Lecture on

Limiting Financial Risks in Private Defined Contribution Retirement Plans

by

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Abstract

Many countries have shifted from public mandatory pay-as-you-go, Defined Benefit (DB), Social Security programs to privately managed, funded, Defined Contribution (DC) retirement plans. The latter are expected to offer better returns than traditional Social Security. To achieve these higher returns, however, contributors are exposed to extra risks associated with financial market fluctuations. Considering alternative portfolios of investments in equities and bonds, evidence of these risks is exhibited by widely varying replacement rates based on simulations of returns in the U.S. and

elsewhere. Gradual annuitization and the purchase of variable annuities can only partially reduce this risk.

To overcome these risks to individuals, governments have offered various types of rate-of-return guarantees. We shall describe these policies and their economic implications, in particular the distortions generated due to moral hazard.

We focus on an alternative, market-based, hedge against these risks, based on a combination of **put** and **call** options. Wherever feasible in developed countries, such contracts, based on the Black and Scholes (BS) model, seem preferable to government guarantees, limiting risks with minimal distortions and at reasonable prices.

Market Risks

Many countries have replaced and others contemplate replacing mandatory public, pay-as-you-go Defined Benefit (DB) Social Security (SS) Systems with mandatory, funded, Defined Contribution (DC) private pensions. The private plans are expected to offer higher returns than traditional SS[1]. Contributors, however, are exposed to extra risks associated with financial market fluctuations. Burtless (2000) and Alier and Vittas (1999) offer evidence on the extent of these risks by considering hypothetical

[1] Moving from a pay-as-you-go to one based on advance funding entails sizeable transition costs. Current workers have to pay for existing SS pension liabilities at the same time that they accumulate their new private accounts. Though sizeable, we shall not discuss these transition costs.

pensions that would be obtained by participants in the U.S. had they accumulated retirement savings in individual accounts.

The hypothetical participants are assumed to contribute a fixed percentage of their wages to private investment accounts. Upon retirement, the accumulated capital is converted to annuities that provide a (nominal) fixed income for life. Contributors differ only with respect to stock market returns, bond interest rates and inflation rates that they face during their working phase.

Privatization proponents suggest that participants in a funded system could reliably earn 4 percent or more on their contributions if these were invested in a mix of stocks and bonds. The implicit rate of return in a pay-as-you-go system is, in contrast, equal to the rate of growth of the work force plus that growth rate in real wages. In the U.S. and other industrialized countries, this may be 1 percent or less.

Moving to private accounts is not essential for obtaining better returns. This can also be accomplished by a public system based on advance funding. Critics are skeptical, though, about a public fund whose investment decisions are controlled by politicians.

One advantage of a public system is that it can spread risks across a broader population and across different generations. In an individual accounts system, in contrast, each participant's pension depends on the level of his/her contributions and the success of his investment strategy. This may create large variations in the level of benefits obtained by individuals with similar earnings history[2].

DC plans pose three kinds of financial risks. First, the risk that the real return on participants' contributions over their working career are lower than the expected norms, leaving then with retirement benefits below acceptable "replacement rates". Second, the price of annuities may fluctuate from year to year, due to interest rate changes. Third, nominal annuities are subject to inflation risk. We shall focus on financial market fluctuations, briefly commenting on the feasibility of indexed or variable annuities.

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[2] Public systems, however, are subject to political, economic and demographic risks, which can threaten future benefits.

Financial Market Fluctuations

Based on historical stock market prices and dividends, bond market returns and price inflation in the U.S. since 1871, Burtless (2000) calculates hypothetical values of accumulated savings that would be available to savers during different working periods. Figure 1 shows real U.S. stock and bond returns over the past century. Each year it shows the annual rate of return on a dollar invested in the stock market 15 years earlier. While smoothing annual volatility, it illustrates wide variability. Returns were negative in 1921-22 and 1980-82, but exceeded 12 percent in the mid 30s, 60s and late 90s.

