INVESTMENTS IN OFFSHORE OIL AND NATURAL GAS DEPOSITS IN ISRAEL: BASIC PRINCIPLES

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INTRODUCTION

1. My name is Robert S. Pindyck, and I am the Bank of Tokyo-Mitsubishi Professor of Economics and Finance at the Sloan School of Management, Massachusetts Institute of Technology. I have been asked to explain how one would find the "normal" or competitive rate of return for investments in the exploration, production, and development of offshore oil and natural gas reserves in Israel. I have undertaken this work with the help of staff from Analysis Group, Inc., an economic consulting firm in Boston.

2. Determining the normal rate of return is important because the government of Israel may impose an excess profits tax on the companies that ultimately develop the reserves and produce and sell the oil and gas. Excess profit is equal to actual profit minus the "normal" profit that would be earned in a competitive market. Because development and production involve large up-front sunk costs, one must determine the normal rate of return in order to calculate the normal profit. In fact, this analysis is needed even if the government were to decide to impose a royalty on production rather than an excess profits tax, because the royalty would likely be determined in a way that yields a normal return on the development investments.

EXECUTIVE SUMMARY

3. For the most part, determining the normal rate of return on oil and natural gas investments involves the application of basic principles of finance. In everyday practice, however, basic principles of finance are often misunderstood or not understood at all. For example, business people sometimes think that a risky investment should necessarily earn a high expected rate of return in order to compensate for the risk, but in fact this is not the case if the risk involved is diversifiable. Thus, I first review some of the basic financial principles involved, and then discuss the results of my study.

4. **Real versus Nominal Returns**. A nominal return is simply the actual measured return. The corresponding real return is the nominal return minus the expected rate of inflation. This distinction between real and nominal is important because in practice people often mix the two up. For example, sometimes people will calculate a net present value, *NPV,* using a nominal discount rate but real expected cash flows (i.e., cash flows that do not incorporate expected inflation). This can lead to highly incorrect results. One can get correct answers by doing all calculations in nominal terms or all calculations in real terms, but not by mixing the two. Unless otherwise noted, I will always use *nominal* cash flows and *nominal* rates of return (discount rates) in this report.

5. **Diversifiable Versus Non-Diversifiable Risk.** A common mistake is to ignore the distinction between diversifiable and non-diversifiable risk. Risk that is diversifiable can

easily be avoided, and therefore should not lead to a high expected return. One should not expect to be compensated for risk that can easily be avoided. If all of the risk associated with an investment is diversifiable, then the investment should earn a *risk-free rate of return*, i.e., the return one would get from holding a nearly riskless asset, such as a U.S. Treasury bill.

6. Oil and gas investments will often have time horizons of 10 years or more, and that must be reflected in the calculation of the appropriate risk-free rate. As explained in this report, a good estimate of the nominal risk-free rate is 3%.

7. The risk of an investment is not completely diversifiable if the outcomes (or payouts) of the investment are at least partially correlated with the overall market. To the extent one faces non-diversifiable risk, one could expect to earn a return higher than the risk-free rate. For example, if one holds a portfolio that matches the performance of the S&P 500 (a collection of 500 U.S. companies), the expected rate of return would be the expected return on the S&P 500, which historically has been about 7% higher than the return on risk-free U.S. Treasury bills.

8. **How Much Non-Diversifiable Risk? The CAPM**. The expected return on a stock can be estimated using the Capital Asset Pricing Model (CAPM). The expected return equals the risk-free rate plus a risk premium that accounts for non-diversifiable risk. That risk premium is equal to the risk premium (or "excess return") on the overall market (the expected return on the market minus the risk-free rate) times the "beta" for the company. The beta measures the extent to which the company's stock price is correlated with the overall market. If the stock price had no tendency to move in the same direction as the overall market, the beta would be zero. If the stock price tended on average to move up and down by the same percentage as the market, the beta would be one.

9. When historical data are available, beta can be measured statistically. According to the CAPM, an investment's return should be explained fully by beta. This does not always occur because the CAPM is a good but somewhat simplified model. There could be other factors that determine returns as well. In addition, any calculation of beta is an approximation based on regression estimates.

10. **Risk-Adjusted Discount Rates for Projects.** The CAPM is also used to get the risk-adjusted discount rate for a project. As explained below, this risk-adjusted discount rate is also the "normal" or competitive expected rate of return on the project. If the project being undertaken by a particular company is similar in risk to that company's overall business then we can use the company's beta in the CAPM formula to compute the discount rate for the project. But if the project is of a different nature, e.g., in a different line of business, then we may need other measures of risk.

11. **The "Normal" or Competitive Rate of Return.** In a competitive market, the *NPV* should be close to zero because actual or potential competition will drive down profits to a

competitive level. With an *NPV* of zero, the firm expects to earn "normal" or competitive profits from the project. If the *NPV* is a large positive number, other firms will enter the market with projects of their own, reducing profits.

12. If a market is not competitive, or if some firms have an advantage over others (e.g., they can buy natural resources or other materials at below-market prices), the *expected* profits can be above the competitive level i.e., there can be *excess profits*. The government could collect some or all of the excess profits through an excess profits tax. The fact that the developer earns a zero *NPV* after the excess profits tax does not mean there are no profits. The developer does earn normal profits each year, equivalent to the competitive rate of return on his investment.

13. **Internal Rate of Return.** The discount rate that makes the NPV of a project equal to zero is called the *internal rate of return* (IRR). If there are excess profits, the IRR will exceed the risk-adjusted discount rate, i.e., it will exceed the "normal" or competitive rate of return. If a project is partly funded by debt and partly by equity, and if the cost of debt is less than the IRR for the project, then the effective rate of return on the equity portion of the project (sometimes called the *equity internal rate of return* (EIRR) will be higher than the overall IRR for the project.

14. **Multi-Stage Projects.** Often projects have two or more stages, where the early stages are risky (although the risk may be diversifiable), and later stages are less risky. Oil and gas exploration and development is an example. A gas project might have two stages: The first stage involves exploratory drilling with a relatively low probability of success. If that first stage is successful, the company will go on to the second, lower-risk stage, in which the reserves are developed so that the gas can be produced.

15. The *NPV* at each stage of the project is the present value of the net revenues from the sale of the natural gas (PV_{NR}) less the present value of the development costs (PV_C): $NPV = PV_{NR} - PV_C$. The present value of the development costs is determined using a discount rate (r_C) that is close to the risk-free rate, because these costs are relatively certain. The present value of the net revenues is determined using a higher discount rate (r_{NR}) because net revenues generally have more non-diversifiable risk.

