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Editorial

Editors' introduction

Thirtieth anniversary of GMM

Since Hansen's (1982) seminal paper on the Generalized Method of Moments (GMM), GMM has been successfully applied in all fields of economics. This annals issue celebrates the thirtieth anniversary of GMM by collecting papers on GMM and its recent developments, including information-theoretic approaches, many moments, non-parametric instrumental variables etc. It grew out of the CIREQ conference on GMM organized by Marine Carrasco and held in Montreal, Canada, on November 16–17, 2007. Out of 21 papers submitted to the special issue, 17 were accepted for publication.

The seventeen articles of this issue are divided into five broad areas. A first set of four papers sheds some new light on standard asymptotic theory for GMM when considered in some special circumstances like respectively underidentification, structural break, singular covariance matrix and two-step estimation. The next two papers are devoted to weak instruments asymptotics as put forward by Stock and Wright (2000) and more generally non-standard rates of convergence in GMM. A tightly related topic is the non-standard asymptotic theory as provided by an infinite set of instruments, the focus of interest of the third set of four papers. Then, another set of four papers concerns the extension of GMM to non-parametric settings. Finally, three papers especially focus on GMM with misspecified models and information-theoretic approaches.

To complete this overview, two remarks are in order.

First, the wish to classify papers as above for the sake of expositional clarity leads to underestimate the internal consistency between most of the recent developments to GMM. The first paper about underidentification seeks to infer the manner in which identification may fail whereas the weak instruments literature maintains the assumption that identification is satisfied, but only just. This first paper uses some developments on continuum of moment conditions as in Carrasco and Florens (2000) while these developments are themselves deeply related to the many instruments asymptotics and to non-parametric approaches as well. The general study of heterogeneous rates of convergence in GMM asymptotic distributional theory (2nd paper of the 2nd set) is relevant not only for weak identification patterns but also for GMM with non-parametric components. Empirical likelihood and new information theoretic approaches show up in many places (in particular about weak identification) and not only in the last set of papers for which the main focus of interest is assessment of misspecified models.

Second, we feel honored and grateful to have received the constant support of Lars Peter Hansen all along the processing of this Annals Issue. The first paper of the issue, co-authored by Lars, Manuel Arellano and Enrique Sentana is an impressive development with the most modern techniques of an old issue already recognized by the early simultaneous equation literature but much overlooked since then: underidentification is testable and should be tested before any use of the estimates. In addition, we are glad to publish a short paper (the fourth paper of the first set) providing many of the proofs of Hansen (1982) that *Econometrica* did not publish at that time. As explained below, this publication has much more than an historical interest.

Revisiting the standard GMM asymptotic theory

The paper by Arellano, Hansen, and Sentana presents a testing method for the null hypothesis that a model is not identified by a set of moment restrictions. The strategy consists in reparameterizing the vector of parameters and investigating if the restrictions hold for several values of the parameters. The test of underidentification can then be expressed as the well-known J-test for overidentifying restrictions (Hansen, 1982). Initially, the paper considers a finite number of values for the parameter. Later on, it considers an interval of values which yields a continuum of moment conditions as in Carrasco and Florens (2000). An attractive feature of the paper lies in the estimation of the function of a scalar variable (referred to as a curve) which represents the direction along which the identification of the original model fails. The method is illustrated by an application to a consumption-based asset pricing model fit to microeconomic data. There, the curve is estimated by cubic spline.

Hall, Han, and Boldea study the estimation and tests of structural changes in linear regressions with endogenous regressors. The paper shows that the GMM estimator may not be consistent whereas 2SLS yields a consistent estimator. It considers two cases of interest, the case where the parameters in the first stage regression are constant and the case where they are subject to discrete shifts which locations are estimated a priory. The instability of the reduced form affects the asymptotic distribution of the Wald test for testing parameter instability which, in this case, differs from that obtained for OLS by Bai and Perron (1998). This paper complements the work by Perron and Yamamoto (2009) who show that tests for breaks based on OLS estimation have power even when the regressors are endogenous. The 2SLS approach of Hall, Han, and Boldea has the advantage to deliver consistent estimates of coefficients while OLS does not.

