential quantity
	Worsening	Ansotegui Esteban (1); Wang Bessler (3) hog quantity, (3) corn price	Lin Tsay (0) 5-bond yields, (3) 4-US interest rates
	No pattern		Joutz (1) residential price; Wang Bessler (3) corn quantity
No pattern or varies	Improving	Hoffman Rasche (3) inflation, (3) gdp; Joutz (1) industrial quantity; Wang Bessler (3) wage	Sarantis Stewart (1) Yen
	Worsening	Lin Tsay (0) 3-Taiwan interest rates; Madden (1) 6-telephone call volume; Shoemaker95 (2) money	Hoffman Rasche (3) commercial paper rate, (3) Tbill; Joutz (1) industrial price
	No pattern	Shoemaker95 (2) inflation, (2) investment, (2) unemployment; Zapata Garcia (0)	
DVAR vs VAR is			
Always better	Improving	Hoffman Rasche (3) gdp; Lin Tsay (0) 5-exch rates, (0) 5-indust prod, (1) 5-imports, (2) 5-exports; Wang Bessler (3) wage; Zapata Garcia (0)	
	Worsening	Hoffman Rasche (3) money	
	No pattern	Clements Hendry (1) cost; Lin Tsay (0) 3-Taiwan interest rates	Hoffman Rasche (3) commercial paper rate
Always worse	Improving	Clements Hendry (1) velocity	Joutz (1) residential quantity, (1) residential price, (1) industrial price
	Worsening	Ansotegui Esteban (1); Wang Bessler (3) corn price	Lin Tsay (3) 4-US interest rates
	No pattern	Wang Bessler (3) hog quantity	
No pattern or varies	Improving	Hoffman Rasche (3) inflation; Joutz (1) industrial quantity; Wang Bessler (3) hog price	
	Worsening		Hoffman Rasche (3) Tbill; Joutz (1) industrial price; Lin Tsay (0) 5-bond yields; Sarantis Stewart (1) DM, (1) FF, (1) Yen
	No pattern		Wang Bessler (3) corn quantity

DVAR vs ECM is			
Always better	Improving	Bessler Covey (1); Clements Hendry (1) cost; LeSage90b (1) Cleveland, (0) Youngstown; Lin Tsay (0) 5-exch rates, (0) 5-indust prod; Shoemaker92 (1) income NC; Wang Bessler (3) hog quantity, (3) wage; Zapata Garcia (0)	Hoffman Rasche (3) commercial paper rate; Joutz (1) industrial price; Lin Tsay (3) 4-US interest rates
	Worsening	Löf Franses (1) Japan	Joutz (1) residential price
	No pattern	Hoffman Rasche (3) gdp	
Always worse	Improving	Clements Hendry (1) velocity; Wang Bessler (3) hog price	Joutz (1) residential quantity
	Worsening	LeSage90a (1) 7-industries, (0) 38-industries; LeSage90b (1) Akron, (1) Dayton; Shoemaker92 (1) sales NY	Lin Tsay (0) 5-bond yields; Sarantis Stewart (1) DM, (1) FF
	No pattern	Hoffman Rasche (3) inflation; Wang Bessler (3) corn price	Copeland Wang (?) 55-investment trusts
No pattern or varies	Improving	LeSage90b (1) Canton; Löf Franses (1) Sweden	Joutz (1) residential price
	Worsening	Hoffman Rasche (3) money; LeSage90b (0) Cincinnati, (0) Columbus; Löf Franses (1) Germany, (1) Italy, (1) US, (1) US money; Shoemaker92 (1) sales NC	Sarantis Stewart (1) Yen
	No pattern	Ansotegui Esteban (1); Joutz (1) industrial quantity; LeSage90b (0) Toledo; Löf Franses (1) UK; Lin Tsay (1) 5-imports, (2) 5-exports; Shoemaker92 (1) income NY	LeSage90a (1) 5-industries; Wang Bessler (3) corn quantity

Notes:
VAR vector autoregression in levels, ECM unit root restrictions imposed, DVAR unit root restrictions imposed on all variables (first differenced).

Forecast accuracy usually measured as RMSFE, the root mean squared forecast error.
"Always better" means that the forecast error from the first model is less than the forecast error from the second model for all horizons, opposite for "Always worse" and "No pattern or varies" indicates either a single or multiple switches between better and worse. "Improving" means that the forecast error from the first model consistently becomes smaller relative to the accuracy or the second model as the forecast horizon increases, "Worsening" means the opposite and "No pattern" means no consistent direction of change.

Each entry is of the form: Author (i) j-variable, where Author is the author(s) names and year if necessary for identification, (i) is the number of cointegrating vectors detected, j is the number of variables the entry refers to, omitted for j=1, and variable is the name of the variable for identification purposes, where the study reports the forecast accuracy of more than one variable.

Appendix References

Ansotegui, C. & Esteban M.V. (2002), "Cointegration for market forecast in the Spanish stock market," *Applied Economics*, 34, 843-857.

Bessler, D.A. & R.A. Babula (1987), "Forecasting wheat exports: Do exchange rates matter?" *Journal of Business and Economic Statistics*, 5, 397-406.