16. **Discount Rate for Oil and Gas Exploration and Development.** I conclude the report with the determination of the nominal discount rate that is appropriate for discounting the nominal cash flows from a typical project involving oil or gas field development. I estimated beta by examining the betas of a representative sample of companies in this industry. By eliminating the effects of leverage (from debt financing) we can get the asset beta, i.e., the beta applicable to projects for such companies.

17. The asset betas for the sample of fourteen companies that I analyzed are similar. This is to be expected since the companies are engaged in similar projects. The average asset beta, 0.88, is consistent with published betas for the industry. To determine the discount rate for oil and gas projects, I used the CAPM with a project beta of 0.88, an

expected risk-free rate of 3% and a market risk premium of 7%. Thus the nominal discount rate is, 3% + (0.88 x 7%) = 9.16%. Given the uncertainty in estimating beta, the variation in beta across different companies in the industry, and the variation that could occur in projects, a reasonable range would be 8% - 10%. By the same token, given how similar are the asset betas for the fourteen companies, and how close they are to published betas for the industry, I view this 8% - 10% range as quite reliable.

18. **Investments in Israel.** One might think that the correct discount rate for an investment in Israel should be higher because of additional risks that are specific to Israel. For example, the returns from an investment in Israel could be affected by the performance of the Israeli economy, by fluctuations in the exchange value of the shekel, or by war or terrorism. These risks, however, are largely diversifiable. For example, the fourteen oil and gas companies that I analyzed operate in many different areas of the world. Furthermore, investors can hold the stocks of companies that operate in different areas of the world (and not just in oil and gas activities). Thus my estimated range of 8% to 10% for the discount rate would definitely apply to oil and gas investments in Israel.

19. **Outline.** The remainder of this report is organized as follows. The next section explains the relationship between risk and return, with an emphasis on natural gas (or oil) exploration, development, and production. I discuss diversifiable versus non-diversifiable risk, the use of the CAPM to measure non-diversifiable risk, and the "leverage" effect that results when a risky first-stage investment is followed by a less-risky second-stage investment. The next section discusses the translation of a normal rate of return to a normal rate of profit. The final section applies these principles to a stylized natural gas project. The objective is not to do a detailed numerical analysis of any one project, but rather to show how these concepts could be used in practice in implementing an excess profits tax.

THE RATE OF RETURN ON AN OIL AND NATURAL GAS INVESTMENT

20. I begin with some basic concepts regarding the expected or "average" rate of return an investor can earn from a project. I first clarify the meaning of real versus nominal returns, and then turn to risk and its measurement.

21. **Real versus Nominal Returns**. Before turning to risk, it is important to clarify the distinction between real and nominal returns, as well as real and nominal cash flows. A nominal return is simply the actual measured return. The corresponding real return is the nominal return minus the expected rate of inflation.

    21.1. For example, consider a one-year government bond that pays the holder 5% interest (plus the principal) at the end of the year. Then the nominal return (or nominal interest rate) on that bond is 5%. Now suppose that expected inflation over the year is 3%, which means that the value, in terms of purchasing power, of the interest and principal will decline by 3%. Then the real return (or real interest rate) on the bond is 5% - 3% = 2%.

21.2. Suppose a project requires a $1 million investment up front, and then in 5 years will yield a risky net cash flow that has an expected value of $2 million, including inflation over the 5 years. The *expected* value is the average value that would result from many independent repetitions of the same hypothetical investment. Suppose the nominal discount rate on this project (the project's opportunity cost of capital) is 10%. Then the Net Present Value (*NPV*) of the investment is $-1 + 2/(1.10)^5 = -1 + 2/1.61 = \$0.24$ million. The nominal expected rate of return on the project is found by solving for *r* in the equation:

$$-1+\frac{2}{(1+r)^5}=0$$

21.3. In this case, the solution is $r = .15$, because $-1 + 2/(1.15)^5 = 0$. Thus the *expected* nominal rate of return is 15%. But now suppose we expect 3% inflation in each of the next 5 years. Then the $2 million cash flow will only be worth $2/(1.03)^5 =$ $1.73 million in real (inflation-adjusted) terms. To get the Net Present Value for the investment we must also use a real discount rate, which would be (approximately) 10% - 3% = 7%.[1] Then the *NPV* is $-1 + 1.73/(1.07)^5 = \$0.23$ million. We got approximately the same answer because we used a real discount rate to discount a real cash flow. And the reader can check that the real expected rate of return on the project is 15% - 3% = 12%.

22. This distinction between real and nominal is important because in practice people often mix the two up. For example, sometimes people will calculate a *NPV* using a nominal discount rate but real expected cash flows (i.e., cash flows that do not incorporate expected inflation). This can lead to wildly incorrect results. One can get correct answers by doing all calculations in nominal terms or all calculations in real terms, but not by mixing the two.

23. Unless otherwise noted, I will always use nominal cash flows and nominal rates of return in this report.

24. **Diversifiable Versus Non-Diversifiable Risk.** A very common mistake is exemplified by the following: "Exploratory drilling for oil or gas is very risky, and therefore it should earn a high expected return, so that investors are compensated for the risk they bear." Wrong! Most of the risk involved in exploratory drilling is diversifiable, so that it can

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[1] We write "approximately" because the real discount rate is actually calculated as (1 + 0.1)/(1 + 0.03) – 1 = 0.068, which is slightly different from 0.07. It is, however, much simpler (and perhaps clearer) to approximate the real rate as 0.10 - 0.03 = 0.07.

easily be avoided.[2] And if it can easily be avoided, it should not lead to a high expected return. One should not expect to be compensated for risk that can easily be avoided.

24.1. How can diversifiable risk be avoided? By diversifying. For example, an oil or gas company does not typically drill a single exploratory well in a single field – it drills exploratory wells at a number of sites. The probability of success for a single well may be small, so that the individual well is a risky investment. But if enough wells are drilled, the successes and failures average out, so that the overall risk is greatly reduced. By drilling multiple wells, the company has diversified away the risk inherent in any single well.

24.2. What if the company only has the financial resources to drill a single well, so that the risk is not diversified away? In that case investors can take care of the diversification. For example, investors can hold the stocks of this oil and gas company along with the stocks of 5 or 10 additional companies that are in the oil and gas exploration business. With that larger number of companies, enough wells will be drilled so that the drilling risk will be diversified away.

24.3. Better yet, investors can hold the stocks of companies in many different industries, as well as the stocks of some oil and gas companies. In this way, investors can diversify away not only the risk of drilling, but also the risk stemming from the fact that oil and gas prices can rise or fall unpredictably.