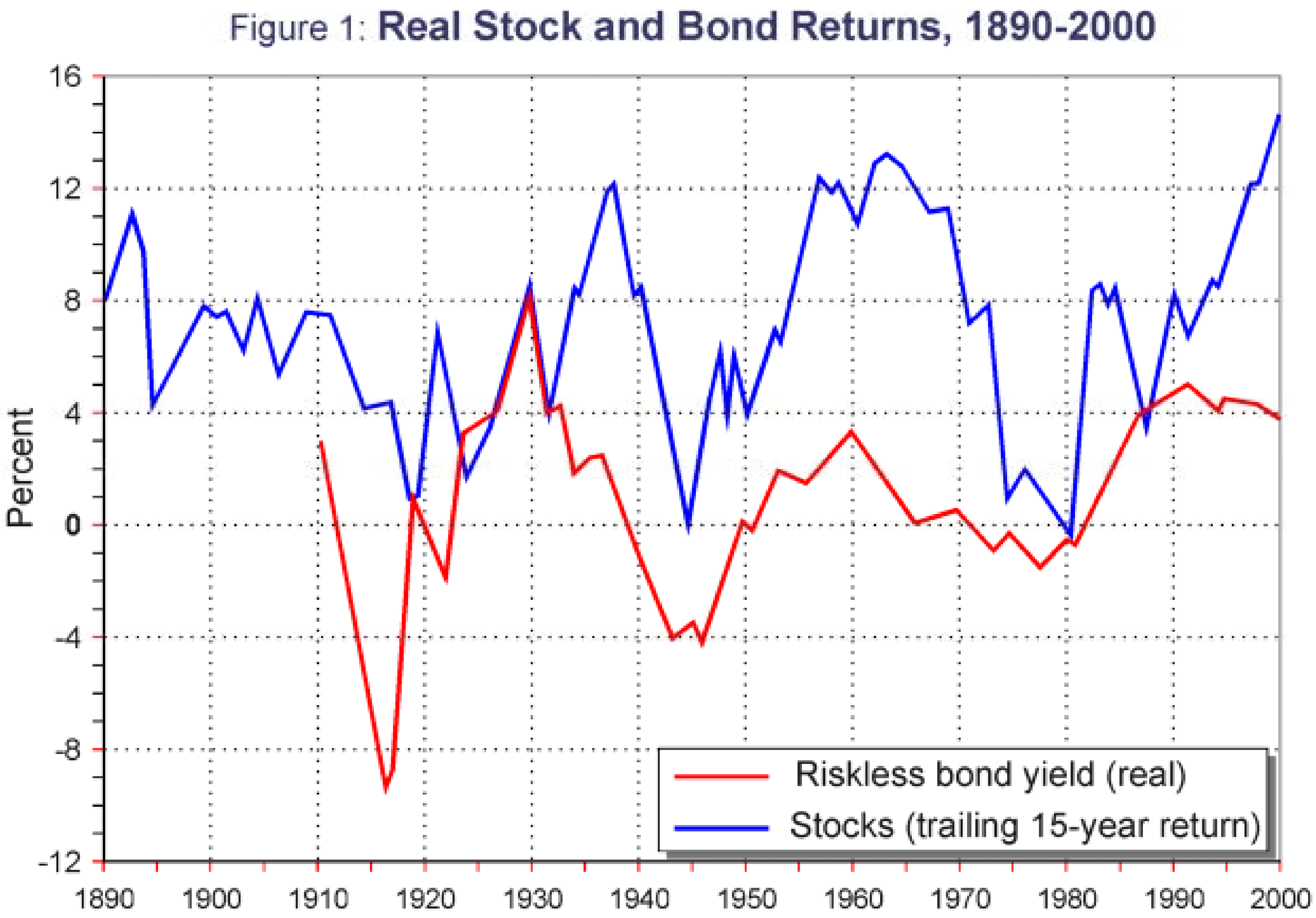
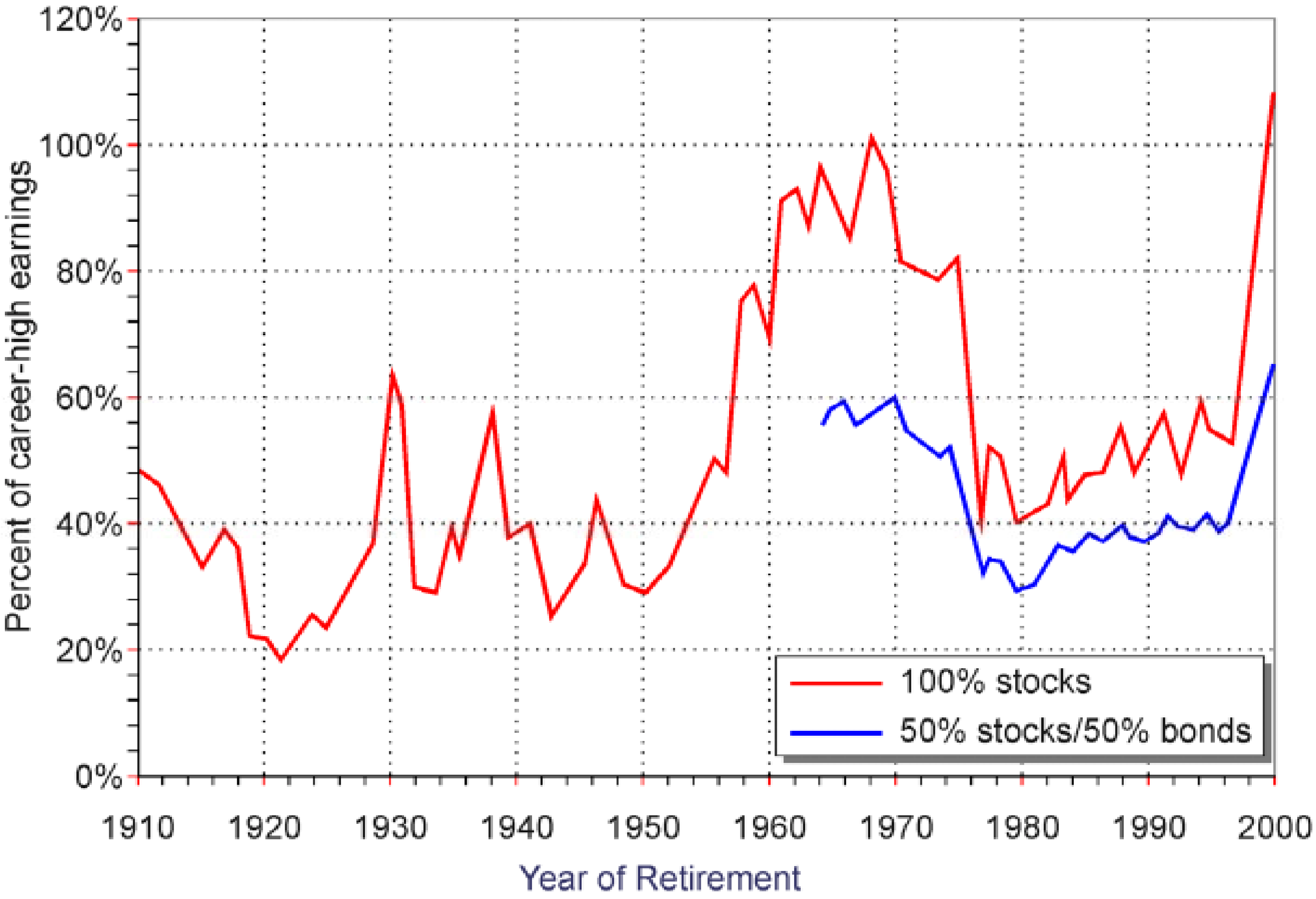


