Recent Advances and Future Directions in Causality, Prediction, and Specification Analysis

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Essays in Honor of Halbert L. White Jr

Xiaohong Chen · Norman R. Swanson
Editors

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Editor's Introduction

With profound sadness, we are forced to note that Hal White passed away during the publication of this volume, at age 61. This Festschrift, thus, now honors both his academic prowess as well as his memory. During Hal's short stay on this earth, he touched so many lives in so many wonderful ways that it is impossible to enumerate all of them. All of those of us who know Hal have many stories to tell of how he has shaped our lives, both in academic and non-academic ways. Hal was always cheerful, intellectually curious, insightful, resourceful, considerate, tolerant, humble, hard-working, well spoken, efficient, engaging, encouraging and energizing. He truly loved and enjoyed everything he did, from teaching and researching, to working on government "think tank" projects and consulting projects of all types; and of course to playing his trumpets. His zest for life was extremely contagious. He gave of himself freely and in some sense with abandon, spearheading literally hundreds of path-breaking research projects in econometrics, financial economics, forecasting, labor economics, causality, law and economics, neural networks, and biostatistics. Hal was always optimistic and never complained about anything. He cared about doing things that would uplift others' spirits, too. He loved his family dearly, and treated all with a kindness not often seen. His work ethic was un-paralleled. Once, Norm was surprised to find, upon meeting Hal at 8am one morning to discuss research, that he had already, that day, written undergraduate and graduate lectures, worked on his new book, thought about and worked on research, and gone to the gym. He was one of the best undergraduate and graduate teachers we have ever known. He was the only undergraduate statistics/econometrics teacher we know of that was given a spontaneous standing ovation by more than 100 students at the end of a quarter's teaching introductory statistics. His exceptional graduate lectures resulted in so many of us pursuing careers in econometrics that we number in hundreds. Hal was extremely smart and knowledgeable, even brilliant, yet he never laughed at any naïve and sometimes stupid questions and comments from his students. He was always patient with his students. He believed in us and encouraged us even though some of us had no clue what we were doing or saying. Xiaohong still remembers vividly that, instead of trying to understand Hal's papers, she told him that his econometrics papers were boring and that some papers on bounded rationality in decision and game theories were much more interesting. To her surprise, Hal did not get angry but replied that he would be happy to supervise her even if she wanted to work on topics in microeconomics. Without Hal's guidance and encouragement, many of us would not have been enjoying our professional lives now.

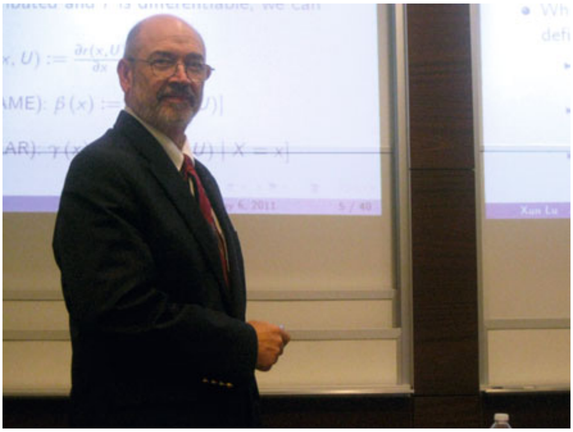
Hal was not just a renaissance man, but so much more.

Dearly missed by all who have had the good fortune and pleasure to have known and interacted with him.

Xiaohong Chen and Norm Swanson—April 2012

This volume gathers together 20 original research papers which were presented at the conference in honor of the pre-eminent econometrician from the University of California, San Diego, Halbert L. White, organized on the occasion of his sixtieth birthday, and entitled *Causality, Prediction, and Specification Analysis: Recent Advances and Future Directions*. The conference was held at the Rady School of Management on the UCSD campus during May 6–7, 2011. The conference was attended by over 100 co-authors, colleagues, and students of White.

Some of Hal White's students that attended the conference.



There is little doubt that Hal White has been one of the most important researchers in econometric theory and in econometrics in general, over the last 35 years. There are many ways of measuring the role that he has played in the profession, and the impact that he has had on research. For example, *A Heteroskedasticity-Consistent Covariance Matrix Estimator and a Direct Test for Heteroskedasticity* (*Econometrica*, 1980), also often referred to as the "White Standard Error" paper, had 5738 citations on the Web of Science in one recent count, and is thus one of the most highly cited papers ever, both in econometrics and in the entire field of economics. Other seminal papers in econometrics have much lower citation numbers, which indicates the broad impact of White's work in economics in general.

