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Black–Merton–Scholes Option Pricing: A 50-year Celebration and Looking Ahead

I'd like to talk today about option technology and its applications, as well as some of my thinking about its likely impact going forward. First, I'd like to go back a step and review major issues we have thought about in modern finance over the last 50-75 years. Finance theory has had a profound effect on applications, and that's very important. Most of what we've done in financial economics is based on a **micro-positive** view. We have developed a theory first, which leads us to a framework that instructs and informs our applications. Our theory is trying to help firms and investors make better decisions to great effect. This, in my view, differs from the **macro-positive** approach in most economics departments. This relates to the famous difference which Marshall said that economists don't tell a beer maker how to make better beer. But we in financial economics and business schools tend to think of how to help the beer maker make better beer (or more profits from it) by thinking about production, marketing, and investment decisions.

Micro-positive vs. macro-positive is a real difference. A major contribution of financial economics is to model uncertainty. The models have informed corporate and investor decision making. Markowitz introduced us to portfolio theory and a capital markets approach, which really developed the benefits of diversification and what risks are important, those risks that are retained and risks that are not retained through diversification. That is a strong micro-positive insight. This was Markowitz's contribution in the 1950s. Milton Friedman, at the time Markowitz proposed his thesis, said that Markowitz's portfolio theory was not economics at all; it was just statistics. Markowitz had a lot of trouble navigating his dissertation process. That turned out to be completely wrong because it had such a profound effect on practice and the evolution of finance to this day. The economics was obviously to identify the important economic risks and the importance of correlations among alternative investments.

Sharpe's work in the 1960s derived the capital asset pricing model, not only addressing the idea of diversification, but also how to measure risk and reduce its dimensionality from the portfolio level to individual securities. This was a significant contribution and has become the framework for much of the applied work in the financial sector today. We now consider Sharpe ratios, information ratios, and benchmarks as we analyze factor risks and evaluate whether there are abnormal excess returns (alphas). Thus, Sharpe and Markowitz defined an entirely new dimension of finance, shaping how we approach it and its applications.

Fama and Samuelson in the 1960s, through efficient market theory and the concept of market prices revealing information, introduced critical questions about how prices inform us and their importance. Markets are efficient to the extent that available information is embedded in prices. Understanding what prices convey in terms of information content has had a profound impact on financial theory and practice.

The Modigliani-Miller models of the 1950s and 1960s played a crucial role in the evolution of corporate finance, positing that underlying asset risk is what counts, not necessarily the method of financing. Modigliani worried for a long time about the adoption of corporate finance models, as they did not take off as rapidly as the Markowitz, Sharpe, and Fama models. A significant factor was the availability of data that allows us to test and validate the efficiency and value-add of these models in decision-making. This area has seen substantial growth in the 2000s, with early forms of blockchains being used to capture and utilize data for informed decision-making.

I appreciate the efforts of this 50-year conference and others held this year. The 1973 Black–Merton–Scholes option pricing technology we developed, along with the concepts of insurance and risk transfer, illustrates the intersection of micro-positive and macro-positive approaches. The Arrow-Debreu state-pricing model theoretically encompasses many states and dates but operationalizing them to use time-state prices was challenging. With the Black–Merton–Scholes option pricing model, we discovered that by assuming a single state variable; that is, the market, we could simplify and make these models operational for capital budgeting and other decisions.

Today, I will delve further into the idea that Merton and Samuelson, particularly Merton, emphasized about the importance of time in investments. They highlighted the need to incorporate time as a crucial component in our research. My perspective is that we must increasingly consider how time and risk changes are crucial and incorporate this understanding into our models. I will elaborate on this shortly.

One whimsical thought I had was to consider what we could have learned if option theory were developed before portfolio theory. By examining what option models reveal about different scenarios and utilizing this information, we could have gained insights into potential developments and applications for portfolio theory and asset pricing and the dynamics of changing risks.