24.4. Remember that a company should operate in the best interests of its shareholders. So what matters is whether the shareholders can diversify away the risk (or part of the risk) of the company's activities.

25. If all of the risk associated with an investment is diversifiable, then the investment should earn a *risk-free rate of return*. And what is a risk-free rate of return? It is the return one would get from holding a nearly riskless asset, such as a U.S. Treasury bill. (The likelihood that the U.S. government will default on its debt obligations is considered by most people to be extremely low.)

25.1. Today the rates on U.S. Treasury bills and bonds are very low – around 0 to 3% nominal, which means close to zero in real terms. Historically these rates have been somewhat higher – but so have rates of inflation in the U.S.

25.2. For near-term cash flows, using the current U.S. Treasury bill rate is appropriate. Today the current rate on a U.S. Treasury bill is less than 0.25%. These rates are unusually low and are unlikely to remain so low for the next 10 to 20 years, which is the expected life of cash flows from projects like natural gas or oil

[2] Diversifiable risk is often referred to as non-systematic risk and non-diversifiable risk is often referred to as systematic risk. These are just different terms that mean the same thing. In this report, I will stick to the terms diversifiable and non-diversifiable risk.

development. For cash flows with longer expected lives, a better rate would be the expected average future U.S. Treasury bill rate.

25.2.1. Longer-term U.S. Treasury bond yields contain information on the market's expectation for future short-term interest rates. However they also contain a risk premium over short-term rates, for example for the risk of inflation in the intervening years. Historically, this premium has been about 1.5%.[3]

25.2.2. Over the past five years, the average yield on a long-term U.S. Treasury bond with an approximate 20-year maturity has been 4.3%.[4] Subtracting the premium of 1.5% from the recent average yield on U.S. Treasury bonds results in an expected average short-term rate of 2.8% over the future 20 years. For numerical calculations in this report, I will use a figure of 3% for the nominal risk-free interest rate, and I will denote that rate by R_f.

26. When is the risk of an investment not completely diversifiable? It is not completely diversifiable if the outcomes (or payouts) of the investment are at least partially correlated with the overall market, which in turn means the overall economy.

26.1. What do we mean by the "overall market"? The overall market would be a broad-based stock market index that would reflect the opportunities of investors to invest in the stocks of many different kinds of companies, and thereby diversify away as much risk as possible. In the U.S., some financial analysts use a broad index of large, medium, and small company stocks on both the NYSE and the NASDAQ. Many financial analysts would include non-U.S. stock markets as well, such as the European and Asian stock markets, because that provides even more opportunity to diversify. (It might be, for example, that the Tokyo stock market outperforms the U.S. market, or vice versa.)

26.2. Suppose you invest in a portfolio that contains the stocks of many different companies, both in the U.S. and worldwide. While you would be well-diversified, you would still face non-diversifiable risk. Why? Because if the world economy went into a deep recession, so that the profits of most companies fell, most stocks would fall in value, and the value of your portfolio would fall. (Of course the opposite would occur if the world economy boomed.)

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[3] The average yields between 1947-2009 on a Long Term Bond, with an approximate 20-year maturity, and a 3 Month Treasury Bill were 6.06%, and 4.59%, respectively. (*Ibbotson SBBI, 2010 Classic Yearbook*. Chicago: Morningstar Inc, 2010, pp. 29-30; and "US Government and Securities/ Treasury Bills," *Board of Governors of the Federal Reserve System*, 8 September, 2010.
http://www.federalreserve.gov/releases/h15/data/Monthly/H15_TB_M3.txt.)
Risk Premium of Long Term Bond over 3 Month Treasury Bill: 6.06% - 4.59 = 1.47%.

[4] *Ibbotson SBBI, 2010 Classic Yearbook*. Chicago: Morningstar Inc, 2010, p. 30.

26.3. To the extent you faced non-diversifiable risk, you could expect to earn a return higher than the risk-free rate of interest. For example, if you held a portfolio that matched the performance of the S&P 500 (a collection of 500 U.S. companies), your expected rate of return would be the expected rate of return on the S&P 500. Over the past 60 years, the return on the S&P 500 has been on average about 7% higher than the return on U.S. Treasury bills.

26.4. I will denote the expected return on the overall market (whether it be the S&P 500 or a broader international index) by R_m. Then the "excess return" on the market, (i.e., the return from holding a broadly diversified portfolio of stocks above and beyond the return on risk-free Treasury bills) is $R_m - R_f$, which, as mentioned above, has been about 7% on average.

26.5. Note that the *actual* return from holding stocks will almost never equal the *expected* return. The expected return refers to an average return over a long period of time. In some years the actual return on the market will be much lower than the expected return, and in some years it will be much higher. Indeed, it is that risk that makes the expected return on the stock market higher than the risk-free rate.

27. **How Much Non-Diversifiable Risk? The CAPM.** Suppose you buy stock in a (make-believe) company called Imaginary Oil and Gas. The stock is currently trading for $100 a share. What is the expected return for this stock? You know that the prices of oil and gas tend to be correlated with the world economy (when the economy is booming, the demand for oil and gas rises, pushing up the price, and when the economy is in recession, demand for oil and gas falls, as does the price). Therefore you know that there is at least some non-diversifiable risk, so that the expected return on this stock will be higher than the risk-free rate. But how much higher? How can we estimate the expected return?

28. The expected return on this stock can be estimated using the Capital Asset Pricing Model (CAPM). I will not derive the model here. Instead I will simply explain what the model says, and show how to apply it.

29. Let R_i denote the expected return on the stock of Imaginary Oil and Gas. Then the CAPM says that R_i is given by the following equation:

$$R_i = R_f + \beta_i (R_m - R_f)$$

30. In words, the expected return on this stock is equal to the risk-free rate plus a risk premium that accounts for non-diversifiable risk. That risk premium is equal to the risk premium (or "excess return") on the overall market (the expected return on the market minus the risk-free rate) times the "beta" for the company, denoted by β_i. The beta for the company measures the extent to which the company's stock price is correlated with

the overall market. If the stock price had no tendency to move in the same direction as the overall market, the beta would be zero. If the stock price tended on average to move up and down by the same percentage as the market, the beta would be one. Roughly speaking, if the stock price tended to move up and down by twice the percentage of the overall market, the beta would be two.[5]

31. When historical data are available, beta can be measured statistically. For our hypothetical company, Imaginary Oil & Gas (IO&G), one can estimate a "linear regression" of the returns of IO&G (net of the risk-free rate) on the return on the market (net of the risk-free rate). A linear regression is a statistical technique that estimates a "best fit line" to the data. In this case, the equation relating the return on IO&G stock and the market would be:

$$R_{IO\&G} - R_f = \alpha + \beta * (R_m - R_f),$$

In the linear regression α and β are chosen to give the best fit of the equation to the data. The coefficient, β (beta), from this regression is the statistical measure of the investment's sensitivity to movements in the market.

