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UNDERSTANDING AND MANAGING RISKS IN LARGE ENGINEERING PROJECTS

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Understanding and Managing Risks in Large Engineering Projects

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Large engineering projects are high-stakes games characterized by substantial irreversible commitments, skewed reward structures in case of success, and high probabilities of failure. Once built, projects have little use beyond the original intended purpose. Potential returns can be good but they are often truncated. The journey to the period of revenue generation takes 10 years on average. Substantial front-end expenditures prior to committing large capital costs have to be carried. During the ramp-up period, market estimates are tested and the true worth of the project appears; sponsors may find that it is much lower than expected. Bankers can discover that covenants will not be respected. Restructuring of ownership and debt may be the only way to save prior investments.

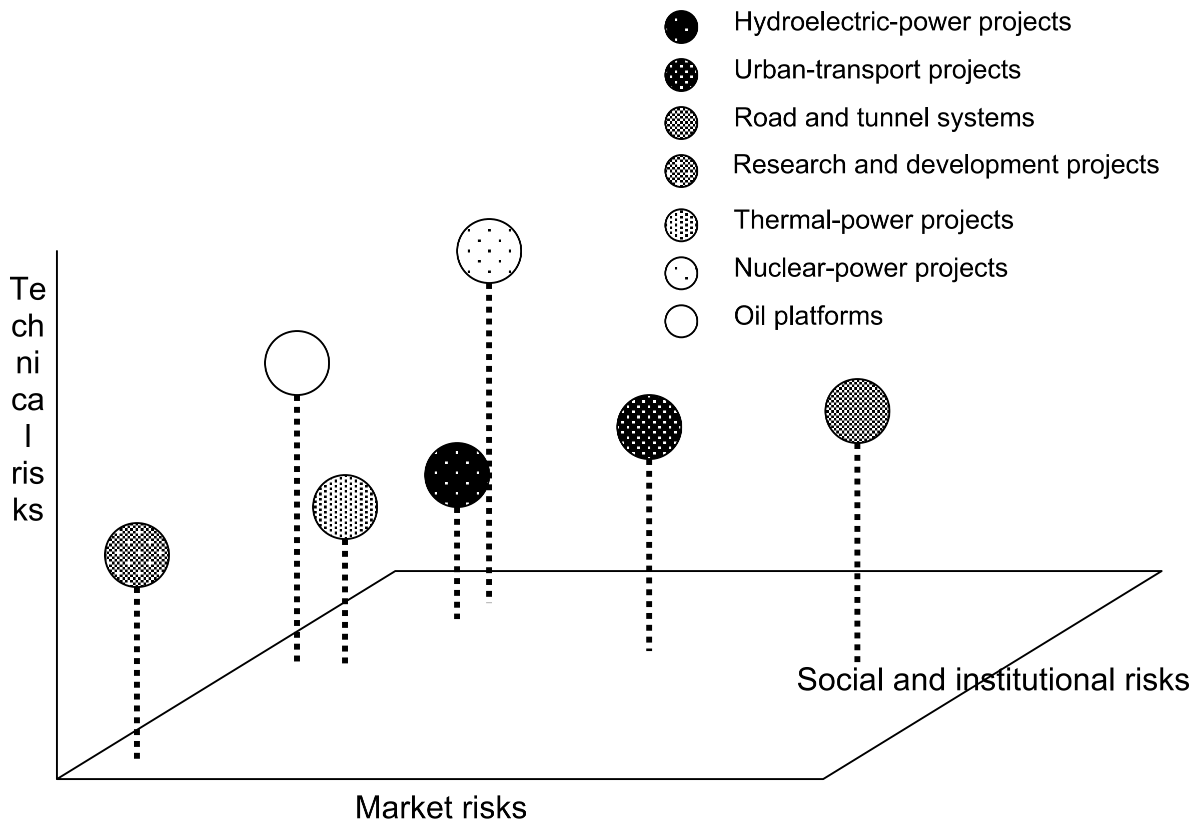
Managing risks is thus a real issue. The purpose of this article is to sketch-out the various components of risk, outline strategies for coping with risk and suggest a dynamic layering model for managing and shaping the risks of projects. The main argument developed in this article is that successful projects are not selected but shaped with risk resolution in mind. Rather than evaluating projects at the outset based on projections of the full sets of benefits, costs and risks over their lifetime, successful sponsors start with project ideas that have the possibility of becoming viable. Successful sponsors then embark on shaping efforts to influence risk drivers. The seeds of success or failure are thus planted and nurtured as conscious choices are made. Successful firms cut their losses quickly when they recognize that a project has little possibility of becoming viable.