Figure 1: Real Stock and Bond Returns, 1890-2000
Percent
16
12
8
4
0
-4
-8
-12
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
Riskless bond yield (real)
Stocks (trailing 15-year return)

Source: Gramlich (2000), using data from Standard and Poor's Composite Stock Price Index (from Schiller (1989) and updated through 2000), Federal Reserve Bank of St. Louis, and U.S. Bureau of Labor Statistics.

Since 1910, the average annual real rate of return on stocks has been 7 percent. The average real rate of return on riskless bonds was only 1.6 percent during the same period. On the other hand, the standard deviation of stocks was 18.7 percent (for annual returns) but just 3.8 percent for bonds.

Figure 2: **Real Replacement Rates for Alternative Investment Strategies**



Source: Gramlich (2000).

Note: "Replacement rate" is the worker's initial (single-life) annuity divided by his average real annual earnings when he was 54-58 years old.

Gramlich calculates the effects of market fluctuations on pensions using a hypothetical time-series of 40-years working career for different generations with the same life expectancy, contribution rate to private investment accounts of 6 percent of earnings and a 2 percent growth rate of real wages. At annuitization, insurers invest the accumulated funds at the long-term riskless bond rate prevailing at that time.

To investigate the impact of portfolio choice, he calculates pensions under two allocation strategies: 100 percent stocks, and 50 percent stocks/50 percent bonds. All stock dividends and bond interest payments are reinvested. The average replacement rate, which measures pension income relative to pre-retirement income (at their peak, between ages 54 to 58), is 53 percent, and half the rates are between 35 and 66. Those who invest half their contribution in bonds receive an initial replacement rate which is typically two-thirds that of those who invest only in equities[3].

[3] Gramlich's calculations disregard transaction costs.

Some of the variation in replacement rates is due to changes in annuity prices, which reflect changes in interest rates. Some of these effects can be avoided by purchasing deferred annuities during the accumulation phase ("phased annuitization").

This exercise demonstrates that replacement rates can widely vary over short periods of time, e.g. they were almost 100 percent for these retiring in 1969, but only 42 percent for the retiring six years later, in 1975.

Alier and Vittas (1999) obtain similar results. During 1871 to 1996, the average replacement rate across all cohorts equals 61 percent, but the ratio of the maximum to the minimum is slightly over 4. Interestingly, they find that investing everything in bonds results in a significantly lower average replacement rate, 22.6 percent, but with little improvement in the max/min ratio (3.78). They also consider more flexible investment strategies. For example, investing everything in equities for the first 35 years and then shifting into bonds, a gradual purchase of annuities and the purchase of variable annuities (to reduce inflation risks after retirement). While these policies reduce the max/min ratios significantly (to about 2.5), they introduce variation in replacement rates during retirement.

Rate of Return Guarantees

Recognizing the need to limit the risks to DC participants, many governments, particularly in Latin America, have provided the same form of rate of return or minimum benefit guarantee. A number of voluntary DC plans around the world also provide such guarantees (Turner, 2001).

Minimum benefit guarantees can be structured so that they are anti-poverty measures that only affect low-income individuals, with a flat universal guarantee. Alternatively, the guarantees can depend on the level of contribution to the pension account.

Guarantees during retirement may be aimed to insure against inflation risks and the risk of outliving benefits (in case of phased withdrawals)[4].

