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COLLABORATING WITH HARRY MARKOWITZ: A REMEMBRANCE

Bruce I. Jacobs[a,b]

Bruce Jacobs recounts his long professional and personal relationship with Harry Markowitz spanning more than 30 years in remarks delivered at the Spring 2024 JOIM Conference at the University of California, San Diego. Bruce and Harry shared similar interests and did complementary work. This led to collaboration, debate, and building upon each other's ideas and research. Their work covered topics on portfolio insurance, portfolio theory, market simulation, and risks of portfolio leverage, and helped to bridge the gap between theory and practice.

Presented at the Spring JOIM Conference honoring Harry Markowitz on March 24–26, 2024 at the Rady School of Management, UCSD.

I had the privilege to honor Harry Markowitz here at UC San Diego in 2015 on the occasion of the 25th anniversary of his winning the Nobel Prize (Jacobs, 2015), and at the Q Group in the Fall of 2009, and at the Q Group memorial for Harry this past October. And I'm delighted to be here today to once again honor Harry's legacy.

My relationship with Harry began more than 30 years ago. In the years leading up to the crash of 1987, I was a devil's advocate and warned that portfolio insurance—an option-replication dynamic hedging strategy—was a positive-feedback strategy that had the potential to destabilize the markets. Mark Rubinstein of Leland O'Brien Rubinstein Associates, the major purveyor of portfolio insurance, later wrote of my "prescience in forecasting the Achilles' heel of the portfolio insurance strategy."

In 1990, I sent my manuscript about the rise of portfolio insurance and the crash of 1987 to Harry and Paul Samuelson. Paul wrote in response that many investors viewed portfolio insurance as a source of reassurance for stretched stock valuations, believing that they could make "a fast exit after the turn, beating most of the mob." I had been skeptical about the feasibility of a fast exit and Harry agreed. Harry's response to the manuscript was very encouraging—he wrote, "I

[a]Jacobs Levy Equity Management, 100 Campus Drive, P. O. Box 650, Florham Park, NJ 07932-0650, USA.
E-mail: bruce.jacobs@jlem.com
[b]Principal and Co-Chief Investment Officer of Jacobs Levy Equity Management in Florham Park, NJ.

find it comprehensive, scholarly, and convincing." I subsequently sent him a copy of an updated draft, to which he replied with a lengthy letter.

Well, I was emboldened, and I called Harry. Toward the end of our conversation, he said: "Bruce, is there something that you wanted to ask me?" I replied: "Yes, Harry, in fact there is. Would you be willing to provide a foreword for the book?" His response was: "I would be delighted to. Of course, it will depend upon whether I find something interesting to say."

Indeed, he did. Harry's foreword (Markowitz, 1999) in my book, *Capital Ideas and Market Realities: Option Replication, Investor Behavior, and Stock Market Crashes* (Jacobs, 1999), lucidly distinguishes between portfolio insurance and portfolio theory and highlights their differing effects on financial market stability.

My later book, *Too Smart for Our Own Good: Ingenious Investment Strategies, Illusions of Safety, and Market Crashes* (Jacobs, 2018), which covers the mortgage-backed structured products fiasco of 2007–2008 and the ensuing Global Financial Crisis, distinguishes between risk sharing—reducing risk through Markowitz diversification, and risk shifting—shifting risk from one party to another, which can be fraught with peril if there is opacity and can lead to market fragility.

In my discussions with Harry over the years, I learned that he liked my article with Ken Levy on disentangling equity return regularities using cross-sectional analysis (Jacobs and Levy, 1988)[1] and our article on the integrated optimization of long-short portfolios (Jacobs *et al.*, 1999).

We were in the process of collecting our equity works into a book, and I asked Harry if he would again write a foreword. At a wonderful dinner with Harry and his delightful wife Barbara, Harry said he would, once again, if he had something interesting to say.

And again, he did. Harry's foreword (Markowitz, 2000) appeared in our book, *Equity Management: Quantitative Analysis for Stock Selection* (Jacobs and Levy, 2000). In his foreword, Harry discusses why mean-variance (MV) investors add constraints on security position sizes and sectors when optimizing a portfolio, despite the theoretical costs of these constraints. As Harry indicated, "constraints are added because the investor seeks protection against contingencies whose probability of 'disutility' is underrated by mean-variance approximation."