Sponsors' difficulties stem largely from the fact that most of what we know about risks has been inherited from either Wall Street or Las Vegas. At the casino, the odds are public knowledge: success is strictly a matter of "beating" them. In financial markets, price fluctuations are not fully probabilistic, but indices make for decision situations that can be modeled with a sophisticated craft. By contrast, risks in real-life projects emerge over time, are indeterminate and often endogenous. External turbulence and surprise shocks can send a project into a degenerating crisis.

A Risk-based Taxonomy of Large Engineering Projects

Risks also differ according to types of projects. Figure 1 positions various types of projects according to the intensity of the risks they pose to sponsors. For instance, *oil platforms* are technically difficult, but they typically face few institutional risks because they are often built far from public attention and are socially desired because of the high revenues they bring to communities and countries. *Hydroelectric-power projects* tend to be moderately difficult insofar as engineering is concerned, but very difficult in terms of social acceptability. *Nuclear-power projects* pose high technical risks but still higher social and institutional risks.

Figure 1: A risk-based taxonomy of large engineering projects



Road and tunnel systems present very high levels of risk. Rock formations usually hide surprises. Social acceptability difficulties abound when user fees are applied. Market risks faced by roads, bridges, and tunnels are very high when they are built by private sponsors under concessionary schemes. *Urban transport projects* that meet real needs pose average market, social, and institutional risks. However, they still pose technical risks, as they regularly involve underground geological work. *Research-and-development projects* present scientific challenges but face fewer social acceptability and market difficulties as they can be broken into smaller testable investments.

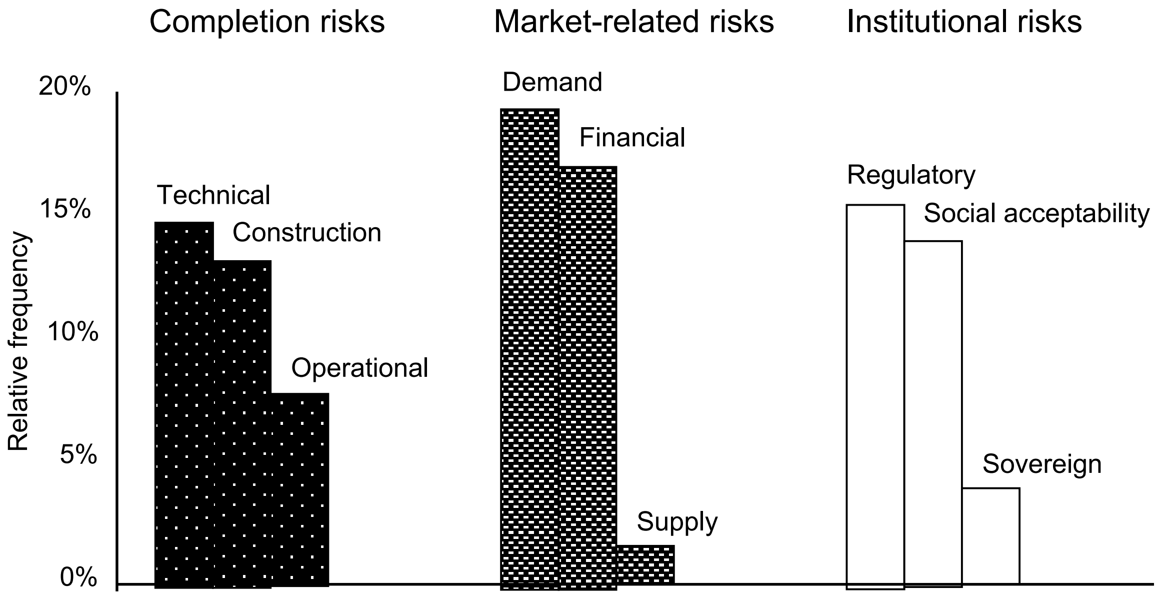
The Nature of Risks in Projects

Risk is the possibility that events, their resulting impacts and dynamic interactions may turn out differently than anticipated. While risk is often viewed as something that can be described in statistical terms, while uncertainty applies to situations in which potential outcomes and causal forces are not fully understood we refer to both as risks Risks are multi-dimensional and thus need to be unbundled for clear understanding of causes, outcomes, and drivers. Nevertheless, since their impacts depend on how they combine and interact, reductionism must be avoided.