Turner (2001) surveys the various methods used for rate of return guarantees during the accumulation phase:

Real or Nominal. The guaranteed rate of return can be . 1 in real or in nominal terms, or a hybrid (as when indexing to COLA less a fixed percent).

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[4] As, for example, in Chile.

Fixed or Relative. It can be a fixed return or one that .2 varies according to a capital market index. The major advantage of guarantee which is based on a synthetic benchmark index and not on the actual rate of return of a particular fund, is the avoidance of 'moral hazard', the tendency of plan managers who are provided such guarantees to undertake excessively risky investments.

Period. The guarantee can be monthly, annual (Chile), . or for a cumulative measure over long periods (New Zealand).

The provider of the guarantees may offer a minimum rate of return in return for a share in profits above that rate or in return to all profits above a maximum rate of return. We shall discuss these below.

The guarantee, even if provided by government in a legal process, may have some residual uncertainty as to whether it will be met. This raises the general issue of assessing the value of guarantees (below).

Assessing the Value of Guarantees

Estimating the value of government guarantees is important for gauging the complete fiscal cost of mandatory DC pensions. Of course, when guarantees are purchased from private insurers, their cost will recorded by the fair market premium.

The approach to assess the cost of pension guarantees is referred to as "contingent claims analysis", "arbitrage pricing theory" or "option pricing theory" (Pennacchi, 2000).

A guarantee is a commitment to make future payments to a firm or individual if particular, pre-specified events occur. These contingent, uncertain, claims are similar to financial options: future payments whose value is tied to another "underlying" security or asset.

Pension guarantees are similar to **put-options**, whose holder has the right to sell a particular underlying asset at a pre-specified price at some future date. This price is referred to as the option's "exercise price" or "strike price". Consider a guarantee of a minimum value for an individual's pension account.

If the future value of this account is lower than the pre-specified minimum pension level, then the individual can "sell" the pension account to the issuer of the guarantee, whether government or insurance firm, and receive the minimum pension. The insurer realizes a future expense equal to the difference between the minimum pension and the value of the account. If the value of the account exceeds the minimum pension, the individual maintains the account and the insurer's realized expense is zero.

The value of such contingent claims has been established by Black-Scholes (BS) (1973) and Merton (1973). This approach notes that a contingent claim inherits the same risk as the underlying security or asset. For example, if the guarantee is for a rate of return on a DC fund, payment is made if the return is below the pre-specified level. The key insight of the BS pricing formula is that the risk of a contingent claim can be **hedged** by trading in the underlying securities.

The cost of purchasing this hedge portfolio, which eliminates the contingent claim, is equal to the implicit value of the claim: "such a hedging portfolio represents an asset whose value perfectly offsets the liability of providing the contingent claim, so that the net liability of the provider always equals zero".

In the context of a government pension guarantees against low security returns, a hedge would be one where the government has a short position in the underlying securities. By short selling, the government "privatizes" its risk by transferring it to institutions (insurance firms) or individuals willing to bear it.

Although governments typically do not attempt to hedge their exposure to guarantees, the option pricing approach values the guarantees at the 'true' marginal cost and therefore it can provide an assessment of the value of the guarantees provided by the government, even when the government does not 'privatize' the guarantees.

Let us look more closely at two types of guarantees and their pricing.

Example of Guarantee Contracts[5]

Two types of guarantees will be considered - one, which guarantees a minimum rate of return against a waiver of part of the profits (**'return/waiver'** contract).

The second one which guarantees a minimum rate of return against a waiver of part or all of the return above a certain maximum (**'collar'** or **'minimum/maximum'** contract).

In the case of waiver, a tender can be issued for the rate of the waiver in the guaranteed contract. In the collar case, the tender is for

[5] Here we follow Elashvili, Sokoler, Wiener and Yariv (2000).

the ceiling rate. For example, in the former type of contract, against a guaranteed return of 2 percent, the fund will offer to waive a certain share of the profits in excess of 2 percent. For an order of magnitude, this can be around 40 percent of the profits for five years (below).

The fund sets the minimal rate of return, using the BS formula and volatility of interest rates in the market to estimate the bids.

What is an appropriate minimum guaranteed real rate of return?

This depends on the market's long-term expected nominal returns, the expected rate of inflation, and the availability of indexed no-risk bonds (now available in the U.S.).

If the minimum rate is set close to the market's expected rate of return, then most of the risk is shifted to the insurer. This is very similar to the proposal put forwards by a group of MIT economists headed by Franco Modigliani.

They propose a mandatory DB system of personal accounts which provides a certain real return to individuals' investments, say, 5 percent ('notional return'). The fund's portfolio is invested in the stock market and has a similar composition to that of the public's tradable-assets portfolio. Upon retirement, cumulative investments and returns are annuitized. Thus, individuals are immune to financial risks, as the government in effect bears the market risk. The 'collar' contract, whether issued by a private insurer or by government, has similar elements.