32. According to the CAPM, an investment's return should be explained fully by beta, so that the best-fit estimate of α is close to zero. This does not always occur because the CAPM is a good but somewhat simplified model. There could be other factors that determine returns as well. In addition, any calculation of beta is an approximation based on regression estimates.

33. Figure 1 below illustrates the use of a linear regression to calculate beta for Imaginary Oil & Gas. In this example we have used five years of monthly data on the stock returns of IO&G and the returns on the S&P 500 stock market index. For each month in the 5-year period, we plot the monthly net return of the stock against the monthly net return of the stock market index. Each point on the graph is one of those monthly observations. The regression determines the "best fit" line that is drawn on the graph. The slope of the line, beta, is 0.88, meaning that a one percent increase in the net return on the overall stock market results *on average* in slightly less than a one percent increase in the net return on Imaginary Oil & Gas's stock. In other words, Imaginary Oil & Gas's stock has slightly less non-diversifiable risk than the overall stock market.

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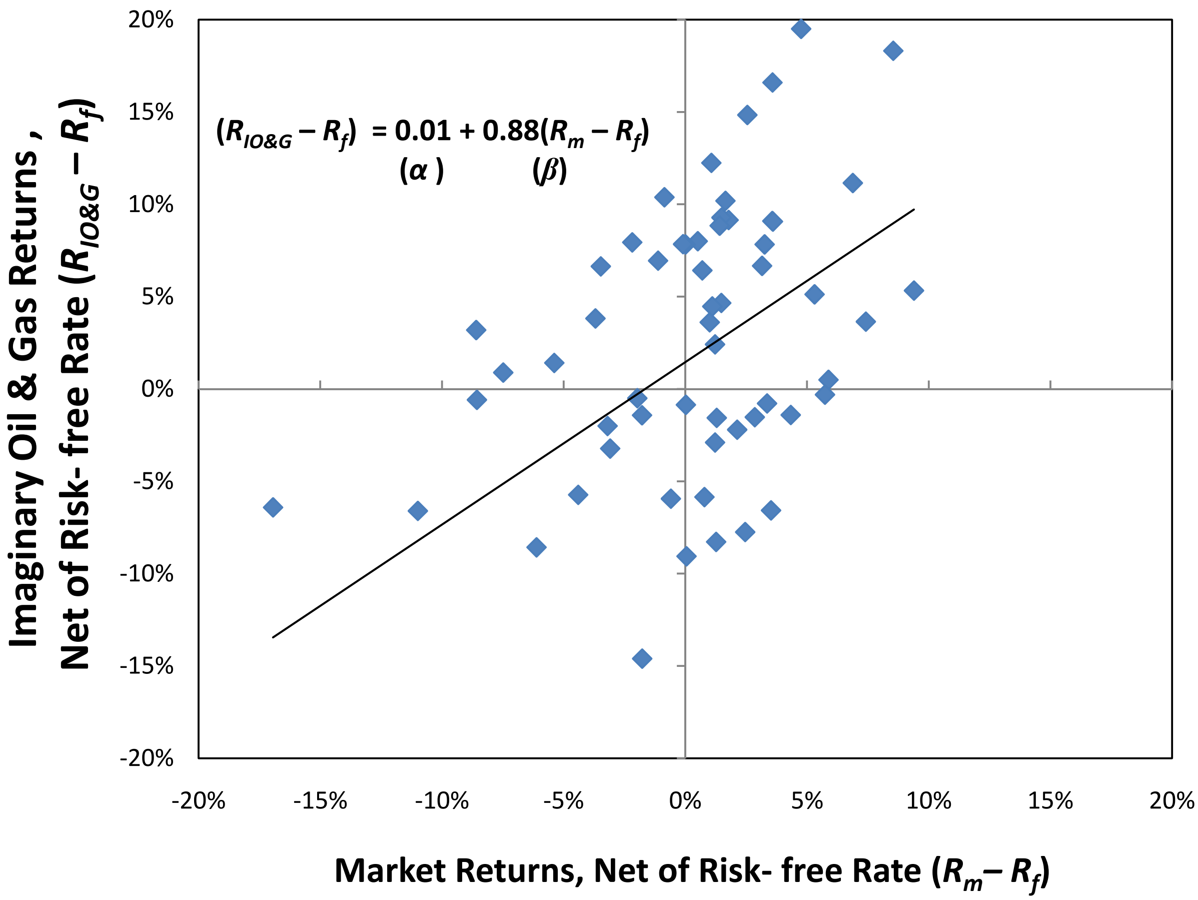
[5] Formally, beta is given by the following equation: $\beta = cov(R_i - R_f, R_m - R_f) / var(R_m - R_f)$. Where R_i is the return on an investment, R_m is the market return, R_f is the risk-free rate, $cov(R_i - R_f, R_m - R_f)$ is the covariance, i.e., a measure of how an investment's returns tend to move in relation to the market's returns (both net of the risk-free rate), and $var(R_m - R_f)$ is the variance, i.e., a measure of the dispersion of the market's returns (net of the risk-free rate).

Figure 1: Imaginary Oil & Gas Stock Beta



34. **Risk-Adjusted Discount Rates for Projects.** So far I have discussed the CAPM in the context of the expected return on a company's stock. But the CAPM is also used to get the risk-adjusted discount rate for a project. As explained below, this risk-adjusted discount rate is also the normal or competitive expected rate of return on the project.

34.1. In the case of a project expected to last 10 years, we must discount cash flows that occur in the future in order to calculate the net present value of the project. There are two main categories of cash flows: net revenues (*NR*) (usually positive), which are revenues net of operating costs, and investment costs (*C*) , such as the cost of drilling wells, etc. If *r* is the risk-adjusted discount rate for the project, then the *NPV* is given by:

$$NPV = \sum_{t=1}^{10} \frac{NR_t}{(1+r)^t} - \sum_{t=1}^{10} \frac{C_t}{(1+r)^t}$$

where Σ indicates that the cash flows from 10 periods of time are being summed. Thus, the equation is equivalent to:

$$NPV = \left(\frac{NR_1}{(1+r)^1} + \ldots + \frac{NR_{10}}{(1+r)^{10}} \right) - \left(\frac{C_1}{(1+r)^1} + \ldots + \frac{C_{10}}{(1+r)^{10}} \right)$$

For the net revenues (NR_t) and investment costs (C_t), we need to estimate the *expected values* based on our knowledge of the project, past experience, and current market conditions and projections.