According to one recent count, White had more than 130 full-length articles spanning all of the very top journals in economics, statistics, and finance. He has also written three seminal books in econometrics, and has edited more than 10 other volumes. His research has had a major impact not only in econometrics and in economics, but also in statistics, finance, and in computer and cognitive science; and in recent years his work has also had an impact even in medicine and the natural sciences. For example, his seminal paper on artificial neural networks (joint with Kurt Hornik and Max Stinchcombe) entitled *Multilayer Feedforward Networks are Universal Approximators* (Neural Networks, 1989) has 3862 Web of Science citations. He even has an article recently appearing in the Michigan Law Review. This multi-discliplinary diversity is indeed a characteristic unique to Hal.

In various discussions, Hal has recounted some details from his "early years".

> I was born and raised in Kansas City, MO, where I attended Southwest High, graduating in 1968. There, I was salutatorian, having gotten edged out from the valedictorian spot by a few thousandths of a GPA point. If I had been smart enough not to take orchestra for credit, I could have been valedictorian,

but since the valedictorian was smart enough to not do that (damned clarinet players!) I always figured she deserved it.

I applied to Harvard and Princeton for college and got rejected from Harvard. Later, when I was deciding whether to stay at Rochester or move, I ended up choosing the UCSD offer over that from Harvard, but not because of my undergrad admission experience. Like Groucho Marx, I apparently wouldn't want to belong to an organization that would admit someone like me (except in California).

Luckily, Princeton accepted me, and I was thrilled to go there, expecting to be a physics major. One problem: I couldn't understand physics to save my life. The only way I made it through physics to satisfy my science requirement was extensive tutoring by Vince Crawford, who was my hall-mate (Dod Hall) freshman year. By second semester sophomore year, I had decided economics was much more interesting and doable, and I was fortunate in having great professors, among them Steven Goldfeld, Richard Quandt, Gregory Chow, Ray Fair, William Branson, George DeMenil, Orley Ashenfelter, Dan Hamermesh, and my senior thesis advisor, Alan Blinder. Alan was a new assistant professor then, fresh out of MIT.

At Princeton, I played my trumpet in the marching band, the orchestra (but not for credit), and the Triangle Club, plus a wide variety of student groups: a brass quintet, several big band jazz groups, and various soul/rhythm and blues bands, including The Nassau Brothers Soul Revue. This time I did manage to grab the valedictorian spot, although at Princeton, this is not determined by GPA, but by departmental nomination and election by the faculty.

Given the large number of my professors who came from MIT, that seemed to be the place to go next. So there I went in the Fall of 1972, along with Vince Crawford. My class at MIT has turned out to be quite distinguished, containing not only Vince, but also UCSD's Roger Gordon, who was my office mate in an office around the corner from Fisher Black and Robert Merton. Our office had no windows, but housed both of us (as well as Zvi Bodie), and gusts of sticky black soot would periodically blow out of the air vent. My illustrious classmates also include Peter Berck, Glenn Loury, Steven Sheffrin, Stephen Figlewski, Allan Drazen, Mario Draghi, Jeff Perloff, and Dennis Carlton. It was at MIT that I unknowingly established a later claim to fame by grading the homework of both Ben Bernanke and Paul Krugman as a TA for Jerry Hausman's econometrics classes. No surprise—they both did well. Frequently, I could use Bernanke's homework as an answer key!

Of course, the faculty at MIT while I was in grad school were stunning: Paul Samuelson, Robert Solow, Evsey Domar, Jagdish Bhagwati, Franco Modigliani, Charles Kindleberger, Frank Fisher, Peter Temin, Stan Fisher, Rudy Dornbusch, Hal Varian, Robert Hall, and very notably Rob Engle, a newly minted Ph.D. from Cornell, and a young Jerry Hausman, fresh out of Oxford.

I had somewhat of a hard time finding a thesis advisor to supervise my dissertation in labor economics, but eventually I knocked on the right door—Jerry's—and found the best advisor a young grad student could hope for. Jerry was always available and encouraging and provided ways forward whenever I hit what seemed to me to be a hopeless roadblock. My dissertation committee also included Lester Thurow (with whom I published my first Econometrica article, in international trade in 1976) and Bob Solow.