Diversification is often considered a free lunch in finance, so it is very important. However, as Darrell Duffie pointed out, **when you have shocks, diversification tends to be lost**. If you experience many high-correlation events, they can cause significant problems for the economy to function normally. One interesting insight of option theory is that an option on a portfolio is less valuable than the sum of the options in the portfolio, unless shocks produce high correlations. We can test this as we have data available every day on Bloomberg on options on individual securities and indices. For example, looking at the value of the implied

at-the-money option for a 3-month option on the S&P 500 compared to the weighted sum of the option prices of the individual components of the S&P 500 tells us the degree of correlation among the assets in our economy. **During shocks, the value of the option on the portfolio will increase to about 97% of the value of the sum of the individual stocks within the index, and it can be as low as 10% at other times**, indicating that beta has no effect. When we have a market of securities versus a securities market, the estimated correlation is in the low 20% range. On average, it tends to be about 40% or 50%, so typically, the portfolio of US options is more valuable than an option on the portfolio. This fluctuates dramatically, however, indicating that during crises, such as in the 2008-09 Financial Panic, in the 2010-2012 European Sovereign Debt Crisis, and in March 2020, the global Coronavirus Pandemic, correlations increased dramatically, which impacts the benefits of diversification. Importantly, this also indicates that discount rates are not constant. With changing risks, the discount rates on equities will be very high in high correlation regimes and low in low correlation regimes. I don't believe that investors should ignore these changing correlations and discount rates in making portfolio decisions. We should move forward to make investment decisions with changing risks. The crowd-sourced information contained in option prices gives us insights into risks ahead. We should drive forward using that information and not rely only on historical risk estimates by looking backwards, through the rear-view mirror.

We have often found that stocks are negatively correlated with bonds, which supports the mean-variance efficiency of a 60–40 portfolio strategy. However, this is not always true. This can't be true economically. Sometimes, Central Bank policies and commercial bank credit policies create positive correlations. And sometimes negative correlations occur during liquidity shocks, when investors move from risky assets to safer assets to reduce their risks. Correlations are hard to estimate using historical data and are not constant between stocks and bonds. If stocks were always negatively correlated with bonds, that would create an arbitrage opportunity by buying bonds and stocks in the right proportions to produce a positive rate of return over the risk-free rate, without incurring risk. Economically, however, we find that sometimes stocks are negatively correlated with bonds, and sometimes positively correlated.

We don't have option data, however, currently on a portfolio of stocks and bonds. However, we have information in the option markets that informs us of the direction of correlation. If we have options on bonds with high positive skewness and conversely, equities with high negative skewness, this indicates a potential negative correlation. Conversely, if both bond and stock option prices indicate the same direction of skewness, this suggests a positive correlation between bond and stock returns. These signals are not constant over time but are good predictors of future correlations.

When I started with Fischer and then Bob, there were no public options traded, only over-the-counter options on a few instruments. When the option market started in 1973, there were 16 options traded only on call options. Now we have over 4,000 options traded each day on myriad instruments around the world with multiple strikes that are very liquid, providing tremendous information about market risks and how they change. We have options on commodities, myriad equities, international equities, domestic bonds, treasuries, corporates, international bonds, and currencies. Some markets are more liquid than others, but the market is deep and thick with cross-sectional information that can be used to deduce diversification and the correlation direction between stocks and bonds. As

Bob argued many years ago, estimating risk is much easier than estimating value. The beauty of option markets is that they give us the crowd-sourced estimates of risk ahead, which are crucial in risk management decisions. Risk management is changing the risk of holdings or hedging risks dynamically.

Another significant contribution from understanding options is the research on "real options." We've learned a lot about how the workhorse discounted cash flow model (DCF) is a static model without uncertainty, without the option to invest, and without asymmetric information. We need to think about real options or real investment opportunities. When options indicate changes in risk or uncertainty, how do we reduce that uncertainty in making real investments easier and more efficient?