Penaranda and Sentana develop an extension of the standard asymptotic theory of efficient GMM able to deal with singularities in the long run variance matrix of the moment conditions. They show that using as a weighting matrix a generalized inverse of this variance matrix (irrespective of the choice of the generalized inverse) leads to GMM estimators asymptotically equivalent to the optimal ones which would have been obtained from a

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reparametrization taking into account the linear relationships between moment conditions. A tricky issue to make their approach feasible is to consistently estimate the generalized inverse of the variance matrix. As already emphasized by Andrews (1987) in the context of Wald testing, one must carefully assess the rank deficiency in order to avoid discontinuities in the generalized inverse operator. The example of interest for Penaranda and Sentana allows them to get this assessment. They want to compare spanning tests for both the Mean–Variance frontier of asset returns as well as the so-called Stochastic Discount Factor frontier (following Hansen and Jagannathan, 1991). They show that all the available overidentification tests are asymptotically equivalent not only under the null hypothesis but also under compatible sequence of local alternatives, despite the fact that the number of parameters and moment conditions can be different. The optimal GMM procedure under singularity that they have developed is crucial in reaching this conclusion. Moreover, they show that by using single-step procedures such as the Continuously Updated version of Hansen et al. (1996), they can make all the different overidentification tests numerically identical. They conclude that one could argue that effectively there is only one GMM-based spanning test.

Finally, Hansen's short paper provides the missing proofs about consistency of GMM estimators. The reader may be surprised that these proofs have been missing since 1982. The author provides these proofs as very close to the original form and does not try to connect them to the subsequent literature. However, it turns out that much can still be learned from this precise account of needed conditions for rigorous proofs. It first takes a Law of Large Numbers for random functions to guarantee the needed uniform convergence. Hansen (1982) had stressed the potential trade-off between assumptions on the parameter space (like compactness) and assumptions on the moment conditions. Under the name of parameter separation, the author proposes a generalization (w.r.t to the original 1982 paper) of his way of relaxing the compactness assumption at the cost of being more restrictive on the structure of moment restrictions. A careful study of random sets emerging as the outcome of the GMM minimization and a corresponding measurable selection rule to properly define a GMM estimator is studied. Finally, a rigorous proof of consistency of a two-step estimation procedure (dubbed recursive estimation in Hansen (1982)) is detailed.

Weak instruments

The so-called weak instruments asymptotics, as devised for non-linear GMM by Stock and Wright (2000) allow some parameters to be poorly identified because the moments that identify them drift to zero with the sample size, even for value of the parameters that do not correspond to the true one.

The paper by Guggenberger, Ramalho and Smith (GRS hereafter) is motivated by the already well documented evidence that GEL (Generalized Empirical Likelihood) alternatives to two-step GMM are likely to provide inference more robust to weak identification. GRS go further in several respects. First, they consider weak identification settings in a time series framework. Thus, extension of the idea of Kitamura and Stutzer (1997) leads them to work with kernel smoothed counterparts of the moment indicators. Second, they use implied probabilities generated by GEL estimation to compute Pearson-type test statistics. The tests discussed in the paper deal with both simple hypotheses and composite hypotheses on a subvector of parameters. The paper not only demonstrates that test statistics are asymptotically pivotal under weak instruments asymptotics but also proves asymptotic power results. The limit properties of the test statistics are evaluated under a fixed alternative for the weakly identified components.

In their survey on weak instruments asymptotics, Andrews and Stock (2007) acknowledge that "despite a great deal of work in the finite sample and Edgeworth expansion literatures, there are few sharp results concerning point estimates" in the presence of weak instruments.

