

*Peter M. Robinson*

Abstract. Panel data, whose series length  $T$  is large but whose cross-section size  $N$  need not be, are assumed to have a common time trend. The time trend is of unknown form, the model includes additive, unknown, individual-specific components, and we allow for spatial or other cross-sectional dependence and/or heteroscedasticity. A simple smoothed nonparametric trend estimate is shown to be dominated by an estimate which exploits the availability of cross-sectional data. Asymptotically optimal choices of bandwidth are justified for both estimates. Feasible optimal bandwidths, and feasible optimal trend estimates, are asymptotically justified, the finite sample performance of the latter being examined in a Monte Carlo study. A number of potential extensions are discussed.

*Matthias Hagmann* (with Gregory Connor and Oliver Linton).

Abstract. This paper develops a new estimation procedure for characteristic-based factor models of security returns. We treat the factor model as a weighted additive nonparametric regression model, with the factor returns serving as time-varying weights, and a set of univariate nonparametric functions relating security characteristic to the associated factor betas. We use a time-series and cross-sectional pooled weighted additive nonparametric regression methodology to simultaneously estimate the factor returns and characteristic-beta functions. By avoiding the curse of dimensionality our methodology allows for a larger number of factors than existing semiparametric methods. We apply the technique to the three-factor Fama-French model, Carhart's four-factor extension of it adding a momentum factor, and a five-factor extension adding an own-volatility factor. We find that momentum and own-volatility factors are at least as important if not more important than size and value in explaining equity return comovements. We test the multifactor beta pricing theory against the Capital Asset Pricing model using a standard test, and against a general alternative using a new nonparametric test.

*Hashem Pesaran* (with Sean Holly and Takashi Yamagata)

Abstract. This paper provides a method for the analysis of the spatial and temporal diffusion of shocks in a dynamic system. We use changes in real house prices within the UK economy at the level of regions to illustrate its use. Adjustment to shocks involves both a region specific and a spatial effect. Shocks to a dominant region - London - are propagated contemporaneously and spatially to other regions. They in turn impact on other regions with a delay. We allow for lagged effects to echo back to the dominant region. London in turn is influenced by international developments through its link to New York and other financial centers. It is shown that New York house prices have a direct but lagged effect on London house prices. We analyse the effect of shocks using generalised spatio-temporal impulse responses. These highlight the diffusion of shocks both over time (as with the conventional impulse responses) and over space.

*Jose Gonzalo Rangel* (with Robert F. Engle)

Abstract. This study models high and low frequency variation in global equity correlations using a comprehensive sample of 43 countries that includes developed and emerging markets, during the period 1995-2008. These two types of variations are modeled following the semi-parametric Factor-Spline-GARCH approach of Rangel and Engle (2008). This framework is extended and modified to incorporate the effect of multiple factors and to address the issue of non-synchronicity in international markets. Our empirical analysis suggests that the slow-moving dynamics of global correlations can be described by the Factor-Spline-GARCH specifications using either weekly or daily data. The analysis shows that the low frequency component of global correlations increased in the current financial turmoil; however, this increase was not equally distributed across countries. The countries that experienced the largest increase in correlations were mainly emerging markets.

*Alain Hecq* (with Sébastien Laurent and Franz C. Palm)

Abstract. We determine the minimum univariate representation of some well known  $n$ -dimensional conditional volatility models. Simple systems (e.g. a  $VEC(0,1)$ ) for the joint behaviour of several variables generate individual processes with a lot of persistence, processes that can be erroneously considered as long memory models for the variance. We are also able to explain the presence of parsimonious univariate representations (e.g.  $GARCH(1,1)$ ) by the presence in multivariate models of factors generating the conditional variances and conditional correlations.

*Paolo Zaffaroni* (with Adam Golinski)

Abstract. This paper proposes a class of essentially affine models for the term structure of interest rate that permits a substantial degree of persistence as observed in the data, both for yields and inflation. Standard models parameterize the factors as stationary vector autoregressions. This paper specifies long memory latent factors. Despite the model is non-Markov, we show how it can be estimated by maximum likelihood based on the Kalman filter recursions yet imposing the no-arbitrage restrictions. We fit the model to the data and it seems crucial to model the expected inflation factor as a long memory process, while we don't find evidence of high persistence in the short rate dynamics. Based on the model estimates we compute the term structure real interest rates, real and nominal risk term premia, and inflation premia for different maturities. The fractional model appears to outperform standard affine models in terms of both in-sample as well as out-of-sample measures.