What does our economics tell us about the need to increase flexibility at lower cost without assuming a static environment in valuing real options. Once we have a constraint (such as an irreversibility constraint) with our option theory we can we change the terms, such as volatility or duration, to think about dynamic investments and how capital moves from hardware to software to increase flexibility but at what incremental cost? This is crucial. The static to dynamic investment transition involves understanding the volatility associated with underlying investments and how to make them more liquid and flexible. This is a future research avenue that is very important. Flexibility is costly but lack of flexibility is also costly. In my view, innovation moves us towards flexible, software solutions at lower and lower cost to reduce the benefits or costs of the static hardware solution.

Option market prices embed insurance prices for multiple possibilities. As risk increases, the prices of options increase, indicating higher risk. Testing for efficiency in markets is challenging due to cash flows, financing policies, discount rates, and cross-sectional dynamics. As Fama argued it is impossible to test for market efficiency without a valuation anchor. However, the option market allows easier efficiency testing. Even in early tests of option pricing and the over-the-counter market in 1972, Fischer and I found the market to be efficient, as it was hard to make money after accounting for transaction costs. This suggests that option market prices are valuable and provide significant insights into changing risks. In corporate decisions, the use of option insights has been dramatically extended. Merton's work, among others, highlighted that risky debt subsumes safe debt in the marketplace. Many options are imbedded into multiple contracts and are valued.

Options and time are crucial because the shapes of underlying distributions of risk are not constant. If we move from average returns to compound returns, risk dominates in the short run. The expected return is not important over the next several months. Risks dominate. Time impacts investment decisions, and time and changing risks must be incorporated in the development and understanding of our models. The risks that are most important in the short run are not the risks in the middle of the distribution but the tail risks. Options inform us of these tail risks.

We have learned that constraints have a large effect on decision-making. Many investors are short a put option. When shocks or tails occur, they may realize they cannot hold their risky positions, leading to risk reduction and, in aggregate, a potential liquidity crisis. Individuals have significant debt related to future consumption, family legacy, healthcare, pensions, and private equity commitments. When these constraints force risk reduction, intermediaries are needed to step in and provide liquidity. Individuals' concerns about being short put options and the consequences

of exercised puts impact markets and decision-making before and after shocks. Time series analysis is important, but cross-sectional signals from option markets are also rich in information of tail risks and changing liquidity risks.

To improve compound returns, we must focus on risk and its changes. Average returns or returns relative to a benchmark should not be our focus. Mathematically, a compound return is less than the expected return due to convexity. As asset risk and correlations change, risk management should consider both downside and upside risk. The risks of passive portfolios are always changing. Volatility reduces compound returns and excess volatility further reduces compounding without affecting average returns. Current passive investing is active in that passive portfolios are not risk managed. Passive investment strategies need to be replaced by risk-managed passive portfolios to increase compound returns.

Volatility does not distinguish between good and bad risk. Markowitz assumed risks were symmetric and therefore taught us that we could use variance as a measure of risk and the power of mean-variance optimization. He claimed that downside risk is crucial, however. We need to think about differences in upside (good) and downside (bad) risk. If volatility were symmetric, then the good and bad are the same. Ashwin Alankar informed us that the option markets provide estimates of good and bad risks. They are not the same and change over time. Doug Breeden showed that in his recent work. Recent tests using S&P 500 data show that implied volatility forecasts dominate historical volatility in estimation of future volatility. Implied volatility from options gives a near-unbiased slope close to 1, and intercept of zero in estimating future volatility over the next 30 or 60 days while using historical volatility adds no additional value in forecasting future risks. This study was on the market portfolio and, interestingly, also on estimating future risk on individual stocks in the Russel 1000. These forward estimates are essential for forecasting 30-day ahead or near-term volatility and changes in volatility as well as the term structures of volatility.