Harry also wrote in his foreword (Markowitz, 2000): "It may be fairly asserted that Jacobs and Levy's work is based on mine and my work is based on theirs. The[ir] portfolio selection models... are special cases of the Markowitz 'general' model... This is the sense in which their work is based on mine... When colleagues and I built the Daiwa Portfolio Optimization System in 1990... our expected return estimation procedures were based on Jacobs and Levy (1988), [our disentangling article]. Thus [he said], our work was based on theirs."

At about this time, my colleagues and I at Jacobs Levy published the article "*On the Optimality of Long-Short Strategies*" (Jacobs *et al.*, 1998). This article examined the optimality of market-neutral long-short portfolios, and in deriving formulas for equitizing such portfolios provided the theoretical underpinnings for 130-30-type strategies.

Harry was intrigued by the article, and this led to a collaborative research relationship. Together, we addressed the optimization of long-short portfolios subject to realistic constraints on shorting, and published two works on this topic (Jacobs *et al.*, 2005, 2006).

People who knew Harry well know that he liked nothing better than to find a challenging technical problem to solve—the more difficult, the better. While he was a Nobel laureate in economics, he once said that he saw himself as "more of an operations research kind of guy." So, Harry went on to create a simulation programming language—SIMSCRIPT, a general-purpose discrete event simulator.

In the early 2000s, Harry, Ken, and I discussed the idea of collaborating on the design of a financial market simulator. Like us, Harry was a computer nerd, and he often liked to joke that when his doctor asked him how he was doing, he would say, "Not so good. I've got a bug again."

At the time, most financial market models were continuous-time models that allowed for analytical solutions. What these models can't do is simulate markets in which changes in regulations or in the composition of market participants change the price process. Nor can continuous-time models tell us whether the behavior of individual financial agents and market mechanisms aggregate to the observed market behavior (Jacobs *et al.*, 2004).

The Jacobs Levy Markowitz simulator, JLMSim, by contrast, is an asynchronous, discrete-time, dynamic market simulator, which allows changes to unfold in an irregular fashion as the result of the actions and characteristics of participants and of the system itself. Market prices result from market participants trading to maximize their own individual utility. Price changes may be discontinuous, gapping up or down in reaction to events (Jacobs *et al.*, 2010).

We found that with the right mix of value and momentum investors the market would be stable, but if there were too many momentum investors prices could increase explosively. We also found that flash crashes, similar to those the market has experienced, can occur when traders are not "anchored" to recent price levels.

Like Harry, Ken and I believe that asynchronous models like JLMSim are better able than continuous-time models to capture the reality of financial markets. JLMSim was presented in two articles, which showed how changes in the proportions of various types of investors affect security prices, and how the simulator can be used to find equilibrium expected returns (Jacobs *et al.*, 2004, 2010). Since we made JLMSim available on our website,[2] it has been used by researchers in more than 70 countries.

Before our collaboration with Harry on JLMSim, he developed a financial decision-making simulator for individuals. Harry's "Game of Life" model would, ideally, allow users to lay out their own savings, investment, and consumption goals, based on their own actual incomes, savings, education and skill sets, health, and so on. A streamlined version of this "game" is incorporated in several products now available to help individuals plan their retirement finances.

I am especially pleased that Harry's groundbreaking work in the field of retirement planning earned him the inaugural Wharton-Jacobs Levy Prize for Quantitative Financial Innovation in 2013

2013 Wharton-Jacobs Levy Prize for Quantitative Financial Innovation (from left to right): Bruce Jacobs, Harry Markowitz, Ken Levy.

(Markowitz, 2013b). The prize, which is awarded by the Jacobs Levy Equity Management Center for Quantitative Financial Research at the Wharton School, recognizes individuals who have undertaken outstanding quantitative research that has contributed to an important innovation in the practice of finance.

