Mijnheer de Rector
Monsieur le Recteur
Mijnheer de Decaan,
Beste Collega's,
Dames and Heren,
Beste studenten

Het is mij een grote eer om de gelegenheid te krijgen aan de VUB te doceren in het kader van de Binnenlandse Francqui leerstoel. Ik bedank heel hartelijk de Vrij Universiteit Brussel en de Faculteit voor Economische, Sociale en Politieke Wetenschappen & de Solvay management school voor de uitnodiging. In februari van dit jaar, inaugureerde onze collega Kris Deschouwer de Chaire Francqui aan ULB. Hij merkte op dat hij behoorde tot de eerste generatie die een tweetalige ULB niet meer heeft gekend. Ik ben in dezelfde situatie. Op oktober 1, 1969(negentien honderd negenenzestig), werd de ULB gesplitst in een Nederlandstalige and een Franstalige universiteit. Dit was ook de dag waarop ik als assistent mijn akademische carrière begon.

Gedurende meerdere jaren werd de band tussen onze universiteiten verzekerd dankzij collega's zoals Henri Vander Eycken, Jacques Nagels en anderen, die in beiden universiteiten doceerden. Nu deze collega's gepensioneerd zijn, is het belangrijk dat we onze relatie behouden en zelfs versterken. Uitnodigingen zoals deze dragen bij tot de verbetering van de vriendschappelijk betrekkingen en verkleinen de afstand tussen onze universeiten.

Je me réjouis des projets de rapprochement entre la Solvay school of management et la Solvay Business School. Nos deux universités, en joignant leurs forces, peuvent offrir un enseignement de qualités délivrés en plusieurs langues. Nous bénéficions d'une position unique à cet égard.

Je tiens à remercier la Fondation Francqui pour l'occasion qui m'est donnée d'assurer cet enseignement. Les Chaires Francqui au titre Belge favorisent les échanges interuniversitaires en Belgique en permettant aux universités d'inviter
des professeurs pour enseigner les matières de leur discipline au plus haut niveau. Elles jouent un rôle important dans la diffusion des connaissances et je suis heureux et fier d'avoir cette occasion de partager ma compréhension d'un domaine qui a connu, au cours des dernières années, un développement spectaculaire tant au niveau académique qu'au niveau pratique. Emile Francqui, qui a mené l’essentiel de sa carrière dans la finance, serait sans doute surpris du chemin parcouru par une génération de chercheurs.

Het thema van deze lessen is opties. Ik weet uit ervaring, dat het beste is dit vak in het Engels te doceren. In het Frans, is het al moeilijk te vermijden een brabbeltaal te spreken. In het Nederland, zou het onmogelijk zijn.

Why are options at the core of finance? In order to answer this question, I will begin by explaining what finance is about. I will then proceed to describe the state of development of the theory of finance prior to publication of the seminal paper by Fisher Black and Myron Scholes in 1973. After that, I will present the contribution of Black, Scholes and Merton. I will finish by showing all the models can be viewed as special cases of a more general model. In my conclusion, the contribution of option pricing theory to portfolio management, capital budgeting and capital structure decisions will be presented.

I hope that you will forgive me for mixing this account of the development of the theory of finance during the last 50 years with my own memories. By accident, I began my research at the very moment when the big bang in finance was taking place in Europe. I stepped into the train as it was leaving the station. I had the privilege to know many of those who created the field and the story of finance is very much my own story. I wish to use this audience to pay a tribute to my intellectual mentors. To quote Isaac Newton in a letter to Robert Hooke in 1676: “If I have seen further, it is by standing on the shoulders of Giants”. Today, I wish to remind who these giants were (a bit pompous, I agree).