Making money in the market involves forecasting future risk premiums or factors and understanding constraints and liquidity risk. Risk management is insurance, reserves (a cushion), and diversification. We do not have a dynamic theory of when to reset options, when to use reserves and what to do when diversification is lost. The option market is telling us that risks and discount rates are changing, going from low to high or the reverse. Some in finance believe that long-term investors should ignore these changing discount rates for they mean-revert (at different frequencies.) Discount rates in the bond market mean-revert. Bond market participants worry about changing discount rates while equity specialists worry more about changing cash flows assuming that historical data is sufficient to estimate a discount rate. Equity specialists need to consider both changing cash flows and discount rates to enhance compound returns.

It's important to think dynamically about how to mitigate constraints and reduce volatility drag. Many investment managers are constrained by clients or their management to stay close to a benchmark or a strategic allocation. A study by Alankar of the 60–40 (60% stock and 40% bond) strategy from 1997 to 2020 compared to a 100% equity strategy with 1-year put spreads protecting a portfolio to a 30% maximum drawdown had a similar maximum 1-year drawdown of around 30% (e.g., 2002 or 2007–2008) when the market dropped over 50%. The put protection strategy returned about 7%. The 60–40 strategy returned about 7%. This was so over a period when interest rates fell and realized correlations between bonds

and equities were generally negative. Although options have different protection shapes than the reserve 60–40 strategy, both have similar costs and returns and protect against large drawdowns.

Considering protection costs, buying a 1-year put (30% down protection) costs around 2% a year, which is comparable to the insurance cost of a 60–40 strategy with an equity risk premium of about 5% (i.e., 40% of 5% is 2%). The main question for either strategy is what to do with the insurance proceeds once the loss is realized.

Do private equity holders earn liquidity premiums or do private assets holders earn liquidity premiums? Should long-horizon investors, low-leverage investors, or those with sufficient liquidity to meet contingencies be selling insurance in the market. Understanding when and how to add liquidity dynamically, based on signals from the option markets, is a key area for future research. Liquidity providers, such as private equity, should be analyzed for their role in providing liquidity and whether their returns justify the liquidity premium. Data from Cambridge Associates shows that private equity returns are like investing in underlying leveraged equity, suggesting that other factors contribute to returns in private equity investments.

The innovation prescription in finance involves efficiently providing financial functions faster, more individualized, and more flexibly, at lower cost. Innovations in finance have aimed to reduce the cost of options and increase flexibility, supporting various financial functions. Constraints affect decision-making and pricing, and reducing the cost of constraints is crucial for improving returns. Constraints arise economically because of lack of trust. They are two sides of the same coin. Lack of trust is an economic cost because of the difficulty of separating cheaters from those providing honest services. Larger uncertainty allows cheaters to hide in the noise. Every model has an error, and cheaters reverse engineer the error of the model. Dynamics suggests that finance will develop technology to reduce errors and unmask cheaters.

Building trust and flexibility through hardware to software transitions in finance is essential. Increased uncertainty requires more flexibility and optionality. Technologies and innovations, such as AI, robotics, and blockchain, aim to reduce uncertainty and enhance decision-making. Innovation, however, must lead infrastructure for economically it is too costly to build the infrastructure with large uncertainty about the possible success of innovations. Reducing uncertainty and creating dynamic governance structures will increase economic efficiency.

Research and development must include testing to reduce uncertainty and the cost of irreversibility. Digital twins in manufacturing are an example of using simulations, building a logical system to simulate a physical system, to reduce volatility and the cost of fixed options. Innovation in finance is often about increasing the value of optionality by reducing constraints.

Although static strategies in finance are prevalent due to lack of trust and resultant constraints, we need to move towards dynamic strategies that consider absolute performance. The option markets and option theory provide useful information on building dynamic approaches to investment management. Corporate finance, liquidity constraints, and investment strategies should be examined dynamically to understand the effects of changing risks on optimal policies. These are growth areas in financial economics.

Thank you for listening today. I am sorry that I was not with you in person. Uncertainty and especially the effects of changes in uncertainty on investment decision making and corporate policies are exciting research areas with great

opportunities ahead. The data clearly show that risks change and that tail risks are important in financial decision making. The micro-positive approach should move to provide decision making tools to inform the investment applications of investors and savers in all areas of financial economics. Thank you to Doug Breeden for excellent comments on this talk and to Ashwin Alankar for many fruitful discussions on these issues.