In the IMEC study in which 60 large projects were investigated across the world, managers were asked to identify and rank the risks they faced in the early front-end period of each project (Miller and Lessard, 2001)[3]. Market-related risks dominated (41.7%), followed by technical risks (37.8%), and institutional/sovereign risks (20.5%). Figure 2 gives the frequency of citations of the risks that managers ranked first, second, and third in the early parts of projects.

[3] The IMEC project studied 60 major engineering projects in Europe, North and South America, and Asia.

Figure 2: Major risks in large engineering projects



- Market-Related Risks

The ability to forecast *demand* varies widely, thus creating high levels of risks. The output of oil projects is a fungible commodity sold in highly integrated world markets: probabilistic forecasts are possible. In contrast, many road projects face a specific set of customers which often have many options. Users of highways, tunnels, bridges, airports, and ports often have alternatives: forecasting is extremely difficult.

The market for *financial inputs* depends on prior risk management. Unless all risks have been addressed by sponsors, financial markets are hard to reach. If a project offers an adequate prospective return, it is often unable to go forward because of the parties' inability to work out acceptable risk-sharing arrangements. *Supply risks* are similar to market risks: both involve price and access uncertainties. Supply can be secured through contracts, open purchases or ownership.

- Completion Risks

Projects face *technical risks* that reflect their engineering difficulties and novelty: some of these risks are inherent in the designs or technologies employed. *Construction risks* refer to the difficulties that sponsors, prime contractors, and contractors may face in the actual building of the project. *Operational risks* refer to the possibility future income flows will not materialize: such risks can be reduced substantially by the selection of an operator with an economic interest in enhancing revenues and controlling costs.

- Institutional Risks

The ability of projects to repay debts and investments depends on law and regulations that govern the appropriability of returns, property rights, and contracts. Some countries are governed under constitutional frameworks and the rule of law, while others are led by powerful political parties or clans. Institutional risks are typically seen as greatest in emerging economies – in countries whose laws and regulation are incomplete and in a state of flux.

Regulations concerning pricing, entry, unbundling, and other elements are presently undergoing major changes in many countries, thus opening opportunities. *Social-acceptability risks* refer to the likelihood that sponsors will meet opposition from local groups, economic-development agencies, and influential pressure groups. *Sovereign risks* in turn involve the likelihood that a government will decide to renegotiate contracts, concessions, or property rights.

Many of these risks emerge over time. Projects that appeared sound at a point in time suddenly become ungovernable. Risks combine and interact to create turbulence. Many risks are linked to the life cycle of the project: regulatory risks, for instance, diminish very soon after permits are obtained: technical risks drop as engineering experiments are performed. Some risks, especially market-related ones continue as they are partly independent of project life cycle. Global market risks that are outside the control of virtually all players.

Approaches to Managing Risk in the Large Engineering Project

It is useful to distinguish between two broad categories of approaches to risk management: (I) decision theoretic approaches that by and large assume that risks are exogenous and (II) managerial approaches that recognize that risk depends on the interaction among exogenous risk drivers, managerial choices during the front end, and the shaping of risk drivers throughout the process.

Decision-theoretic approaches view projects as gambles in which sponsors attempt to identify options and probabilities. Strategists select a move with a high payoff, make a bet, and wait for the probabilities to materialize. Groups of executives brainstorm to identify likely events and decision trees are built to identify the solution with the highest expected utility.