1. What is finance about?
To begin, let us first review briefly some the questions that the theory of finance wishes to address.
In order to operate, companies invest capital in fixed assets and in working capital requirement. This capital is provided by stockholders and bondholders who require a return on their investment. The cash flow generated by the company should be sufficient to remunerate the providers of funds. As the goal of the corporate firm is to increase the market value of stockholders’ equity, a project should be accepted if its cost is lower than the value of future cash flows that it will generate. The measure of the value added by a project is called the net present value.
In finance, values are calculated by using current market prices of other "similar" securities. This method is based on the law of one price or the principle of no risk-free arbitrage: two securities with identical future payouts, no matter how the future turns out, should have identical current prices. There are no free lunches in competitive markets.

Sometimes, prices are available and the calculation is relatively straightforward. Consider, for instance, a project that will generate cash flows denominated in US dollars and Japanese yen. The value of these cash flows can be easily calculated using the exchange rates quoted on the market without having to develop a full model of exchange rate determination.

More often, prices are not available and have to be calculated. This is where asset pricing models enter. The story of finance since 1950 is the story of increasingly more sophisticated models.

These models have to account for two related dimensions: time and uncertainty.

2. The diffusion of the discounted cash flow method

Let us first consider the time dimension. Cash flows take place at different points in time. The law of one price tells us that the present value of a certain cash flow $C_t$ to be received in $t$ years from now is equal to the cash flow multiplied by the unit price of 1 euro available in year $t$.

$$PV(C_t) = C_t \times v_t$$

The unit price $v_t$ is called a discount factor. It is equal to the market value of the most elementary financial instrument: a zero coupon with a face value equal to unity. If prices of zero coupons are available, the present value calculation for a set of future cash flows $C_1, \ldots, C_n$ is straightforward:

$$PV = \sum C_t v_t$$

If the discount factors are not observable, they must be calculated. The most widely used model to do that is the discounted cash flow method: recent surveys reveal that it is used by about 80% of companies for making their capital budgeting decisions (see, for instance, Graham and Campbell 2001).*

$$PV = C_0 + \frac{C_1}{(1+r_t)} + \frac{C_2}{(1+r_t)^2} + \ldots + \frac{C_n}{(1+r_t)^n}$$

where $\{C_t\}$ are the expected cash flows and $r_t$ are the required rate of returns.

The origin of present value calculation is not known. Some authors trace its roots to the early days of financial economics in the 15th century. Others look for the origin even further in time.

Up to the advent of computers, present value was a topic for mathematicians and engineers. As far as I remember, I was exposed to this formula for the first time in the early 1960s in a course on insurances taught by a mathematician. I loved the mathematics, but working out the result with a slide rule was a nightmare.
This, of course, explains the low rate of penetration of the DCF method at that time. A survey in the US published in 1959 indicates that only 19% of the respondents were using the method.

The penetration rate of DCF techniques increased rapidly after the mid 1950's (Callahan and Haka, 2002). Two reasons explain this evolution. First, computation ceased being an issue. By the mid 1950's, tables of discount factors started being produced on computers. Some year later, calculators appeared. We now have spreadsheets that do the calculation.

A second reason explains the diffusion of DCF techniques. From 1950 on, economics entered business schools. The economic foundation of the present value rule had been laid down by Irving Fisher in 1930 in his famous treaty on interest but the practical implication of his work had not been fully grasped. In 1950, Joel Dean, a professor at Columbia University published Capital Budgeting, the book that made DCF techniques accessible to business managers. During the following years, problems related to the techniques were clarified and solved by academics.

By the end of the 1950s, the battle for the present value had been won (the paper by Jack Hirshleifer published in 1958 is still a classic). However, the way to deal with uncertainty, the second dimension of any financial decision, was largely still uncharted territory. One knew, of course, that the required return (the discount rate) should increase with risk but one didn’t know by how much. Harry Markowitz traced the way to the answer in his paper published in 1952.

3. Markowitz and the birth of modern portfolio theory

I have devoted my career to finance because of Harry Markowitz. His paper "Portfolio selection" is considered as the beginning of modern finance. For the first time, a precise definition of risk (the variance) was used. A solution, based on mathematical statistics, was found for the composition of an optimal portfolio. Markowitz then devoted the following years to finding an algorithm to compute the composition of the portfolio when short sales of stocks were prohibited. This was, at that time, a challenging mathematical problem: finding the minimum of a quadratic function subject to non negativity constrains. His results were published in 1959 in his book "Portfolio Selection: Efficient Diversification of Investment".