34.2. We can use CAPM to estimate the discount rate. If the project being undertaken by a particular company is similar in risk to that company's overall business then we can use the company's beta in the CAPM formula to compute the discount rate that is properly risk-adjusted for this particular project. If, however, the project is of a different nature, e.g., the company is considering the project in a different line of business, then we may need to find measures of risk other than the company's beta.

34.3. Assume we determine that the risk-adjusted discount rate for natural gas production is 9%. We can use this discount rate to discount the expected net revenues of a natural gas project under consideration and determine an *NPV* for the project. Table 1 below shows the *NPV* calculation for a very simple example. In this example, all of the exploratory work has been completed and proved successful, yielding an estimate of gas reserves sufficient to produce revenues over the next four years totaling $12.1 billion with operating expenses totaling just over $800 million. Upfront development costs are estimated to total $4.5 billion. At a discount rate of 9%, the project has a net present value of $4.645 billion.

Table 1: Net Present Value of a Project

	Year 1	Year 2	Year 3	Year 4	Year 5
Cost					
Development Cost	(4,500)	-	-	-	-
Net Present Value of Cost (NPV_C)	**(4,500)**	-	-	-	-
Revenues					
Revenues	-	3,000	3,100	3,200	2,800
Operating Expenses	-	240	248	160	168
Net Revenues	-	2,760	2,852	3,040	2,632
Discount Rate (9%)					
Net Present Value of Revenues (NPV_{NR}) at Year 0	-	2,532	2,400	2,347	1,865
Total Net Present Value of Revenues (NPV_{NR})	**9,145**				
Net Present Value of Cash Flows (NPV)	**4,645**				

34.4. In the simple example above, one discount rate was sufficient to account for the risk of the net revenues. In some cases, different parts of the project should be discounted at different rates, because the extent of non-diversifiable risk may differ for different parts of the project. For example, the capital costs for a project might be known almost with certainty, while the future revenues from the project might depend on economic conditions. In that case, any future investment costs would be discounted at a lower rate, closer to a risk-free rate, while the revenues would be discounted at a higher risk-adjusted rate.

35. **The "Normal" or Competitive Rate of Return.** In a competitive market, the *NPV* should be close to zero. Why? Because actual or potential competition will drive down profits to a competitive level. If the *NPV* is a large positive number, other firms will enter the market with projects of their own, reducing profits.

35.1. In the example above, the *NPV* computed using a risk-adjusted discount rate of 9% (the rate for a competitive market) was $4.645 billion, much greater than zero. The fact that the *NPV* is greater than zero at a 9% discount rate means that the project is yielding a higher rate of return on the investment than 9%. We can determine the actual rate of return on the project by solving for the discount rate that would result in an *NPV* of zero. In our example this rate of return for the project is 50.79%, well in excess of 9%. The reason for the positive *NPV* and the higher rate of return is that in our example the market is not competitive: the *expected* profits are above the competitive level, i.e., there are *excess profits*. In this case, the excess profits have a net present value of $4.645 billion.

35.2. The government could collect all of the excess profits through a tax. As Table 2 shows, a tax rate of 51% on net revenues could be used to bring the *NPV* to zero.

35.3. The fact that the developer earns a zero *NPV* after the excess profits tax does not mean there are no profits. The developer does earn profits each year, equivalent to the 9% normal annual rate of return on his investment.

36. **Internal Rate of Return.** The discount rate that makes the NPV of a project just equal to zero is call the *internal rate of return* (IRR). In a competitive market with no excess profits, the IRR will equal the risk-adjusted discount rate. In the example discussed above (and shown in Table 2), the IRR is 50.79%, far above the risk-adjusted discount rate of 9%. Insofar as the IRR applies to rate of return on a project, it is sometimes referred to as the *project internal rate of return* (PIRR).

36.1. Projects are often financed partly by debt and partly by equity. If that is the case, and if the cost of debt is less than the PIRR, then the effective rate of return on equity – sometimes called the *equity internal rate of return* (EIRR) – will be higher than the PIRR.

36.2. For example, if the PIRR were 9% and the cost of debt were 6%, and if the project happened to be financed with 80% debt and 20% equity, then the EIRR would be 21%.[6]

Table 2: Net Present Value of Stylized Project with Profit Tax

	Year 1	Year 2	Year 3	Year 4	Year 5
Cost					
Development Cost	(4,500)	-	-	-	-
Net Present Value of Cost (NPV_C)	**(4,500)**	-	-	-	-
Revenues					
Revenues	-	3,000	3,100	3,200	2,800
Operating Expenses	-	240	248	160	168
Net Revenues	-	2,760	2,852	3,040	2,632
Tax Rate (51%)					
Excess Profit Tax	-	1,402	1,449	1,544	1,337
Net Cash Flow to Investors	-	1,358	1,403	1,496	1,295
Discount Rate (9%)					
Net Present Value of Revenues (NPV_{NR}) at Year 0	-	1,246	1,181	1,155	918
Total Net Present Value of Revenues (NPV_{NR})	**4,500**				
Net Present Value of Cash Flows (NPV)	**0**				

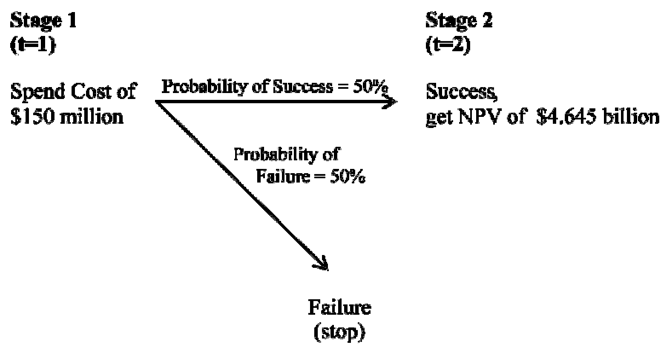
37. **Multi-Stage Projects.** In the simplified example above, we assumed that the exploration phase was already complete. Often projects have two or more stages, where the early stages are risky (although the risk may be diversifiable), and later stages are much less risky. Oil and gas exploration and development is an example of this. A gas project might have two stages where the first stage involves exploratory drilling with a relatively low probability of success. If that first stage is successful, however, the company will go on to the second, lower-risk stage, in which the reserves are developed so that the gas can be produced. A two-stage project is shown in Figure 2.