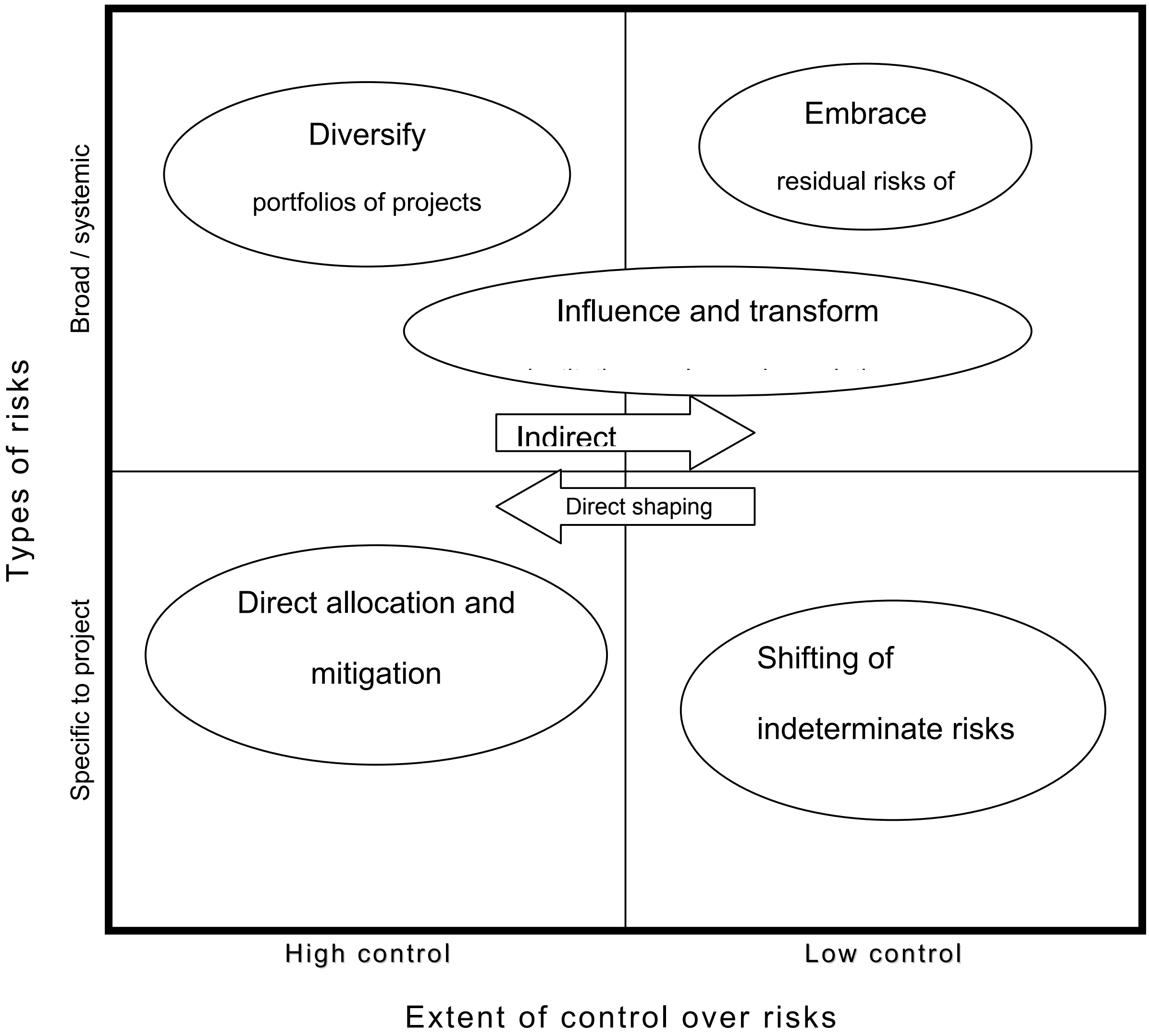
The gamble metaphor is however not always applicable to real-life projects. First, it is simply impossible to predict the future of projects over the 10-15 year period of shaping, building, ramping up, and early operation – not to mention the entire life of the project. Second, the intellectual exercise in which the complete set of relevant futures can be laid out is difficult to achieve under conditions of turbulence. Decisioneering approaches also *view LEP's as ventures that can be planned and specified in advance.* The future of projects is said not to be dictated by circumstances but by management (Urban and Hauser, 1980; Cooper 1997). Careful analyses of trade-offs between costs and risks, it is claimed, can yield good approximations for the appropriate timing of investment in projects. Accelerating a project will increase development costs to the point that there is a danger of sinking it. Proceeding with prudence increases the danger of missing the opportunity that the project aims for.