What is the appropriate stock index for the guarantee contract? This could be any wide-based index such as the S&P 100. It is preferable to have an index based on stocks whose return is reinvested in the market.

Pricing of Guarantee Contracts

Waiver Contract. A minimum real rate of return is guaranteed, in exchange for waiving part of the profits in excess of the minimum. The initial cost of the guarantee is zero. If at maturity, the

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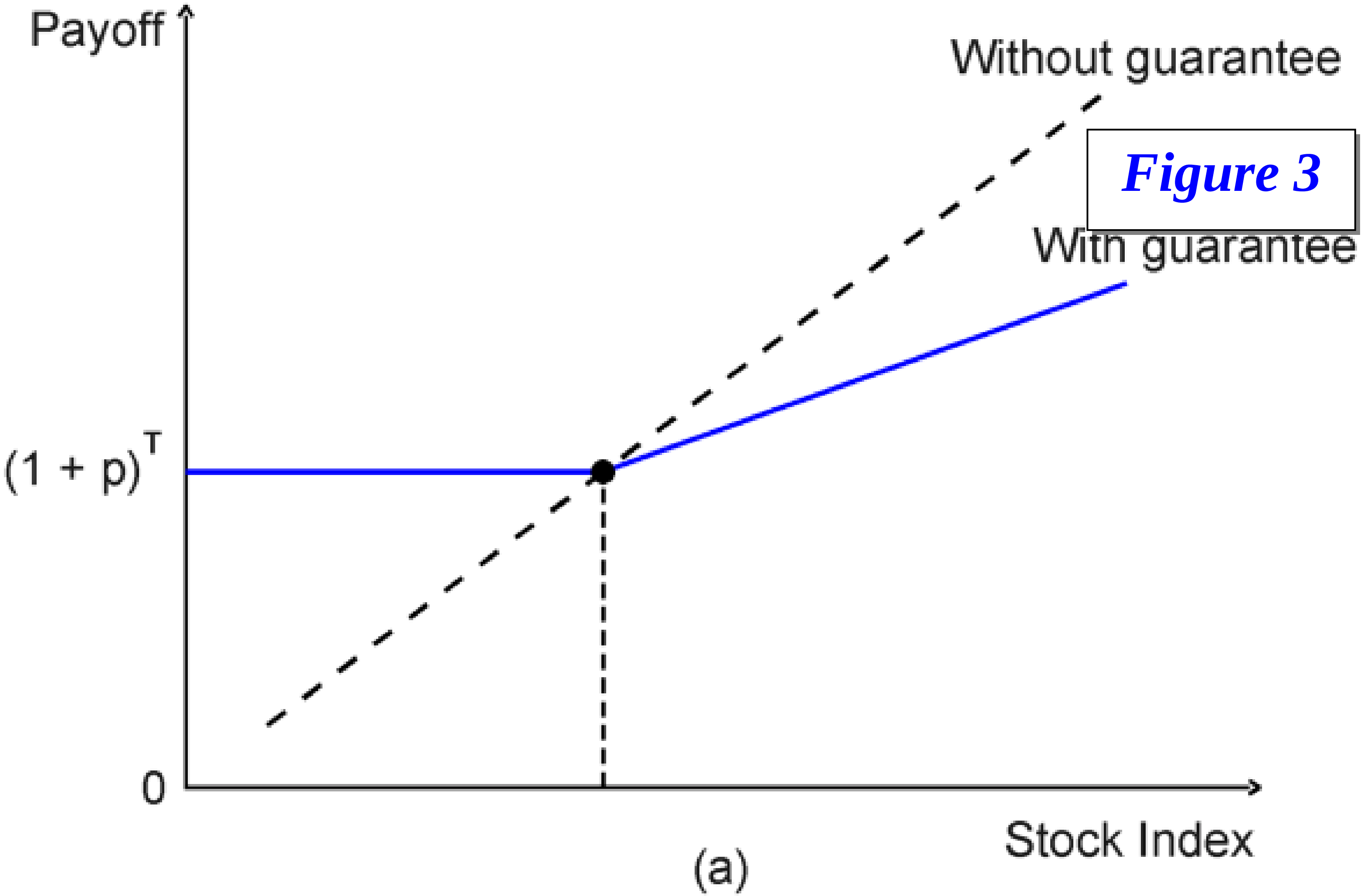