Bessler, D.A. & T. Covey (1991), "Cointegration: Some results on U.S. cattle prices," *Journal of Futures Markets*, 11, 461-474.

Bessler, D.A. & S.W. Fuller (1993), "Cointegration between U.S. wheat markets," *Journal of Regional Science*, 33, 481-501. Clements, M.P. & D.F. Hendry (1995), "Forecasting in cointegrated systems," *Journal of Applied Econometrics*, 10, 127-146.

Bradley, M.G. & S.A. Lumpkin (1992), "The Treasury yield curve as a cointegrated system," *Journal of Financial and Quantitative Analysis*, 27, 449-463.

Brown, J. P., H. Song, & A. McGillivray (1997), "Forecasting UK house prices: a time varying coefficient approach," *Economic Modelling*, 14, 529-548.

Clements, M.P. & D.F. Hendry (1995), "Forecasting in cointegrated systems," *Journal of Applied Econometrics*, 10, 127-146.

Copeland, L.& P. Wang (2000), "Forecasting the returns on UK investment trusts: a comparison," *European Journal of Finance*, 6, 298-310.

Eitrheim, O., T. A. Husebo & R. Nymoen (1999), "Equilibrium-correction vs. differencing in macroeconometric forecasting," *Economic Modelling*, 16, 515-544.

Fanchon, P. & J. Wendell (1992), "Estimating VAR models under non-stationarity and cointegration: Alternative approaches to forecasting cattle prices," *Applied Economics*, 24, 207-217.

Funke, M. (1990), "Assessing the forecasting accuracy of monthly vector autoregressive models: The case of five OECD Countries," *International Journal of Forecasting*, 6, 363-378.

Hall, A.D., H.M. Anderson & C.W.J. Granger (1992), "A cointegration analysis of Treasury bill yields," *Review of Economics and Statistics*, 74, 116-126.

Hoffman, D.L. & R.H. Rasche (1996), "Assessing forecast performance in a cointegrated system," *Journal of Applied Econometrics*, 11, 495-517.

Joutz, F.L., G.S. Maddala, & R.P. Trost (1995), "An integrated Bayesian vector autoregression and error correction model for forecasting electricity consumption and prices," *Journal of Forecasting*, 14, 287-310.

Kaylen, M.S. (1988), "Vector autoregression forecasting models: Recent developments applied to the U.S. hog market," *American Journal of Agricultural Economics*, 70, 701-712.

Kling, J.L. & D.A. Bessler (1985), "A comparison of multivariate forecasting procedures for economic time series," *International Journal of Forecasting*, 1, 5-24.

LeSage, J.P. (1990a), "A comparison of the forecasting ability of ECM and VAR models," *Review of Economics and Statistics*, 72, 664-671.

LeSage, J.P. (1990b), "Forecasting turning points in metropolitan employment growth rates using Bayesian techniques," *Journal of Regional Science*, 30, 533-548.

Lin, J-L. & R.S. Tsay (1996), "Co-integration constraint and forecasting: an empirical examination," *Journal of Applied Econometrics,* 11, 519-538.

Liu, T-R., M.E. Gerlow & S.H. Irwin (1994), The performance of alternative VAR models in forecasting exchange rates," *International Journal of Forecasting*, 10, 419-433.

Löf, M & P.H. Franses (2001), "On forecasting seasonal time series," *International Journal of Forecasting*, 17, 607-621.

Madden, G., S. J. Savage & G. Coble-Neal (2002), "Forecasting United States–Asia international message telephone service," *International Journal of Forecasting*, 18, 523-543.

Metin, K. & G. Muradoğlu (2000), "Forecasting stock prices by using alternative time series models," *ISE Review*, 4, 17-24.

Park, T. (1990), "Forecast evaluation for multivariate time-series models: The U.S. cattle market," *Western Journal of Agricultural Economics*, 15, 133-143.

Robertson, J. C. & E. W. Tallman (2001), "Improving federal-funds rate forecasts in VAR models used for policy analysis," *Journal of Business and Economic Statistics*, 19, 324-330.

Romilly, P., H. Song & X. Liu (2001), "Car ownership and use in Britain: a comparison of the empirical results of alternative cointegration estimation methods and forecasts," *Applied Economics*, 33, 1803-1818.

Sarantis, N. & C. Stewart (1995), "Structural, VAR and BVAR models of exchange rate determination: A comparison of their forecasting performance," *Journal of Forecasting*, 14, 201-215.

Shoesmith, G.L. (1992), "Cointegration, error correction, and improved medium-term regional VAR forecasting," *Journal of Forecasting*, 11, 91-109.

Shoesmith, G.L. (1995), "Multiple cointegrating vectors, error correction, and forecasting with Litterman's model," *International Journal of Forecasting*, 11, 557-67.

Tegene, A. & F. Kuchler (1994), "Evaluating forecasting models of farmland prices," *International Journal of Forecasting*, 10, 65-80.

Tse, Y.K. (1995), "Lead-lag relationship between spot index and futures price of the Nikkei stock average," *Journal of Forecasting*, 14, 553-563.

Zapata, H.O. & P. Garcia (1990), "Price forecasting with time-series methods and nonstationary data: An application to monthly U.S. cattle prices," *Western Journal of Agricultural Economics*, 15, 123-132.