Managerial approaches by contrast view projects as complex adaptive systems facing endogenous risks as well as exogenous surprises that cannot always be anticipated in advance. Diligent sponsors do not sit idle, waiting for the probabilities to yield a "win" or a "loss," but work hard to influence outcomes and turn the selected initial option into a success. They shepherd their choice in light of changing conditions and often succeed against odds. Dynamic complexity, because of its turbulent and unpredictable nature, has to be met by versatile managerial approaches. The front-end decision processes observed by IMEC were messy, often chaotic: the untidiness reflected the various moves made by managers.

Managerial strategies to cope with risks

Sponsors strategize to influence outcomes by using four main risk-management techniques: (I) shape and mitigate; (II) shift and allocate; (III) influence and transform institutions; and (IV) diversify through portfolios. Figure 3 illustrates these techniques along two axes: the extent to which risks are controllable and the degree to which risks are specific to a project or systematically affect large numbers of actors. When risks are "endogenous" – that is, specific and controllable – the prescription is to mitigate with traditional risk management approaches. In contrast, when risks are specific but outside the control of any of the potential parties, shifting or allocating them using contracts or financial markets is the appropriate solution. When risks are poorly defined and under the control of affected parties, governments, or regulators, transforming them through influence is the way for sponsors to gain control. When risks are broad, systematic, but controllable, the approach is to diversify exposure through portfolios or projects. Residual, systematic, and uncontrollable risks have to be embraced by sponsors.

