Country risk, country risk indices, and valuation of FDI:
A real options approach

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March 30, 2001

Abstract

Country risk and in particular political risk may constitute a large part of the total risk investors face when investing in emerging markets. It is not a straightforward task to quantify and include these types of risks in the evaluation and valuation of real investments. We suggest a method involving country risk indices. The approach is based on the real option approach for valuation of real investments. (67)

JEL classifications: G31, G38, G12

Key words: Country risk, political risk, real options, investments

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1 Country risk**

The term *country risk* is often used in connection with cross border investments and analyzed from the foreign investor's perspective. The country risk for a given country is therefore the unique risk faced by foreign investors when investing in that specific country as compared to the alternative of investing in other countries. Country risk is the unique part of the investment's risk caused by the location within national borders. Country risk is often meant to measure the possibility of loss only, or what we might call downside risk. What we understand by the term country risk will to some degree depend on the type of investment. It is common to use three categories when describing foreign investments: lending, equity investment, and foreign direct investment (FDI), see Figure 1. Lending covers direct lending or the purchase of bonds from the state, government, or from private companies in a country. Equity may cover investments in companies that may be listed at the country's stock exchange or not. Foreign direct investment covers investments in factories and resources, such as mines or oil fields, and other real assets. Regarding lending, the borrowers may be categorized into two groups, the government and government guaranteed borrowing, and borrowing from private companies without public guarantee. When the term country risk is used in cross-border lending, and when the borrower is a government, the credit risk is known as sovereign risk, or sovereign credit risk. Credit risk is the risk that the borrower will not completely fulfill the obligations in the loan agreement such that the credit provider, or lender, suffers losses. Calverley (1990) distinguishes between country risk when the bond

issuer is a government and country risk when lending to private borrowers, termed *generalized country risk*, and this term may also be extended to cover equity investment and FDI. The general use of the term risk covers both the upside potential and downside risk and may, e.g., be measured by the variance in return. Country risk may therefore be more properly labeled as country effects in return on investments. The downside risk, however, is also related to total risk. This is best recognized by the fact that reduced probabilities for negative events in most cases will increase the value of the investment.

(Insert Figure 1 approx. here)

The reasons why a given investment is influenced by country specific factors are many, and it is common to analyze country risk by specifying sub-categories of risk. One possible division of country risk is into economic risk, commercial risk, and political risk. Economic risk is risk related to the macroeconomic development of the country, such as the development in interest and exchange rates that may influence the profitability of an investment. Commercial risk is risk related to the specific investment, such as the risk related to fulfillment of contracts with private companies and local partners. The third category, political risk, may in many countries be the most important one. A country is a political entity, with country specific rules and regulations applying to the investment. In addition to the specific regulations, e.g., laws protecting private property rights, a government's willingness and ability to change these rules and regulations will constitute a source of risk to the investment. Political risk may also be caused by the behavior of the state or state-owned companies in the market place, or by more extreme situations like war and civil unrest[1]. Jodice (1985) defined

political risk as:

> "Changes in operating conditions of foreign enterprises that arise out of political process, either directly through war, insurrection, or political violence, or through changes in government policies that affect the ownerhip and behavior of the firm. Political risk can be conceptualized as events, or a series of events, in the national and international environments that can affect the physical assets, personnel and operation of foreign firms".

Root (1972) lists examples of political risk situations, i.e., examples of events affecting real investments. Root distinguishes between three types of political risk: transfer risk, operational risk, and ownership-control risk. Transfer risk is risk related to the transfer of products and services across national borders, or the transfer of funds such as payments of dividends. Operational risk is risk related to the operation and profitability of an investment in the host country, such as the operation of an assembly plant. Examples of operational risk are price controls and possible requirements that the producer should use sub-standard or expensive local suppliers. The final category, ownership-control risk, is linked to events influencing the owners' ability to control and manage the investment. The investment may be expropriated, or the initial owner may be forced to let local partners get an ownership share at a discount price.

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1 When studying mainly financial assets such as stocks and bonds, the term country risk, and especially political risk, is in most cases used to describe the possibility of shocks in financial markets caused by some unforeseen event. The term *event risk* may also be used.

The term *country risk analysis* describes the activity of predicting future conditions for the investment in a host country. There are at least three sources of information the predictions may be based on: written reports, information deduced from financial markets, and summary measures like risk indices and ratings. We are here primarily interested in how these sources of information may be used when deriving the value of an investment. Because it often is difficult to quantify country risk, all three sources of information used together are likely to provide the investment analyst with the best estimates. We comment on the first two before we turn to country risk indices. Written reports usually contain descriptions of possible future developments in a country. Such reports may be issued by private companies or governmental organisations like OECD or the World Bank. Figures from national accounts may be presented in these reports, but in many cases the analysis is primarily qualitative and in textual form. Written reports are useful in providing background information, but may often be too general and give little guidance to the numerical evaluation. The second source of information is analysis of prices of assets traded in financial markets. The procedure is as follows: A valuation model for the asset is assumed. Based on observation(s) of price(s), one or several parameter values making the theoretical value equal to the actual value are extracted. Here we are primarily interested in parameter values reflecting country risk. Consider an example with default probabilities deduced from prices of bonds influenced by country risk. A one period discount bond is issued by a government with principal X_1. If the loan is fully repaid, the holder of the bond will receive X_1. If the country defaults, the bond holders receive a fraction k. The default probability is p, the risk free interest rate is r, and we assume that the default risk does not reflect systematic risk. The present value of the bond is then

$$V_0[X_1] = \frac{E(X_1)}{1+r} = \frac{X_1}{1+r}(1-p) + \frac{X_1 k}{1+r} p. \tag{1}$$

