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A New Model of Capital Asset Prices

Theory and Evidence

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To my wife Karie and son Wes
—James W. Kolari

To my wife Na and daughters Ashley and Chelsea
—Wei Liu

To my wife Lan and sons Tian-shu and Tian-da
—Jianhua Z. Huang

Preface

This book proposes a new capital asset pricing model dubbed the *ZCAPM* that consistently outperforms existing popular models in empirical tests using U.S. stock returns. The ZCAPM's dominance of established multi-factor models in out-of-sample cross-sectional tests—the gold standard in comparative tests—is remarkable. We believe that the ZCAPM represents the next step in the evolution of asset pricing models. Consequently, this book is intended for academics and finance professionals that employ these models in their research activities. Finance Ph.D. students and professors can apply our ZCAPM to asset pricing problems. And, finance professionals, including portfolio managers, securities traders, and quants, can utilize the ZCAPM in their investment activities.

Early chapters in the book establish the theoretical foundation for the ZCAPM by mathematically deriving a special case of Fischer Black's renowned *zero-beta CAPM*. Black's model is a more general form of the famed *Capital Asset Pricing Model* (*CAPM*) by Nobel Laureate William Sharpe. Both models depend heavily on the mean-variance investment parabola of Nobel Laureate Harry Markowitz. In later chapters we document extensive empirical evidence supporting the ZCAPM based on more than 50 years of U.S. stock return data, many different samples of stocks, and comparisons to several popular multifactor models. These substantive tests using stock return data show that the ZCAPM is the premier asset pricing model in terms of surpassing the significance of other models in commonly used cross-sectional tests used to validate models. Also, we demonstrate practical applications of the ZCAPM in the areas of momentum investing and diversified portfolio formation with superior return/risk performance.

As a backstory, in summers from 2002 to 2017, James Kolari taught a graduate international finance seminar at the Hanken School of Economics in Vaasa, Finland. A long-time puzzle in financial economics is the very small impact of exchange rate movements on stock returns as measured by asset pricing models. After reviewing this vast literature, he began to suspect that problems in asset pricing models may be complicit in the puzzle. In the 1970s, researchers observed that stock return data only weakly supported the lauded CAPM. Motivated by this evidence, Black proposed the zero-beta CAPM to help reconcile CAPM theory and stock return evidence. However, he did not provide empirical proxies for the two efficient and inefficient (zero-beta) portfolios in his model.

In a series of 1990 papers, Eugene Fama and Kenneth French argued that things were worse than previously believed. The beloved CAPM was dead. They accumulated evidence that the CAPM's hypothesized relation between beta risk associated with proxy market portfolio returns and the cross-section of average U.S. stock returns did not hold. Due to this failure, to better fit stock return data, they proposed a three-factor model that augmented the CAPM's market portfolio factor with size and value factors. Responding to the Fama and French studies, Black criticized their three-factor model because: (1) it was developed by means of data snooping, and (2) there was little or no theoretical foundation. He continued to believe that, despite growing evidence to the contrary, the CAPM was valid. What if Black was right?

The biography *Fischer Black and the Revolutionary Idea of Finance* by Perry Mehrling (John Wiley & Sons, Inc.) was published in 2005. As recounted there, after working at the University of Chicago and Massachusetts Institute of Technology, Black took a job at Goldman Sachs in 1984 and worked there until he died in 1995. Always in the relentless pursuit of solutions to finance puzzles, as the first quant at Goldman Sachs, he worked one day a week on independent research. Over these years, he likely continued to develop his zero-beta CAPM ideas. Was it possible that he found an alternative form that bridged the gap between pure theory and practical investment in the real world?

In summer 2010 Kolari met Wei Liu, at the time a Ph.D. finance student at Texas A&M University. Liu had previously earned a Ph.D. in physics from Texas A&M and published numerous scientific papers.

Together, they set out to rediscover what Fischer Black may have learned about the zero-beta CAPM but did not publish due to proprietary research at Goldman Sachs. Their main goal was to find an alternative form of the zero-beta CAPM that could be readily estimated. Given Black's criticism of Fama and French's three-factor model, they focused on building a model based on the theoretical tenets of the CAPM and related zero-beta CAPM. In this regard, Liu's previous physics training was instrumental in using random matrix theory to better understand the asymptotic behavior of the minumum-variance investment parabola. By 2011 they had derived a special case of Black's zero-beta CAPM dubbed the *ZCAPM* that contained readily available asset pricing factors—namely, average market returns and the cross-sectional return dispersion of all assets' returns.