I discovered Markowitz's work some years later. I had graduated from Solvay and I was doing a master program (a “Licence Spéciale” as it was called at that time) in Applied Mathematics. I was interested in operation research. I had studied linear programming techniques used to optimise a linear function subjected to non negativity constrains. The mathematical tools were elegant (I
have warm memories of Kuhn and Tucker). As Markowitz's problem was more
general (the objective function is non linear), it was a good topic for a master's
thesis.
I was mainly interested in the computation side of his work and, to be honest, I
hadn't perceived the key insight namely, the power of diversification.
Markowitz main contribution was to show the importance of covariances (or
correlations) in the determination of the risk of a portfolio. His counterintuitive
result shows that a volatile stock (characterized by a high degree of
uncertainty, a high variance of returns) could end up being viewed as riskless in a
portfolio if the average covariance with the portfolio is sufficiently low. The
risk of this stock might even be negative: increasing the proportion invested in
that stock might decrease the risk of the portfolio.
Implementing the Markowitz approach was, and still is, a challenge. The data
requirement is impressive (about 5,000 parameters have to be estimated for a
portfolio of 100 different securities). A sophisticate algorithm is needed to
calculate the optimal solution. No wonder that Markowitz, who was working for
IBM, might have had secret hopes that his algorithm would be an important
source of revenues for the company.
Ironically, economists were to discover some years later that the composition of
the optimal portfolio can be found without having to use the Markowitz's
algorithm. But the contribution of Markowitz has not been lost. It is now used
daily by financial institutions to calculated their so called Values at Risk, the
worst loss that they could experience over a target horizon with a given level of
confidence (for details, see Jorion, 2001). Riskmetric, a firm founded by JP
Morgan in the mid 1990's, has even made the variances and covariances required
to apply Markowitz's model available on the net. Moreover, Excel includes a
command (Solver) which makes the problem accessible to dummies.
But the estimation of the mean (the expected value) is the real challenge. I will
come to it in a few minutes. But before, let me proceed with my personal
memories.

4. CAPM: the relationship between expected returns and risk
After completing my studies, I went to work in a company as a computer analyst.
My ambition was to apply operation research to the production planning process
of the firm. The company did not accept my project. A teaching assistant
position opened at ULB and gave me an opportunity to start a doctorate. I had to
find a topic. I remembered Markowitz and I thought that portfolio management
would be an interesting area to study. This was the early days of mutual funds in
Belgium and I paid a visit to one of their managers. He was interested in my idea
but made a remark which has orientated the rest of my life: "Doing research on
portfolio management is interesting but, how do you know whether a portfolio is
better managed than another?" The difficulty when comparing realized returns of portfolios is how to account for the differences in risks. Risky portfolios should achieve on average higher return than low risk portfolios.

Back to my office in the attic of DULBEA (with collega Jef Vuchelen working on his PhD next door), I started looking for an answer to this question. I soon found that an answer had been recently offered by Michael Jensen in his PhD dissertation at the University of Chicago. Using recent developments in the theory of asset pricing by Sharpe and Lintner, Jensen had formulated a measure of a portfolio's performance. He was thus able to evaluate "a portfolio's manager predictive ability - that is ability to earn returns through successful prediction of security prices which are higher than those which we would expect given the level of riskiness of his portfolio" (Jensen 1968)

Through this paper, I discovered a whole new world. A few year earlier, in 1964-1965, Sharpe and Lintner had independently formulated the relationship between expected returns and risk in a model known as the Capital Asset Pricing Model. The prediction of the model is strikingly simple: when all markets are at equilibrium, the optimal portfolio is the market portfolio, a value weighted portfolio comprising all existing stocks. The distribution of expected rates of returns across all risky asset is a linear function of a single variable, each asset's sensitivity to the market portfolio, known today as the beta of the asset.

\[ r = r_f + [r_m - r_f] \times \beta \]

where \( r \) is the expected return on a risky asset, \( r_f \) is the one-period interest rate, \( r_m \) is the expected return on the market portfolio and \( \beta \) is the sensitivity of the asset to the market portfolio.