*Massimiliano Marcellino (Sandra Eickmeier and Wolfgang Lemke)*

Abstract. We propose a classical, Kalman filter-based, approach to analyze factor-augmented vector autoregressive (FAVAR) models with time variation in the factor loadings, in the factor dynamics, and in their conditional variance-covariance matrix. When the time-varying FAVAR is estimated using a large dataset of US variables, the results indicate minor changes in the factor dynamics and more marked variation in their volatility and their impact on key macroeconomic variables. Forecasts from the time varying FAVAR are substantially more accurate than those from a constant parameter FAVAR, especially for several inflation, financial and monetary variables, also over the more recent period. Finally, when the time-varying FAVAR is used to assess how monetary transmission to the economy has changed, we find substantial time-variation in the volatility of monetary policy shocks and their transmission to real activity and inflation.

*Anindya Banerjee (with Paul Mizen and and Victor Bystrov).*

Abstract. The financial crisis has focused attention on the inter-bank market for wholesale funding. This market is important not only because banks have in recent years relied more heavily on wholesale markets to provide funding for their retail products, but also because our understanding of the causes and impact of the current crisis is helped by studying the relationship between wholesale and retail markets.

Most empirical studies have concentrated on the relationship between current retail rates, current wholesale rates and lagged terms in these rates. The implicit assumption is that the retail rate has a unique contemporaneous relationship with a single, current wholesale rate representing the cost of funds, and any dynamic adjustment is backward looking. This ignores any projection, or forecast, of rates that might be undertaken by banks, and neglects a large amount of information available in the plethora of interest rates and macroeconomic data.

We contribute to the literature by emphasizing that financial institutions seek to anticipate the direction of future rates and use these to determine whether to change retail rates in response to changes in the wholesale market. This introduces expectations of future wholesale rates into retail rate setting decisions. We implement this forward-looking framework in our estimations by allowing retail rates to depend on forecasts of wholesale rates several months ahead as well as current and past changes in wholesale and retail rates. In order to generate these forecasts of wholesale rates with relevant maturities at different horizons, we investigate the performance of a wide variety of autoregressive, vector autoregressive and, most significantly from our perspective, dynamic factor models. We utilize rich datasets, for four of the largest economies of the Euro area (France, Germany, Italy and Spain) as well as for the aggregate Euro area and the United Kingdom.

We find a significant role for expectations of future interest rates in determining short- and long-run pass through, especially for longer maturity retail products such as mortgages and long-term loans. We show that pass through rates tend on the whole to be higher when such expectations are taken into account, and we argue that models which do not include future rates are misspecified.

*George Kapetanios (with Jan J. J. Groen)*

Abstract. This paper revisits a number of data-rich prediction methods that are widely used in macroeconomic forecasting, such as factor models and Bayesian shrinkage regression, and compares these methods with a lesser known alternative: partial least squares regression. In this method, linear, orthogonal combinations of a large number of predictor variables are constructed such that the linear combinations maximize the covariance between the target variable and each of the common components constructed from the predictor variables. We provide a theorem that shows that when the data comply with a factor structure, principal components and partial least squares regressions provide asymptotically similar results. We also argue that forecast combinations can be interpreted as a restricted form of partial least squares regression. Monte Carlo experiments confirm our theoretical

results that partial least squares regression is at least as good as principal components regression and close to Bayesian regression when the data has a factor structure. These experiments also indicate that when there is no factor structure in the data, partial least square regression outperforms both principal components and Bayesian regressions. Finally, we apply partial least squares, principal components, and Bayesian regressions on a large panel of monthly U.S. macroeconomic and financial data to forecast CPI inflation, core CPI inflation, industrial production, unemployment, and the federal funds rate across different subperiods. The results indicate that partial least squares regression usually has the best out-of-sample performance when compared with the two other data-rich prediction methods.