Excited about this new theoretical model with measurable factors, they began experimenting with different empirical approaches to estimate the theoretical ZCAPM. After some initial failures, empirical methods were adapted to take into account positive and negative effects of return dispersion on asset returns. Early tests of these methods corroborated the theoretical ZCAPM. However, these empirical tests relied on fitting regression models that use the response variable to define a signal variable indicating the sign of the effect of return dispersion. Soon thereafter, they met with Jianhua Huang, a statistics professor at Texas A&M University, who recommended a reformulation named the *empirical ZCAPM* that treats the unobservable sign as a latent or hidden variable and employs the expectation–maximization (EM) algorithm for the estimation of parameters. Importantly, this maximum likelihood approach enables the estimation of the probability that returns are positively versus negatively affected by movements in the return dispersion factor. A major refinement, the EM approach to estimating the empirical ZCAPM computes regression parameters, estimates the probability of positive or negative return dispersion effects, substantially boosts the goodness-of-fit of the model, and provides a statistically well-founded empirical methodology.

With both the theoretical and empirical ZCAPM in hand, we wrote a research paper using U.S. stock returns and submitted it to finance conferences. In 2012 our paper won the Best Paper in Investments Award at the largest finance conference in the world sponsored by the Financial Management Association. An attendee invited by us to the conference from the Teachers Retirement System of Texas (TRS) proposed that we set up an investment company and work privately with them on research and development (R&D) for pension fund management. An agreement was made to not publish our work in any manner, including the internet, academic journals, books, etc. From 2012 to 2015 we worked privately with TRS and Texas A&M University, which deepened our applied knowledge of the ZCAPM. During this time, Liu managed the investment company, conducted paper trading experiments, and actively rebalanced an R&D pension fund. Unfortunately, due to changes in management at TRS, our relationship was ended.

After closing our investment firm, we continued to develop the ZCAPM. Our research gradually grew beyond the normal bounds of published papers in academic journals with page length and other restrictions. For this reason, we opted to publish our ZCAPM research in a book. By presenting the theoretical derivation of the ZCAPM from the zero-beta CAPM, a weight of empirical evidence about the ZCAPM and its outperformance compared to other popular models, and useful applications to investment practices, we hope to blunt the natural skepticism that confronts any new and novel model with strong asset pricing claims.

To develop the ZCAPM we benefited greatly from previous work by Black on the zero-beta CAPM. As already mentioned, our ZCAPM is a special case of the zero-beta CAPM that takes on a new functional form with measurable factors. More precisely, the ZCAPM is comprised of *beta risk* associated with average market returns (i.e., CRSP index, S&P 500 index, or other general market indexes) and *zeta risk* related to the cross-sectional standard deviation of all stocks' returns in the market (i.e., return dispersion). Notice that beta risk in the ZCAPM is associated with average market returns rather than the theoretical market portfolio in the CAPM. Together, beta and zeta risks in the ZCAPM serve as a proxy for Sharpe's beta risk as proposed by the CAPM.

Another novel aspect of our ZCAPM model is taking into account positive and negative sensitivity of asset returns to return dispersion movements over time. To estimate the probability of these opposite forces, a mixture model comprised of two factor models is specified. No previous asset pricing models utilize a mixture model to our knowledge. As we will show, return dispersion is a powerful market factor that helps to explain stock returns but must be modeled as in our empirical ZCAPM to fully capture its dual positive and negative nature and be consistent with the theoretical ZCAPM.

Readers are encouraged to conduct empirical tests using our Matlab and R computer programs.

- Matlab codes used in our cross-sectional tests of the empirical ZCAPM are provided at the end of this book. Matlab is licensed software that combines a desktop environment with a programming language for matrix and array mathematics.
- R programs for estimating and testing the empirical ZCAPM are available on GitHub (https://github.com/zcapm). R is a free software environment for statistical computing and graphics. It compiles and runs on a wide variety of UNIX platforms, Windows, and MacOS. Readers can find our Matlab and Python codes at the GitHub website also.

We should note that our R programs execute at a faster speed than the Matlab and Python programs. We challenge readers to use our software and prove for themselves the superior efficacy of the ZCAPM.