After the Global Financial Crisis, Ken and I tackled a problem that had long concerned us—the impact of financial leverage. Leverage, whether stemming from outright borrowing, from the use of derivatives, or from shorting, magnifies a portfolio's volatility. Modern portfolio theory (MPT) implicitly assumes that portfolio volatility increases linearly with leverage.[3]

We started thinking about the risks of leverage that are not captured by MPT. Most significantly, there is a risk of margin calls, which requires the sale of portfolio holdings if additional capital is not provided. These forced liquidations are often at "fire sale" prices. We refer to these risks as the "unique risks of leverage." Not only are these risks for leveraged investors, but also for the market overall as the forced selling can have contagious effects.

To limit portfolio leverage, investors often adopt the classic solution of incorporating a leverage constraint in portfolio optimization. Harry himself outlined methods for doing so (Markowitz, 1959). But constraints cannot solve the whole problem. An investor can determine the portfolio that is optimal for a given level of constraint, but which level of constraint is optimal? MV optimization takes into account the tradeoff between expected return and volatility risk, but investors need a method to take into account the tradeoffs between expected return, volatility risk, and leverage risk.

In a series of articles (Jacobs and Levy, 2012, 2013a, 2013b, 2014a, 2014b), we proposed adding to the MPT utility function a term that captures aversion to the unique risks of leverage. Just as an investor averse to volatility risk will give up some expected return in exchange for a lower volatility, an investor averse to leverage risk will give up some expected return in exchange for less exposure to the unique risks of leverage.

The resulting mean-variance-leverage (MVL) optimization model selects the optimal portfolio with the right amount of leverage and the right kind of diversification, considering an investor's volatility aversion and their aversion to the unique risks of leverage. Further, use of a MVL model will provide optimal portfolios with more modest leverage levels than those based on the MV model (Jacobs and Levy, 2013a).

In response, Harry suggested an alternative solution—extending the general MV portfolio selection model by including a measure of short-run volatility, as determined by a stochastic margin call model (Markowitz, 2013a). We responded that such a model has yet to be developed, whereas the MVL model is available for immediate use (Jacobs and Levy, 2013b). An increased awareness and consideration of leverage risks in portfolio formation can have salutary effects for the market and economy.

Jason Zweig (2012) of the *Wall Street Journal* quoted Harry and me:

> "Conventional portfolio theory says not to hold all your eggs in one basket," says Jacobs. What that misses, he adds, is that "using leverage is like piling baskets of eggs on top of one another until the pile becomes unsteady." Borrowed money can make an optimally diversified—and theoretically "safe"—portfolio risky.
>
> Prof. Markowitz agrees. If you're a diversified investor who can afford to be patient, you should worry primarily about how you'll do on average in the long run, he says.

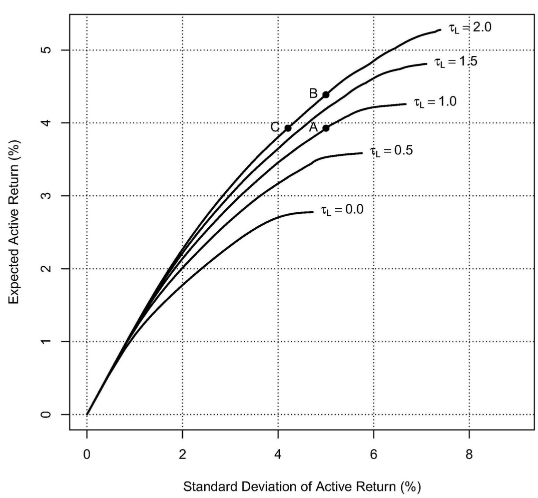
"But if you're leveraged, then you can get wiped out before the long run comes," he says. Keeping that in mind as you diversify, he adds, is "very important."

Harry graciously wrote the foreword (Markowitz, 2017) to the second edition of our *Equity Management* book (Jacobs and Levy, 2017), now with the subtitle "The Art and Science of Modern Quantitative Investing." He wrote: "Some of the new sections include works on which Jacobs, Levy, and I collaborated—or, in the case of leverage aversion, debated—so, we have continued to build on each other's research."

