PRICING THE FUTURE

FINANCE, PHYSICS, AND THE 300-YEAR JOURNEY TO THE BLACK-SCHOLES EQUATION

A Story of Genius and Discovery

George G. Szpiro

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BASIC BOOKS
A MEMBER OF THE PERSEUS BOOKS GROUP
New York

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It is my sincere hope that
by the time you read this,
Gilad Shalit is back with his family.

PREFACE

Options have been traded for hundreds of years, at least since the sixteent century, when they were used to buy and sell commodities in Antwerp an Amsterdam. But nobody knew what the true value of an option really was. Fo centuries, their prices were determined by supply and demand, with investor estimating their value on the basis of gut feelings. Indeed, it was not even know what determines the value of an option, whether the current price of th underlying stock, commodity, or asset, the rate of interest, investors' attitude toward risk, the time remaining until expiration of the option, and so on. Howeve options do have a mathematically precise value. The equation that gives th correct price was found by financial economists Fischer Black, Myron Schole and Robert Merton in 1973. Their discovery was considered a singula achievement, comparable to Newton's discovery of the laws of motion. Schole and Merton were awarded the Nobel Prize in 1997. (Fischer Black had died tw years earlier, at the age of 57.) However, disaster followed the Nobel Prize. Th spectacular near bankruptcy of Long-Term Capital Management, the billion-dolla company that Scholes and Merton had helped found, proved that high academ achievements do not guarantee financial success.

Spanning the period from the middle of the seventeenth century until near today, this book traces the historical and intellectual developments that led to th options pricing formula. It describes the search for the elusive equation bu emphasizes the personalities behind that search. Some of the people who appea are medical doctor Robert Brown (of Brownian motion fame), three Frenc accountants and stockbrokers (Jules Regnault, Henri Lefèvre, and Lou Bachelier), Albert Einstein, Wolfgang Döblin (a German Jewish soldier in th French army during World War II), MIT mathematician Norbert Wiener, Russian pioneer of probability theory Andrey Kolmogorov, Japanese mathematicia Kiyoshi Itō, and American economist Paul Samuelson.

At this point in a preface, it is customary to thank those who helped in th preparation of the book. Here I must make an exception. One organization t which I can offer no thanks is the Institut des Actuaires in Paris. It is one of th very few places where the early volumes of the Journal des Actuaires Français ar stored, which contain some articles pertinent to this book. Unfortunately, after had been given the runaround for approximately half a year by an extraordinari unhelpful secretary, it was only when my wife visited Paris that the articles coul be copied. It took her all of fifteen minutes . . . apparently too much for a unwilling secretary.

My sincere thanks do go to Tim Bartlett, Adina Berk, and Collin Tracy of Bas
Books for making the text much more readable than it was at the outset, and t
Chrisona Schmidt for careful copyediting. My agent, Roger Williams of Ne
England Publishing Associates, is always there when I need him. My wif
Fortunée, did much more, of course, than just photocopy articles in Paris. I ar
also grateful to Simon Benninga, Franck Jo-vanovich, Wolfgang Hafner, Bernhar
von Stengel, and Heinz Zimmermann for offering encouragement and readin
parts of the manuscript.

I had lots of fun researching and writing this book, and I hope you, the reade
will enjoy it too.

JERUSALEM, JUNE 201

INTRODUCTION

In June 1940, in a barn somewhere near the western front, a young man wearin
a French army uniform burns a sheaf of papers filled with mathematical symbo
and equations. He must move quickly; German troops are closing in on the Frenc
village where he is hiding. The soldier, the German-born son of a famous Jewis
novelist, is determined not to be captured alive by the Nazis and not to let h
scientific legacy fall into their hands. A few weeks earlier he had sent
manuscript containing a novel mathematical theory to Paris for safekeeping b
the Académe des Sciences. Now he must destroy any evidence of his work.

The sad story of Wolfgang (a.k.a. Vincent) Döblin is only a small part of th
narrative that will be related in this book. For three centuries, accountant
speculators, investors, and scientists endeavored to find the holy grail of financi
markets, the equation that could be used to compute the true value of a certai
financial instrument: the elusive options pricing formula.