By observing the value of the bond today, $V_0[X_1]$, observing the interest rate r, and making

an assumption about k, we can solve equation (1) with respect to the probability of default,

p. Whether the deduced parameter value is correct depends on whether the observed price is

correct and whether the model is correct[2]. The bond may not be traded every day, so that an

estimate for the price must be made. The valuation model on the right hand side of (1)

depends on the unobservable recovery fraction k. Depending on the assumption about k, we

will get different levels of p. Another question is how the information extracted from one

class of assts may be used to evaluate assets in another class. The probability of default

extracted from (1) may be used when finding the expected future cash flow from similar

bonds. Beyond the cases where default is caused by major events like war or change of

government leading both to default and, e.g., expropriation, it may be difficult to relate the

event of default to the cash flow from a real investment. In addition to the problem of

relevance between the deduced probability from bonds and probabilities of events affecting

other types of investments, comes the problem of whether default probabilities are constant

over time. If not, it is not possible to deduce the probability of default at a given future date

from the price of a bond. If several bonds with different maturities are traded, it may be

possible to deduce some sort of term structure of default probabilities. It may be the case that

the probability of default mainly is linked to a given period, e.g., close to an election date.

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2 For a discussion of issues related to extraction of information from financial markets, see,
e.g., Bodie and Merton (1995).

Country risk indices are, as the name implies, indices measuring the level of country risk. A high level of an index corresponds to either a high or low level of risk, depending on the specification of the index. What is meant by country risk is determined by the way the index is constructed. The use of sub-indices is a typical way of making a risk index. As an illustration we present the rating system of the International Country Risk Guide (ICRG) as presented in Coplin and O'Leary (1994), see Table 1. The ICRG composite risk index consists of three sub-indices: indices measuring economic, financial, and political risk. These sub-indices are again made up of more detailed indices. We may define three generic types of risk indices and a fourth which is a combination of the first three types. The first generic type of index is a number referring to the *current conditions* in the country. The ICRG political risk index and the economic risk index is mainly a rating of the current conditions in the country. The second type of risk index refers to the probability that a *specific event* will occur during some future time period. An example is the sub-index covering the event of expropriation in the ICRG financial risk index. The third type of risk index is similar to the previous one, but here the event refers to a situation where the investors experience a *worse* condition than the current one. An example is where an index refers to an increase in a tax rate during some future time period, but where the size of the increase is not specified. The fourth type of risk index is a weighted average of the three first indices, and is exemplified by the ICRG composite risk rating. The composite risk rating for the ICRG is therefore a specific measure of country risk, where the risk is defined by the structure of the index.

(Insert Table 1 approx. here)

The variables or parameters in a valuation model may be related to the *level* of the index, either the present or future level, or to the future *path* of the index. Consider the case where an investment may be expropriated. The probability of expropriation during the lifetime of the project may be directly related to the present level of a risk index. If the ICRG indices are used, lower levels of the index would correspond to higher risk of expropriation. Whether the project has been expropriated at a future date may be related to the future levels of the index. This is an example of conditioning the probability of expropriation on the future level of the risk index. It may, e.g., be more likely that the project has been expropriated if the future index is low, as compared to the situation with a high index level. This approach necessitates that the future development in the indices must be estimated. This corresponds to an estimation of the development in the country with regard to country risk. Used in this way, the country risk indices becomes variables like any other variables, e.g., like the oil price. It is then the future value of the variable that determines the future cash flow from the investment. The occurrence of expropriation may also depend on the future path of the index. If the risk index has dropped sizably over a short period of time, the analyst may be willing to assume that the probability that the investment has been expropriated is large as compared to the situation when such a change does not occur. It may also be relevant to relate the probability of expropriation to the time the index spends in different risk categories. The ICRG , see Coplin and O'Leary (1994) p. 249 categorized the the ICRG composite risk index into five risk categories. The risk level for these categories were named (index intervals in brackets): very high (0-49.5), high (50-59.5), moderate (60-69.5), low (70-84.5), and very low (85-100). Consider the example with expropriation. The probability that the project has been expropriated at a future date will depend on the levels of expropriation risk the project has

been exposed to up to that date. This is illustrated in Figure 2. At time t the probability that the investment will be expropriated during the next increment of time, provided that it has not been expropriated previously, is p_t. This probability is subordinated the level of a risk index, ψ_t. The expropriation probability equals p_1 if the index level is between L_1 and L_2, p_2 if the index level is between L_2 and L_3, and p_3 otherwise. If higher index levels imply lower risk, it is reasonable to assume that $p_1 < p_2 < p_3$.

(Insert Figure 2 approx. here)

The exact calibration of the valuation model with regard to country risk is of course not a straightforward task. It must be based on a thorough investigation of the specific investment and the given risk index or sub-indices. In order to secure consistency, the modeling of country specific conditions and country risk based on risk indices should be in line with the estimates based on the other two sources of information, i.e., written reports and analyses of market data.