The paper by Antoine and Renault addresses more generally the issue of efficient GMM estimation when identification goes through several pieces of information with different rates of convergence. This case encompasses the so-called situation of nearly-weak identification as first dubbed by Hahn and Kuersteiner (2002) and studied more systematically in non-linear settings by Caner (2010) and Antoine and Renault (2009). In these circumstances GMM estimates are consistent asymptotically normal (by contrast with standard weak identification) but with rates of convergence slower than root-T. The paper gives several other examples of similar situations, stemming either from kernel smoothing, tail trimming, or any kind of regularization. The many weak instruments asymptotics studied in the next set of papers is also a natural setting to consider rates of convergence slower than root-n. The key message of Antoine and Renault is twofold as soon as heterogeneous rates of convergence coexist in a minimum distance program. On the one hand different directions in the parameter space will come with different rates of convergence. On the other hand, thanks to self-standardization, the knowledge of these directions is not needed for efficient inference.

Many instruments or many regressors

A group of papers, namely Anatolyev, Carrasco, Kuersteiner, and Caner's papers, are concerned with inference in presence of either many regressors or many moment conditions. A crucial difference is that in Carrasco, Kuersteiner and Caner the dimension of the parameter of interest remains constant, whereas in Anatolyev it increases so that the estimators are no longer consistent but testing is still possible.

Anatolyev's paper considers a linear regression with homoskedastic error and studies testing when the number of regressors grows proportionately to the sample size. He shows that when the number of tested restrictions is fixed, the rescaled versions of F, LR, and LM tests are asymptotically Chi-squared distributed. However, when the restrictions are numerous, this result does no longer hold. He proposes modified versions of the tests that are robust in this situation, even so the coefficient estimators are not consistent. Interestingly, the exact F test that uses the critical values for the F distribution is also asymptotically valid.

Carrasco considers the estimation of regressors in a linear model with i.i.d. homoskedastic error. The number of instruments may be very large, countable infinite or a continuum. The covariance matrix is typically singular in finite sample (the number of observations is smaller that the number of restrictions) but is non-singular at the limit. However it is very ill-conditioned and some regularization or stabilization of the inverse is needed. Carrasco proposes a modified version of the GMM estimator where the inverse of the covariance matrix is stabilized via a Tikhonov, Spectral cut-off or Landweber Fridman regularization. She analyzes the higher-order expression of the MSE of the estimator and derives a data-driven method to select the regularization parameter. The advantage of working with a simple linear model contrary to a more complex non-linear one is that the role of the regularization becomes clear. Indeed, the regularized 2SLS estimator is equivalent to the 2SLS estimator that would be obtained using a non-parametric estimator of the optimal instrument.

Kuersteiner considers GMM estimation in a time-series context where an increasing number, M, of lags of the series are used as instruments. He derives the higher-order MSE of the estimator in order to select the optimal M. He also proposes an alternative estimator where the instruments are weighted by a decreasing kernel function. This kernel has the effect to reduce the bias and can be regarded as a regularization technique similar to those used in

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Carrasco. The derivation of the higher-order MSE is more difficult in time-series than in cross-section because it is not possible to condition on the instruments.

Caner and Yildiz focus on the estimation of a finite dimensional estimator using many weak instruments. They assume that the covariance matrix of the moments, although non-singular in the finite sample, becomes asymptotically singular as in the near singular design of Knight and Fu (2000). This is the crucial difference with Newey and Windmeijer (2009). Caner and Yildiz show that the standard Continuous Updated Estimator (CUE) is still consistent under the near singular design and the testing procedure of Newey and Windmeijer (2009) remains valid.