This formula provided, for the first time, an exact formulation of the relationship between expected return and risk. It could be used by companies to set discount rates when calculating present values. Although the empirical investigations are still underway, it has been widely adopted by companies. Graham and Campbell 2001 report that more than 70 percent of companies use the CAPM to determine their cost of equity capital.

The CAPM formula also provided a way to measure the predictive ability of a portfolio's manager. A superior forecaster would indeed pick stocks whose expected returns at high relative to their risk. The average return of this manager would be higher than the return associated with its risk.

\[ r = \alpha + r_f + [r_m - r_f] \times \beta \]

where \( \alpha \) is the excess return due to the forecasting ability. Jensen applied his model to a sample of 115 open mutual funds in the period 1945-1964 using annual data. The result was striking. The average value of excess returns was negative (-1.1% per annum). Portfolio managers were achieving worst results than those that passive investors would have realized.
My PhD dissertation found a similar result for internationally diversified European mutual fund. This result has been confirmed in later studies.

5. The efficient market hypothesis: do stock prices move randomly?
How to explain this result? Beginning in the mid 1950's, statisticians had begun modelling the evolution of stock prices. Their attempts had not been successful. In 1959, Osborne, an astrophysicist at the U.S. Naval Research Laboratory (part of a group involved in war games and submarine hunting) published a paper “Brownian Motion in the Stock Market” showing that stock prices behaved like molecules that move randomly. At about the same time, Eugene Fama started working on his doctorate at the University of Chicago. The university had just acquired a new computer (an IBM 709) and Fama remembers that, with a member of the physics department, they were the only one at the university who knew how to use it. Moreover, a huge data basis had been created by two members of the Chicago faculty, Lorie and Fisher, to measure the performance of all stocks listed on the New York Stock Exchange from 1926 to 1960. Fama was the first researcher to have both a large data basis and computing power at his disposal. His thesis, published in 1965, showed that stock prices moved randomly: changes in stock prices were uncorrelated through time. The random walk model was born. It was to become the cornerstone of the option pricing model.

6. Modigliani – Miller: does the financial structure of a company matter?
Let us go back to the present value equation. As we have seen, by the end of the 1960s, rapid advances in computer technology had made calculations faster and cheaper. Moreover, the Capital Asset Pricing Model provided a way to adjust the discount rate according to the risk. One question remains: does the funding of the project modify the required return?
Modigliani and Miller had provided a simple answer to this question in 1958: under some conditions, no. The market value of the firm is independent of its capital structure. When asked to explain the theorem of American TV viewers, Miller presented the proposition as follow “Think of the firm as a gigantic pizza, divided into quarter. If now you cut each quarter in half into eights, the M and M proposition says that you will have more pieces but not more pizza” Or, as Yogi Berra, the famous basket ball player, would put it: “You better cut the pizza in four pieces because I’m not hungry enough to eat six” The MM proposition implies that the choice of the financing instrument is irrelevant for the required rate of return. This required return depends solely on the risk of the investment, regardless how it is financed.
With his usual sense of humor, Miller adds: “hardly a happy position for professors of finance to explain to their students being trained, presumably, in the art of selecting optimal structures”.

The situation is not totally desperate, though, for the MM theorem also provides the list of factors that could explain why the required return on a project might be a function of its financing.

Two factors play a critical role: taxes and costs of financial distress. Taxes play a role because interest expenses are tax deductible. As a consequence, the cost of capital of a project could be lower if the project is partly financed with debt. But, on the other hand, a higher level of debt increases the probability of financial trouble for the company. If these are costly, the required return would have to be raised if debt is used to finance a project. The interaction between these two factors leads to the so called “trade-off model” of the capital structure. We will discover that options are required to use this model.