*Eric Hillebrand* (with Huiyu Huang, Tae-Hwy Lee and Canlin Li).

Abstract. We examine how one can use information in the yield curve to improve forecasts of output growth and inflation. First, we consider two ways of forming the forecast model: combining forecasts (CF), with each individual forecast obtained from using one yield at a time, and combining information (CI) from all yields into one large regressor matrix. For both CF and CI methods, we consider two alternative factor frameworks: principal components (PC) and Nelson-Siegel (NS) factors. We make two contributions in this paper. The first is to show that the factors in the CF scheme are “supervised” for the forecast target, while the factors in the conventional CI scheme are not. We formalize the concept of supervision and introduce measures of supervision. We show analytically and in simulations how supervision works in CF factor extraction. The second contribution is to introduce NS factors for CF (CF-NS), which is a new way of combining forecasts when the yield curve is used for forecasting. In out-of-sample forecasting of U.S. monthly output growth and inflation, we find that supervised CF factors using principal components (CF-PC) and using NS factors (CF-NS) are substantially better than conventional (unsupervised) CI factors. The advantage of supervised factors is even greater for longer forecast horizons

*Lynda Khalaf* (with Jean-Marie Dufour and Maral Kichian)

Abstract. Weak identification is likely to be prevalent in multi-equation macroeconomic models such as in dynamic stochastic general equilibrium setups. Identification difficulties cause the breakdown of standard asymptotic procedures, making inference unreliable. While the extensive econometric literature now includes a number of identification-robust methods that are valid regardless of the identification status of models, these are mostly limited-information-based approaches, and applications have accordingly been made on single-equation models such as the New Keynesian Phillips Curve. In this paper, we develop a set of identification-robust econometric tools that, regardless of the model’s identification status, are useful for estimating and assessing the fit of a system of structural equations. In particular, we propose a vector auto-regression (VAR) based estimation and testing procedure that relies on inverting identification-robust multivariate statistics. The procedure is valid in the presence of endogeneity, structural constraints, identification difficulties, or any combination of these, and also provides summary measures of fit. Furthermore, it has the additional desirable features that it is robust to missing instruments, errors-in-variables, the specification of the data generating process, and the presence of contemporaneous correlation in the disturbances. We apply our methodology, using U.S. data, to the standard New Keynesian model such as the one studied in Clarida, Gali, and Gertler (1999). We find that, despite the presence of identification difficulties, our proposed method is able to shed some light on the fit of the considered model and, particularly, on the nature of the NKPC. Notably our results show that (i) confidence intervals obtained using our system-based approach are generally tighter than their single-equation counterparts, and thus are more informative, (ii) most model coefficients are significant at conventional levels, and (iii) the NKPC is preponderantly forward-looking, though not purely so.

*Lucrezia Reichlin*

Abstract. The paper reviews selected key results in the econometrics of large dynamic models, from factor models to Bayesian shrinkage and their main applications in macroeconomics. Rather than being exhaustive, the presentation aims at giving a personal view on what progress we have made in the last ten years and what are the successful empirical applications.

*Yacine Ait-Sahalia* (with Julio Cacho-Diaz, Ton Hurd and Roger Laeven)

Abstract. Adverse shocks to stock markets propagate across the world, with a jump in one region of the world seemingly causing an increase in the likelihood of a different jump in another region of the world. To capture this effect mathematically, we introduce a model of asset return dynamics involving mutually exciting processes. In the model, a jump in one region of the world or one segment of the market increases the intensity of jumps occurring both in the same region (self-excitation) as well in

other regions (cross-excitation). The model generates the type of jump clustering that is observed empirically. Jump intensities then mean-revert until the next jump. We develop and implement an estimation procedure for this model. We find that most US jumps get reflected quickly in other markets, while there is little statistical evidence for the reverse.