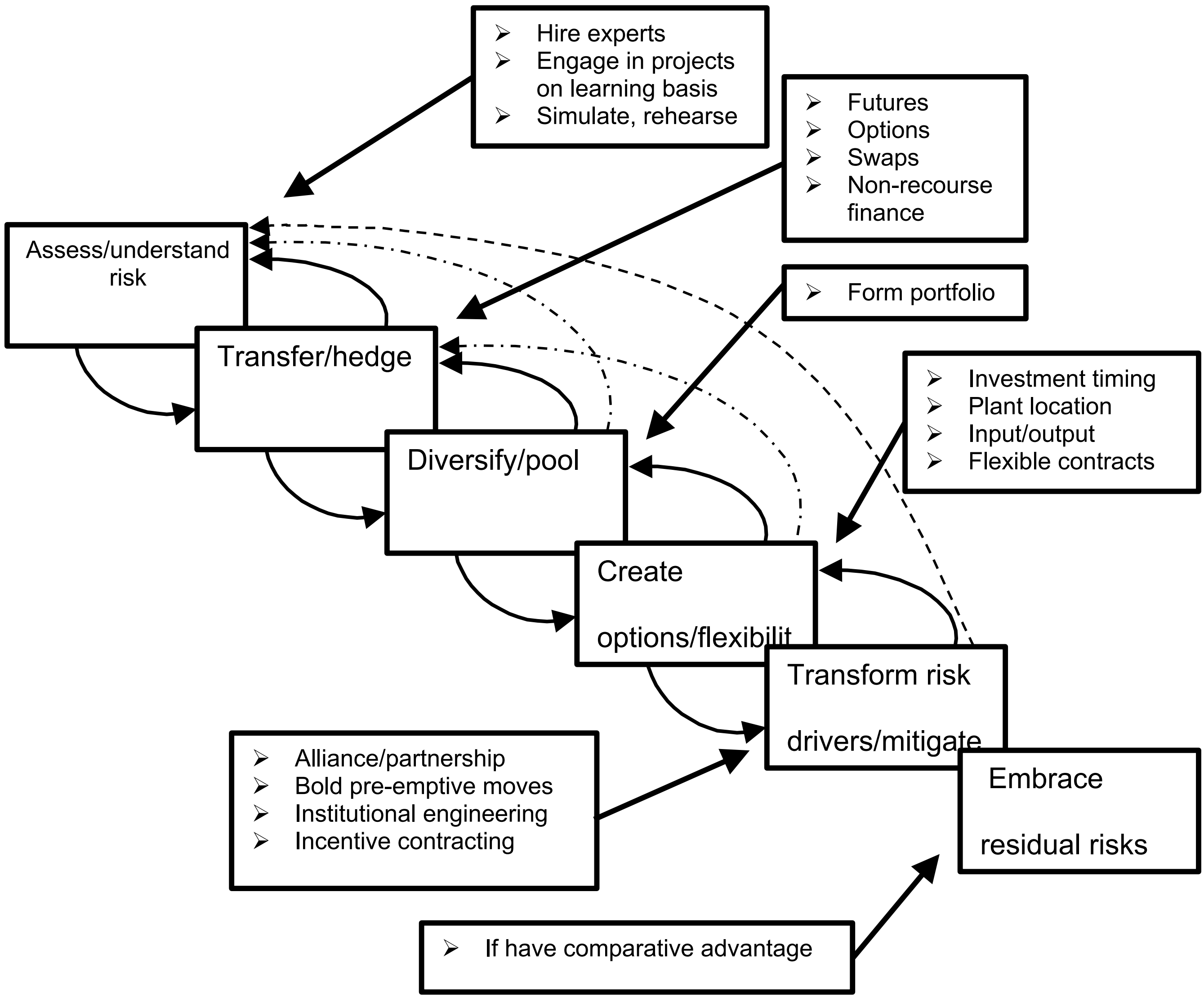
Figure 3: Strategies to cope with risks



The process of strategizing to understand and manage risks through mitigation, allocation, influence, and diversification prior to embracing residual uncertainties is best described as interactive layers of choices. The reasoned assignment of knowable risks starts by discovering and assigning them to a coping strategy. Some risks will be dealt with by using financial markets, others by institutional shaping, still others by project coalitions. Many can be assigned to partnership members in accordance with these parties' knowledge, influence, and ability to shape, exploit, and bear them.

Tracing risk management in 60 large engineering projects, we identified six primary mechanisms used by managers for coping with risks (see figure 4). First, risks are understood by hiring experts or undertaking analysis and simulations. Second, risks that are significant but transferable, especially if they are closely matched by market instruments, are transferred to parties that can best bear them. Third, project risks are pooled through the constitution of large portfolios. Fourth, options are designed to allow a greater range of responses in line with future outcomes. Fifth, remaining risks are shaped or transformed through influences on drivers as they are the result of behaviors by other social agents. Finally, residual risks are embraced by sponsors. This layering process is repeated in many iterative episodes until final commitments are made.

Figure 4: The layering process



Potential participants do not have equal comparative advantages in risk bearing. Participants to be selected for membership in a project structure should display complementary comparative advantages in taking the lead with a particular risk. Relative superiority in risk bearing may arise for any one of three reasons: some parties may have more information about particular risks and their impacts than others; some parties or stakeholders may have different degrees of influence over outcomes; or some investors differ in their ability to diversify risks. Figure 5 illustrates how potential partners differ in their ability to control risks and enjoy a comparative advantage. For instance, local partners can influence outcomes but have little ability to diversify risks and little knowledge about commercial prospects worldwide. World portfolio investors certainly diversify risks, but their ability to know about local commercial prospects or to influence outcomes is low.[4]