If there is a relationship between the future cash payments generated by an investment and the future level or path of a risk index, it may be appropriate to value the investment by applying the contingent claims valuation methodology. This valuation methodology facilitates the valuation of investments where managerial decision making concerning the investment project is a prominent feature. The options to abandon the investment or to increase the scale of the investment are potentially valuable when investing in emerging markets. These decisions are often closely related to the development of country specific conditions, i.e., to country and political risk. The contingent claims valuation methodology is based on the same

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principles used when pricing derivatives written on financial securities, as in Black and

Scholes (1973). For an introduction to and description of the real option literature, see, e.g.,

Amran and Kulatilaka (1999), Dixit and Pindyck (1994), or Trigeorgis (1996). Central to the

valuation approach is the modeling of state variables as stochastic processes. A risk index

may be considered to be, without loss of generality, a transformation of some not directly

observable state variable, i.e.,

$$\psi_t = f(x_t), \tag{2}$$

where the risk index ψ_t is a function $f(\cdot)$ of the unobservable state variable x_t. The

stochastic behavior of the risk index is then given by the choice of $f(\cdot)$ and the stochastic

behavior of x_t. If the history is relevant when predicting the future, this may be considered to

be an empirical problem. In addition, in order to facilitate the contingent claims pricing

approach, $f(\cdot)$ and x_t cannot be chosen freely. Some technical restrictions must be imposed[3].

In the next section we demonstrate how country risk indices may be directly included in the

evaluation of an investment project when the real option pricing methodology is applied. We

consider an investment in an oil field, and we report the result from empirical investigations

of the plausibility of the model assumptions. We then present a numerical example before

summarizing the main points in the final section.

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3 See, e.g., Ingersoll (1987) p. 283.

2 The Model

2.1 Risk index

In order to implement a valuation model, we need to specify equation (2). We assume that

$$\psi_t = L_{MIN} + (L_{MAX} - L_{MIN})N(x_t / \sigma_\upsilon),\tag{3}$$

where $N(\cdot)$ is the cumulative distribution function for the unit normally distributed variable, σ_ν is a nonnegative constant, L_{MIN} is the minimum level of the index, and L_{MAX} is the maximum level of the index. The choice of (3) is motivated by studying the situation the country experts are facing when they rate a country. Suppose that the country is either of type L_{MIN} or L_{MAX}. This corresponds to a binary choice problem as, e.g., described by Green (1993) p. 642. We consider an indicator variable, z_t, equaling one if the government at time t is of type L_{MAX} and zero if not. We interpret x_t, a real number, as the "stock of relevant information" the country expert possesses about the country's type. If x_t is negative, the country is of type L_{MIN}, and otherwise it is of type L_{MAX}. The country expert's stock of information is, however, influenced by noise v_t. We assume that the noise is normally distributed with expectation zero and variance σ_ν. At time t the country expert's estimate of the probability that the country is of type L_{MAX} is then

$$P(z_t = 1) = P(x_t + v_t \geq 0) = P(v_t \geq -x_t) = N(x_t / \sigma_\nu),$$

where we have used the symmetry of the normal distribution. With this interpretation the risk index in equation (3) is a scaling of the country expert's estimate of the probability that the

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country is of type L_{MAX}. For a given variance of the noise, σ_ν, the country expert's *future* opinion of the country's type will depend on the arrival of new information. We assume that the state variable x_t, reflecting the "stock of relevant country specific information", will be updated continuously with increment given by

$$dx_t = \mu_x dt + \sigma_x dB_t^{(x)}, \tag{4}$$

where $dB_t^{(x)}$ is the increment of a standard Brownian motion and where μ_x and σ_x are constants.

Two testable implications of equation (4) are that the increments of x_t are independent and normally distributed. Based on available ICRG indices and Institutional Investor's country credit rating (IICCR), we used equation (3) to derive time series for the unobservable state variable x_t for forty four oil producing countries. The forty four countries were those listed in the BP (British Petroleum) Statistical Review 1997, see Table 2. The sample period is covering nine years starting in 1988 and ending in 1996. One of the main events in the oil market during this period was the Gulf War. Iraq invaded Kuwait on August 2 1990 and operation Desert Storm withdrew from Kuwait on February 27 1991. Events affecting the political risk during this period was, e.g., the fall of the Berlin wall and the opening up in China with the establishment of free economic zones.

The average of the countries' ICRG composite risk indices in March 1996 was 68.7. The countries with highest composite risk, i.e., lowest CR, were Iraq, Angola, Algeria, Cameroon,

and Congo. The countries with the lowest risk according to ICRG CR were Brunei,

Denmark, Norway, and USA. As for the ICRG indices, high/low IICCR-values corresponds

to situations with low/high risk. The highest possible level of IICCR is 100 and the lowest

possible level is zero. The average of the IICCR at the beginning of the sample period was

41.3. The lowest rated countries were Iraq, Angola, Congo, and Uzbekistan. The highest

rated countries were USA, United Kingdom, Norway, and Denmark.

The results of the tests of the increments of the deduced variables are summarized in Table 3.
 For the ICRG indices the tests were based on monthly, quarterly, and half yearly

observations. For the IICCR, only half yearly observations were available.

For the ICRG indices with monthly observations, the case against a rejection for almost *all*

countries is very strong. For the ICRG CR, all the countries are rejected. The reason why

this rejection is strong may, of course, be because the assumptions are wrong, i.e., equation

(3) and/or (4). Another possibility is that the data is censored. The risk indices are only

quoted with one or two decimals. A small change in the underlying variable x_t would then

not lead to a change in the risk index ψ_t. By increasing the length between observations, we

would expect that x_t would change more and thereby lead to changes in ψ_t. This would,

hopefully, make the problem with censored data less severe. On the other hand, by increasing

the length between observations the number of observations become fewer and thereby

making it harder to reject any hypothesis due to the smaller sample size. We see from Table

3 that by increasing the time span between observations from monthly to quarterly, the

process assumptions for the ICRG economic risk and composite risk indices cannot be

rejected for 8 of the 41 countries for which there is data. By increasing the length from

quarterly to half yearly observations, the process assumptions cannot be rejected for most of the countries, expect for the ICRG FR, and for the ICCCR.