Next, I'll show some exhibits that illustrate the results of MVL optimization.

Exhibit 1 shows efficient frontiers for various leverage tolerance cases across a range of volatility tolerances. The frontier portfolios are constrained by a 10% active security weight constraint (for other details, see Jacobs and Levy, 2013a).[4] The zero-leverage-tolerance curve represents an investor unwilling to use leverage, that is, an investor who prefers long-only portfolios.

Exhibit 1. Efficient frontiers for various leverage tolerance (τ_L) cases.



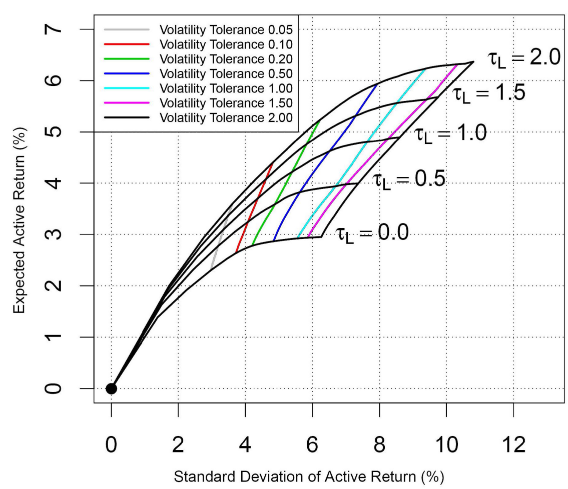
Source: Jacobs and Levy (2013a).

As Exhibit 1 shows, increasing leverage tolerance allows higher efficient frontiers; hence, improved portfolio efficiency compared to long-only portfolios.

Consider the three portfolios labeled A, B, and C. Portfolio A is optimal for an investor with a leverage tolerance of 1 and a volatility tolerance of 0.24. This is a 125-25 long-short portfolio with a standard deviation of active return of 5% and an expected active return of 3.93%. Of note, this investor prefers Portfolio A to Portfolio B, which has a higher expected return and the same volatility, and also to Portfolio C, which has a lower volatility and the same expected return. Portfolios B and C are preferred by investors having a leverage tolerance of 2. Both Portfolio B (139-39) and Portfolio C (135-35) have too much leverage risk for the investor with a leverage tolerance of 1 who prefers Portfolio A.

Exhibit 2 illustrates the efficient frontiers without the active weight constraints for various levels of investor leverage tolerance and for various levels of investor volatility tolerance. With no constraint on the security active weights, the curves linking

Exhibit 2. Efficient frontiers for various leverage (τ_L) and volatility (τ_V) tolerance cases with no security active weight constraint.



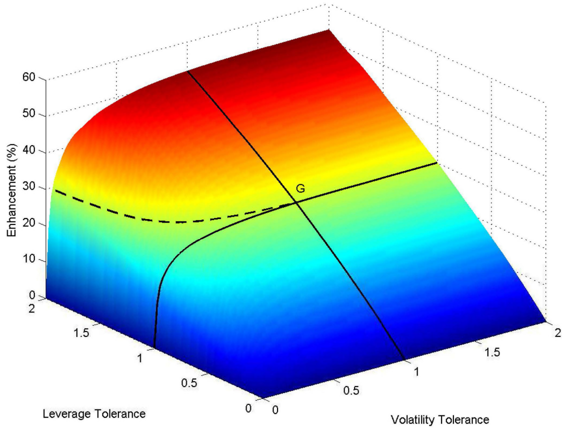
Source: Jacobs and Levy (2013a).

the optimal portfolios at each level of leverage tolerance are smooth (unlike in Exhibit 1). Every leverage-tolerance level has a corresponding two-dimensional MV efficient frontier. Similarly, for a particular level of volatility tolerance, there is a corresponding two-dimensional MV efficient frontier.

Furthermore, without the security active weight constraints, both the standard deviation of active return and the expected active return ranges are higher than in Exhibit 1. As either volatility tolerance or leverage tolerance declines from 2, the frontiers shift to the left and downward. When volatility tolerance is zero, the optimal portfolio—an index fund—lies at the origin. Depending on an investor's leverage and volatility tolerances, the optimal portfolio will lie somewhere in the MVL *efficient region* shown. Once again, the critical roles of both leverage and volatility tolerance in portfolio selection are apparent.