Like most chronicles of intellectual breakthroughs, this is a story of relentless
driven and innovative people. I will tell this story of the development of idea
through the lives of the protagonists—accountants and economists, physicists an
chemists and mathematicians, academics and professional traders. After prelude
in seventeenth- and eighteenth-century Amsterdam and Paris, the intellectua
action began in nineteenth-century France. In the first half of the twentiet
century, it moved all over Europe, then to Russia and then to Japan, before
finally reached its climax in the second half of the twentieth century in the Unite
States.

Say you want to build a house in the suburbs and you find a plot for $100,000
Since you can’t afford to buy it until next year, the seller is willing to reserve it fo
you—at next year’s price. The price could double or it could drop by half. Wha
should you do? If prices fall, you will profit, but if they rise you won’t be able t
afford the plot. Then the real estate broker has an idea. For a flat fee, she wi
assume the risk. If the price falls, you will pay the lower market price; if it rise
you will pay a maximum of $100,000, with the broker making up the differenc
What a great idea! You will profit if the price falls, and you will not have to bea
the risk of the price rising. The question is, How much should you pay the broker
How much does she demand?

Or think of a farmer who will need to buy fertilizer in six months. Unfortunatel
the price is volatile and a high price would significantly cut into his profits. H
cannot afford the uncertainty. A middleman offers him the following deal: pay m

a flat fee, and in six months I will sell you 300 pounds of fertilizer for 60 cents pe
pound, no matter what the actual price may be. The farmer agrees, a contract
drawn up, the fee is paid, and the waiting begins. Six months go by. When th
time comes to execute the contract, the price of fertilizer has dropped to 55 cen
per pound. The farmer buys what he needs on the open market and lets th
contract expire. The middleman breathes a sigh of relief and happily pockets th
fee. Chalking up the fee as an insurance premium against the risk of highe
prices, the farmer is also happy. He got the fertilizer for a lower price. The crucia
question, however, is, How much did the farmer have to pay the middleman?

The two tales exemplify the use of options—contracts that give the right, but d
not entail the obligation, to buy or sell something, usually a good or a security, a
a certain date at a certain price. Options maybe considered the granddaddy of th
financial derivatives that are all the rage nowadays. They have been traded sinc
at least the seventeenth century, with their prices determined by the market—b
supply and demand. But is there an intrinsic, true value for options? Yes, there is
The discovery of the options pricing formula was a breakthrough, both in th
history of ideas and in the effort to understand financial markets.

Many historians of science rank the options pricing formula, as developed b
Fischer Black, Myron Scholes, and Robert Merton, up there with Isaac Newton
Universal Law of Gravitation, at least in terms of a scientific discovery. In th
seventeenth century, the notion of action at a distance—earth pulling an apple o
the tree—required an enormous intellectual leap by Newton's contemporaries.
similar leap was required from economists in the twentieth century, when
turned out that the value of options does not depend on investors' attitude towar
risk.

Who would have thought that drunken sailors staggering around in the stree
the random motion of minute particles suspended in a liquid, or the diffusion
heat in an object would be the starting points in the description of pric
movement on the stock exchange? Such processes, which later became known a
Brownian motion, were investigated in the early twentieth century mainly b
biologists studying evolution, chemists and physicists studying diffusion—amon
them Albert Einstein and several other Nobel Prize winners—and one forlor
mathematician dabbling in the stock market.

Serious attempts to ascertain the true value of options started to make headwa
toward the middle of the twentieth century. Even so, for a long time, the prices a
which options were traded were still based on hunches and rule of thumb. Option
trading was put on a sound footing only after the heroes of our narrative—Fische
Black, Myron Scholes, and Robert Merton—developed the sought-after formul
thereby discovering that the volatility of the underlying stock plays a crucial ro
and that the investors' attitude toward risk plays none. The feat earned Merto
and Scholes a Nobel Prize in 1997. (Fischer Black had died two years earlier.)