My job market experience in 1975–1976 was a harrowing one. I had 27 interviews, including the University of Chicago, where among my interviewers was Jim Heckman. The interview consisted of him demolishing my labor economics job market paper. I did end up with a good number of flybacks, including UCSD, but I did not get a UCSD offer (although Vince Crawford did, and took it!). Nor did I have any top 5 or 10 flybacks, and especially not Chicago! Only at the last minute, the night before I was just about to accept a very good but not great offer did I get a call from the University of Rochester offering me a flyout with a practically guaranteed offer. After consulting with Jerry, I decided to turn down my existing offer and bet my future on the Rochester possibility. In hindsight, I strongly suspect that Jerry was operating behind the scenes to generate that opportunity, making sure that his #2 thesis advisee (Roger Gordon was his first) was well treated in the market.

Rochester did come through with an offer, and an extremely attractive one at that—$16,000 for the academic year! Plus, I was thrilled to be going to a truly distinguished department, including, among others, Lionel McKenzie, Sherwin Rosen, Stanley Engerman, Robert Barro, Walter Oi, Eric Hanushek, Elhannon Helpman, and James Friedman. Econometrician G.S. Maddala had just left for Florida, but Charles Plosser and Bill Schwert were in the U of R Graduate School of Management just a few steps away, so I did have econometric colleagues handy. The thing was, at that time, I was a primarily a labor economist and only secondarily an econometrician. So there were some semesters that I taught macro and urban economics instead of econometrics. (Not that I knew macro or urban—these were just what was left over after the more senior faculty had chosen their courses!) I did accidentally learn a valuable lesson, though, in teaching those classes: make the first lecture about using the method of Lagrange multipliers to do constrained optimization. Not only is almost everything in economics a special case of this, but it causes half of those enrolled to drop the class immediately.

My transition from labor economist to econometrician took place in the first few years at U of R. One factor was that all of my labor economics articles based on my thesis chapters got rejected from all of the field journals. Another was that I learned measure theory from Bartle's superb book, Measure and Integration, in a small study group consisting of game theorist Jim Friedman, general equilibrium theorist Larry Benveniste, and myself. Each week we met and worked through a chapter of Bartle's book and presented solutions to the exercises. From this, I finally began to understand asymptotic distribution theory.

At the same time, I was deeply concerned by the prevalence of misspecification in econometric models and the fact that not much was known at a general level about the consequences of misspecification. Especially puzzling was the then common wisdom that OLS applied to a misspecified model gave you a Taylor-series approximation to whatever the true relation was. This made no sense to me, so I wrote a paper called *Using Least Squares to Approximate Unknown Regression Functions*. Amazingly to me, this was accepted by the International Economic Review for publication. Since, thanks to measure theory, I now seemed to know what I was doing, and since I had finally succeeded in getting an article published, I then began to think that maybe econometrics was a better place for me than labor economics or international trade. (As an interesting aside, the IER paper now has nearly 300 citations, according to Google Scholar, but there are still lots of people who think least squares gives you a Taylor approximation!)

This paper then led to my famous Econometrica paper on heteroskedasticity, where my final conversion to an econometrician was effected by a referee who said that he would recommend publication, provided that the included labor economics example was removed. Finally, I got it! Econometrics was my way forward.

An especially outstanding feature of the U of R was the wonderful group of graduate students it attracted. Eventually, I did get to teach the graduate econometrics classes. Two of my now distinguished students there were Gary Gorton and Glenn MacDonald. And one of the most important relationships of my life began when Charley Bates showed up in my office one day with his little Lhasa Apso dog, Li Po, to see about studying econometrics. Charley had just finished an undergrad degree at UCSD with a double major in math and economics. Charley ended up taking my econometrics classes, and, after an interesting oddyssey, eventually became my thesis advisee. As it turned out, that was just the beginning of a lifelong friendship and collaboration with Charley that has had an extremely positive impact on both my professional and personal life. Among other things, we co-founded our economics consulting firm Bates White, LLC, together with a small group of econ Ph.D.s that Charley had hand-picked. The firm will soon celebrate its twelfth anniversary, and it now employs over 150 highly talented people, many of whom have direct or indirect connections to UCSD. I am especially gratified that the firm is now well known for setting new quality standards in the economic and econometric analysis of legal disputes.

Another transition began in those early days at the U of R, and that was my transformation from an East Coast type with a Midwestern background to a California type. That transition began with a phone call in early May of 1977 from Rob Engle, who was by then at UCSD with Clive Granger. Rob's call came just one day after Rochester had received three FEET of snow (in May!) in a still famous blizzard. He inquired if I might be interested in being a visiting assistant professor at UCSD. I had to think about that for a while—perhaps ten seconds. As it turned out, I was not able to visit the next academic year, but it did work out that I was able to visit UCSD in Winter and Spring quarters of 1979. So it was that in December of 1978 I flew out of Rochester during a blizzard and arrived in 75° San Diego sunshine to begin a visiting appointment at UCSD.