38. The *NPV* at each stage of the project is the present value of the net revenues from the sale of the natural gas (PV_{NR}) less the present value of the development costs (PV_C): $NPV = PV_{NR} - PV_C$. The present value of the development costs is determined using a discount rate (r_C) that is close to the risk-free rate, because these costs are relatively certain. The present value of the net revenues is determined using a higher discount rate (r_{NR}) because net revenues generally have more non-diversifiable risk.

[6] PIRR = (%Debt)R_d + (%Equity)EIRR, where R_d is the cost of debt. In this example, .09 = (.8)(.06) + (.2)(EIRR), so EIRR = .21.

39. To calculate the *NPV* of the entire project, we work backwards, starting with the *NPV* of the second stage. Suppose the development phase of the project is the same as our earlier example. We calculate the *NPV* of this phase exactly as before. Now assume that in Stage 1 of the project, $150 million is spent on exploration which takes one year, and that there is a 50% probability of success. If it fails, then there are no further costs or revenues. If successful, then the development and production stage is undertaken. We already know that at that point, the present value of the net revenues equals $9.145 billion and the present value of the costs equals $4.5 billion so that the *NPV* is equal to $4.645 billion (See Figure 2).

Figure 2: Multi-Stage Project



40. Table 3 shows the calculation of the net present value of the project. To calculate the *NPV* at Stage 1, we start by determining the present values of the net revenues at this stage. At Stage 1, there is a 50% chance of receiving the second stage net revenues which have a present value of $9.145 billion after a period of one year. The same discount rate of 9% that we used in Stage 2 applies to discounting these revenues from Stage 2 back one year. The present value of the net revenues at Stage 1 is calculated as follows:

$$PV_{NR,1} = (0.5) * (\$9.145 \text{ billion} /(1 + 0.09)) = \$4.195 \text{ billion}$$

41. Next we determine the present value of the development costs. At Stage 1, there is a 50% chance of having to incur the second stage costs which have a present value of $4.5 billion after a period of one year. We use a discount rate closer to the risk-free rate because those costs are known with a higher level of certainty. Costs also include $150 million exploration costs that are not discounted because they are assumed to occur at Stage 1. The present value of the costs at Stage 1 is calculated as follows:

$$PV_{C,1} = (0.5) * (\$4.5 \text{ billion} /(1 + 0.05)) + \$150 \text{ million} = \$2.293 \text{ billion}$$

42. The *NPV* of the project at Stage 1 is the present value of net revenues less the present value of the exploration and development costs:

$$NPV_1 = \$4.195 \text{ billion} - \$2.293 \text{ billion} = \$1.902 \text{ billion}$$

Table 3: Net Present Value of a Multi-Stage Project

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
Cost						
Development Cost Stage 1	(150)	-	-	-	-	-
Development Cost Stage 2	-	(4,500)	-	-	-	-
Discount Rate (5%)						
Success Rate (p=0.5)						
Net Present Value of Cost *(NPV_C)* at Year 0	(150)	(4,286)	-	-	-	-
Total Net Present Value of Cost (NPV_C)	(4,436)					
NPV_c at Year 0 adjusted for p=0.5	**(2,293)**					
Revenues						
Revenues	-	-	3,000	3,100	3,200	2,800
Operating Expenses	-	-	240	248	160	168
Net Revenues	-	-	2,760	2,852	3,040	2,632
Discount Rate (9%)						
Success Rate (p=0.5)						
Net Present Value of Revenues (NPV_{NR}) at Year 0	-	-	2,323	2,202	2,154	1,711
Total Net Present Value of Revenues (NPV_{NR})	8,390					
NPV_R adjusted for p=0.5	**4,195**					
Net Present Value of Cash Flows (*NPV*)	**1,902**					

43. **Excess Profits.** The addition of the exploratory phase has lowered the *NPV* in our simple example. However, as before, the *NPV* of the project at Stage 1 is greater than zero, which reflects the fact that the market for exploration and development in our hypothetical example is not competitive.

44. The excess profits are $1.902 billion. A tax could again be used to bring the *NPV* of the project to zero. In order for the *NPV* of the project to be zero, the present value of net revenues and future costs must be equal to the exploration cost at Stage 1. Taking into account the exploratory phase results in a tax of 45% on net revenues. This is because a positive *NPV* at Stage 2 is required to compensate the developer for the investment in exploration costs at Stage 1. Table 4 below shows the tax that would be required.

Table 4: Net Present Value of Multi-Stage Project with Tax to Eliminate All Excess Profits

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
Cost						
Development Cost Stage 1	(150)	-	-	-	-	-
Development Cost Stage 2	-	(4,500)	-	-	-	-
Discount Rate (5%)						
Success Rate (p=0.5)						
Net Present Value of Cost *(NPV_C)* at Year 0	(150)	(4,286)	-	-	-	-
Total Net Present Value of Cost *(NPV_C)*	(4,436)					
NPVc at Year 0 adjusted for p=0.5	**(2,293)**					
Revenues						
Revenues	-	-	3,000	3,100	3,200	2,800
Operating Expenses	-	-	240	248	160	168
Net Revenues	-	-	2,760	2,852	3,040	2,632
Tax Rate (45%)						
Excess Profit Tax	-	-	1,251	1,293	1,378	1,193
Net Cash Flow to Investors	-	-	1,509	1,559	1,662	1,439
Discount Rate (9%)						
Success Rate (p=0.5)						
Net Present Value of Revenues (NPV_{NR}) at Year 0	-	-	1,270	1,204	1,177	935
Total Net Present Value of Revenues (NPV_{NR})	4,586					
NPVR adjusted for p=0.5	**2,293**					
Net Present Value of Cash Flows (*NPV*)	**0**					

PROGRESSIVE TAXATION OF OIL AND NATURAL GAS PROJECTS

45. The difficulty with actually implementing a tax like the one illustrated in Table 4 is that the taxing authority would have to know in advance, or forecast with reasonable accuracy, the cash flows of the project throughout its life. An alternative structure is to begin taxing the producer once it has earned a competitive rate of return, bringing in additional tax revenue while still allowing the producer to keep some of the gains, to preserve its incentive to produce additional amounts.

46. Table 5 shows how such a tax could be implemented with the same project costs and net revenues as used in the previous example. In each year, the realized rate of return is calculated based on the cumulative cash flows earned by the project to date. Once the realized return reaches some threshold, say 9%, the profit tax begins the following year. The tax rate can be progressive, increasing as realized returns increase. For example, in Table 5, the tax rate is 25% once the IRR exceeds 9% and 75% once the IRR exceeds 25%.