*Ana-Maria Dumitru (with G. Urga)*

Abstract. We make use of the Barndorff-Nielsen and Shephard (2006) and Andersen et al. (2007) -Lee and Mykland (2008) nonparametric procedures to detect jumps and common jumps in the US Treasury market, for a period lagging from January 2003 to March 2004. We find that macroeconomic announcements are the major factor that causes abrupt changes in the term structure. We also examine different market activities, such as spread, depth, trading volume and order flow around the time of the jump. Finally, we investigate the informativeness of the order flow in the proximity of a jump. We show that the trading information has a low impact on prices before a jump takes place, which increases to a very high level immediately after the jump and then dissipates gradually, maintaining itself at quite high levels up to 20 minutes after a jump occurs.

*Heather Anderson (with Yin Liao and Farshid Vahid).*

Abstract. This paper proposes a tobit multivariate factor model for jumps coupled with the standard multivariate factor model for continuous sample path to jointly forecast volatility in three Chinese stocks. Out-of-sample forecast analysis shows that separate multivariate factor models for the two volatility sources outperform single multivariate factor model for the total realized volatility, and multivariate factor models of realized volatility outperform univariate models.

*Marco Lippi (with Mario Forni, Marc Hallin and Paolo Zaffaroni)*

Abstract. With a few exceptions (see in particular Forni, M., M. Hallin, M. Lippi, and L. Reichlin, 2000, The generalized dynamic factor model: identification and estimation, *The Review of Economics and Statistics*, 82, FHLR hereafter, and Hallin, M. and R. Liska, 2007, The generalized dynamic factor model: determining the number of factors, *Journal of the American Statistical Association*, 102), generalized dynamic factor models have been studied under the assumption that there exists a static representation with a finite number of static factors. We argue that this is quite a severe restriction, ruling out very important cases, and go back to the general model. Assuming that the spectral density of the common components is rational, we derive a one-sided, actually a finite autoregressive, representation for the common components, thus solving a problem that had remained unsolved within the frequency-domain approach in FHLR. The paper builds upon results in FHLR and recent work by Anderson and Deistler on stochastic processes whose spectral density is rational and singular.

*Gabriele Fiorentini (with Enrique Sentana)*

Abstract. We derive score tests of serial correlation in the levels and squares of common and idiosyncratic factors in static factor models. The implicit orthogonality conditions resemble the orthogonality conditions of models with observed factors but the weighting matrices reflect their unobservability. We robustify our tests against fat tails, and derive more powerful versions when the conditional distribution is elliptically symmetric, which can be either parametrically or semiparametrically specified. We conduct Monte Carlo exercises to study the finite sample reliability and power of our proposed tests. Finally, we illustrate our methods with an empirical application to monthly US stock returns.

*Dalibor Stevanovic (with Jean-Marie Dufour )*

Abstract. In this paper we generalize the existing approximate factor model analysis by specifying vector autoregressive moving average (ARMA) dynamics for latent factors. We show that when factors are obtained as linear combinations of observable series their dynamic process is generally a VARMA. Moreover, this generalization can be motivated by the usual arguments of parsimony, invertibility and marginalization issues in which VARMA models outperform the VAR representations. Hence, approximating factors' dynamics by an identified VARMA representation can be useful in both macroeconomic empirical fields where the factor analysis became popular in last 10 years: forecasting key macroeconomic indicators and structural analysis. To see how our approach performs in real data, we apply it in a pseudo-out-of-sample forecasting exercise using 128 U.S. monthly economic indicators, and find that considering VARMA representation for factors helps in predicting several key macroeconomic aggregates relatively to standard factor-based forecasting models.

*Mehmet Caner*

Abstract. Recently, Bai, Ng (2002, *Econometrica*) introduced information criterion that helps select the number of factors in large multi-factor models. In this paper we introduce a new way of finding the number of factors. These are based on Bridge Estimators that are used in statistics (Huang, Horowitz, Ma, 2008, *Annals of Statistics*). They can simultaneously select and estimate the model. They can select the model better than information criterion, and have better finite sample properties in post selection, estimation stage. These properties are also shown recently in GMM framework by Caner (2009, *Econometric Theory*).