By placing a value on options, the pricing formula made financial markets mor
efficient. The success of the Chicago Board Options Exchange, which today tallie
about 5 million contracts a day, is due to this scientific achievement. Nowadays
financial instruments, based in large part on the methodology developed by Blac

Scholes. and Merton, allow traders to buy and sell risk like any other commodit
For a certain price, risk-averse individuals can unload part or all of th
uncertainty contained in their portfolio to investors who are willing to assume i
thus producing a more efficient economy and positively impacting people's live
By utilizing tools from mathematics and physics to compute that price, Blac
Scholes, and Merton and their predecessors may be considered representatives
a new profession: the quants.

Understandably, the quants were not content to simply enjoy their intellectua
pursuits; they also wanted to make money—a lot of money. And indeed many did
Jules Regnault, the self-taught broker's assistant, died a very rich man. Merto
and Scholes made and lost a fortune, and the spectacular blowup of their firm
nearly resulted in the first financial crisis touched off by quants. More woul
follow.[a] And so this story of brilliant, driven, innovative characters is also a story
what may happen when greed and hubris get the better of us.

ONE

Flowers and Spices

IN THE 1630S AN UNPRECEDENTED FRENZY OF BUYING AND selling seize
large parts of the population in Holland. People sold all their belongings and eve
went into debt in order to invest in a commodity that had no intrinsic value. Whe
investors finally realized this, the price of the commodity plummeted and man
lost their assets. To save those clamoring most loudly for protection from furthe
disaster, the government took action, thus worsening the crisis.

What was this article of trade that caught the fancy of investors, speculator
and fortune hunters? Businessmen, mainly from Spain, Portugal, England, an
Holland, had been roaming the world looking for extravagant merchandise to tak
to Europe. Among these luxury items was a very special flower found in Persi
and Turkey. First described around the middle of the sixteenth century by th
Austrian ambassador to the court of Suleiman the Magnificent in the Ottoma
Empire—he described them as having little or no scent—the flower becam
popular among the European upper classes, especially in Holland. It was the tuli
Admired for its variations in color and beauty, the tulip soon became a symbol o
wealth and opulence.

It was not wild tulips that elicited the Dutch people's passion but cultivate
ones, many of them carrying a virus that gave their petals highly unusual pattern
but also made them hard to grow and consequently all the more rare an
desirable. By 1636 this admiration for tulips went far beyond an appreciation o
their beauty. Tulip bulbs became objects of speculation, first among th
cognoscenti, then among simple folks, with investors buying them not for th
esthetic value of the eventual flowers but in the hope of rising prices. Th
journalist Charles Mackay devoted a chapter of his 1841 book Extraordinar
Popular Delusions and the Madness of Crowds to what he called tulipomani
Even though his description was not correct in every detail, the name stuck.

Since no man of fortune could be without a collection of tulips, preposterou
prices were paid for a single bulb. "A trader at Haarlem was known to pay one
half of his fortune for a single root, not with the design of selling it again at
profit, but to keep it in his own conservatory for the admiration of h
acquaintance," Mackay recounted. One of the most celebrated species, th
Semper Augustus, whose petals exhibited dramatic red and white streaks, wa
valued as the equivalent of twelve acres of building ground, and, another time, a
the equivalent of a carriage with two horses, harnesses, and a sizable amount o
money. No more than a handful of specimens existed in all of Holland. The owner
had acquired them with the specific obligation not to cultivate them in order t

keep their numbers low.

Anecdotes abounded, for example, the one about the sailor who consumed bulb of Semper Augustus for breakfast, thinking it was an onion, and then spent few months in jail on felony charges brought against him by the owner. Or th British botanist who used his penknife to peel an unknown bulb that he found i the conservatory of a wealthy Dutchman and then proceeded to cut it into piece only to be informed by the furious owner that he had just destroyed an Admira van der Eyck.

The activities took on a frenzied pace. Markets were established on the stoc exchanges of the larger cities to facilitate the trade in rare tulips. In smaller town where no stock exchange existed, taverns became the meeting places for tuli enthusiasts, with the rich and the poor rubbing shoulders to trade bulbs. “Noble citizens, farmers, mechanics, sea-men, footmen, maid-servants, even chimney sweeps and old clothes-women dabbled in tulips,” according to Mackay.