47. When calculating the IRR, the probability of failure at the exploration phase can be accounted for by increasing the value of exploration costs. In the example, the exploration phase had a 50% probability therefore the exploration costs are included in the calculation at $300 instead of $150.

48. With the tax as implemented in this example, the producer is still earning excess profits as can be seen by the positive NPV of the project. This result occurs whenever the tax is less than 100%. In Table 5, profits beyond the normal competitive rate of return are first realized in year 3. In Years 0 and 1, only costs are incurred. In Year 2, there are Net Revenues, but not enough to offset all of the costs incurred to date. In Year 3, the realized 11% rate of return exceeds the 9% benchmark. Thus, a 25% profit tax is applied in Year 4. Even with this additional tax, the realized rate of return increases from 11% to 29%. In the following year, Year 5, the tax rate on profits increases to 75%, which still leaves the producer receiving a higher rate of return (as well as accruing tax revenues to the government).

Table 5: Net Present Value of Example Project with Phased in Taxes

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
Cost						
Development Cost Stage 1	(150)	-	-	-	-	-
Development Cost Stage 2	-	(4,500)	-	-	-	-
Revenues						
Revenues	-	-	3,000	3,100	3,200	2,800
Operating Expenses	-	-	240	248	160	168
Net Revenues	-	-	2,760	2,852	3,040	2,632
Realized Return to Date With No Tax				11%	34%	44%
Progressive Tax Rate					25%	75%
Excess Profit Tax	-	-	-	-	760	1,974
Net Revenues After Tax			2,760	2,852	2,280	658
Adjusted Cash Flow for IRR	(300)	(4,500)	2,760	2,852	2,280	658
Realized Return to Date After Tax	Negative	Negative	Negative	11%	29%	33%
NPV Calculations						
Net Present Value of Cost *(NPV_C)* at Year 0	(150)	(4,286)	-	-	-	-
Total Net Present Value of Cost *(NPV_C)*	(4,436)					
NPV_c at Year 0 adjusted for p=0.5	**(2,293)**					
Net Present Value of Revenues (NPV_{NR}) at Year 0	-	-	2,323	2,202	1,615	428
Total Net Present Value of Revenues (NPV_{NR})	6,568					
NPV_R adjusted for p=0.5	**3,284**					
Net Present Value of Cash Flows (*NPV*)	**991**					

Note
Discount Rate for Costs = 5%, and Discount Rate for Revenues = 9%

THE DISCOUNT RATE FOR NATURAL GAS AND OIL PROJECTS

49. In the examples used thus far in the report, we have been assuming a discount rate of 9%. This section sets out the analysis and conclusion that 9% is an appropriate discount rate for a typical project involving oil or gas exploration and development.

50. Earlier we determined the expected return for Imaginary Oil & Gas using the CAPM by calculating a beta based on the stock's sensitivity to movements in the stock market. The expected return for Imaginary Oil and Gas captures the non-diversifiable risk in all of this particular company's activities combined. To determine a discount rate that can be used for any project involving oil or gas exploration and development, we estimated a beta by examining the betas of a representative sample of companies in this industry.

50.1. Table 6 shows a list of fourteen companies whose activities are primarily related to oil and gas exploration and development.[7] These companies range in size from a market capitalization of approximately $3 billion to approximately $35 billion. I use the equity returns and debt-equity ratios for these companies to estimate a beta for a typical oil or gas development project. For each company, I computed the beta of the stock (i.e., the equity beta) using linear regression analysis as described above. Table 6 shows the equity betas obtained from these regressions using 10-year weekly data. A relatively long time is appropriate to use particularly in this case because the time frame of anticipated development projects will be quite long. Betas can vary over time, but over a long time could be expected to revert back towards the mean.[8]

50.2. Table 6 shows the betas for each company. The equity betas range from a low of 0.9 to a high of 1.5 but generally cluster around 1.2. I also calculated the standard error of each company's beta. The standard error is a statistical measure of the standard deviation of the true value around the estimate. The true value will be within plus or minus one standard deviation of the estimate approximately two-thirds of the time. Table 6 shows that the standard errors of the betas I calculate are typically 0.1 or less.

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[7] I reviewed the annual reports of those companies to verify the nature of their business activities.

[8] To determine the extent to which the choice of time period matters, I also used regressions of 2 years and 5 years, and I also did a regression using monthly data. In general, the use of shorter time periods resulted in a higher beta.

Table 6: Beta Calculation for Oil and Gas Companies

Company	Equity Beta	Standard Error of Beta	Debt to Equity Ratio [1]	Asset Beta [2]
Anadarko Petroleum Corp.	1.13	0.07	0.47	0.87
Apache Corp.	1.03	0.07	0.14	0.79
Cabot Oil & Gas Corp	1.17	0.09	0.31	0.90
Chesapeake Energy Corp.	1.18	0.10	0.74	0.90
Denbury Resources Inc.	1.28	0.10	0.41	0.98
Devon Energy Corp.	0.92	0.07	0.20	0.71
EOG Resources, Inc.	1.01	0.08	0.14	0.77
Forest Oil Corp.	1.51	0.09	0.56	1.16
Newfield Exploration Company	1.09	0.08	0.30	0.83
Noble Energy	1.07	0.07	0.21	0.82
Petrohawk Energy Corporation	1.15	0.13	0.50	0.88
Pioneer Natural Resources Company	1.22	0.09	0.36	0.94
Range Resources Corp.	1.07	0.09	0.30	0.82
Southwestern Energy Company	1.17	0.10	0.09	0.89
Mean	**1.14**		**0.34**	**0.88**
Median	**1.14**		**0.31**	**0.87**

Notes
[1] Debt to Equity Ratio = Total Liability/Total Equity
[2] Asset Beta = Beta Levered/ (1 + (1 - Corporate Tax Rate) * Debt to Equity Ratio); corporate tax rate is assumed to be 35%

51. When a company has debt, its equity returns are levered (i.e., magnified), and that use of leverage increases the risk (and potential returns) to an equity holder.[9] We want to measure the risk of the project, independent of financing. Using a simple formula along with each company's debt-equity ratio, we can back out the portion of beta that is due to a company's use of leverage.[10] The result is an unlevered, or asset, beta.