GMM with non-parametric components

While Hansen' initial GMM was focused on inference on a finite dimensional vector θ of structural unknown parameters, a more recent literature has considered extensions involving non-parametric components. In such a general setting, the object of interest is typically a functional element φ belonging to some Hilbert space E. Then, identification requires a set of orthogonality conditions at least as rich as the infinite dimension of φ. Then, a convenient general framework is to describe the set of orthogonality conditions through a linear operator T from the Hilbert space E to some other Hilbert space F and a target function r given in F. More precisely, the testable implications of the structural model are encapsulated in a linear inverse problem $T\varphi = r$. This inverse problem is used for inference about the unknown object φ based on a consistent estimator of r. Similar to the Method of Moments, asymptotic normality of estimators of φ will be derived from asymptotic normality of the sample counterpart of the population vector r. However, it is worth realizing that the functional feature of r introduces an additional degree of freedom that is not common for GMM with a finite number of unknown parameters, except possibly for many weak instruments asymptotics. More precisely, the rate of convergence to asymptotic normality heavily depends on the choice of instruments, namely of the choice of the inverse problem to solve. It must actually be kept in mind that this choice is to some extent arbitrary since the $T\varphi = r$ can also be transformed by any operator K to be rewritten $KT\varphi = Kr$. An important difference with standard GMM is that even the transformation by a one-to-one operator K may dramatically change the rate of convergence of the estimators of the right-hand side of the equation. Some operators are noise-reducing (as integration or convolution) whereas some others (as differentiation or deconvolution) actually magnify the estimation error. In particular some specific linear functional of φ may exist allowing root-n asymptotic normality of their estimators.

The paper of Severini and Tripathi addresses this issue in a non-parametric regression model where the regressors are endogenous and instruments are used to identify the unknown function φ. This problem has been studied by many authors, e.g. Florens (2003), Hall and Horowitz (2005) and Darolles et al. (2011). In this setting, Severini and Tripathi are able to characterize a condition for root-n estimability of linear functionals of the instrumental variables regression function φ. As a by-product, they are able to derive the efficient bound for estimating linear functional of φ that remain valid even when φ is not identified. Their efficiency bound generalizes, albeit with a different proof, a former result of Ai and Chen (2007) who consider estimating a weighted average derivative of φ.

The paper by Ai and Chen in this issue sets the focus on the semiparametric efficiency bound for finite dimensional parameters θ that are identified by sequential moment restrictions containing unknown functions. This model includes the semiparametric and non-parametric panel data models where the information set expands over time. It also nests semiparametric models that are estimated via two-stage plug-in procedures. It extends the work by Chamberlain (1992b) and Ai and Chen (2003) to the case of nested information sets and those of Chamberlain (1992a) and Brown and Newey (1998) to the case with unknown functions of possibly endogenous variables. The authors use the efficiency bound to derive a root-n asymptotically efficient estimator of θ.

Florens and Simoni also consider a non-parametric regression model where the regressors are endogenous and instruments are used to identify the unknown function φ. Their paper is arguably the first to revisit this issue with a Quasi-Bayesian approach. They stipulate a Gaussian prior distribution for φ. As the dimension of φ is infinite, the problem is ill-posed and the posterior distribution is not consistent in a frequentist sense. To address this issue, the authors compute a regularized posterior distribution of φ as in Florens and Simoni (2012). This distribution is like the exact posterior distribution where the mean and variance have been replaced by new moments where the inverse of the sample covariance operator has been regularized using Tikhonov regularization. They show that it is consistent in a frequentist sense.

The paper by Gospodinov and Otsu studies estimation of conditional moment restriction models in a time series context. The focus of interest is the local (with kernel smoothing) GMM (LGMMM) estimator that resembles localized versions of the generalized empirical likelihood estimator as introduced and developed by Kitamura et al. (2004), Smith (2007) and Antoine et al. (2007). While all these papers investigate the properties of the local estimators for i.i.d. data, Gospodinov and Otsu set the focus on conditional moment restrictions for time series but with a martingale structure. Therefore, by contrast with Kitamura (1997), the time series context does not require local averaging of moments to account for the long run variance. Local averaging is only used to approximate the conditional moment restrictions as in the aforementioned papers do in the i.i.d. setting. Antoine et al. (2007) had shown that a localized version of Euclidean Empirical Likelihood (LEEL) amounts to minimize a sum over the sample points of (squared) norms of (kernel smoothed) conditional moment restrictions with a weighting matrix which is a local (kernel smoothed) version of the weighting matrix of continuously updated GMM (CUE as in Hansen et al. (1996)). The objective function of LGMM is similar in spirit except that the weighting matrices are computed as kernel estimators of uncentered second moments (instead of kernel counterpart of conditional covariance matrices for LEEL). Point by point, this norm for LGMM is an increasing function of the CUE-type norm of LEEL but the LGMM estimator, obtained by minimization of sums (over the sample points) of such norms will numerically differ from the LEEL. However, one may expect the same asymptotic properties and very similar finite sample properties. Gospodinov and Otsu show that the LGMM estimator is consistent, asymptotically normal and attains the semiparametric efficiency bound for conditional moment restrictions with a martingale difference structure. Moreover, higher order asymptotics are discussed in the simple framework of an AR(1) model with i.i.d. errors. While, for positive autocorrelation, the OLS estimator is known to have a negative bias, the LGMM estimator reveals the presence of two bias terms of opposite signs that may offset each other.