Based on the results of the tests reported in Table 3 we may conclude that, for some countries, the risk indices may be modeled according to equations (3) and (4). For other countries we may also conclude that this model is questionable, based on empirical data for the sample period.

(Insert Table 2 approx. here)

(Insert Table 3 approx. here)

2.2 Spot price of oil

In the oil industry country risk and oil price risk are probably the two most important risk factors. We use a standard assumption in the contingent claims and model the spot price of oil as a geometric Brownian motion with constant parameters, i.e., the increment of the oil price may be written as

$$\frac{dS_t}{S_t} = \mu_S dt + \sigma_S dB_t^{(S)}, \tag{5}$$

where $dB_t^{(S)}$ is the increment of a standard Brownian motion and where μ_S and σ_S are constants. The Brownian motions governing the oil price and the risk index may be correlated, i.e., $dB_t^{(S)} dB_t^{(x)} = \rho dt$.

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Having investigated properties of the variables deduced from a set of risk indices in the previous section, we also wanted to investigate the properties of the oil price during the same sample period. For the spot price of oil we used the Brent Blend crude oil prices. The statistics for the sample period are reported in Table 4. For the whole period, the coefficient of correlation, either lagged one or two periods, is significantly different from zero at five per cent significance level, and the test based on the studentized range statistic indicates that the hypothesis of normally distributed increments can be rejected. By excluding the period for the Gulf War, only the coefficient of correlation between the lagged increments for quarterly data are significantly different from zero. Statistics are also reported for the period before and after the Gulf War.

We also estimated the coefficients of correlation between the various risk indices and the oil price. These estimates are summarized in Table 5A. A positive coefficient of correlation between the deduced variable and the state variable governing the oil prices means that the risk, as measured by the index, is reduced when the oil price increases. When the coefficient is negative, an increase in the oil price is likely to occur together with an increase in risk. There are some intuitive explanations for why the correlation should be positive or negative. If the country is mainly dependent on the production and sale of oil for its revenue, a reduction in the oil price may lead to political turmoil, i.e., increased risk (positive correlation). A large drop in the oil revenue combined with a lack of willingness to cut back on public spending may reduce the country's credit rating. On the other hand, if the country is a major oil producer then a political uncertain situation in the country may lead the participants in the oil market to believe that there is a chance for a reduction in the supply of

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oil. This can cause oil prices to rise. In this instance the risk indices and the oil prices are negatively correlated. A negative coefficient of correlation may also be expected if the country is a large net importer of oil. An increase in the oil price will increase the cost of an important input factor and may cause the economy to slow down. This may again lead to political instability due to, e.g., unemployment concerns. The credit rating for the country may also drop.

For the sample period, there were more countries with negative estimated correlation coefficients than nonnegative, see Table 5A. The estimated coefficients were, however, rarely significantly different from zero. For Kuwait the correlation coefficient was significantly different from zero for all indices. The estimates were the following (coefficient): ICRG political risk index (-0.54), ICRG financial risk index (-0.68), ICRG composite risk index (-0.68), and IICCR (0.49).

(Insert Table 4 approx. here)

2.3 Valuation

If we want to find the value of claims on future levels of the oil price and /or risk indices, we may use the standard valuation methodology from the real options. This valuation approach is based on the same principles as those used when pricing derivatives on financial securities, as in Black and Scholes (1973). The *risk premium* for a financial asset solely influenced by risk of type i is $\pi^{(i)}$. The required expected return from holding a financial asset with an amount of risk equal to σ_i is μ_i^*, i.e.,

$$\mu_i^* = \pi^{(i)}\sigma_i + r \quad , \quad i = x, S , \tag{6}$$

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where r is the instantaneous risk free interest rate, assumed to be a constant. We define the drift adjustment or convenience yield, δ_i, as the difference between the required drift and the actual drift, i.e., $\delta_i \equiv \mu_i^* - \mu_i$. It is necessary to find the convenience yield in order to apply the *risk neutral valuation* principle. Consider the value at time zero of a claim equal to the index level at time t. The value of this claim is given by

$$V_0[\psi_t] = e^{-rt} E^* [L_{MIN} + (L_{MAX} - L_{MIN})N(x_t / \sigma_v)] \ , \tag{7}$$

where the notation E^* means that the when computing the expectation we use the "risk neutral process"

$$dx_t = (r - \delta_x)dt + \sigma_x dB_t^{(x)}. \tag{8}$$

When determining the required drift μ_x^* for the variable governing the risk index, we may determine the risk premium by applying the CAPM, as in Dixit and Pindyck (1994) page 115.

For the sample period 1988-1996 we estimated the betas for the variables deduced from a set of risk indices. As the risk free interest rate we used the six month Eurodollar rate. We used the Morgan Stanley Capital International World Index (MSCIWI), measured in US dollars, to represent the market portfolio. MSCIWI is a value weighted index reflecting reinvestment of dividends. The return on the market portfolio and the Eurodollar interest rate were all end of the month observations measured in nominal units. A summary of the beta estimates for the

country indices are shown in Table 5B. A positive beta means that high excess return on the market portfolio is expected to occur at the same time as a reduction in the country's risk level, as measured by the appropriate index. For most countries we expect a beta close to zero. The important fact to be aware of is that the variables deduced from the indices are not related in any clear way to prices of actually traded assets. A priori, it does not seem clear that the estimated betas should be different from zero, unless perhaps for big countries like USA. For large countries influencing the world economy we would expect that decreasing levels of risk occur at the same time as we observe high levels of market return, i.e., a positive beta. Most of the estimated betas were close to zero. We see from Table 5B that almost none of the estimated betas were significantly different from zero. This indicates that we may consider country risk, as measured by the indices, to be unsystematic risk.