Figure 3

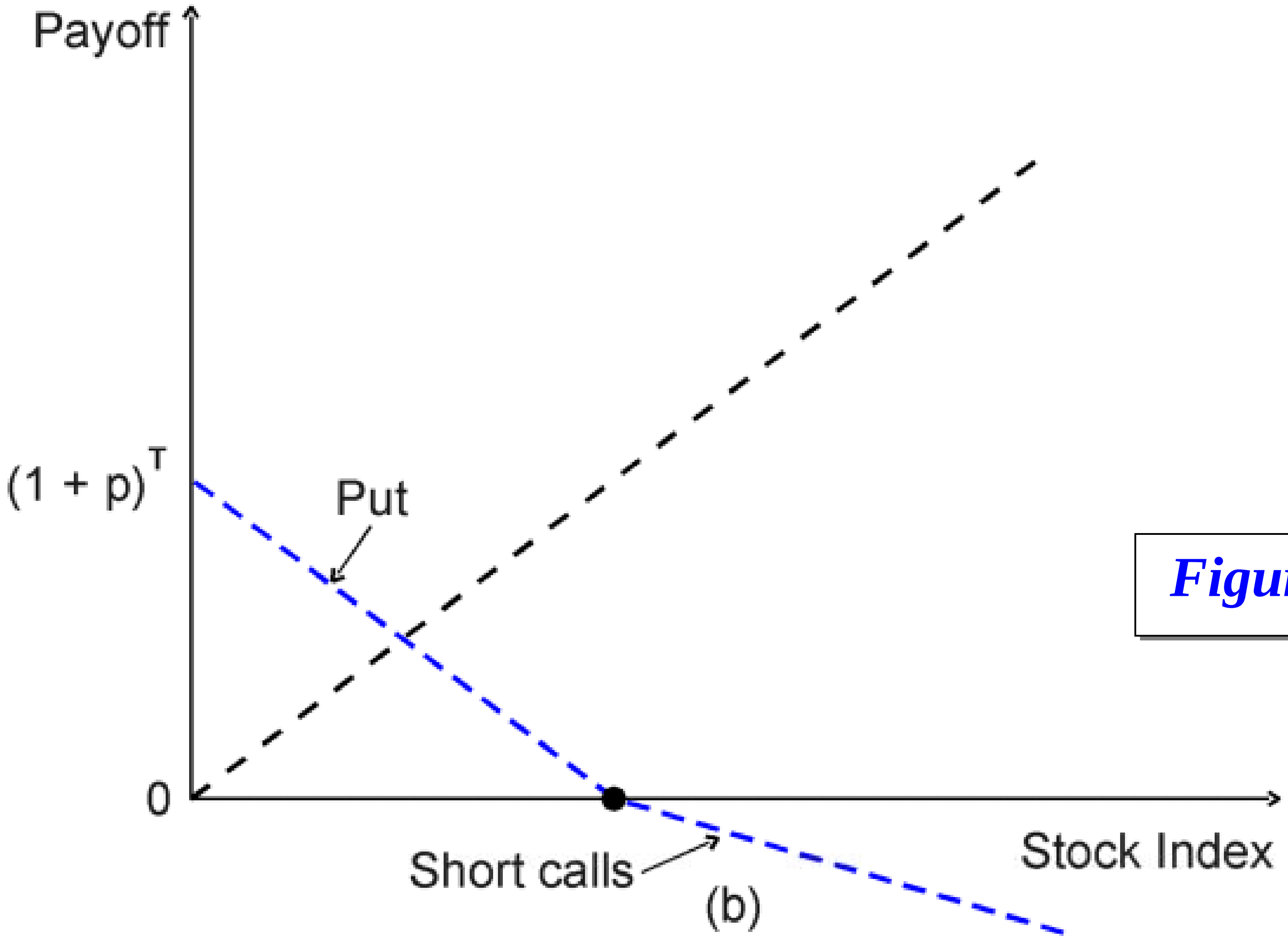
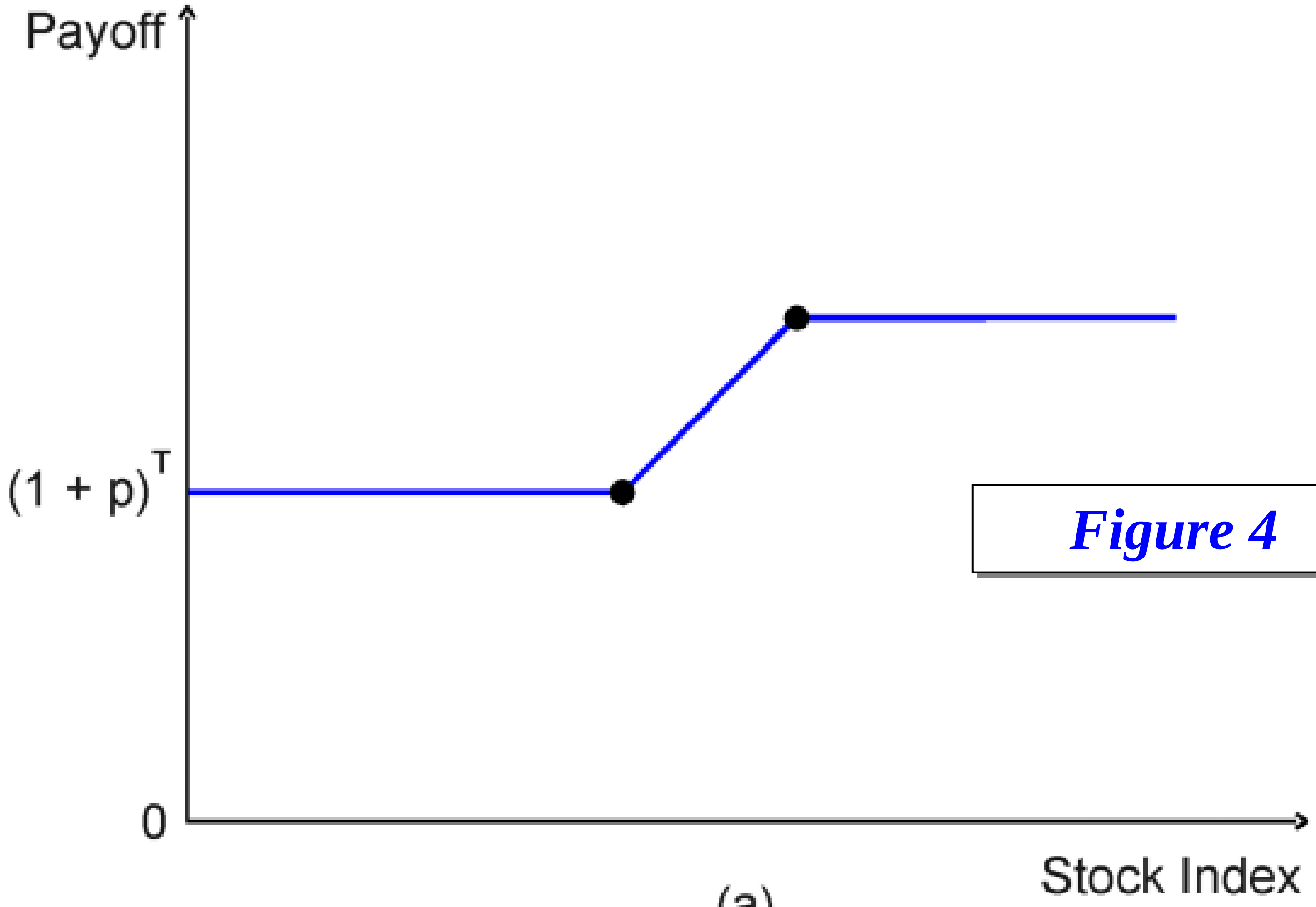