Tulip bulbs must be planted by the late summer, and the flowers bloom for n more than a week or two during the following April or May. The original bul disappears but another one, and possibly some buds, appear in its place. Thes can be dug up starting in June but must be replanted by September. Hence actua trades could only be made during the four summer months. But the dealers di not take a break during the remaining eight months. Throughout the rest of th year, buyers and sellers made contracts with the intention of carrying them ou during the summer. The traders agreed on the species of the tulip, the number o weight of the bulbs, the price, and the date of delivery and payment. Today suc an agreement is known as a forward contract: the actual delivery of and paymen for the bulbs are delayed to some specified date in the future. (A contract fo immediate execution is called a spot trade.)

A code of laws was drawn up for the guidance of the traders, florists organize themselves into a self-regulating guild, and specialized tulip notaries wer appointed. In spite of such protective measures, trading activities soon took o forms of gambling. Many homeowners converted all their property into cash wit the sole purpose of purchasing tulips. Houses and real estate were offered a ruinously low prices so the proceeds could be invested in bulbs.

People had started buying bulbs in order to resell them at a profit, and price spiraled ever upward to new heights. In early 1637 some single tulip bulbs sol for more than ten times the annual income of a skilled craftsman. Eventual sober-minded traders began to realize that these flowers were just . . . flowers. I February 1637 the bubble burst, and businessmen were left sitting on worthles bulbs. In Mackay’s words, “Many who, for a brief season, had emerged from th humbler walks of life, were cast back into their original obscurity. Substantia merchants were reduced almost to beggary, and many a representative of a nobl line saw the fortunes of his house ruined beyond redemption.”

Once the bulb bubble burst, buyers refused to take possession of, and pay fo the useless merchandise. Day after day, defaults were reported from all ove Holland. Sellers tried to get legal remedy through the judicial system, but th courts offered no help. Arguing that monetary disputes which resulted from tuli

contracts were nothing more than gambling debts, the judges refused to ge involved.

Tulip traders vociferously aired their grievances at public meetings. (The luck few who had got rid of their stock in time invested the proceeds in overseas fund and kept mum, so as not to arouse the envy of their neighbors.) Representative from all over the country were sent to consult with the elders in Amsterdam, th country's, indeed Europe's, center of commerce and trade. They came up with good idea: let the buyers and sellers devise a plan. Discontent grew stronge Loudest among those clamoring for relief were tulip buyers, including numerou state officials who had been making a pretty penny on the side and now faced th danger of losing it all. They wanted to renege on their obligations to pay fo worthless merchandise. The traders turned to the Provincial Council in Th Hague. After three months of deliberations, they came up with the age-old excus they needed more information in order to make a decision.

Eventually, on February 24, 1637, the guild of Dutch florists issued a decree First, all tulip contracts made before November 30, 1636, were null and voi Second, all purchasers who had entered into a contract between November 3 1636, and spring 1637 would be freed from their engagement if they paid th vendor a penalty of between 3.5 and 10 percent of the agreed-upon price. Th was an unprecedented upheaval of traditional business practices. Whereа previously, buyers had been obliged to buy the bulbs they had contracted for, the now had a choice. If the price dropped between signing of the contract and th date of delivery, buyers had the option of simply walking away from th transaction. All they had to do was pay the vendor a relatively small premiun Thus traditional forward contracts were turned into what came to be known a options contracts. In due course, the decree was ratified by the Dutch parliament

Predictably, this did not make everyone happy. Vendors would receive at mos 10 percent of the sum they had contracted for, while purchasers complained tha even that was too high a price for worthless onions. But the new regulation als created fresh opportunities. Since the risk of a transaction was limited to fraction of the contracted sum, many businessmen saw prospects for profits, an the market for options contracts took off. If prices had been sky-high before, the now rose into the stratosphere.

Finally, at the end of February, the Dutch authorities put a stop to the trading Prices plummeted. "Those who were unlucky enough to have had stores of tulip on hand at the time of the sudden reaction were left to bear their ruin a philosophically as they could," Mackay recounts. The country as a whole suffere from the aftereffects of tulipomania. "The commerce of the country suffered severe shock, from which it was many years ere it recovered." The episode woul be chalked up as a lesson—not always learned—for generations to come about no only the vagaries of luxury items but also the dangers that lurk in the trading options.