Hal in the early days

One of the things Hal first did upon arriving at UCSD was to write his book *Asymptotic Theory for Econometricians* (1984). This was path breaking. Hal realized that in order to develop econometric theory, and also in order to be a competent user, not limited by the availability of ready-to-use procedures, one should be able to understand and combine all of the relevant tools from probability theory and mathematical statistics. He was the first to develop and make accessible to econometricians the necessary tools for deriving the properties of estimators and constructing tests under a full menu of realistic settings. Hal was the first to teach us about the interplay between properties of the data (e.g., how much dependence there is in the series and how many moments are finite) and theoretical features of the model postulated by the researcher, as dictated by econometric theory. Whether an estimator has a well defined probability limit depends on the statistical properties of the data, but the meaning and economic interpretation of that probability limit depends on the theoretical model. One of the fundamental insights Hal emphasized is that all models are an approximation to reality, and are thus generally incorrect. Nevertheless, we can learn important things, even from an approximation of reality. Furthering this idea, a complete and rigorous treatment of estimation and inference with misspecified (i.e., generally incorrect models), is given in his book entitled *Estimation, Inference and Specification Analysis* (1994). There is little doubt that modern econometric theory was pioneered by Hal. Moreover, Hal's contributions have been fundamental not only to the field of theoretical econometrics, but also to the field of empirical economics. In particular, thanks to Hal's work, standard econometric tools, such as hypotheses testing and inference in general, are now utilized correctly, in a variety of realistic contexts.

It is impossible to list all of his contributions. Hence, we confine our attention to five particular standouts.

White Standard Errors

Empirical work often requires one to test the null hypothesis that a parameter, say that associated with conveying the returns to an extra year of schooling, is zero or is instead strictly positive. Standard computer packages have always provided a ready-to-use solution to this problem. However, the classical solution is correct only under a particular assumption, known as conditional homoskedasticity. This assumption states that the variance of the error in a given model, conditional on the explanatory variables, is constant. This is a very restrictive assumption, often violated in practice. In fact, often the variance of the error depends on the individual covariates, in an unknown manner. However, if conditional homoskedasticity fails to hold, the inference that we draw based on the classical solution is incorrect, and may lead to the wrong conclusion (e.g., we might conclude than an extra year of schooling has no effect on wages, when instead it does). This is because the variance/standard error estimator used by standard packages is only consistent for the "true" variance/standard error under conditional homoskedasticity. Hal, in *A Heteroskedasticity-Consistent Covariance Matrix Estimator and a Direct Test for Heteroskedasticity* (*Econometrica*, 1980), developed an estimator of the covariance which is robust to the presence of conditional heteroskedasticity of unknown form. This estimator is now routinely available in all computer packages, and is called "White Standard Errors". It is now common practice to report both "classical" and "White" standard errors.

White Standard Errors, although crucial to applied econometric analysis, still require that the error of the model is not autocorrelated (i.e. the error does not depend on its past). This is typically the case when we have cross-sectional observations, for example (e.g., we have data on a group of individuals at a given point in time, rather than data that are measured over time, such as the consumer price index). If we do have data measured over time, called time-series data, then the error is not autocorrelated only if the model is "dynamically correctly specified". For dynamic correct specification, we mean that both the functional form of the model and the dynamics specified for the model (e.g. the number of lags or past values) are correct. However, in practice, dynamic misspecification is more the rule than the exception. In articles co-authored with Ian Domowitz (*Journal of Econometrics*, 1982 and *Econometrica*, 1984) and as elaborated in his book *Asymptotic Theory for Econometricians* (1984), Hal proposed a variance estimator that is robust to both heteroskedasticity and autocorrelation of unknown form, and which is now known as a HAC (heteroskedasticity and autocorrelation robust) estimator. Whitney Newey and Ken West, in a famous *Econometrica* paper published in 1987, refined White's estimator to ensure positive definiteness, which is crucial for empirical application, yielding the famous so-called Newey-West estimator. Of course, all of this work was predicated in large part on the initial 1980 *Econometrica* paper and Hal's seminal work with Domowitz.