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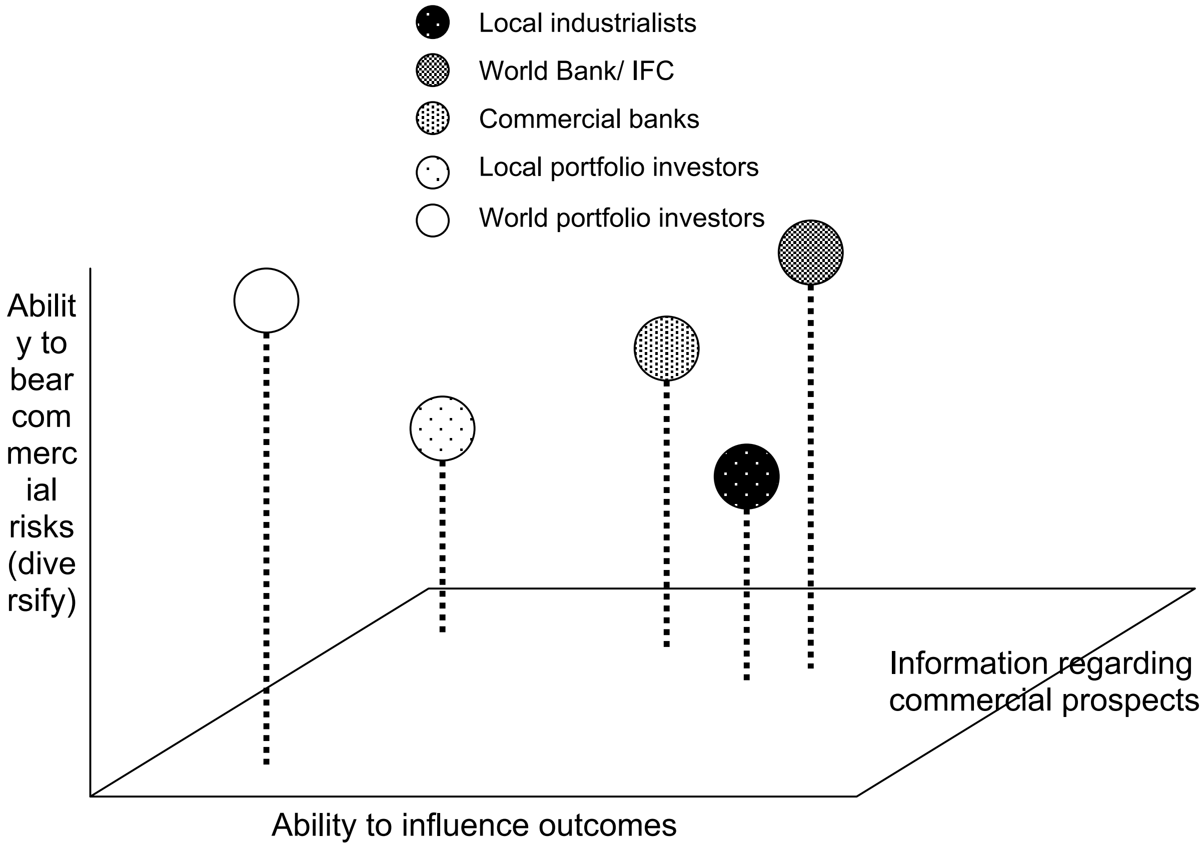
[4] This concept is developed in Lessard [1989]2311234.

Figure 5: Comparative advantage in risk taking



Strategizing about risks is almost always beneficial, but at some point diminishing returns set in and the costs of acquiring additional information or gaining control over risks fall short of their value. The design of responses to risks must be judged on a cost-benefit basis. Aligning performance incentives is critical when particular parties to the project have a significant degree of control over the economic value created by the project but do not have an incentive to maximize this overall value.

Conclusion: Creation and Exercise of Options

The front-end process to cope with risks is consistent with the real-options framework that is currently revolutionizing academic treatments of project evaluation. [5] However, while the emphasis of the real options literature is how to "price" the risks involved, ours is on the managerial process of recognizing, shaping, and realizing these options. In fact, as is often the case with cutting-edge practice, managers have been successful at creating value through the development and exercise of sequential options without explicitly framing the process in options terms. Academics have simply codified this practice in the form of a new conceptual framework.

The real-options approach recognizes that decisions that determine project cash flows are made sequentially over many episodes. The key insight of this approach is that uncertainty or volatility can actually increase the value of a project, as long as flexibility is preserved and resources are not irreversibly committed. As a result, the economic value of a project when it is still relatively unformed is often greater than the discounted present value of the expected future cash flows. Value is increased by creating options for subsequent sequential choices and exercising these options in a timely fashion. Thus, sponsors seek projects that have the potential for large payoffs under particular institutional and technical circumstances.

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[5] The real-options framework is based on the same logic as that of financial options as developed by Black and Scholes (1974). Dixit and Pindyck (1995) and Trigeorgis (1996) extend it to real options.

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