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IN MEMORY OF STEPHEN A. ROSS

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1 Mark Kritzman's tribute

At the 2017 *Journal of Investment Management* (*JOIM*) Spring Conference Mark Kritzman paid tribute to Steve Ross, who died suddenly on March 3, 2017 at age 73. Ross, a good friend of *JOIM*, was best known for the development of the arbitrage pricing theory (APT) (Ross, 1976), a generalization of the capital asset pricing model, which showed that an asset's expected return is related to numerous risk factors. Ross's model showed how arbitrageurs would eliminate any mispricing.

Kritzman, CEO of Windham Capital Management, was also a Massachusetts Institute of Technology (MIT) colleague of Ross. Kritzman's moving tribute reflected on the many facets of Ross: as a student, as a scholar, as an honoree, as an advisor, as a mentor, as someone with whom you didn't want to disagree, and finally as a colleague.

2 The student

As part of the American Finance Association's Masters of Finance video series, Ross was interviewed by University of California, Los Angeles professor and co-author Richard Roll (Roll and Ross, 2009). Roll asked Ross what he had been like as a student. Ross modestly replied, "I was a pretty good student. My sister was a better student." Ross went from high school in Brookline, Massachusetts to California Institute of Technology (CalTech) where he did his undergraduate degree in physics. At college, Ross had some superb and memorable professors. One of his CalTech professors and mentors was Richard Feynman, recipient of the 1965 Nobel Prize in Physics for his contributions to the development of quantum electrodynamics. According to Ross, "I had him for four years. I had him for freshman physics, and sophomore physics. I also had him for a seminar is cosmology in my junior year, and in my senior year I attended his theoretical physics workshop. To this day he's the smartest guy I ever met." Another professor was Linus Pauling, recipient of the 1954 Nobel Prize in chemistry, for his work in quantum chemistry, and recipient of the 1962 Nobel Peace Prize for his peace activism and the only person awarded two unshared Nobel Prizes. Contrasting Feynman, his first class professor, with Pauling, his second class professor, Ross noted, "Everyone in the room knew the guy at the front [Feynman] was smarter than any of us. The second class was Linus Pauling teaching

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chemistry. We all thought, he's no Feynman." Ross did his doctoral studies in economics at Harvard. There he met Kenneth Arrow, recipient of the 1972 Nobel Prize in Economics, who also recently passed away. "I had the great fortune of Ken Arrow coming, and I was his assistant. He asked if I would TA for him, and that is when I discovered the real genius of economics."

3 The scholar

As a scholar, Ross wrote over one hundred articles (Ross, 2017) in academic journals and was a major contributor in a wide range of areas. In addition to his seminal work developing the arbitrage pricing theory, Ross's diverse work included the economic theory of agency (Ross, 1973) (the principal–agent problem), the Cox–Ross risk-neutral pricing model (Cox and Ross 1976), the Cox–Ross–Rubenstein binomial option pricing model (Cox *et al.*, 1979), the Cox–Ingersoll–Ross term structure model (Cox *et al.*, 1985), and, very recently, the recovery theorem (Ross, 20115) (extracting probability distributions from option prices). Ross also wrote a number of textbooks including the popular *Corporate Finance* book with Randy Westerfield and Jeff Jaffee (Ross *et al.*, 2015a) (9 editions), *Fundamentals of Corporate Finance* with Randy Westerfield and Bradford Jordan (Ross *et al.*, 2015b) (9 editions), and *Neoclassical Finance* (Ross, 2005).

4 The honoree

Ross was honored for many awards, including:

- Deutsche Bank Prize in Financial Economics, for his work developing pricing models that have provided standards for pricing options and other assets;
- Onassis Prize for Finance, for his lifetime contribution by leading academics in the area of finance;
- *Financial Analysts Journal's* Graham and Dodd Award for financial writing;
- The Morgan Stanley Prize for excellence in finance;
- Pomerance Prize for excellence in the area of options research;
- University of Chicago's Leo Melamed Prize for the best research by a business school professor;
- International Association of Financial Engineers (IAFE) Financial Engineer of the Year Award;
- Smith Breeden Prize for the best article in the *Journal of Finance;*
- Chicago Mercantile Exchange (CME)/Mathematical Sciences Research Institute (MSRI) Prize in Innovative Quantitative Application;
- Toulouse School of Economics' Jean-Jacques Laffont Prize, for internationally renowned economist whose research combines both theoretical and empirics;
- Q Group's Roger F. Murray Prize for excellence in quantitative research in finance;
- Fellow of the Econometric Society;
- Member of the American Academy of Arts and Sciences; and
- President of the American Finance Association.