While tulipomania, one of the most spectacular early aberrations of a market, ca
be ascribed to human stupidity, the Dutch East India Company failure in 1798 wa
due to a combination of bad luck, corruption, and incompetence. The history
this company is closely linked to the emergence of the first formal market fo
options.

It all started with spices. Throughout the ages, people have tried to put mor
flavor into the often bland diets they managed to scrape together from the
gathering and hunting activities. Salt, for example, added some taste to food bu
was expensive. According to the naturalist Pliny the Elder, who lived in the firs
century AD in the Roman Empire, “the soldier’s pay was originally salt, and th
word salarium [salary] derives from it.” Exotic seasonings, which were also use
as medicines and preserving agents, were even more expensive. In the Middl
Ages spices such as cinnamon, black pepper, cumin, nutmeg, ginger, saffron, an
cloves were considered among the most luxurious items in Europe. Only th
wealthy and the mighty could afford to season their opulent meals with them. Lik
silk, textiles, ivory, precious stones, and drugs, spices were imported fron
faraway lands by adventurous seafarers. Their locations of origin, often obscur
islands, were usually kept secret by traders. The expeditions were expensive no
only because boats and crews had to be outfitted but also because many ships di
not return from their voyages. Shipwrecks were common and their costs, huma
and financial, had to be taken into account.

In spite of the dangers, the trade in spices blossomed. It was a welcome chang
from the dull dealings in salt, herring, wheat, and wine with their narrow profi
margins. Lured by the prospect of great earnings, boats set sail for India, Java
Borneo, and China, braving the dangerous route around the Cape of Good Hope
Seafaring nations like Portugal and Spain effectively monopolized trade with th
East. But traders from other countries, mainly the Netherlands, wanted to elbo
their way into the lucrative business and began to finance the dangerou
undertakings. The Iberians did not take kindly to the new competitors. To kee
challengers from infringing on their profitable sinecure, Portugal and Spai
closed their ports to foreign ships. Shortages of luxury goods ensued in th
Netherlands and the price of spices rose.

Nevertheless, the Dutch persisted. They realized that boats equipped, staffe
and financed by individual businessmen stood little chance of completing the
voyages. So, in 1602, seventeen businessmen founded the Verenigd
Nederlandsche Geoctroyeerde Oostindischen Compagnie (VOC, Unite
Netherlands Chartered East India Company), known as the Dutch East Indi
Company for short. The company was organized around six “chambers
Amsterdam being the most important.

Pooling resources and sharing profits and risk was nothing new, in principle
For millennia, overland and overseas trips had been organized by consortia o
businessmen who pooled their resources and shared the eventual profits o
losses. Partnerships were formed ad hoc for individual voyages, with capita
returned and profits distributed at the end of the voyage. VOC was different.
was to be a long-term venture, initially for twenty-one years. The charter wa

renewed several times, for a total of two centuries. Furthermore, participatio
was not limited to businessmen. Without being required to help run the compan
ordinary citizens could buy shares and watch their capital grow . . . or diminis
all the while receiving dividends . . . or not.

VOC was led by seventeen directors, the Heren XVII, who made all th
decisions: how many ships left from which port, where they sailed, what carg
they carried, and what wares they would bring back. The directors decided ho
to sell the cargo and whether to reinvest the proceeds in further voyages o
distribute them as dividends to the regular stockholders, the participanten. Th
latter had no say in how the company's affairs were run. In fact, they did not eve
have the right to inspect the books. Their only function was to receive dividend
whenever the directors decided to distribute any. If they were not happy with ho
the company was run or if they were disappointed with low dividends, they coul
return the shares and demand their capital back, or at least they could in th
beginning. A few years later, the clause that allowed shares to be returned i
exchange for a full refund was rescinded. As I will recount below, this would hav
important consequences.

The Dutch government was only too happy to oblige the company. After al
everybody would profit from increased wealth and higher tax receipts. Th
government gave the company monopoly powers and wide privileges. Nobod
except the VOC was allowed to send ships from the Netherlands to the area eas
of the Cape of Good Hope and west of the Straits of Magellan. Neither wa
anybody but VOC allowed to trade. VOC's charter even conferred on it the right t
wage war in the overseas territories—in what is today Indonesia and beyond—
the chief stockholders deemed it necessary in order to safeguard the company
interests. VOC became a state within a state. It owned 150 trading vessels an
had 20,000 seamen and 50,000 civilians in its service. Significantly, it also had 4
warships and 10,000 soldiers under its command.