Exhibit 3 shows the optimal amount of leverage, called here the "enhancement." It shows that MVL optimization provides a three-dimensional efficient surface as a function of the investor's volatility tolerance and leverage tolerance. Here, for an investor with a volatility tolerance of 1 and a leverage tolerance of 1, the optimal portfolio enhancement, at point G, is about 30% for a 130-30 long-short portfolio. For investors with greater (lesser) tolerances, the optimal portfolio enhancement will be greater (lesser).

Exhibit 3. Mean-variance-leverage efficient surface.



Source: Jacobs and Levy (2014a).

A few additional comments about Harry.

Bill Sharpe once said about Harry: "Ordinary people think about problems; extraordinary people think about how to think about problems."

MPT is not simply a solution to a problem. It is a revolutionary way of thinking about the problem of investment uncertainty. From it evolved the vast field of quantitative finance that has produced extraordinary innovations for more than 70 years.

Harry had a wry sense of humor. I'd hear Harry say: "I often get blamed for things I didn't do or say. By the same token, I often get credit for things I didn't do or say." But when it comes to financial economics over the past half century, it's hard to find a thing Harry *didn't* do, or at least have a hand in, from portfolio theory in 1952 to financial market simulation in 2010.

Harry's body of work is extraordinary, not only for its caliber but also for its range. Of course, he did have a secret weapon—his wife Barbara. Harry's love for Barbara was apparent to anyone who saw them together. A story exemplifying this is when Harry and Barbara were at Princeton, where we were giving a talk on the Jacobs Levy Markowitz Market Simulator. After having lunch with some professors, as we were driving along Princeton's main road, Harry spotted his wife walking on the sidewalk. He quickly lowered his window, stuck out his head, and in a very un-Nobel-laureate-like fashion, bellowed at the top of his voice, "Hey beautiful, wanna ride?"

You might ask: Why did Harry work into his 90s? Barbara would ask Harry about retirement, and he would say: "Well, when I do retire, I'd want to do something I really enjoy. And that's what I'm doing now—every day—playing in my sandbox."

Harry always believed strongly that theories, including his own, are improved by incorporating the innovations of others. That is why I feel confident in predicting that many future generations of researchers will benefit from his insights.

We salute you Harry for your many contributions, past, present, and, yes, future, because your monumental body of work will endure and be an inspiration to others.

You will be missed—your love of learning, your lifelong dedication to the field, and your knowledge creation. Your legacy will live on for generations.

Harry often closed his e-mails with "Cheers." Well, cheers to you Harry for all that you have given to the world!

Thank you.

Q&A

Myron Scholes: We have a leverage constraint. What is the cost function that you use for leverage? And how does that create a solution?

Bruce Jacobs: A leverage constraint was espoused by Harry—most investors think in terms of constraining leverage, say 2-to-1, or, for a long-short strategy, say 130-30. The constraint is often determined in a basic gut or judgmental fashion, as opposed to considering what the tradeoffs are. So, instead of considering just the tradeoff between expected return and risk or volatility, one also needs to consider the likelihood of a margin call when leveraging. Volatility can arise from leveraged long positions or short positions. The third dimension we added to the MV model considers whether you're leveraging assets that are more stable or assets that are more volatile. That third term in the MVL model is the product of the variance of the leveraged portfolio's total return and the square of the portfolio's leverage. The solution is created by the optimization that trades off expected return with volatility risk (the second term) and leverage risk (the third term). Recently, in an *Operations Research* article (Edirisinghe *et al.*, 2023), a liquidity dimension was added as well for an MVLL model.

Myron Scholes: MVL and liquidity, so the whole notion of a constraint would be very similar to an investor deciding to constrain volatility to a certain level, without considering the tradeoff between expected return and volatility and the utility preferences for that sort of tradeoff. Have you considered the dynamics?