Q & A.

Hossein Kazemi: Thank you very much, Professor Scholes. I have a couple of questions. One is general: since the publication of the article, what has surprised you on the upside and what has disappointed you in terms of developments in options or their applications? We've heard Warren Buffett refer to options as weapons of mass destruction. What are your thoughts and surprises in the development of the markets over the last 50 years?

Myron Scholes: I don't know what Warren Buffett meant by weapons of mass destruction. I think he was referring to long-dated options and the losses that he incurred on long-dated contracts on acquiring an insurance company. We must avoid absolute statements. But I understand what he is saying. The growth of option trading and option contracts generally has been amazing over the years since I first became involved in the late 60s. They have survived and prospered. As I said earlier, innovation leads infrastructure, but infrastructure catches up if the innovation is valuable. Valuable is certainly the case with options and their applications.

What surprised me most when Fischer and I developed the option pricing model, and with Merton's work, was how it changed the nature of investments. We thought we were just explaining existing contracts and options embedded in many decisions and assets. The model development created a shift from the agency model to the principal model in financial innovation; that is, using technology, mathematics, and modeling to price securities and allow clients to decide what risks they want to retain and investment banks to act as a principal to manufacture these contracts. This reduced costs, increased the speed, allowed for individual solutions to client problems and created flexibility. Moving from an agent to a principal model in investment banking and finance added huge value. This evolution was surprising.

As I discussed, I would like to see faster developments in the dynamic risk management sphere. Businesses are creating more flexibility in their activities, which is not surprising. Monetary policy and theory haven't taken uncertainty as primary and developed models accordingly. They should. It makes little sense to have certainty models, add an error to the model and then integrate out the error.

Hossein Kazemi: One more question, then I'll ask the audience. I liked your chart comparing the 60-40 to the put-protected portfolio. That was during the bond bull market. Going forward, would it be better to use the put protector rather than continue with the 60-40 strategy?

Myron Scholes: It could be. The 60-40 strategy is static and has liner protection while the option strategy starts with less and then adds more and more protection as the market experiences larger drawdowns. The option prices could change with different correlations. One problem with assuming a normal or log-normal distribution is that a 2 standard deviation move implies a 20% drawdown. But in 2008-09, the market fell more than 50%, and similar shocks occurred in 2001-02, 2010, 2012, and 2020. These great drawdowns suggest that the correlation structure is not always negatively correlated. A strategy with more equity

and tail protection might provide superior results because of the ability dynamically to adjust risk. There's no necessity to buy the same level of protection always.

From the Audience: I have a question regarding correlation. Hedge fund trades are getting crowded due to competitiveness and market efficiency. What is your view about the future of the hedge fund domain?

Myron Scholes: The important consideration is liquidity and supply-demand imbalances caused by constraints. Liquidity needs create supply-demand imbalances. We must understand how these imbalances affect supply. How does demand change? Hedge funds presumably have expertise in particular markets and supply liquidity. Modeling on how to supply liquidity and knowing when and how much to supply to earn a return generates hedge fund returns. Returns can be low at times, and greater at other times due to increased demand for liquidity. Understanding why and when demand for liquidity occurs and how it is mitigated over time through intermediation is crucial (whether by banks or hedge funds). Sometimes there are too many suppliers and at other times too many demanders of liquidity. Understanding who supplies liquidity, when, and how is an important problem. Hedge funds will have an intermediation role to mitigate these imbalances.

Sanjay Nawalkha: Thank you so much, Professor Scholes. This was a great occasion and a terrific honor to celebrate the 50th anniversary of your model.

Myron Scholes: You are very welcome. I'm happy that we are approaching the end of the 50th year. Now maybe we can get on and plan to celebrate the 75th year of the Black–Merton–Scholes technology. That would be great. I will sign up to talk again then. No option calculations allowed on the value of my sign up, however.