According to Kritzman, given the impact of this broad range of work, Ross was probably a contender for the Nobel Prize in Economics.

5 The advisor

Ross played an active role in bridging theory and practice as an advisor to a diverse group of organizations. He was an advisor to numerous government bodies including the U.S. Treasury, the U.S. Commerce Department, and the Internal Revenue Service. He was also an advisor to EXIM Bank. Ross was Chairman of the American Express Advisory Panel. He was a director of many organizations including General Re, Freddie Mac, and CREF. Ross was also a trustee of his alma mater, the California Institute of Technology.

6 The mentor

Ross was a thesis advisor or mentor to many masters and PhD students who went on to distinguished careers. These included:

- Anat Admati
- Torben Andersen
- Jonathan Berk
- John Campbell
- Zhiwu Chen
- Raymond Chiang
- Gregory Connor
- Thomas Copeland
- Douglas Diamond
- Philip Dybvig
- William Goetzmann
- Mark Grinblatt
- Yasushi Hameo
- Jennifer Huang
- Gur Huberman
- Shmuel Kandel
- Leonid Kogan
- Laurence Kotlikoff
- Stephen LeRoy
- Paul Pfliederer
- Chester Spatt
- Nancy Stokey
- Anant Sundaram
- David Teece
- Jonathan Tiemann
- Laurence Weiss
- Jaime Zende

In 2008, these twenty-seven former students got together and published a book in honor of Ross (Grinblatt, 2008). In it they included a selection of their prominent articles based on the type of research that Ross had taught them and also shared short stories about their personal relationship with Ross. Kritzman noted that Ross was beloved by his students.

Prior to that, in 2006, this group of Ross's former students also began to secretly raise funds amongst themselves to establish the Stephen A. Ross Prize in Financial Economics (see, http://farfe.org/ross_prize.html), to recognize published research that exemplified Ross's research style and values. The group raised more than $600,000, surpassing an initial $250,000 goal, and established the Foundation for the Advancement of Research in Financial Economics to award the prize. The $100,000 award honors a paper in finance or economics published in the previous 15 years that develops or tests a financial economics theory and has been granted four times between 2008 and 2015.

7 Someone with whom you didn't want to disagree

By way of background, Kritzman noted that Ross's APT was quite controversial when it was first introduced and there was a lot of pushback among academics. Ross and co-author Richard Roll published a seminal empirical investigation of the APT that was published in the *Journal of Finance* in 1980.[14] In 1984, Phoebus Dhrymes, a Columbia University economics professor, published a paper in the same Journal, with several Wharton co-authors, critical of the APT testability and empirical evidence, including the research by Ross and Roll (Dhrymes *et al.*, 1984). Around that time Dhrymes published a practitioner-focused article in the *Journal of Portfolio Management* reiterating the APT empirical evidence critiques, to which Ross replied in-print, which was followed by a Dhrymes reply and a final Ross reply (Dhrymes, 1984, 1985; Ross, 1984, 1985). These series of articles may stand as one of the most memorable—and entertaining—public slugfests among academics in the Finance literature.

Ross's 1984 article was titled "Reply to Dhrymes: APT *is* empirically relevant". He immediately set the tone with a quotation from *Alice's Adventures in Wonderland*, Chapter 5:

"*Really, now you ask me,*" *said Alice, very much confused,* "*I don't think -*"

"*Then you shouldn't talk,*" *said the Hatter.*

In the article itself, Ross made a number of Alice in Wonderland references: "I am worried that practitioners might be misled by the blizzard of tables and numbers in his [Dhrymes] statistical Wonderland into thinking that his arguments have content simply because they look 'scientific'" (p. 55); and "The Mad Hatter in Wonderland might think this is 'fair' but no student of elementary logic would think so" (p. 55). More generally and most pointedly: "The remaining tests Dhrymes reports fall into three categories. They are either wrong, they are beside the point and misdirected, or they are so mystifying that we cannot determine into which of the first two categories they fall" (p. 55).

