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Time-Series Econometrics in Macroeconomics and Finance

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I. Introduction

Ninety years ago, Slutsky (1927) and Yule (1927) opened the door to the use of probability models in the analysis of economic time series. Their vision was to view economic time series as linear responses to current and past independent and identically distributed impulses or shocks. In distinct contributions, they showed how to generate approximate cycles with such models. Each had a unique background and perspective. Yule was an eminent statistician who, in the words of Stigler (1986), among his many contributions, managed "effectively to invent modern time series analysis" (361). Yule constructed and estimated what we call a second-order model and applied it to study the time-series behavior of sunspots. Slutsky wrote his paper in Russia in the 1920s motivated by the study of business cycles. Much later, his paper was published in *Econometrica*, but it was already on the radar screen of economists, such as Frisch. Indeed Frisch was keenly aware of both Slutsky (1927) and Yule (1927) and acknowledged both in

his seminal paper (1933) on the impulse and propagation problem. Building on insights from Slutsky and Yule, Frisch pioneered the use of impulse response functions in economic dynamics. His ambition was to provide explicit economic interpretations for how current-period shocks alter economic time series in current and future time periods.[1] The *Journal of Political Economy* provided an important platform for research that confronts Frisch's ambition in substantively interesting ways.

II. Rational Expectations Econometrics

A stumbling block for implementing Frisch's (1933) ambition was how to capture people's beliefs about the future. Investment and other decisions are in part based on people's views of the future. Constructing prudent economic policy depends in part on how private agents will respond in the future. Once economic decision makers are included in formal dynamic economic models, their expectations come into play and become an important ingredient to the model specification. Thus the time-series econometrics research agenda grounded in economics had to take a stand on how people inside economic models made forecasts.[2] The rational expectations approach pioneered by Muth (1961) and Lucas (1972a, 1972b) provided a coherent and model-consistent way to capture people's beliefs. It has been implemented in different ways in econometric practice. One way is to exploit the resulting rational expectations equilibrium by fully specifying the underlying economic model. The resulting model solution then determines the beliefs of the economic agents inside the economic model. Empirical evidence comes into play because econometricians face uncertainty about the underlying parameters of the rational expectations equilibrium and use data to infer their values. This vision is well articulated in Sargent's (1981) *JPE* treatise on interpreting economic time series. The restrictions are sometimes implemented with two-step shortcuts whereby parameters of processes for exogenous dynamics are estimated and plugged into econometrically derived relationships. Additional parameters are estimated in a second step. Other approaches start with partially specified models and then use historical time-series evidence to impose rational expectations without fully solving for the dynamic equilibrium. Econometric support for this approach was provided in my 1982 paper with an initial application in the *JPE* (Hansen and Hodrick 1980). This second paper

[1] Sims (1980) and others advanced this idea by developing tractable multivariate time-series methods and engaging in the identification of interpretable shocks in the multivariate setting.

[2] See Hansen (2014) for more discussions of modeling challenges for econometricians and economic agents inside the models that they build.

added a new perspective to the empirical link between forward and spot exchange rates.

III. Consumption and Permanent Income

Friedman's (1957) famed permanent income model has implications for both macroeconomic time series and microeconomic cross-sectional data. Its rational expectations counterpart is perhaps most simply depicted with a quadratic utility function, uncertain labor income, and a subjective rate of discount equal to the rate of return on assets. Insights have broader implications, but in this simplest setup, consumption is a martingale. This observation was featured by Hall (1978) in his well-known *JPE* paper on consumption and income dynamics. Permanent income theory in this guise illustrates how even transient implications for income can have permanent consequences for consumption while maintaining Friedman's basic insight that the permanent shocks to income are absorbed much more prominently into the consumption responses. The impact of the transient shocks is mitigated through savings behavior.

The Hall approach is a stark example of a partially specified model exploiting rational expectations. The martingale implications for consumption can be tested, as was done by Hall (1978), without having to specify correctly the income dynamics. Flavin (1983), also published in the *JPE*, completed the model specification and discussed the implied cross-equation restrictions of the type featured in Sargent (1981) to represent the excess sensitivity of consumption to transitory income. To derive the cross-equation restrictions as implied by a rational expectations equilibrium requires specifying the information about income used by consumers. For instance, information other than lagged income could be pertinent in predicting future income suggesting that the correct equilibrium may include other state variables. Testing the predictability of the first difference of consumption, however, does not require this complete specification. In this Hall-Flavin setup, the first difference of consumption reveals a news component in the information set of consumers (abstracting from measurement error). As Hansen, Roberds, and Sargent (1991) emphasized, this news component should be present-value neutral and offset by future income responses to this same shock. This gives a testable restriction on the corresponding impulse response function of income to the consumption news.