(Insert Table 5 approx. here)

3 Example

We provide a stylized example of how risk indices may be included in the evaluation of an investment in an oil field under expropriation risk. The cash payment from the investment opportunity, provided it has not been abandoned at time t, is

$$C(S_t) = (S_t - k_t)q_t - K_t, \qquad (9)$$

where S_t is the spot price of oil, k_t is the variable costs per barrel produced, q_t is the quantity of oil ready for sale measured in barrels, and the payable fixed costs at time t is K_t.
The oil price dynamics is described by equation (5). If the decision to invest in phase one is

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made at time t, the investor will pay an amount I_t.

The oil field may be expropriated by the government in the country where the oil field is located with no compensation to the original owners. The expropriation is an irreversible decision by the government. We facilitate the presentation by introducing an integer valued stochastic process γ_t with jump intensity λ_t. This Poisson process starts at zero, and we assume that the oil field is expropriated the first time a jump occurs in this process. If the government has not expropriated the oil field at time t, the intensity of the Poisson process during the next increment of time, dt, is $\lambda(\psi_t)$. This intensity will depend on the level of risk in the country, as measured by a country risk index, in the following way:

$$
\lambda(\psi_t) = \begin{cases}
\lambda_1 = 0.00 & if\ 85 \leq \psi_t \leq L_{MAX} = 100 \\
\lambda_2 = 0.01 & if\ 70 \leq \psi_t < 85 \\
\lambda_3 = 0.02 & if\ 60 \leq \psi_t < 70 \\
\lambda_4 = 0.03 & if\ 50 \leq \psi_t < 60 \\
\lambda_5 = 0.04 & if\ L_{MIN} = 0 \leq \psi_t < 50
\end{cases} \qquad , \qquad (10)
$$

where we have used the same five risk categories for the index, just as an example, as the ICRG composite risk index, see Coplin and O'Leary (1994) p. 249. According to these categories, if the ICRG composite risk index is lower than fifty, the risk is categorized as "very high risk" and when the index is 85 or higher the category is "very low risk". The level and the dynamics of the risk index is assumed to be governed by a not directly observable state variable with numerical value equal to x_t at time t, as described by equations (3) and (4). The corresponding levels of this state variable are reported in Table 6. We also report the probability for expropriation during the next quarter and during the next year. These

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figures are based on the simplifying assumption that the probability that the project will be

expropriated at time $t + \Delta t$, assuming that it has not been expropriated at time t, is given by

$$P(1_{\{\gamma(t+\Delta t)\}} = 1 \mid \psi_t, \gamma_t = 0) = 1 - \exp(-\lambda(\psi_t)\Delta t), \qquad (11)$$

where the time step is Δt and where the indicator variable $1_{\{\gamma(t+\Delta t)>0\}}$ equals one only if the

project is expropriated at time $t + \Delta t$.

Because an option to abandon the investment may be valuable, especially in the presence of

expropriation risk, we include this option in the evaluation. The value of the investment

opportunity, given that the investment is made, with an option to abandon the investment will

satisfy the equation

$$F(S_t, \psi_t, \gamma_t) = Max[0, C(S_t) + V_t[F(S_{t+dt}, \psi_{t+dt}, \gamma_{t+dt})]] \cdot (1 - 1_{\{\gamma(t)>0\}}) \qquad (12)$$

where $F(S_t, \psi_t, \gamma_t)$ is the value of the oil field at time t. We have assumed that the salvage

value in case of abandonment is equal to zero. When deriving the value

$V_t[F(S_{t+dt}, \psi_{t+dt}, \gamma_{t+dt})]$ in (12), we use the "risk neutral" processes for the oil price and the

state variable governing the risk index, as implied by (8).

We calibrated the model and solved it numerically by using discrete time steps and a two-

dimensional binomial tree. For an explanation of this procedure see, e.g., Clewlow and

Strickland (1998). We used a time step of 0.25, i.e., three months. We selected a production

quantity of one barrel per time step (four barrels per year) for ten years. The fixed and variable costs were set to, respectively, USD 2.5 per quarter and USD 8 per barrel. The volatility of the spot oil price was set to 0.2 and the convenience yield to 0.05. The risk premium for the volatility of the process governing the risk index was set equal to zero, and the correlation coefficient between this process and the oil price was also zero. The risk free interest rate was assumed to be six per cent per year, and the investment amount was USD 100. Based on these assumptions we computed the value of the investment if it were done today. We also computed the value of delaying the investment decision one year. The break even spot price of oil if the investment is made today, time t, or never is S_t^{N*}. The spot price of oil that makes investing today preferred to waiting is S_t^{W*}. We define the relative hurdle for the spot price of oil at time t, H_t, to be the relative relationship between these break even prices, i.e., $H_t \equiv S_t^{W*} / S_t^{N*}$. The number H_t is a measure of the incentive to wait compared to the alternative of investing now.