Before moving to option, let us summarize the state of finance in the late 1960s:
- DCF had emerged as the criteria to use for capital budgeting decisions and calculation was not longer an issue
- The market portfolio had been identified as the optimal portfolio for investors and a formula was available to adjust the required return for risk
- The evolution of stock prices had been identified as being random.
- The financing of a project was considered as irrelevant for its valuation.

7. Black, Merton, Scholes

Let us now move to options.

Options are contracts giving the owner the right to buy or sell an asset at a fixed price any time on or before a given date. An option to buy is named a call option, an option to sell a put option. The fixed price is called the striking price or exercise price. The act of buying or selling the underlying asset via the option contract is referred to as exercising the option. If the option may be exercised anytime up to the expiration date, the option is qualified as an American option. If, on the other hand, the option can be exercised only on the expiration date, the option is European.

Consider, as an example, a European put options on FORTIS with an exercise price €20 and 6 months to maturity. The owner of the option has the right to sell one FORTIS share in 6 months for a price of €20. Why would anyone want to buy such an option?

Imagine someone have one FORTIS share in her portfolio. Buying a put option sets a floor on the future value of her portfolio, a guarantee that the value of her portfolio will not drop below the level of the exercise price. If the price of FORTIS is higher than €20, the option would mature without being exercised.
If, however, the price of FORTIS drops below €20, she would exercise the option and sell her FORTIS share. A put option is thus very similar to an insurance contract. As for an insurance contract, a premium has to be paid upfront.

The same result can be achieved by combining a call option with a bond. Buying a call option and a bond yields the same payoff as holding a share of the stock and buying a put written on that share.

The insurance market is a market where risk can be transferred. Option contracts offer a way for investors to protect themselves against adverse price movements in the future while still allowing them to benefit from favourable price movements.

Of course, there should be a counterpart. In traditional insurance contracts, the counterpart is an insurance company. For option contracts, the counterparts are the speculators who wish to take a position on the market.

The reasons why options are a unique financial instrument is because they give the buyer the right, but not the obligation, to do something. Their value should thus take into account the future decision.

Initial attempts to formulate an option pricing model were based on the traditional present value approach: the option would be valued by discounting its expected future value at a risk adjusted discount rate. As reminded by Black (1989), that method has two problems: you have to know the stock's expected return to find the option's expected value at expiration, and you have to choose a discount rate for the option. No single rate will do, however, because the risk of the option depends on stock price and time. Hence, the discount rate depends to stock price and time too.

Black and Scholes turned around the obstacle. Instead of using the CAPM, they analysed combinations of options with the stock. As the value of the option is a function of the stock price, the value of the option changes when the stock price change. Suppose, for instance, that the value of option change by €0.50 when the stock price changes by €1.00. A hedged position can be than be created by selling two options contracts and buying one stock. This position would be riskless.

Of course, in order to do this, you should know by how much the value of the option will change when the stock price changes. This is the role of the option pricing model. The model gives the recipe to create an option by combining the underlying asset with borrowing or lending.

Once you have the recipe, the value is known. This results again from the law of one price or the principle of no risk-free arbitrage: any two securities with identical future payouts, no matter how the future turns out, should have
identical values. The twist of the proof is in showing that money can be made without risk is the price is different from the value.

Robert Merton, a young mathematician, provided the mathematical tool to work out the solution in continuous time. He provided the technique to calculate the derivative of a function of a random variable known as Ito's lemma. His contribution pioneered the use of continuous-time modelling in financial economics. Continuous-time methods have now become an integral part of financial economics and are widely used by practitioners. The price of an option, or of any derivative, is the solution of a partial differential equation. The Black Scholes formula is the solution of this PDE for European option on a non dividend paying stock.

The level of mathematics is however beyond the level of knowledge of an average business school student or, for that matter, of an average finance professor. But, a simpler binomial model is sufficient to understand a large fraction of the option pricing literature. I will use this approach extensively in the following lectures.