IV. Consumption and Asset Pricing

While the original Hall-Flavin research featured aggregate (and micro) implications with constant interest rates, the *JPE* published a variety of

papers that explored the empirical challenges that allowed for time variation in these rates. In addition, this literature built links between the macroeconomy and asset pricing with the aim of explaining empirical heterogeneity in the cross section of financial returns. As an outcome of this research, macroeconomists have featured the so-called equity premium, the observed gap between expected aggregate equity returns and Treasury bill returns, but the observed heterogeneity is much more pervasive. The Hall (1978) style reasoning turned out to be directly extendable to "Euler equation" representations of multiple assets, not just bonds and aggregate equity returns. Such representations support the equilibrium representation of asset prices using so-called stochastic discount factors that both discount the future and adjust for risk whereby the stochastic discount factors are explicitly linked to the macroeconomy through variables such as consumption. This stochastic discount factor approach provided a platform for empirical analysis. The conceptual underpinnings for this line of research were supported by theoretical derivations in Rubinstein (1976), Lucas (1978), and Breeden (1979).

The *JPE* published several important papers that explored empirical evidence related to this research. Hansen and Singleton (1983) used a linear time model to depict the implied linkages between consumption and returns. It featured restrictions across the predictable component of the time series and could accommodate a small cross section of returns. The linear time series approach had nice pedagogical value, making the overidentifying restrictions transparent, but it required a lognormal assumption without any scope for stochastic volatility. This linear time series approach was in contrast to the approach used by Hansen and Singleton (1982), who avoided the distributional assumption by studying alternative conditional moment restrictions. Both papers allowed for econometricians to understate the information used by economic agents. Moreover, both papers are among a collection of papers that document the empirical challenge posed by a representative or stand-in consumer model with time-separable power utility preferences as was commonly used in the macroeconomics literature. The power utility specification led to a stochastic discount factor that was a simple function of consumption growth. While many refer to this as the equity premium puzzle, it really is a more general phenomenon pertaining to the pricing of a heterogeneous cross section of returns.

In a later *JPE* paper, Hansen and Jagannathan (1991) provided a further characterization of the puzzle by stripping away the parametric structure of the stochastic discount factor. In the absence of arbitrage, there exist valid stochastic discount factors; however, they may possess different properties than what are implied by models with more parametric structure. Allowing for a much larger class of stochastic discount factors eliminated the possibility of fully identifying the stochastic discount factor

process from data and changed the econometric challenge to characterizing the set of potential stochastic discount factors that are consistent with empirical evidence. Specifically, Hansen and Jagannathan derived sharp bounds on the implied mean–standard deviation trade-off for stochastic discount factors that are consistent with the evidence from financial markets. Subsequent research extended and refined this analysis in a variety of ways. Empirical puzzles are well defined only relative to a family of models, and the bounds in the Hansen and Jagannathan paper and its extensions provided a more general way to pose puzzles with the aim of suggesting what is needed to construct models with better empirical underpinnings.

In response in part to the empirical challenges, the *JPE* has published several innovative papers that explored different specifications of investor preferences. For instance, Constantinides (1990) built a fully specified model in which investors have preferences that display habit persistence. Investors' period utilities depend not only on current-period consumption but also on that consumption relative to a habit stock of past consumptions. In effect, the habit stock provides a reference point for current consumptions.[3] Campbell and Cochrane (1999) altered these preferences in two ways. They featured a model in which the habit stock contributes a socially determined reference point based on past social consumptions. In addition, the counterpart to the habit stock has a nonlinear evolution equation. The Campbell and Cochrane paper, in particular, featured a model in which the market compensation for the exposure to macroeconomic risk is larger in bad macroeconomic times than in good ones. They provided an endogenous mechanism for this variation. While stylized, their analysis was supported by some empirical evidence, much more so than its counterpart with a power utility function. Others have extended and refined this as an empirically relevant asset pricing model.

A different strand of empirical research explored an alternative specification of investor preferences based on a recursive utility formulation. Such preferences, by design, feature investor concerns about the intertemporal composition of risk. This research built on theoretical underpinnings provided in Kreps and Porteus (1978) and Epstein and Zin (1989) and was prominently represented in two important *JPE* papers: Epstein and Zin (1991) and Campbell (1996). The stochastic discount factor in recursive utility models depends on the next-period continuation value relative to a risk-adjusted counterpart. This continuation value, familiar from recursive methods in economic dynamics, encodes investor perceptions about the future consumption prospects. Thus recursive utility preferences bring in a forward-looking contribution into the valuation of even short-

[3] Becker and Murphy (1988), also published in the *JPE*, used a similar formulation in a microeconomic analysis of "rational addiction."