The relative investment threshold for different combinations of expected development and volatility of the variable governing the risk index, i.e., μ_x and σ_x, are shown in Table 7. The incentive to wait is higher for lower levels of the index, i.e., when the risk is high. The lowest level of H_t is 1.35 and the highest is 1.52. The intuition behind this result is that if the risk level is high (low index level), then it is more likely that the project will be expropriated. The value of waiting is therefore relatively lower, making the investment threshold smaller. The same reasoning may be used when explaining that the investment threshold tends to be reduced when the expected change in the risk index, here represented by μ_x, is reduced. The effect of increased volatility depends on the index level. At low index

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levels, an increase in the volatility, represented by σ_x, makes it more likely that the risk is reduced in the future (higher index levels). The investment threshold may therefore be increased. The opposite effect will apply with an initial high index level.

(Insert Table 6 approx. here)

(Insert Table 7 approx. here)

4 Summary

Country risk and in particular political risk may constitute a large part of the total risk investors face when investing in emerging markets. We examine how country risk may be defined and at the sources of information country risk analysis may be based on. We suggest a valuation model based on the contingent claims valuation methodology, where country risk indices are used as state variables. We report summaries of tests made to examine whether the assumptions underlying this model are reasonable. These tests are based on a selection of country risk indices for oil producing countries. We demonstrate how such a model may be implemented when evaluating an investment in an oil field under expropriation risk. Finally, we provide a numerical example demonstrating how the incentive to wait may depend on the present level of a country risk index and the dynamic behavior of this index.

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Definition of risk:

Risk = dispersion

Country effects in return on investment

Risk = loss

	Lending	Equity	FDI
	Private borrowers, generalized country risk	Generalized country risk, equity investments	Generalized country risk, FDI
	Lending to governments, sovereign (credit) risk		

Type of investment:

Figure 1   Use of the term country risk

Political Risk (PR)	Max Points	Financial Risk (FR)	Max Points	Economic Risk (ER)	Max Points
Economic expectation vs. reality	12	Loan default or unfavorable		Inflation	10
Economic planning failures	12	loan restructuring	10	Debt service as a percent of export	
Political leadership	12	Delayed payment of suppliers'		of goods and services	10
External conflict	10	credit	10	International liquidity ratios	5
Corruption in government	6	Repudiation of contracts by		Foreign trade collection experience	5
Military in politics	6	governments	10	Current account balance as a	
Organized religion in Politics	6	Losses from exchange		percentage of goods and services	15
Law and order tradition	6	controls	10	Parallel foreign exchange rate	5
Racial and nationality tensions		FR5 Expropriation of			
Political terrorism	6	private investments	10		
Civil war	6				
Political party development	6				
Quality of bureaucracy	6				
Maximum Possible Rating	**100**		**50**		**50**

Composite Risk Rating (CRR)=(PR+FR+ER)/2.

General Principle: The higher the rating, the lower the risk.

Table 1   The ICRG rating system. Source: *The handbook of country and political risk*, Political Risk Services, USA, 1994
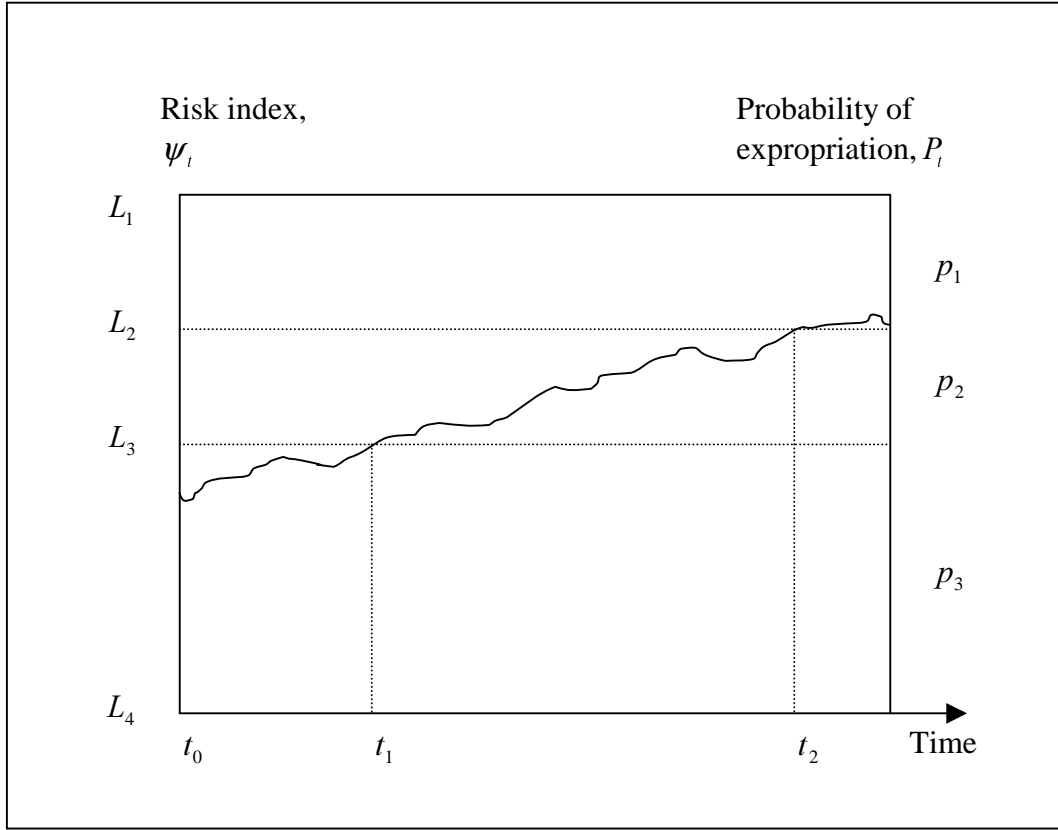
Figure 2   Example of a relationship between the probability of an immediate expropriation of an investment and the level of a risk index