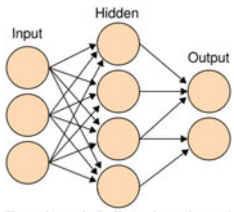
Maximum Likelihood Estimation of Misspecified Models

Another key contribution due to Hal is *Maximum Likelihood Estimation of Misspecified Models* (*Econometrica*, 1982). This paper is also among the most cited ever, with 1389 citations on the Web of Science. The idea underlying Maximum Likelihood Estimation (MLE) is that the estimators we compute are those maximizing the probability of observing the sample of data that we actually observe. If we correctly specify the conditional density of the data, then ML estimators are the "best estimators"—they are consistent, asymptotically efficient, and invariant to reparameterization. However, we almost never know the correct conditional density. For example, sometimes we are able to correctly specify only the conditional mean and maybe the conditional variance; and sometimes we are not even able to correctly specify the conditional mean. In the end, as Hal emphasized, models are just approximations of reality and so they are generally incorrect. But, what happens if we estimate misspecified models using Maximum Likelihood? Hal shows that the MLE generally converges to the parameter values minimizing the Kullback-Leibler Information Criterion (KLIC). Namely, MLE always converges to the parameters minimizing the "surprise" that we get when we believe that our data are generated by a given model, but instead we learn that they are generated by a different one. Further, if we misspecify the conditional distribution, but we still correctly specify the conditional mean, then the ML estimator, under very mild conditions, converges to the same value, as in the case of "full" correct specification. Nevertheless, the asymptotic variance is different, and this should be taken into account when performing hypothesis testing. This observation led to the celebrated Dynamic Fisher Information Matrix test due to Hal. The main practical implication of his work on MLE with misspecified models, is that one can simply estimate models via Gaussian Maximum Likelihood (i.e. one can proceed as if the errors are conditionally normal, even if they are not). This has had tremendous impact on applied work. Estimation with Gaussian likelihood is very simple to implement, and it's incredibly useful to know that it can deliver valid inference even if conditional normality does not hold.

This work also played a part in inspiring the subsequent literature on the estimation of conditional autoregressive models (ARCH and GARCH models). In this context, one postulates a model for the conditional mean and the conditional variance, even though the conditional density of the error is generally unknown, and typically has fatter tails than those associated with a normal random variable. However, Gaussian ML generally gives consistent parameter estimates and allows for correct inference as a consequence of Hal's theory. Hal's 1982 paper was also the starting point for a literature based on the use of the KLIC for model specification and testing (see e.g. the recent applications of the KLIC to measuring serial dependence by Yongmiao Hong and Hal White in *Econometrica* in 2005 and to forecast evaluation by Rafaella Giacomini and Hal White in *Econometrica* in 2006.

Neural Network and Consistent Specification Tests

Neural network models were introduced by cognitive scientists, in an attempt to build computers that could learn from experience instead of having to be programmed. Such models are characterized by input variables (sensory information) that "pass through" one (or more) hidden processing layers, yielding an "output" (a classification, prediction, or action) In a series of seminal papers, some joint with Ron Gallant or with Kurt Hornik and Max Stinchcombe, Hal has shown that such models have a "universal approximation" property, in the sense that they are able to approximate any generic function, as well as its derivatives, up to an arbitrary level of accuracy, given mild conditions. Although not as well known to economists, one of Hal's key papers on this subject, entitled *Multilayer Feedforward Networks are Universal Approximators* (Neural Networks, 1989) has received 3862 citations on the Web of Science, as mentioned above.



The workings of a feedforward neural network

The flexibility of a neural network model is ensured by its dependence on a number of parameters, which have to be estimated. Hal developed novel techniques for estimating neural network models and derived their statistical properties in a number of papers, including *Some Asymptotic Results for Learning in Single Hidden Layer Feedforward Network Models* (*Journal of the American Statistical Association*, 1989). These fundamental contributions to neural network theory have had a big impact in the cognitive sciences, medicine, engineering, and psychology. But what impact have they had in the field of econometrics? For one thing, artificial neural networks now have their own JEL number, C45. Further, neural networks play a major role in the crucially important literature on testing for the correct functional form of a model. Suppose that we want to test whether a linear model is correctly specified for the conditional mean. In this case, we want to have a test that is able to detect all possible departures from linearity, including small ones. A test that is able to detect any generic deviation from the null hypothesis is said to be "consistent". If the linear model is correctly specified, then the error is uncorrelated with any arbitrary function of the regressors. How can we approximate any arbitrary function of the regressors? With a neural network, of course, as they are capable of approximating any generic function. A very nice example of the use of neural network in testing for the correct functional form of a model is Hal's paper with T.H. Lee and Granger entitled *Testing for Neglected Nonlinearity in Time-Series Models: A Comparison of Neural Network Methods and Standard Tests* (*Journal of Econometrics*, 1993).

