Editors' Introduction: The Legacy of Stephen A. Ross

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The Legacy of Stephen A. Ross

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Stephen A. Ross was a towering intellect. He will be remembered for a body of work that has transformed finance and continues to influence and inspire financial research and practice. His foundational concepts include agency theory, the arbitrage pricing theory (APT), risk-neutral pricing, and the recovery theorem. His contributions to the Cox–Ross–Rubinstein binomial option pricing model and the Cox–Ingersoll–Ross model of the term structure of interest rates are also among his notable achievements. He was awarded numerous prizes, including the 2006 Smith Breeden Prize, the 2015 Deutsche Bank Prize, and (posthumously) the 2017 Wharton–Jacobs Levy Prize for Quantitative Financial Innovation.

We think Steve would have agreed that prizes were less important to him than the impact his ideas had on his students, coauthors, and colleagues. In a career spanning almost five decades, Steve taught at the Wharton School of the University of Pennsylvania, the Yale School of Management, and the MIT Sloan School of Management. He authored or coauthored over 100 articles, as well as one of the most popular textbooks on corporate finance. Somehow, he also managed to find the time to serve on numerous advisory boards and to start two investment firms.

Many of his former students and colleagues have contributed to this special issue of *The Journal of Portfolio Management*. Their articles discuss what they learned from Steve, how Steve's ideas influenced their own research, and how these ideas are being adapted and refined for current and future financial markets. Ludwig Chincarini and Frank Fabozzi's "Stephen A. Ross: Excellence Beyond Recognition" and John Campbell's "The Influence of Stephen A. Ross: Reflections of an Empirical Finance Economist" provide overviews of Steve's most significant contributions. These articles illustrate that one of Steve's most characteristic and valuable talents was his ability to translate economic theory into rigorous but intuitive concepts that were useful in the practice of finance and that blazed many trails for further research.

A number of the articles here explore research inspired by the APT. The Cox–Ross–Rubinstein binomial model has been equally fruitful; Stephen Brown [2017] described it as "the workhorse of most, if not all, options trading concerns and options strategy implementations." Steve's work on agency theory and risk-neutral pricing has also prospered; Ian Martin's "Options and the Gamma Knife" discusses the influence of risk-neutral pricing on his own work and how it inspired his own suggested approach

to inferring joint risk-neutral distributions from option prices.

The power and longevity of Steve's insights are in part attributable to his meticulous attention to research methodology. "Stephen Ross's Contribution to Ex Post Conditioning and Survival Bias in Empirical Research" by Stephen Brown and William Goetzmann extols Steve's contributions to "the epistemology of empirical research," including his insights that sources and treatment of data can affect the implications drawn from them. Philip Dybvig's "What Steve Ross Taught Me about Contracting" discusses Steve's work on agency theory and its applications to areas such as portfolio performance evaluation and compensation. Steve's financial research has had real-world implications.

Steve brought to finance the disciplines of economic theory (for which he received his PhD from Harvard) and physics (for which he received his BS from Caltech). Jonathan Berk, in "What I Learned from Steve Ross," remembers Steve as a staunch proponent of equilibrium theory who had the talent and curiosity to look beyond the theory to the intuition behind it. Steve, he notes, "emphasized that you needed to start by thinking about what happens when everybody reacts to prices. How do markets clear?"

Steve's work with John Cox and Jonathan Ingersoll provided a general equilibrium framework for asset pricing, in which their well-known model of the term structure of interest rates was developed. Nonetheless, Steve's most famous "discovery," the APT, does not hinge on a traditional equilibrium argument. As Steve noted in one of his last published pieces:

> the APT differs from the capital asset pricing model (CAPM) on a fundamental level—and not just because it models many sources of risk that can be priced rather than a single one. The intuition that motivates the APT is based on the strongest force in economics, the absence of arbitrage, which differs from the traditional demand and supply equilibrium argument of the CAPM. (Ross [2017])

The APT frees asset pricing from a number of the strict assumptions underlying the CAPM. For example, it does not require that all investors be mean–variance-optimizing, rational individuals. The APT also does not specify the characteristics or the sensitivities of security returns to those characteristics. It thus opens the door to numerous opportunities in research and practice. David Musto, in "The Role of the APT in the Hunt for Alpha: An Insight from Long Ago," shares an insight about the APT as a prescriptive technique, gained from his time working at Roll and Ross Asset Management: The key question to ask when implementing the APT is how many factors are priced, not how the factors are defined.

Nevertheless, in the more than 40 years since the publication of Steve's seminal APT article, there have been hundreds of papers exploring the factors driving security returns (some written by Steve himself). Edwin Elton and Martin Gruber, in their article "The Impact of Ross's Exploration of APT on Our Research," discuss their forays in this area, such as empirically developing multi-index models for a return-generating process and applying the APT to estimating the cost of capital and evaluating mutual fund performance. Mark Grinblatt and Konark Saxena, in "Improving Factor Models," take one of the APT's insights—that factor portfolios can be repackaged into a single-factor portfolio—and propose a weighting scheme that results in a single-factor benchmark that is better at pricing assets than traditional factor models.

Leonid Kogan and Dimitris Papanikolaou's "Equilibrium Analysis of Asset Prices: Lessons from CIR and APT" notes that Cox, Ingersoll, and Ross's (CIR) general equilibrium framework for asset pricing fills some gaps in models such as the CAPM and the APT by introducing real-economy considerations, such as production processes and capital accumulation. The CIR model of a production economy can produce insights into the economic content of APT return factors. "Industry Rotation and Time-Varying Sensitivity by VIX" by Maggie, Michael, and Thomas Copeland examines the cross-sectional relationship between industry returns and changes in the VIX—the Chicago Board Options Exchange Volatility Index. They show that industry sensitivity to changes in the VIX is time-varying, which helps to justify multidimensional factor investment.

As Chincarini and Fabozzi point out, the APT has provided a theoretical basis for the multifactor models that are standard in the practice of finance today. It has certainly influenced the adoption and growth of so-called smart-beta strategies. Steve himself voiced some skepticism of these approaches (Ross [2017]); he suggested in

his editorial that requiring a *t*-statistic of 5 might curtail the exponential increase in the number of factors that has led to so many spurious results. Perhaps a remedy can be found in machine learning, if common pitfalls are avoided, as suggested by Marcos López de Prado in "The 10 Reasons Most Machine Learning Funds Fail." Or perhaps improvement at the portfolio level can come from a more dynamic approach to trading; Richard Grinold's article, "Linear Trading Rules for Portfolio Management," offers a linear trading rule that can provide a portal into the dynamic portfolio management space.

The authors in this issue represent only a fraction of the many (including ourselves) who have drawn from the well of Steve's insights into financial economics.[1] They can only scratch the surface of his contributions. We expect that Steve's works will continue to inspire and influence financial research and practice for many years to come.

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[1] For example, the APT recognizes that mispricing can occur—and even be exploited—before being arbitraged by market forces. Bruce I. Jacobs and Kenneth N. Levy [1988] found mispricing opportunities in "Disentangling Equity Return Regularities: New Insights and Investment Opportunities." The binomial option pricing model has been extended by Frank J. Fabozzi with Young Shim Kim, Stoyan V. Stoyanov, and Svetlozar T. Rachev in "Multi-Purpose Binomial Model: Fitting All Moments to the Underlying Geometric Brownian Motion" (Kim et al. [2016]) and "Enhancing Binomial and Trinomial Equity Option Pricing Models" (Kim et al. [2018]).