Its trading routes connected Amsterdam to Africa, India, the Persian Gul
Japan, and China. But VOC did not limit itself to trade between the Orient an
Europe—textiles from India, tea from China, pepper from Indonesia, silver fro
Japan, coffee from Arabia and Java, and, of course, fine spices from all over. It wa
also heavily involved in the Persian Gulf, Zanzibar, Ceylon, India, China, Japan
and the islands of southeastern Asia. VOC traded spices for salt, salt for clove
cloves for gold, gold for tea, tea for silk, silk for copper, copper for spices, and s
on.

These traders did not go about their business quietly. VOC operations were ver
noisy, constantly accompanied by the clanking of war. The company acquire
monopoly status by fire and sword: brutal military operations, massacres of loca
populations, murders of European competitors. The invasion and occupation o
the Banda archipelago, a group of tiny islands north of Australia, gave th
company a monopoly over nutmeg and mace, the conquest of Ceylon ove
cinnamon, the capture of Makassar over cloves. To further consolidate contro
over the spice trade, VOC envoys uprooted trees in many fertile areas in order t
concentrate a valued crop on a single island in their possession. As a further blo

to erstwhile competitors, VOC captured ports that had been used by seafarers a
way stations on their voyages from and to Europe. By then, Portuguese, Spanish
and English traders had fallen far behind the Dutch.

In spite of the high costs of trading and waging war, VOC made huge profits. O
average, goods were sold at VOC's semiannual auctions for nearly three time
what they cost at their origin. And this was only an average. Rare spices ofte
fetched three hundred times their purchase price. Even after the cost of buildin
and outfitting ships was deducted, and after losses and shipwrecks were take
into account, dividends averaged over 16 percent annually for the first fifty year
of the company's operations. VOC's good fortune was felt throughout th
Netherlands. Magnificent buildings and the paintings of Rembrandt, Vermeer
and others attest to the wealth of the country.

When the company was formed, over one thousand individuals purchase
shares in Amsterdam alone. They were a cross-section of the citizenry, with som
investing as little as 20 guilders and others up to 85,000. Demand for shares wa
so great that even before they were actually issued, their price was already 10 t
15 percent above par. After all, it did not hurt to subscribe. By statute, share
could be returned in exchange for a full refund of the paid-in capital.

In 1609, however, the directors decreed that capital was no longer refundable
Whoever bought shares was stuck with them, for better or worse. But to hav
one's money tied up in the company's shares for many years could creat
problems. Shareholders might not be satisfied with the size of dividends or wit
the manner in which the company was run and would prefer to get rid of th
share. Or a sudden illness, a home renovation, or a daughter's marriage migh
require additional funds. How could a businessman make use of his wealth if h
money was tied up in VOC?

A so-called secondary market was created to give stockholders the opportunit
to liquidate their holdings. This was a stock exchange where shares of VOC coul
be bought and sold. Thus VOC in Amsterdam was the first company to issue stoc
that could be freely traded. The price of the shares fluctuated widely, dependin
on the fortunes or misfortunes, real or imagined, of the latest voyage. Astut
traders quickly learned that they could influence the price of the stock by rumor
of war or peace, of shipwrecks or safe voyages, of market gluts or shortages. I
the first few years of its existence, about 6 to 7 percent of the capital of th
Amsterdam chamber changed hands annually. By 1607 only two-thirds of th
original owners remained.

Even foreigners were welcome to purchase a stake in the company. Whenever
an exchange was made, the shares were registered under the names of the ne
purchasers in the company's stock ledger. But registration could only take plac
when the books of the company were opened, usually to record the payment o
dividends. To allow a market to operate not only on these rare dates but ever
day, there evolved a market for so-called forward trades at the Amsterdam stoc
exchange. Whenever a buyer and a seller reached agreement, the "future
contract" was recorded but the actual transaction—the delivery of the title an
the registration of the new owner—occurred on the specified date in the future.