Nowadays, a new branch of economics, labeled neuro-economics, is rapidly gaining momentum. The objective is to study the link between the functioning of the brain and economic behavior. For example, which part of the brain controls our behavior when playing the stock market? Which characteristics of the brain make an individual a "better" player in the stock market? There is little doubt that in the near future, neural network theory will play a major role in the formalization and in the development of neuro-economics.

Reality Check and Data Snooping

A Reality Check for Data Snooping (*Econometrica*, 2000), is one of the most (if not the most) influential papers in the study of financial econometrics as well as in forecasting, over the last few years. Begin with a "benchmark" model, typically the most popular model, or the easiest to estimate, and consider a (potentially long) list of competing models. Assume that we want to test whether there exists at least one competitor that truly outperforms the benchmark. Hal starts from the observation that if we use the same dataset to sequentially test each model versus the benchmark, then eventually we're sure to find one or more models that beat it. This is because of the well known "data-mining" or "data-snooping" problem associated with sequentially comparing many models using classical statistical testing approaches. That is, we will eventually find a model that, simply due to luck, appears to be superior to the benchmark. Hal provides a novel solution to this problem. By jointly considering all competing models, his reality check procedure ensures that the probability of rejecting the null when it is false (i.e., the probability of a false discovery), is smaller than a prespecified level, say 5 %.

Evaluation of asset trading rules has been one of the most challenging issues in empirical finance. An investor can choose from a very long list of trading strategies. Say that she wants to pick the strategy giving the highest return. However, because of the data-snooping problem, she may simply pick a strategy that by luck appears to be successful, but it is truly not. Hal's Reality Check provides a formal way of choosing among trading strategies, controlling for the probability of picking "winners" just because of luck. This idea is clearly illustrated in his paper with Ryan Sullivan and Allan Timmermann, entitled, *Data Snooping, Technical Trading Rule Performance, and the Bootstrap* (*Journal of Finance*, 1999).

Causality and Structural Modeling

In recent years, Hal's interest has also focused on the issue of measuring causal effects, in very general settings. This is one of the most challenging problems in econometrics and statistics. Suppose that we want to evaluate the effect of an increase of police per capita on the crime rate. However, the crime rate may also increase in areas because of urban decay, which may be impossible to properly measure, and police per capita may be (positively or negatively) correlated with urban decay. Disentangling such cause/effect relationships is a problem that has been addressed numerous times over the last 100 years, and the problem remains vexing and complicated. Exactly how can we carry out valid statistical analysis of the sort needed? The difficulty is that we need to measure the effect of a cause or treatment that is "endogenous" – that is, the cause of interest (police per capita) is correlated with unobservable drivers (urban decay) of the response (the crime rate). The two most common solutions to this problem are the use of instrumental variables, i.e., the use of variables that are correlated with the observable cause but independent of the confounding, unobservable cause—i.e. the "error". The second approach consists of finding control variables, such that the endogenous cause, conditional on the control variables, is independent of the unobservable causes. There is growing consensus that the latter approach is preferable. However, it is often difficult to find adequate control variables. In this case, one has to rely on the instrumental variable approach. Still, there is a problem, as this approach works only for separable models, in which the error enters in an additive manner, that is, the unobservable causes do not interact with the observable causes.

In one of his recent important works in this area with Karim Chalak and Susanne Schennach, entitled *Estimating Average Marginal Effects in Nonseparable Structural Systems* (2011), Hal studies the case of nonseparable models, in which the effects of unobserved causes cannot be separated from those of the observable endogenous causes. They consider a different route to evaluate the marginal effect of an endogenous cause on the response variable, via use of the ratio of the marginal effect of the instrument on the response variables and the marginal effect of the instrument on the endogenous cause. In particular, they provide sufficient conditions on the structure of the model for the validity of the approach, and they develop a novel estimator. There is little doubt that this work will have a large impact on empirical microeconomics, as it considers very general and realistic settings. In another recent work with Stefan Hoderlein, entitled *Nonparametric Identification in Nonseparable Panel Data Models with Generalized Fixed Effects* (2011), Hal is also considering identification of marginal effects in nonseparable panel data models with non-additive fixed effects. This is a daunting challenge, and their results are bound to open new frontiers in both the nonparametric identification and the nonlinear panel data literatures.