51.1. Table 6 shows for each company the leverage ratio (debt to equity) and the calculation of the asset beta. The asset betas across the companies show little variation around the mean. This is to be expected: since the companies are engaged in similar projects, we expect the risk to be similar. The mean and median asset betas were 0.88 and 0.87 respectively.

[9] Debt is a senior claim (i.e., debt holders are paid before stockholders receive any return). The risk of the residual claim, equity, is higher than for debt, and increases with the debt-to-equity ratio.
[10] The unlevered, or asset beta is calculated as follows: Asset Beta = Beta Levered/ (1 + (1 - Corporate Tax) * Debt to Equity Ratio)

51.2. As a check, I reviewed a widely used source for industry betas.[11] For the SIC code 1311 "Crude Petroleum and Natural Gas" the industry composite unlevered beta was 0.91, which is consistent with my results and reinforces the reliability of those results.

52. **Use of a Single Discount Rate for Oil and Gas**. Companies in this sample have differing mixes of revenues from natural gas versus oil and other hydrocarbon production (e.g., propane). However, the companies have similar beta values, and I found no clear relationship between a company's beta and its mix of production. I have therefore concluded that there is insufficient evidence to support different discount rates for oil and gas, and thus a single discount rate should be used for both oil and gas projects.[12] Accordingly, I have calculated a single nominal discount rate for all oil and gas projects, rather than separate ones for oil or for gas (or for gas to be liquefied, etc.)

53. **Use of CAPM**. To determine the discount rate for oil and gas projects, the CAPM is used with the project beta of 0.88. With an expected risk-free rate of 3% and a market risk premium of 7%, the formula is

$$3\% + (0.88 \times 7\%) = 9.16\%.$$

54. Given the uncertainty in estimating beta, the variation in beta across different companies in the industry, and the uncertainty in determining the 3% risk-free rate and the 7% market risk premium, I conclude that a reasonable range for the discount rate would be 8% - 10%.

55. **Weighted Average Cost of Capital**. Companies often compute what is known as their weighted average cost of capital, or WACC, for use as a discount rate for project cash flows. Companies can be financed with debt or equity and typically use some combination of the two. The WACC reflects the cost of the debt financing (the interest rate) and the cost of the equity (the return demanded by shareholders) weighted appropriately for the mix of financing. The WACC will vary by company because both the cost of the debt and the cost of the equity depend on a company's individual circumstances.

56. Table 7 reports the WACC for each of the sample oil and gas development companies. I found that the mean and median WACCs were 9.2% and 9.1%, respectively, consistent with the project discount rate I calculated using the asset betas. This result is to be expected, as the WACC calculation, like the asset beta, reflects the overall risk of the company's assets.

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[11] *Ibbotson Cost of Capital, 2010 Yearbook*. Chicago: Morningstar Inc, 2010.

[12] I also examined changes in gas and oil prices as compared to the overall market. I found that both the beta for gas prices (measured at the Henry Hub) and the beta for oil prices (both Brent and WTI) were less than 1 and that the beta for gas was less than that for oil, which would be consistent with a lower discount rate for gas projects.

57. As is clear from Table 7, these WACCs are very close together and very close to the mean of 9%. This is further evidence that 9% is the correct discount rate to be used for evaluating oil and gas investments.

Table 7: Weighted Average Cost of Capital ("WACC") of Oil & Gas Companies

Company	Market Cap of Equity ($ millions)	Total Liabilities ($ millions)	Cost of Equity	Cost of Debt	WACC
	[1]	[2]	[3]	[4]	[5]
Anadarko Petroleum Corp.	26,355	12,351	10.9%	4.9%	8.5%
Apache Corp.	35,868	5,012	10.2%	4.0%	9.2%
Cabot Oil & Gas Corp [A]	3,258	1,015	11.2%	NA	NA
Chesapeake Energy Corp.	14,099	10,501	11.3%	6.7%	8.3%
Denbury Resources Inc.	6,616	2,712	11.9%	6.7%	9.7%
Devon Energy Corp.	28,780	5,624	9.4%	4.2%	8.3%
EOG Resources, Inc.	25,951	3,734	10.0%	4.0%	9.1%
Forest Oil Corp.	3,351	1,868	13.6%	7.6%	10.5%
Newfield Exploration Company	7,347	2,169	10.6%	4.9%	8.9%
Noble Energy	12,051	2,584	10.5%	4.3%	9.1%
Petrohawk Energy Corporation	4,880	2,440	11.1%	7.6%	9.0%
Pioneer Natural Resources Company	7,064	2,531	11.6%	6.5%	9.6%
Range Resources Corp.	6,118	1,860	10.5%	6.7%	9.0%
Southwestern Energy Company	12,854	1,179	11.2%	4.9%	10.5%
Mean			**11.0%**	**5.6%**	**9.2%**
Median			**11.0%**	**4.9%**	**9.1%**

Notes

[A] Cost of debt and WACC calculations could not be performed for Cabot Oil & Gas' because Bloomberg did not report the company's credit rating

[1] Total equity is the company's market capitalization as of September 2, 2010

[2] Total liabilities is the interest bearing debt that the company has on its balance sheet as of the company's last 10-Q (as of September 2, 2010).

[3] Cost of Equity = Risk Free Rate + (Equity Risk Premium * Equity Beta)

[4] Cost of Debt is the September 1, 2010 value of Bloomberg's US Industrial Index for the current market yield of the company's S&P credit rating

[5] WACC = [3]*([1]/([1]+[2])) + ([4]*([2]/([1]+[2]))*(1- Corporate Tax Rate)); corporate tax rate is assumed to be 35%

58. **Investments in Israel.** One might think that the correct discount rate for a gas or oil investment in Israel should be higher than a similar project in the U.S. because of additional risks that are specific to Israel. For example, the returns from a gas or oil investment in Israel could be affected by the performance of the Israeli economy, by fluctuations in the exchange value of the shekel, or by war or terrorism. These risks, however, are largely diversifiable.

58.1. For example, the fourteen oil and gas companies that I analyzed operate in many different areas of the world, and thus already have a considerable degree of diversification. Furthermore, investors can hold the stocks of different companies that operate in different areas of the world (and are not just involved in oil and gas activities).

58.2. Likewise, investors can largely hedge exchange rate risk by holding futures positions in currencies whose movements are correlated with movements in the shekel, or can diversify away any exchange rate risk by holding the stocks of companies with investment in different parts of the world.

59. Thus my estimated range of 8% to 10% for the correct nominal discount rate would not need any adjustment for the fact that the oil and gas investments under consideration are in Israel. Furthermore, for the reasons discussed above, one can have considerable confidence that the correct discount rate is in this 8% to 10% range.