Bruce Jacobs: Yes, exactly as you describe, and the question of dynamics is, of course, very important. Our model, like Harry's, is a single-period model. So, for our clients, we wanted to discern what's the optimal amount of leverage. Half of our assets under management are running 130-30 strategies nowadays, and some 150-50 strategies for clients who are more leverage tolerant. The question from the client is often, what is the right amount of leverage? And, of course, that can't be answered with MPT because it doesn't take leverage risk into account.

An article by Kroll *et al.* (1984) assumed a linear relationship between leverage and volatility. As leverage increases, volatility was assumed to increase linearly. But that assumed a world where margin calls don't occur. It's a belief that there's always funding available, or you can always sell or cover positions with no liquidity costs. However, in the real world, we know that when you leverage a portfolio, and the more you leverage it, the more likely you're going to get hit with a margin call.

MPT is perfectly correct for long-only portfolios where there's no shorting and no leverage. But once you introduce shorts and/or leverage, MPT is missing an important element of risk, which is the risk of a margin call, bankruptcy, and so forth. So that's what we brought to bear in the single-period setting to help our clients determine what's a good level of leverage in a 130-30-type portfolio, where, of course, the amount of leverage is dependent upon the client's tolerance for leverage risk. On the MVL efficient surface, one takes on greater leverage if willing to tolerate more leverage risk.

To estimate an investor's own volatility and leverage tolerances, the investor could select different portfolios from the efficient surface, run a Monte Carlo simulation that generates a probability distribution of ending wealth for each portfolio, and then infer their volatility and leverage tolerances based on their preferred ending wealth distribution.

We found this third dimension important because MBAs typically learn about MPT from a MV model perspective. They don't learn from the model that when you put on leverage, you're taking leverage risk and there are implications. That risk does not have a linear relationship with leverage because of the potential for a margin call.

Myron Scholes: What about my debts, debts for my children, health care expenses, all those sorts of things? If I invest in a risky portfolio and it tanks, I might then be forced to reduce my risk-taking.

Bruce Jacobs: Exactly so, in that case. It's important to not be overleveraged and to balance the potential rewards with the risks and costs.

Myron Scholes: Is there a difference between margin leverage and other forms of leverage as you see it?

Bruce Jacobs: There's a similarity in that, with indebtedness, if your assets decline, you may reduce the amount of risky assets so that you have the funds to meet your liabilities. The difference is that with margined leverage, if losses are incurred, the prime broker can immediately force liquidations, which are often made at undesirable prices. Further, others may be getting margin calls at the same time, triggering further liquidations at distressed prices. There have been so many accidents associated with margin leverage where the presumption is that there'll be more funding, or that one can liquidate without any costs.

These accidents have repercussions not only for the investor, but for the markets. My book, *Too Smart for Our Own Good* (2018), tells that story. While it was practical to address the leverage question for our clients, it also has broader market implications.

Myron Scholes: Absolutely. There's always sorts of things, things that happen unbeknownst that give rise to problems associated with the leverage debt, which is an obligation to the broker, and those unfortunate margin calls. Who's on the other side of that?

Bruce Jacobs: Well, then, you get big gaps in prices until the demand appears. Big drops because there's no one. No natural trader on the other side, with the same speed and size to take on that trade. So, you get large price adjustments, and you suffer from that, and the market suffers as well. Hence, the importance of incorporating leverage risk in the model.

Endnotes

[1] The cross-sectional analysis that we pioneered has greater explanatory power than the time-series approach based on portfolio sorts (such as the return differences between small- and big-capitalization stocks and between high- and low-book-to-price stocks) that has

dominated the asset pricing literature (Jacobs and Levy, 2021; Jacobs *et al*., 2025).

[2] Those interested in finding out more about JLM-Sim, or experimenting with it, can access it from https://jlem.com/research#/market-simulation/5,/selection/1.

[3] For further discussion and cites of this linearity assumption in the literature, see Jacobs and Levy (2024a, 2024b).

[4] Because different security active weight constraints become binding as one moves along each of the constant leverage–tolerance frontiers, the curve connecting the endpoints is not smooth.

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