In other recent work with UCSD Ph.D. Xun Lu, (*Granger Causality and Dynamic Structural Systems*, 2010) Hal shows that Granger causality is not devoid of true causal content. Instead, as Hal shows, it is equivalent to true structural causality under well defined conditions.

Hal and Teresa at the Xiamen Conference on Specification Testing in 30 Years

Turning our attention to the papers published in this volume, it is worth stressing that they comprise 20 original research papers. All of the papers investigate econometric questions in the broad areas of specification analysis, causality, and prediction. In the first paper, entitled: *Improving GDP Measurement: A Forecast Combination Perspective* by Boragan Aruoba, University of Maryland, Francis X. Diebold, University of Pennsylvania, Jeremy Nalewaik, Federal Reserve Board, Frank Schorfheide, University of Pennsylvania, and Dongho Song, University of Pennsylvania, the authors examine a forecast combination approach to "predict" GDP growth for the U.S., using both income side and expenditure side versions of GDP, and uncover interesting features of their new measure. In the second paper, entitled *Identification without Exogeneity under Equiconfounding in Linear Recursive Structural Systems* by Karim Chalak, Boston College, the author provides alternative identification results on structural coefficients in linear recursive systems of structural equations without requiring that observable variables are exogenous or conditionally exogenous. He provides conditions under which equiconfounding supports either full identification or partial identification.. In the third paper, entitled *Optimizing Robust Conditional Moment Tests: An Estimating Function Approach* by Yi-Ting Chen, Academia Sinica and Chung-Ming Kuan, National Taiwan University, survey robust conditional moment (RCM) tests under partial model specification, discuss a generalized RCM type test, and introduce methods for improving local asymptotic power of suboptimal RCM tests. In the fourth paper, entitled *Asymptotic Properties of Penalized M Estimators with Time Series Observations* by Xiaohong Chen, Yale University and Zhipeng Liao, University of California, Los Angeles, the authors establish convergence rates for penalized M estimators with weakly dependent data. They then derive root-n asymptotic normality results for plug-in penalized M estimators of regular functionals, and discuss consistent long-run covariance estimation. Turning our attention again to forecasting, in the fifth paper, entitled *A Survey of Recent*