Information-theoretic approaches

The three papers of this set share not only a common tool but also a common goal: comparison or assessment of misspecified models based on some information measurement.

The paper by Hall, Inoue, Nason and Rossi contributes to the literature on the estimation of dynamic stochastic general equilibrium (DSGE) models. This literature replaces the calibration practice by sound econometric inference based on moment

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matching in a GMM/Minimum Distance framework. The paper follows the methodology put forward by Dridi et al. (2007) to reconcile rigorous econometric inference with the need to live with misspecified structural models. While Dridi et al. argued that in order to make valid inference on structural parameters in spite of misspecification of the structural model, one must carefully select the moments to match, Hall et al. put forward techniques for selecting the moments to match. They do so by using information criteria to elicit valid moments, albeit always within the class of impulse response functions. Out of them, they select the most informative ones through the so-called relevant impulse response function criteria. These criteria can be used in combination to select the subset of valid impulse response functions with minimum dimension that yield asymptotically efficient estimators. They show that the use of their criteria significantly affects estimates and inference about key parameters in new Keynesian DSGE models.

The paper by Marmer and Otsu addresses more generally the issue of comparison of misspecified models, all defined by a set of moment conditions. While the former paper had set the focus on a specific loss function, the popular impulse response functions, the originality of the present paper is to consider the loss function as elicited by the practitioner and to discuss optimal comparison between misspecified models for a given loss function. The goal is to devise an optimal test of the Vuong (1989) and Rivers and Vuong (2002) type null hypothesis that the two models are equivalent under the given measure of fit. Optimality is defined with a Generalized Neyman–Pearson approach that is by optimizing the decay rates of the type I and II error probabilities under fixed non-local alternatives. The contribution of the paper is twofold. Not only does it derive in general an optimal but practically infeasible test, but it also provides a feasible approximation in the particular case of a loss function based on the weighted Euclidean norm of moment restrictions. A simulation study confirms that this approximate test may be more powerful than the Rivers–Vuong test.

Almeida and Garcia put forward the general tool of the Cressie Read family of discrepancies to revisit the Hansen and Jagannathan (1997) distance for assessing misspecified asset pricing models. It is an extension parallel to the new approach of GMM through GEL. More precisely, while traditional GMM was based on Euclidian norm, the family of GEL methods, including empirical likelihood, has referred more generally to the whole Cressie Read family of discrepancy functions for statistical inference on moment based models. Hansen and Jagannathan (1997) while remaining true to Euclidian norms, had shown how we should modify the GMM criterion if we only want to assess the degree of misspecification rather than fishing for an efficient estimator within a well specified model. While GEL is well-known to improve on GMM in terms of higher order bias of estimators, the improvement to Hansen and Jagannathan (1997) brought by Almeida and Garcia is related to the pricing of higher order moments of asset returns. More precisely, it is well documented that beyond the traditional mean-variance approach, investors care for higher order moments and this concern is testable from observed asset returns. Therefore, it is worth considering Hansen and Jagannathan type correction of misspecified pricing models based on non-quadratic loss functions.

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