Kritzman noted that Ross took finance very seriously and was very generous and forgiving to people like himself, but with some people he was less forgiving to.

8 The colleague

Here is what many of his MIT colleagues said about Ross:

- Leonid Kogan: "*Steve was a scholar. If the model tells you otherwise and the results go against his beliefs, he updates his beliefs. His main position wasn't dogmatic. He was trying to get to the truth.*"
- Andrew Lo: "*Steve Ross was one of the giants of modern finance with a razor sharp intellect and a heart of gold. The cold, hard logic of his mathematical theories stood in sharp contrast to the warmth of his personality.*"
- Robert Merton: "*I'm going to miss his smile. He could be a very tough guy. He had high standards and he made no bones about expressing them. But he also had a nice way about him.*"
- Jiang Wang: "*Ross conducted himself in an 'artful' manner, both professionally and in personal encounters. He was always very positive, very optimistic, not just about research, but about other people. And yet he didn't compromise a bit when it came to intellectual pursuits.*"

Kritzman noted that the common theme among these comments was Ross's genius and being a really, really, nice person.

9 Some personal stories

Kritzman shared a few personal stories about Ross, whom he had known for about 35 years. Years ago Kritzman had the occasion to invite Ross to present at what today is called the Society of Quantitative Analysts (SQA), formerly the Investment Technology Association (ITA). The conference was structured as an after-lunch presentation and Kritzman explained to Ross that he would take the speakers out to lunch before the presentation. He also explained to Ross that an honorarium was paid. Ross replied, "Mark, don't worry about the honorarium, I don't need the honorarium. Just let me order the wine." It turned out that Ross was quite a connoisseur of fine wines, and later Kritzman reflected that for the person who invented APT, turning down the honorarium in return for ordering the wine was a pretty good arbitrage!

At another event, Ross was being given the Financial Engineer of the Year award. He was asked how he was able to produce so many great articles like Cox–Ross–Rubenstein, Cox–Ingersoll–Ross, and Cox and Ross. Ross replied, "It was easy—you just made sure that John Cox kept working!" Ross was generous in giving credit to his co-authors.

Kritzman noted that Ross could be tough on people as well. Kritzman recalled a conference at New York University, in the midst of a number of financial "blow-ups." Ross was into forensic finance at the time and was reflecting on the mid-to-late 1990s Long Term Capital Management (LTCM) event. LTCM, a hedge fund founded by John Meriwether, that combined arbitrage trading strategies with considerable leverage, suffered major losses in 1998 at the time of the Russian financial crisis when the government defaulted on their bonds. Ross reflected on comments made by one person at LTCM—who would expect a sovereign government to default on its debt? Ross noted that this person should have looked at an important statistic: Russia had been issuing bonds since 1827, and not one of them had ever reached maturity! Kritzman noted this as an example of Ross's clever way of putting things.

Kritzman reflected that in 2011, at MIT's sesquicentennial celebration, there were various symposiums, and one featured a panel of MIT's finance luminaries, including Ross. The panelists were asked to explain to the audience how they got into finance. Ross explained that he was an undergrad at CalTech, and in order to get your degree you had to take at least one course in the humanities. Ross chose linear programming! Later, after graduating with his PhD in economics from Harvard, Ross was hired by the University of Pennsylvania's economics department. Ross was soon bored by the Economics Department seminars and so someone suggested he sit in on the Finance seminars. The first seminar he went to was given by Richard Roll (his later co-author). The second was given by Fischer Black, who was explaining the option pricing model. Ross explained to the audience that at Harvard he had taken a course by Howard Raiffa (a prominent Bayesian decision theorist) and was a good Bayesian, so he just assumed that this was the average quality of finance research.

Ross was a kind, good-natured, generous, decent person. While saddened by the loss of Ross, Kritzman found some solace knowing that Ross led a really good life—he enjoyed fine wines, knew the best restaurants in every city, was adored by his family, was beloved by his students, and was honored over and over again. Ross was a great role model—while most known for being brilliant, he went through life with good humor. Ross will be missed by many, but his contributions will live on.

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