College Station, USA — James W. Kolari
San Antonio, USA — Wei Liu
College Station, USA — Jianhua Z. Huang

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Many people at academic institutions and investment firms have shared useful comments with us over the years, including Ali Anari, Will Armstrong, Ihsan Badshah, Geert Bekaert, Grant Birdwell, Saurabh Biswas, Jaap Bos, Yong Chen, Gjergji Cici, Brett Cornwell, Lammertjan Dam, Huaizhang Deng, Bilal Ertuk, Wayne Ferson, Paige Fields, Tristan Fitzgerald, Markus Franke, Wesley Gray, Klaus Grobys, Yao Han, Britt Harris, Tim Jones, Hagen Kim, Johan Knif, Sudhir Krishnamurthi, Anestis Ladas, Scott Lee, Qi Li, Yutong Li, Kelly Newhall, Chris Pann, Francisco Penaranda, Ralitsa Petkova, Mike Pia, Seppo Pynnönen, Liqian

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About the Authors

Professor James W. Kolari is the JP Morgan Chase Professor of Finance and Academic Director of the Commercial Banking Program in the Department of Finance at Texas A&M University. After earning a Ph.D. in Finance from Arizona Station University in 1980, he has taught financial institutions and markets classes and been active in international education, consulting, and executive education. In 1986 he was a Fulbright Scholar at the University of Helsinki and Bank of Finland. He has served as a Visiting Scholar at the Federal Reserve Bank of Chicago, Senior Research Fellow at the Swedish School of Business and Economics (Hanken), Finland, and Faculty Fellow with the Mortgage Bankers Association of America, in addition to being a consultant to the U.S. Small Business Administration, American Bankers Association, Independent Bankers Association of America, and numerous banks and other organizations. With over 100 articles published in refereed journals, numerous other papers and monographs, and over 15 co-authored books, he ranks in the top 1–2% of finance scholars in the United States. His papers have appeared in domestic and international journals, including the *Journal of Finance*, *Journal of Business, Review of Financial Studies, Review of Economics and Statistics, Journal of Money, Credit and Banking, Journal of Banking and Finance*, *Journal of Economic Dynamics and Control, Journal of Financial Research, Real Estate Economics, Journal of International Money and Finance*, and *Scandanavian Journal of Economics*. Papers in Russian, Finnish, Dutch, Italian, Spanish, and Chinese have appeared outside of the United States. He is a co-author of leading college textbooks in commercial banking, introductory business, and global business courses.

Dr. Wei Liu received his first Ph.D. in Physics in 2004 from Texas A&M University. His research focused on particle physics theory. After working as a postdoc for a few years, he changed his career path and earned a second Ph.D. in Finance in 2013 from Texas A&M University with an emphasis on asset pricing. From 2013 to 2016, he served as the manager and part owner of a small investment company. Developing asset pricing models based on statistical analysis, he created U.S. equity investment strategies to manage $100 million for the Teachers Retirement System of Texas. Subsequently, in 2017 he joined IberiaBank Corporation in Birmingham, Alabama as a senior analyst building and documenting risk models. Internal risk models for the bank as well analyses for regulatory agencies were implemented. In 2018 he returned to Texas working for USAA Bank in San Antonio as a senior quantitative analyst with duties designing and implementing models for bank stress testing, loss forecasts, allowance for loan and lease losses, and credit risk management analysis. Recently, Dr. Liu has been engaged with various marketing issues at the bank.

Professor Jianhua Z. Huang is Professor of Statistics and Arseven/Mitchell Chair in Astronomical Statistics in the Department of Statistics at Texas A&M University. He received his B.A. in Probability and Statistics (1989) at Beijing University, M.A. in Probability and Statistics (1992) at Beijing University, and Ph.D. in Statistics (1997) at University of California at Berkeley. His areas of expertise are in statistical machine learning, computational statistics, statistical methods for big data sets, nonparametric and semi-parametric statistical modeling and inference, functional data analysis, spatial data analysis, application of statistics in business, social and natural sciences and engineering. He has supervised 21 Ph.D. students and published over 100 refereed papers. He is a Fellow of American Statistical Association, Fellow of Institute of Mathematical Statistics, and Elected Member of International Statistical Institute. Additionally, he has served on the editorial board of *Chemometrics and Intelligent Laboratory System*, *Journal of American Statistical Association*, *Journal of Multivariate Analysis*, and *STAT*.

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PART I

Introduction