term returns. The empirically oriented Epstein and Zin and Campbell papers accommodated this forward-looking perspective in different ways. The Epstein and Zin (1991) research followed an econometric approach similar to that in Hansen and Singleton (1982) modified by using a clever measurement scheme. Under their parametric specification, the return on wealth reveals the relevant information about the continuation value contribution to the stochastic discount factor. Campbell (1996) used a time-series formulation with forward-looking restrictions of a type that is common in linear rational expectations models but applied to financial variables. Campbell cleverly avoided using consumption data and instead featured the time-series properties of the market return, including its predictability. One reason to avoid using aggregate consumption data, as in Campbell, is that only a limited segment of the population participates in security markets. There has been a variety of subsequent empirical work that has built on these initial empirical contributions and their insights. Many of the resulting papers have demonstrated that the forward-looking channel added by recursive utility could have an important impact in asset pricing. Bansal and Yaron (2004) is a prominent example. In a related *JPE* contribution, Hansen, Heaton, and Li (2008), like Campbell, used linear time-series methods and rational expectations restrictions. Specifically, Hansen et al. characterized and measured long-term risk components that are simultaneously in the macroeconomic time series and in the cash flows from broad-based portfolios of equities.

V. Imperfections in Financial Markets

Markets are not fully complete, and there are limits as to how much risk they can share. The presumed market structure also alters the predicted equilibrium pricing of financial securities. For instance, suppose that consumers/investors face idiosyncratic components to labor income risk that cannot be fully diversified in financial markets. Two prominent examples of papers that took this as a starting point are Krusell and Smith (1998) and Constantinides and Duffie (1996). Both were published in the *JPE*. Krusell and Smith featured dynamic models for which the impact of market incompleteness was relatively benign in the sense that simple averages could be used to summarize distributional impacts for representing the evolution of the macroeconomy. In contrast, Constantinides and Duffie featured models in which idiosyncratic shocks to labor income have permanent components. Moreover, they presumed that there are macroeconomic impacts on the distributions of these idiosyncratic shocks. In their model, the equilibrium stochastic discount factor inherits these macroeconomic impacts. Both papers have interesting benchmark economies, and their contributions have had a remarkable impact on subsequent

research. In a *JPE* paper related to Constantinides and Duffie (1996), Heaton and Lucas (1996) probed into the microeconomic evidence and explored the quantitative implications of market incompleteness for asset pricing.

One rationale for why financial markets cannot fully diversify labor income risks is that idiosyncratic shocks are private information. The Kocherlakota and Pistaferri (2009) *JPE* paper took this perspective and presumed that the observed cross-sectional allocations are Pareto optimal after taking account of the private information. They derived the corresponding asset pricing implications and contrasted them with the ones implied by the incomplete market formulation of Constantinides and Duffie (1996) and others. Different attributes of the cross-sectional distribution of shocks come into play for the private information economy. Kocherlakota and Pistaferri exposed some of the resulting measurement challenges for asset pricing.

VI. Conclusion

Journal of Political Economy publications have played a prominent role in the study of macroeconomics and finance using time-series methods. The research disseminated by this journal delivered on Frisch's (1933) and others' ambition to use economic dynamic models to interpret time-series evidence. The published research characterized empirical challenges and explored implications of new models designed to confront these challenges.

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Asset Pricing: Models and Empirical Evidence

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Hansen and Singleton (1982, 1983), Shiller (1982), Mehra and Prescott (1985), and Weil (1989) pose a major challenge in economics in the context of a Lucas (1978) exchange economy. Hansen and Singleton (1982) reject the Euler equations of per capita consumption at any level of relative risk aversion (RRA). Mehra and Prescott (1985) show that the average premium of the stock market over the risk-free rate cannot be rationalized in a calibrated standard economy and coin the "equity premium puzzle." Mehra and Prescott (1985) and Weil (1989) further show that the puzzle is a dual one: as the assumed RRA is increased to rationalize the equity premium, the implied risk-free rate becomes too high. More generally, the challenge is to simultaneously explain the moments of aggregate consumption and dividend growth, risk-free rate, market return, market price-dividend ratio, and the term structure of interest rates in the context of an economy with rational economic agents. The voluminous research effort to address this challenge continues to this day and includes explorations of preferences for early resolution of uncertainty, absence of complete consumption insurance, uncertainty about the state of the economy, habit persistence, macroeconomic crises resulting in a catastrophic drop in consumption, uncertainty about the economic model and its parameters, borrowing constraints, and deviations from rationality. In this essay I describe some of these explorations without providing an exhaustive review of the literature. My apologies to authors who are not being cited here.