Forward trades were carried out to eliminate the risk of future changes in th price of shares. Since price and date of the transaction are specified when th contract is signed, all relevant parameters are known at the outset and there is n uncertainty. But an element of risk remains. If the share price rises during tha period, the seller will regret his decision because he could have received mor money had he waited. If the price falls, the buyer will kick himself since he coul have obtained the share for less money had he waited. In that sense, we ar actually speaking more of regret than of risk. (There was also the risk that one o the parties would default on its obligation, but this could be remedied by takin recourse to the well-functioning court system.)

Apart from allowing stockholders to liquidate their holdings of VOC shares, th stock exchange had a further beneficial effect on the economy of the Netherland Entrepreneurs routinely needed to borrow money in order to finance ongoin operations and expand their business. To guarantee the loan, merchants had t put up their businesses, homes, or other assets as collateral. The interest rate c the loan was then determined by how secure the collateral was and by ho readily it could be converted into cash in case the borrower defaulted. The share ofVOC were highly valued as collateral. The company was well-known and th ownership of the shares was clear due to registration in the company's stoc ledger. But above all, the shares could be easily sold on the Amsterdam stoc exchange. Thus there was less risk to the lender that he would be stuck wit collateral that could not be converted into cash. As a consequence, interest rate fell, benefiting commerce in general.

VOC itself took advantage of this possibility. At the company's founding, tota capital was about 6.5 million guilders. It stayed at that level throughout th company's existence; no additional capital was ever raised. So how did VO finance its ever growing business? It borrowed money. Short-term capital need were satisfied by issuing bonds for up to twelve months. VOC pledged its ow assets as collateral.

However, for the lender there remained a question: what would the value of th shares be a year from now when the loan matured? If a businessman took out loan corresponding to 90 percent of the share's value, but the price of the shar fell by 20 percent in the course of that year, the lender would be in a bad spo After all, the borrower would have every reason to default. Instead of returnin the loan he could just walk away from his debt, leaving the lender with a shar that was worth less than the amount he owed. The borrower would lose only h good reputation. Lenders would have to safeguard themselves against such scenario.

And this is how, not long after the tulip fiasco, the market for options developed

A lender needed to protect the value of the collateral. Afraid that the price o VOC shares would drop, he would look for an investor who believed that it woul not. Then, for a fee, the two of them would enter into a new kind of arrangemen Say that the current price of a share of VOC is 100 guilders. Let's call the perso who lent the money and is afraid that the share price will fall Pessimist, and th investor who believes the share price will not fall, Optimist.

Pessimist pays Optimist a fee of 3 guilders. In exchange Optimist undertakes t
buy one VOC share from Pessimist one year from now, at the current price of 10
guilders, if the latter so desires. Other than paying the fee, Pessimist is no
obliged to do anything. But when the day arrives and if the share price is, say
only 90 guilders, Pessimist will demand that Optimist buy the share from him fo
100 guilders. Even if Pessimist is not in possession of the share (maybe th
borrower did not default and was not forced to hand over the collateral), there
no problem. Pessimist simply buys it on the market for 90 guilders and delivers
to unhappy Optimist, who has to fork over 100. Altogether Optimist will have los
7 guilders—he initially received the fee of 3 guilders but then lost 10 on th
purchase. Pessimist, on the other hand, will have received the 100 guilders tha
he was hoping for at the beginning of the year, all for a fee of 3 guilders.

Let us now assume that VOC shares rise to 110 guilders during the course o
the year. Come the day of reckoning, Pessimist will certainly not sell the 110
guilder share for the contracted 100 guilders. (He probably does not even have
because the original borrower would surely have repaid his debt and kept th
much more valuable share.) The option will simply expire. Optimist will be happy
he gets to keep the fee of 3 guilders.

In modern parlance, such a contract is called a put option. I will say a bit mor
about put options below, and much more about all kinds of options in futur
chapters. Suffice it to say for now that options are a sort of insurance. For a sma
premium, the buyer of the put option buys the right to sell the underlying share a
a specified date in the future at a specified price, even if the value of the share ha
fallen in the meantime. But he is not obliged to do so. It the price rises, he will le
the option expire. The seller, on the other hand, is obliged to purchase th
underlying share at the previously agreed price, if the buyer desires it.