The model leads to surprisingly simple solution. The value of an option is obtained as the risk neutral expected value discounted at the risk free interest rate. We will, in the next lecture, show that this simple formula is the BMS PDE under a new disguise.

But the story is not over. Like Zeus who is said to change form to seduce mortal women, the PDE turns out to be one manifestation of an abstract theory in economics, the Arrow-Debreu general equilibrium model.

8. Beyond BMS: state prices and stochastic discount factors
When I joined the university, my first teaching responsibility was to teach microeconomics. My thesis promoter, Jean Waelbroeck, had just signed an agreement with UCL and KUL to join CORE. At that moment, CORE, under the leadership of Jacques Drèze, was at the forefront of general equilibrium theory. There, I discovered the work initiated by Kenneth Arrow to model equilibrium under uncertainty. Arrow, in a paper published in 1953, had introduced a representation of uncertainty based on a list of future states of the world. He showed that, under some general conditions, prices could be calculated for 1 unit to be received conditional on the realization of a given state. This was extremely elegant but, for someone focused on applications, not very relevant.

But the Arrow state price approach has now reappeared as to the most general formulation of asset pricing under uncertainty under a new name, the stochastic discount factor method.
In his survey of asset pricing ("Asset Pricing at the Millenium"), Campbell writes: "In the absence of arbitrage opportunities, there exist a stochastic discount factor that relates payoffs to market prices for all assets in the economy. This can be understood as an application of the Arrow-Debreu model of general equilibrium to financial markets".

9. Preview of following lectures
The implications of the BMS model are far reaching. On one hand, it has been a main driving force in the spectacular development of the derivative industry. This industry was non existent in the early 1970s. Its size is now measured in trillions of dollars. On the other hand, the BMS model has now moved to the center of the theory of finance. This will be the topic of the following lectures. We will first examine the logic leading to the partial differential equation and to the Black Scholes formula. Special attention will be paid to a discrete formulation based on a binomial evolution of the stock price. We will learn that derivatives can be priced by assuming a so called risk neutral world. We will relate risk neutral pricing to the fundamental pricing theory of Arrow - Debreu and the law of one price.

In the next lectures, portfolio decisions, investment decisions and financing will be revisited using the BMS framework. Portfolio management will be our first application of options theory. Portfolio management is, of course, the field where options are the most useful. Banks now offer a huge number of mutual funds to their customers. Financial papers, such as L'Echo or De Tijd, devote more space to mutual funds reporting than to stock prices. The number of funds is staggering: approximatively 350 for Dexia, 430 for Fortis, 325 for ING, 750 for KBC.

These numbers are even more impressive for those trained in modern portfolio theory. Remember that the CAPM indicates that only two funds are needed to achieve an optimal asset allocation: a money market fund and the market portfolio. Of course, the model is an abstraction based on simplifying assumptions and you would expect to need more funds in the real life. However, one would expect to need tens of funds, not hundreds or thousands of funds. A substantial fraction of the funds offered are structured funds, the name use to indicate that they include options. Some of these options are pretty basic. The most straightforward options are those that guarantee the capital. These are simple put options. Other options are more sophisticated. You meet, for instance cliquets which lock in the guarantee value if the underlying asset goes up by some amount. You have reverse cliquets. You can even buy a product with a Napoleon option through which an investor can earn a high coupon each year plus the worst monthly performance of the underlying.
We will then revisit capital budgeting. One big limitation of the DCF method is that it does not take into account flexibility. Consider, for instance, a company that is considering launching a new product. As the success of this product is uncertain, the project has embedded options. If, for instance, demand exceeds expectations, the company might decide to expand the size of its operation. But, the company also has the option to abandon the project if things do not work out as expected. These future potential decisions look very like the exercise of options. The option pricing models could thus be extended to value investments in real assets such as land, buildings or plans. This method is now known as real options.