*James H. Stock* (with Mark W. Watson)

Abstract. Dating business cycles entails the identification of turning points in the economy. Broadly speaking, there are two approaches in the literature. The first approach, which dates to Burns and Mitchell (1938), is to identify turning points individually in a large number of series, then look for common dates that could be called an aggregate turning point. The second approach, which has been the focus of more recent academic and applied work, is to look for turning points in a few, or just one, aggregate. This aggregate could be an observable series or an estimate of a latent dynamic factor. This paper examines these two approaches to the identification of turning points. Specifically, we consider a number of estimators, both parametric and nonparametric, of turning points of individual series and ask whether macroeconomic turning points are better estimated by an aggregate of turning points or turning points of aggregates. The dynamic factor model provides a benchmark for the latter approach. The empirical part of the analysis is based on a data set of approximately 200 disaggregated monthly real economic time series for the U.S.

*Lorenzo Trapani* (with C. Kao and G. Urga)

Abstract. In this paper, we discuss the estimation and testing for parameter instability in cointegrated panel regressions with common and idiosyncratic shocks. We develop tests for structural change for the slope parameters under the null hypothesis of no structural break against the alternative hypothesis of (at least) one common change point which is possibly unknown. Finally we derive the limiting distributions of the proposed test statistics. Monte Carlo simulations examine size and power of the proposed tests.

*Jean-Marie Dufour* (with Marie-Claude Beaulieu and Lynda Khalaf)

Abstract. We propose identification robust inference methods for structural multivariate factor models with rank restrictions. Such models involve nonlinear reduced rank restrictions whose identification may raise serious non-regularities leading to the failure of standard asymptotics. First, we prove several invariance and nuisance-parameter reduction results for commonly used eigenvalue and minimum root based statistics; we also derive useful scale-invariance results for heteroskedasticity-autocorrelation robust multivariate Wald-type criteria. Second, we derive confidence set estimates for structural parameters based on inverting minimum-distance type pivotal statistics. We provide analytical solutions to the latter problem which hold exactly (or asymptotically) imposing (or relaxing) Gaussian fundamentals. Simulation-based counterparts are also suggested for non-Gaussian hypotheses. Results are not restricted to the intertemporal i.i.d. setting. The statistics we invert include Hotelling's  $T^2$  criterion, which is widely used in multivariate analysis for test purposes. Our proposed confidence sets have much more informational content than Hotelling-type tests, and extend their relevance beyond reduced form specifications. Our approach further provides multivariate extensions of the classical Fieller problem, and may be viewed as a generalization of Dufour and Taamouti's (*Econometrica*, 2005) quadratics-based set estimation method beyond the linear limited information simultaneous equations setting. Third, we provide a formal definition of a statistically non-informative factor and prove necessary conditions linking the presence of such factors to unbounded set estimation outcomes. We also document the perverse effects of adding such factors on J-type minimum-root-based model tests. Fourth, we provide a unified analytical treatment of point estimation. With reduced rank constraints, normalizations raise uniqueness issues that may not matter in some contexts, yet in many econometric or financial structural models, normalizations are motivated by underlying theory. Fifth, proposed inference methods are applied to a multi-factor Capital Asset Pricing type model with unobservable risk-free rates and an Arbitrage Pricing Theory based model with Fama-French factors.

Results reveal dramatic differences between the standard Wald-type confidence set estimates and our proposed identification robust ones and illustrate the severe implications of redundant factors. In particular, we find that the term structure variables and the momentum factor are statistically non-informative in many sub-periods. This causes tests for model fit to spuriously pass the underlying pricing restrictions, though associated confidence sets are much too wide. These results document the serious pitfalls of usual asset pricing tests and illustrate the worth of our proposed confidence set based analysis.

*Michael Massmann (with Siem Jan Koopman)*

Abstract. Dynamic factor models have recently seen their popularity surge in econometrics. One of the reasons for this development is that they allow the information contained in a large number of explanatory variables to be condensed in a few unobserved factors which, in turn, may be used for predicting a variable of interest. Many different procedures for dynamic factor analysis have been developed in the past years and more recently. This paper builds on this literature by developing a state space representation of a reduced-rank regression model that allows the convenient likelihood-based estimation of and testing for dynamic factors. A Monte Carlo analysis examines the size and power properties of the test for dynamic factors before we present an empirical illustration in which we compare the forecasting performance to existing procedures.