Algeria	Canada	India	Mexico	Romania	United Arab
Angola	China	Indonesia	Nigeria	Russian	Emirates
Argentina	Colombia	Iran	Norway	Federation	United Kingdom
Australia	Congo	Iraq	Oman	Saudi Arabia	USA
Azerbaijan [*,**]	Denmark	Kazakhstan[*]	Papua New	Syria	Uzbekistan[*]
Brazil	Egypt	Kuwait	Guinea	Trinidad &	Venezuela
Brunei	Equador	Libya	Peru	Tobago	Vietnam
Cameroon	Gabon	Malaysia	Quatar	Tunisia	Yemen[**]

[*] For this country the ICRG indices were not available.
[**] For this country the IICCR was not available.

Table 2   Oil producing countries listed in BP Statistical Review, 1997.

Time between observations	Number of countries	Risk index				
		The ICRG index for				Institutional investor's country credit rating
		Political risk	Financial risk	Economic risk	Composite risk	
Monthly[1]	Total in sample	41	40	41	41	N.A.
	Nos. rejected	41	40	41	41	N.A.
	- normality[4]	30	32	28	33	N.A.
	- indep. increments[5]	0	0	0	0	N.A.
	- both normality & indep. Increments	11	8	13	8	N.A.
Quarterly[2]	Total in sample	41	40	41	41	N.A.
	Nos. rejected	34	37	33	33	N.A.
	- normality[4]	26	25	23	29	N.A.
	- indep. increments[5]	2	0	7	3	N.A.
	- both normality & indep. Increments	6	12	3	1	N.A.
Bi-annual[3]	Total in sample	41	40	41	41	41
	Nos. rejected	16	29	16	18	27
	- normality[4]	16	23	12	14	10
	- indep. increments[5]	0	3	2	3	15
	- both normality & indep. Increments	0	3	2	1	2

From a time series of observations of risk indices ($\psi_1, \psi_2, \ldots, \psi_N$), a corresponding time series of a variable ($x_1, x_2, \ldots, x_N$) is deduced by using the equation $\psi_t = L_{MIN} + (L_{MAX} - L_{MIN}) N(x_t / \sigma_v)$, where N(.) is the cumulative distribution function for the unit normally distributed variable and σ_v was set equal to one. The reported tests are based on the increments of x, i.e., $x_{t+1} - x_t$.

(1) Number of observations: 152 for all countries, except for the following: 148 (Papua New Guinea), 146 (Oman), 145 (Quatar), 141 (China), 137 (Congo), 131 (Angola, Brunei, Vietnam), 53 (Russian Federation), and 45 (Yemen).

(2) Number of observations: 50 for all countries, except for the following: 49 (Papua New Guinea), 48 (Quatar, Oman), 47 (China), 45 (Congo), 43 (Angola, Brunei, Vietnam), 17 (Russian Federation), and 15 (Yemen).

(3) Number of observations for ICRG indices: 25 for all countries, except for the following: 24 (Quatar, Oman, Papua New Guinea), 23 (China), 22 (Congo), 21 (Angola, Brunei, Vietnam), 8 (Russian Federation), and 7 (Yemen). Number of observations for IICCR: 25 for all countries, except for the following: 8 (Russian Federation, Kazakhstan, Uzbekistan), and 9 (Vietnam).

(4) The test of normality is based on the p-value of the Bera-Jarque test of normality and the studentized range. The assumption about normality for a country is reported as rejected if we, based on *any* of these tests, may reject the normality hypothesis at the five per cent significance level. The Bera-Jarque test is based on the statistic $J = n[(\text{coeff. of skewness})^2/6 + (\text{excess kurtosis})^2/24]$. In case of normality, J is chi squared distributed with two degrees of freedom.

(5) The test of independence between increments is based on computing the correlation between lagged increments. We lagged the increments one and two periods. If the hypothesis of no correlation can be rejected at the five per cent significance level, the respective country is reported in the table.

Table 3   Summary of the numbers of countries rejected when testing for independence and normality of increments of variable deduced for a selection of risk indices. Data for time period 1984-1996.

Period	Observations	N	Mean	t-value[1]	Variance	Coeff of skewness	Excess kurtosis	B-J[2], p-value	Studentized range	$\rho_1^{[1],[4]}$	$\rho_2^{[1],[4]}$
Whole period	Bi-annual	17	0.0239	0.29	0.1170	0.252	2.340	0.13	4.65 h**	-0.546 *	0.090
	Quarterly	35	0.0079	0.21	0.0520	1.848	7.331	0.00 **	5.83 l**	-0.190	-0.417 *
	Monthly	105	0.0026	0.28	0.0095	0.645	3.988	0.00 **	7.37 h**	0.237 *	-0.017
-excl.Gulf War	Bi-annual	15	0.0225	0.42	0.0427	0.967	1.635	0.13	4.02	-0.485	0.029
	Quarterly	32	0.0032	0.13	0.0194	0.339	-0.591	0.58	3.95	-0.091	-0.401 *
	Monthly	98	0.0029	0.39	0.0054	-0.102	-0.224	0.83	5.01	0.018	-0.115
Pre Gulf War	Monthly	31	0.0022	0.14	0.0083	0.089	-0.442	0.86	4.06	0.090	-0.212
Post Gulf War	Monhtly	67	0.0032	0.41	0.0042	-0.314	-0.449	0.44	4.15	-0.043	-0.041

Whole period: 1988-1996. Gulf War: August 1990-February 1991. [1] * and ** indicates whether the estimate is signifcantly different from zero, using a two sided test and a significance level of five and one per cent, respectively. [2] The p-value of the Bera-Jarque test of normality, based on the statistic $J=n[(\text{coeff. of skewness})^2/6+(\text{excess kurtosis})^2/24]$. In case of normality, J is chi squared distributed with two degrees of freedom. The reported p-value is the probability of observing a J statistic equal to or lower than the samle statistic J. [3] h* and h** indicates that in a normal distribution with n observations, the probability of the observed studentized range being this high is less than 0.05 and 0.02, respectively. Similarly, l* and l** indicates that the probability of the observed studentized range being this low is less than 0.05 and 0.01. [4] Coeffcent of correlation between observations, where one observation is lagged one or two periods.