The next three lectures will be devoted to the financing of companies. The title of the original Black Scholes paper was: “The Pricing of Options and Corporate Liabilities”. The latter part was added after the paper had been rejected by two previous editors. By changing the title, Black and Scholes hoped to convince the editors of the Journal of Political Economy that the paper was about economics, not just mathematical statistics. Why are options relevant for the study of corporate liabilities?

The most important feature of corporations is limited liability. The maximum loss that stockholder can experience is the money that they have invested in the company. Black and Scholes pointed out in their article that limited liability assimilates a firm’s equity to a call option on the firm, with a strike price equal to the face value of the outstanding debt. This point was later on elaborated by Merton in a article in 1974 and is now known as the Merton model. We will analyze this model in detail.

In the Merton model, the MM proposition holds. As a consequence, the model does not enable to gauge the trade off between the tax shield and the cost of financial distress. In a recent paper published in 1994, Leland has formulated a very elegant model that gives closed-form results for the optimal capital structure when a firm asset value follows a diffusion process with constant volatility such as in Black and Scholes. This model provides for the first time a framework to go beyond qualitative considerations for the determination of the optimal capital structure of a company. This will be the topic of the fifth lecture.

The last lecture will be devoted to the analysis of default risk and credit spreads. Given of the risk of default by borrowers, the measurement and management of credit risk are important for financial institutions. In this lecture, we will focus on the quantification of credit risk. This has become a
very important issue with the spectacular development during the last few years of a market for credit derivatives.

Conclusion
Let me conclude. In my opening remarks, I mentioned that I belong to the first generation of professors of an exclusively French speaking ULB. I also belong to the first generation of finance professors to have built their research and teaching activities on the paradigms developed during the 50s and the 60s. I am, so to say, a son of Arrow, Black, Fama, Lintner, Markowitz, Merton, Modigliani, Miller, Sharpe and Scholes. I suspect that I might have other fathers but the list would then become too long.
I was fortunate to witness a revolution in my field of expertise. The big bang initiated by the founding fathers of finance has sent shock waves that are visible everywhere. Financial economics is now a very active academic discipline with many subfields and a high rate of publications. More interestingly, the models are widely used by companies and financial institutions. All portfolio managers now use benchmarks. A large number of mutual funds include options. Companies such as Airbus or Merck use option pricing models to analyse their capital investment decisions. Rating agencies rely on option pricing models to determine the ratings of corporate bonds.
I hope, in the coming lectures, to convince you that options are the area where action takes place.
Thank you very much for your attention.
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Notes

1 See Poitras (2000) or Rubinstein (2002). Goetzman (2003) argues that one of the early formulations of the net present value rule was presented by Leonardo of Pisa – better known as Fibonacci – around year 1200. Maor (1994) reports one early formulation of financial calculation in a clay tablet from Mesopotamia dated to about 1700 B.C.

2 In an article published in 1955 in the Journal of Finance, Charles Christenson, of Harvard, describes how the tables were calculated on the Mark IV Calculator of Harvard University Computation Laboratory. These tables were quickly included in popular textbooks.

3 In 1972, HP launched the HP35, the first handheld scientific calculator (http://www.hpmuseum.org). It was unfortunately too expensive (around $1,000) for a young teaching assistant. I had to wait until 1973 to buy my first calculator (a Commodore at $500) and so be able to calculate present values without pain.

4 James Lorie, Leonard Savage, Harry Roberts, Jack Hirshleifer, all at the University of Chicago – note that Lorie, Savage and Roberts were professors of statistics, finance was not yet recognized as a discipline.

5 Interestingly, Milton Friedman voted against his thesis in the economic department of the University of Chicago on the ground that it was not really economics.

6 As Emanuel Derman puts it: You can think of a derivative as a mixture of its constituent underliers, much as a cake is a mixture of eggs, flour and milk in carefully specified proportions. The derivative’s model provides a recipe for the mixture, one whose ingredients’ quantity vary with time. Market and models, Risk July 2001

7 Arrow was elected Fellow of the American Finance Association in 2003, a late recognition of his contribution to the theory of finance.