Does this sound confusing? It did to Dutch speculators in the seventeent
century. This is why the merchant Joseph de la Vega decided to publish Confusio
of Confusions in 1688, a booklet that attempts to explain the intricacies of th
stock exchange. The full title was Confusión de confusiones: Diálogos curioso
entre un philosopho agudo, un mercader discreto, y un accionista erudito
descriviendo el negocio de las acciones, su origen, su ethimologia, su realidad, s
juego, y su enredo. (Confusion of confusions: Curious dialogues between a kee
philosopher, a prudent merchant, and a learned shareholder, depicting the stoc
business and its origins, etymology, reality, gambling, and plot). It may seem a bi
strange that a speculator trading shares in Amsterdam would publish a how-t
book about the stock exchange in Spanish, the language of VOC's bitter rivals. T
explain the reason for this, I must recount a bit about Joseph de la Vega, the firs
person to clarify options in writing.

Joseph de la Vega was born in about 1650 to a Marrano family. Marranos were
Jews who had been forced to convert to Christianity by the inquisitional forces i
Spain. In contrast to most of their persecuted brethren who were killed o
expelled, Marranos stayed in Spain, pretending to be Christians but clandestinel
keeping their Jewish faith. They followed their traditions in secret, celebrating th
Sabbath, for example, by lighting candles in a cupboard every Friday nigh

Joseph's birthplace is not certain; he may have been born in the Spanish city
Espejo whence his father hailed, or in Amsterdam, the family's ultimat
destination after they fled the Inquisition. His parents were Isaac Penso Felix an
Esther de la Vega. His mother's family hailed from a prominent Jewish family wh
had founded the Talmudic school in Livorno, Italy. In later years, Joseph would us
both their names, Penso and de la Vega, interchangeably.

In spite of all the hardships, his father remained committed to his Jewish faith
While imprisoned in a Spanish dungeon, he vowed that he would return t
Judaism as soon as he was set free and could leave the inhospitable country. An
indeed, upon his release from prison, he fled to Antwerp and promptly returned t
the fold. Isaac eventually became a wealthy banker, but he never forgot hi
unfortunate past. He became a benefactor, giving tithes of his income to goo
causes and to the poor. It is said that by the time he died in 1683, he had donate
80,000 guilders (about 500 times the yearly wage of a skilled laborer) fo
philanthropic purposes.

Isaac and Esther had five sons, the second of whom, Joseph, published his firs
literary work, a three-act drama in Hebrew, at age seventeen. Meant as a
inspiration to Marrano youth, Asirei ha-Tikvah (The captives of hope) features
young man expounding on the high value of a virtuous life, holding up a mirror t
his peers who had become accustomed to Spanish decadence in the years befor
their emigration. Subsequently de la Vega turned to business and became
wealthy merchant. But he never lost his taste for literature and wrote a larg
number of poems, moral and philosophical reflections, eulogies on princes, an
novels. The novels, especially, became quite popular in their time.

The work for which he is remembered most today concerned the stock marke
As he stated in the preface, he did not write the book merely for his own pleasur
On the one hand, his aim was to describe "this most honest and most useful of a
businesses in Europe" to those who were not in the financial business. On th
other hand, he wanted to disclose the tricks and treacheries that are employed b
less than honest men, both in order to entertain and to warn.

In the spirit of Socrates and Plato, the setting de la Vega chose for Confusion
Confusions was a collection of four dialogues—or rather tria-logues—between
merchant, a philosopher, and a speculator. While the doubtful philosopher an
the skeptical merchant ask profound questions, the speculator extols on th
beauties of the stock market, all the while explaining its intricacies. He describe
what stocks are, how they are bought and sold, various forms of transaction
speculative maneuvers, the operations of the Dutch trading companies. With h
book de la Vega meant to put a more respectable face on the scorned professio
of speculation.

The first dialogue deals with the origins of the securities trade, the partie
involved, and the various types of transactions. In the second dialogue, the autho
turns to stock prices and the reasons for their variation, bull and bear market
the principles of speculation, the role that expectations play in the formation
prices, and the irrational behavior of market participants. In the third dialogu
the author focuses on stock exchange practices, as well as various types