Figure 3

The contract can be constructed as a package consisting of a purchase of a put option and the sale of a certain quantity of a call option. Both options have the same striking price of $(1 + p)^T$.

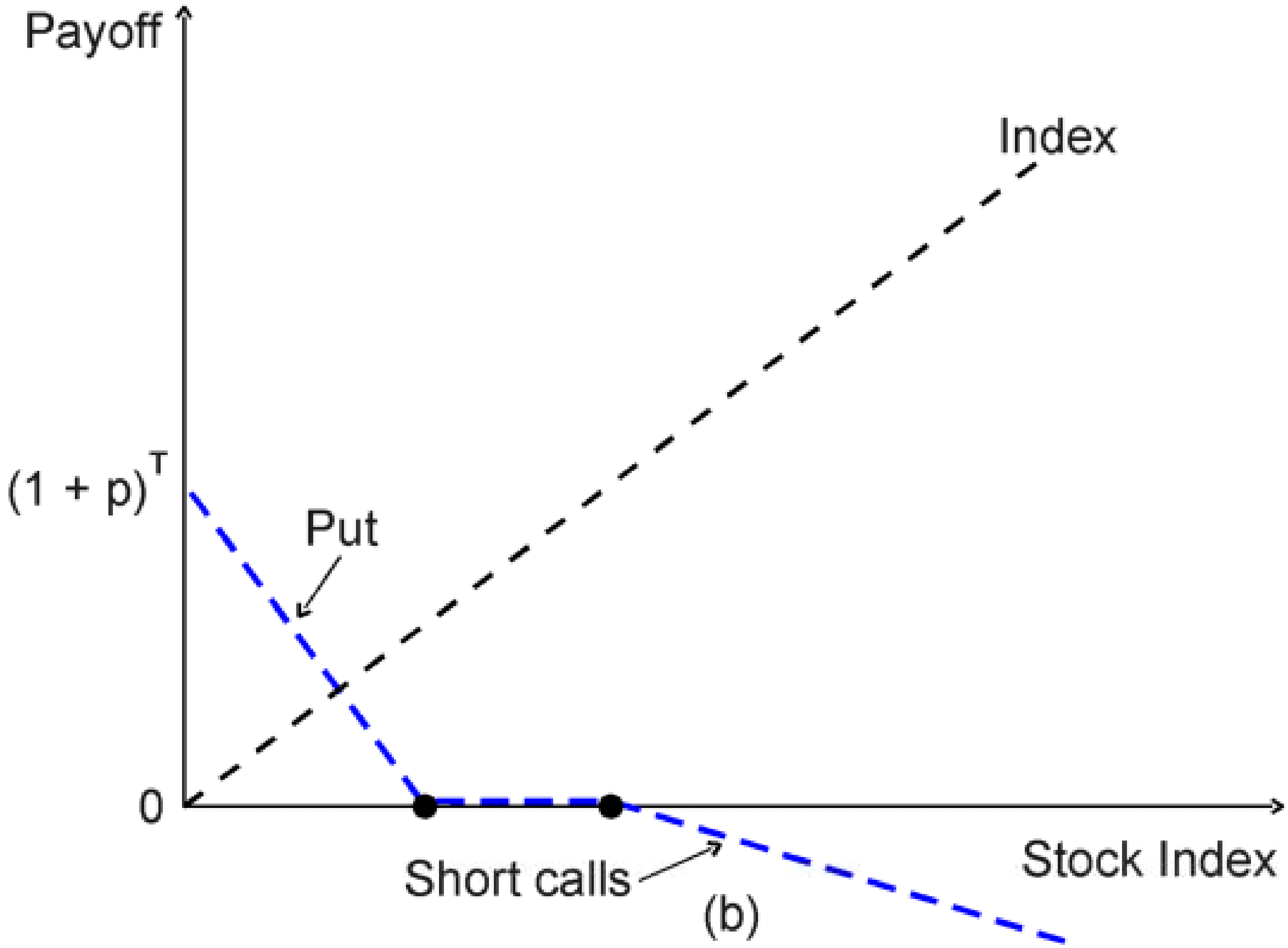
Collar Contract. The final payoff is shown in *Figure 4*. Again, this contract can be seen as consisting of put and call options, but in this case the quantities of both are the same, same underlying asset and the same maturity, but different striking prices. The striking price of the call option, K, which makes the initial price of the contract zero is obtained from the equation:

$$\mathrm{Put}(1,(1+p)^T, T, \delta, R) = \mathrm{Call}(1, K, T, \delta, R)$$



(a)

Figure 4


Payoff
Index
$(1 + p)^T$
Put
0
Stock Index
Short calls
(b)

Appendix (Elashvili **et-al**, 2000)

The BS formulas for option pricing are based on the no-arbitrage and efficient-market assumptions.

Notation:

T - time to maturity

r - continuously compounded risk-free interest-rate

K - strike price of an option

S - underlying asset (stock index, including all reinvested dividends) σ - standard deviation ('volatility') of underlying asset

$N(\cdot)$ - cumulative normal distribution function

BS option pricing formulas:

$$c = SN(d_1) - Ke^{-rT}N(d_2)$$

$$p = -SN(-d_1) + Ke^{-rT}N(-d_2)$$

where

$$d_1 = \frac{\ln\frac{S}{K} + (r + \frac{\sigma^2}{2})T}{\sigma\sqrt{T}}$$

and

$$.d_2 = d_1 - \sigma\sqrt{T}$$

Waiver contract has a put option with strike price of $(1 + p)^T$, and of call options sold short. For a zero $\alpha (0 < \alpha < 1)$ some amount : $\alpha = {}^{p}\!/_{c}$ or $p - \alpha c = 0$, initial value of the contract,

$$\alpha = \frac{p}{c} = \frac{-SN(-d_1) + Ke^{-rT}N(-d_2)}{SN(d_1) - Ke^{-rT}N(d_2)} =$$

$$= \frac{-N(-d_1) + (1+p)^T e^{-rT}N(-d_2)}{N(d_1) - (1+p)^T e^{-rT}N(d_2)}.$$

For example, if $\sigma = .2$, $r = .05$, $p = .02$ and $T = 3$, then □ = 51.7%,

where

$$d_1 = \frac{\ln\frac{5}{K} + (r + \frac{\sigma^2}{2})T}{\sigma\sqrt{T}} = \frac{\ln\frac{1}{(1+p)^T} + (r + \frac{\sigma^2}{2})T}{\sigma\sqrt{T}} =$$

$$= \frac{\ln(1.02)^{-3} + (.05 + \frac{(.2)^2}{2})3}{(.2)\sqrt{3}} = .43$$

$$d_2 = d_1 - (.z)\sqrt{3} = .09$$

Collar

The strike price of the put option is defined by the guaranteed floor. The strike of the call option is used to set the initial contract , is the solution.$(K > (1 + p)^T)$value to zero. The strike price, K

$$\text{Put}\ (1, (1 + p)^T, T, \sigma, R) = \text{Call}\ (1, K, T, \sigma, R)$$

Or

$$-N\left[\frac{-\ln\frac{1}{(1+p)^{T}}-(r+\ \cdots}{\sigma\sqrt{T}}\right]$$

The numerical solution is K = 1.3 and the equivalent annual yield is 9.2%.

$$+(1+p)^{T}e^{-rT}N\left[\frac{-\ln\frac{1}{(1+p)^{T}}-(r-\frac{\sigma^{2}}{2})T}{\sigma\sqrt{T}}\right]=$$

$$=N\left[\frac{\ln\frac{1}{K}+(r+\frac{\sigma^{2}}{2})T}{\sigma\sqrt{T}}\right]-Ke^{-rT}N\left[\frac{\ln\frac{1}{K}+(r-\frac{\sigma^{2}}{2})T}{\sigma\sqrt{T}}\right]$$

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