Table 4   Statistics for sample of the logarithm of relative Brent Blend oil prices

Estimated parameter	Categories for estimated parameters	Risk index			
		The ICRG index for			Institutional investor's country credit rating
		Political risk	Financial risk	Composite risk	
Total number of countries		41	40	41	41
Table 5A					
Coefficient of correlation [1]	$0.5 < \rho \leq 1$	0	0	0	1
	$0 \leq \rho \leq 0.5$	16	18	16	16
	$-0.5 \leq \rho < 0$	22	20 [1]	21	23 [2]
	$-1 \leq \rho < -0.5$	3 [3]	2 [2]	4 [3]	1 [1]
Table 5B					
Beta [2]	$1 < \beta$	3	1	2	0
	$0 \leq \beta \leq 1$	19 [1]	14 [2]	17 [2]	24 [2]
	$-1 \leq \beta < 0$	19	25 [1]	22 [1]	17
	$\beta < -1$	0	0	0	0

The estimates were based on half yearly observations. Number of observations for ICRG indices: 25 for all countries, except for the following: 24 (Quatar, Oman, Papua New Guinea), 23 (China), 22 (Congo), 21 (Angola, Brunei, Vietnam), 8 (Russian Federation), and 7 (Yemen). Number of observations for IICCR: 25 for all countries, except for the following: 8 (Russian Federation, Kazakhstan, Uzbekistan), and 9 (Vietnam).

(1) From a time series of observations of risk indices ($\psi_1, \psi_2, \ldots, \psi_N$), a corresponding time series of a variable ($x_1, x_2, \ldots, x_N$) is deduced by using the equation $\psi_t = L_{MIN} + (L_{MAX} - L_{MIN}) N(x_t / \sigma_v)$, where N(.) is the cumulative distribution function for the unit normally distributed variable and σ_v is equal to one. The coefficient of correlation between the increments of x, i.e., $x_{t+1} - x_t$, and the log of relative Brent Blend oil prices is then estimated. The number in brackets, [.], corresponds to the number of countries for where the estimated parameter was significantly different from zero at the five per cent significance level

(2) The estimation of beta was based on the equation $[(x_{t+1} - x_t) - r_t] = \alpha + \beta (R_t - r_t) + \varepsilon$, where r_t is the six month Eurodollar interest rate, R_t, is the six month return on the Morgan Stanley Capital Internal World Index, and ε is the error term. The number in brackets, [.], corresponds to the number of countries for where the estimated parameter was significantly different from zero at the five per cent significance level

Table 5   Summary of the numbers of estimated correlation coefficients and betas. Data for time period 1988-1996.

Country risk and FDI valuation

Risk category[*]	Unobservable variable[**]	λ_t	$P(1_{\{\gamma(t+\Delta t)>0\}} = 1\}$[***]	Annualized[***][*]
$85 \le \psi_t \le 100$	$1.036 \le x_t \le \infty$	0.00	0.000	0.000
$70 \le \psi_t < 85$	$0.524 \le x_t < 1.036$	0.01	0.002	0.010
$60 \le \psi_t < 70$	$0.253 \le x_t < 0.524$	0.02	0.005	0.020
$50 \le \psi_t < 60$	$0.000 \le x_t < 0.253$	0.03	0.007	0.030
$0 \le \psi_t < 50$	$-\infty \le x_t < 0.000$	0.04	0.010	0.040

[*] Corresponds to the categories given for the ICRG composite risk index, see Coplin and O'Leary (1994) p. 249. [**] Derived by using the equation $\psi_t = L_{MIN} + (L_{MAX} - L_{MIN}) \, N(x_t / \sigma_v)$, where $N(x_t / \sigma_v)$ is the cumulative distribution function for the unit normally distributed variable and σ_v is equal to one. [***] Rounded to three decimals. $\Delta t = 0.25$ [****] Approximated by the formula $1 - (1 - P(1_{\{\gamma(t+\Delta t)>0\}} = 1))^{1/\Delta t}$, rounded to three decimals.

Table 6   Risk indices and probability of expropriation

Level of index today	Expected change, μ_x	Volatility, σ_x			
		0,05	0,1	0,15	0,2
90	-0.05	1.47	1.47	1.47	1.46
	0.00	1.52	1.50	1.50	1.49
	0.05	1.52	1.52	1.51	1.51
70	-0.05	1.38	1.39	1.39	1.39
	0.00	1.44	1.43	1.43	1.42
	0.05	1.47	1.47	1.47	1.46
50	-0.05	1.35	1.35	1.36	1.37
	0.00	1.37	1.38	1.38	1.39
	0.05	1.41	1.41	1.42	1.42

Table 7   Investment threshold for the numerical example for different combinations of present index level, expected development, and volatility