Advances in Forecast Accuracy Comparison Testing with an Extension to Stochastic Dominance by Valentina Corradi, Warwick University and Norman R. Swanson, Rutgers University, the authors survey recent advances in predictive accuracy testing, with focus on distributional and density forecasting. They then introduce a new model selection type forecast accuracy test based on the use of standard principles of stochastic dominance. The sixth paper is entitled *New Directions in Information Matrix Testing: Eigenspectrum Tests* by Richard M. Golden, University of Texas at Dallas, Steven S. Henley, Martingale Research Corporation and Loma Linda University, Halbert White, University of California, San Diego, and T. Michael Kashner, Loma Linda University. In this paper, the information matrix test of White (1982) is extended by considering various non-linear functions of the Hessian covariance matrices commonly used when carrying out such model specification tests. The paper entitled *Bayesian Estimation and Model Selection of GARCH Models with Additive Jumps* by Christian Haefke, Institute for Advanced Studies and Leopold Sogner, Institute for Advanced Studies is the seventh paper in this volume. In this paper, novel Bayesian simulation methods are used to carry out parameter estimation and model selection in a class of GARCH models with additive jumps. In the eighth paper, entitled *Hal White: Time at MIT and Early Days of Research* by Jerry Hausman, M.I.T., the author briefly discusses Hal White's early experiences at MIT, where he carried out his graduate work. Hausman then undertakes an interesting examination, via Monte Carlo simulation, of a variety of different estimators of White heteroskedasticity consistent standard errors, including one based on a Rothenberg second-order Edgeworth approximation. Turning now to the paper entitled *Open-model Forecast-error Taxonomies* by David F. Hendry, University of Oxford and Grayham E. Mizon, University of Southhampton, we are treated to a paper wherein "forecast-error taxonomies" are developed when there are unmodeled variables, and forecast failure to shifting intercept issues is discussed. The tenth paper in the volume is entitled *Heavy-Tail and Plug-In Robust Consistent Conditional Moment Tests of Functional Form* by Jonathan B. Hill, University of North Carolina. In this paper, the author considers consistent specification test of a parametric conditional mean function for heavy-tailed time series models, in which the dependent variable has only finite conditional first moment while all the higher moments could be infinite. The author derives chi-squared weak limit of his test statistics and provides a Monte Carlo study.. In the eleventh paper, entitled *Nonparametric Identification in Dynamic Nonseparable Panel Data Models* by Stefan Hoderlein, Boston College, and Halbert White, University of California, San Diego, the authors tackle the issue of nonparametric identification of covariate-conditioned and average partial effects in dynamic nonseparable panel data models. They show that the panel structure can be used to find control functions that in turn can be used for identification. The paper entitled *Consistent Model Selection Over Rolling Windows*, which is the twelfth paper in the volume, and which is written by Atsushi Inoue, North Carolina State University, Barabara Rossi, Duke University, and Lu Jin, North Carolina State University, analyzes the asymptotic properties of a test statistc based on the use of simulated out-of-sample predictive mean square errors when carrying out model selection amongst nested models using rolling data estimation windows. In particular, the authors discuss instances under which test consistency obtains, hence validating the use of the statistic in empirical contexts. Next, we have the paper entitled *Estimating Misspecified Moment Inequality Models* by Hiroaki Kaido, Boston University and Halbert White, University of California, San Diego. In this interesting paper, partially identified structures defined by a finite number of moment inequalities are examined, in the context on functional misspecification, a pseudo-true identified set whose elements can be interpreted as the least-squares projections of the moment functions that are observationally equivalent to the true moment function is found, and a set estimator for the pseudo-true identified set is proposed. The fourteenth paper in the volume is entitled *Model Adequacy Checks for Discrete Choice Dynamic Models* by Igor Kheifets, New Economic School and Carlos Velasco, Universidad Carlos III de Madrid. In this paper, the authors propose a consistent specification test for possibly nonstationary dynamic discrete choice models. They apply an extension of the probability integral transformation of data, and convert the null hypothesis of correct specification of conditional distribution of the original model into test of uniform marginal with no series dependence of the transformed data. This paper is followed by the piece entitled *On Long-Run Covariance Matrix Estimation with the Truncated Flat Kernel* by Chang-Ching Lin, Academia Sinica and Shinichi Sakata, University of Southern California, the authors propose simple modifications to truncated flat kernel estimators of long-run covariance matrices which enforce positive definiteness and have good small sample properties. The following paper, which is the sixteenth in the volume, and which is entitled *Predictability and Specification in Models of Exchange Rate Determination,* is authored by Esfandiar Maasoumi, Emory University and Levent Bulut, Emory University. In this paper, metric entropy tests are used to examine a variety of parametric models of exchange rate determination, and it is found that random walk models, both with and without drift, almost always dominate models based on various conditioning information sets. The seventeenth paper in the volume is entitled *Thirty Years of Heteroskedasticity-Robust Inference* by James G. MacKinnon, Queen's University. In this paper, the author discusses the revolutionary idea of White (1980) on inference that is robust to heteroskedasticity of unknown form. He also presents the recent developments to improve the finite sample properties of White's original standard error estimators. The eighteenth paper in the volume, entitled *Smooth Constrained Frontier Analysis,* is authored by Christopher F. Parmeter, McMaster University and Jeffrey S. Racine, McMaster University. In this paper, the authors propose a class of smooth constrained nonparametric and semiparametric estimators of production functions that are continuously differentiable and are consistent with the optimization axioms of production. Turning now to the second last paper in this volume, entitled *NoVaS Transformations: Flexible Inference for Volatility Forecasting* by Dimitris Politis, University of California, San Diego and Dimitrios D. Thomakos, University of Peloponesse, the authors present some new findings on the NoVas (''normalizing and variance stabilizing'') transformation approach to volatility prediction. They conduct detailed simulation studies about the relative forecasting performance of NoVaS with that of a benchmark GARCH(1,1) model.. Finally, we have an interesting paper entitled *Causal Efficacy and the Curse of Dimensionality* by Maxwell B. Stinchcombe, University of Texas, Austin and David M. Drukker, STATACorp Statistical Software. This paper gives a new geometric representation of various nonparametric conditional mean regression estimators, including the sieve least squares estimators (Fourier, wavelet, splines, artificial neural networks), the kernels and other locally weighted regressions. The authors establish that for any estimator having their new geometric representation, the nonparametric rate of convergence does not suffer the well-known curse of dimensionality, at least asymptotically.

Hal White's Key Publications

Books

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2. A.R. Gallant and H. White: *A Unified Theory of Estimation and Inference for Nonlinear Dynamic Models*. Oxford: Basil Blackwell (1988).
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