The Decision of Investment and its Funding in an Undergoing Institutional Environment: the Case of a Nuclear Equipment

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1. The French Context

- Modification of the industrial structure:
  - EdF is a public integrated monopoly
  - The European Electricity Directive of December 19th, 1996
  - Opening of the generation sector to competition

    Objectives of technical and allocative efficiency
  - The organization will be decided at the total opening,

    on July 1, 2004-2007

    It will be characterized by uncertainty of prices
  - EdF will be an IPP, which can be privately owned

    The capital of IPPs is divided between equity and debt

- Question of the renewal of the NPPs
  - 80% of the French production is of nuclear origin
  - Privatization of nuclear power producers in competitive markets: British Energy
  - 2 market imperfections:
    - corporate taxes,
    - possibility of bankruptcy

2. Problem

What influence can the opening of capital of the electricity producer have on its decision to invest in an additional nuclear equipment?

- **Intuition:** NPPs are irreversible investments – Debt gives some ability to the firm to « resell » its capacity

3. Literature

- The Real Options Theory (ROT):

  H threshold to invest / M threshold to invest (NPV)

  - A firm with an opportunity to invest is holding an "option" :

    It has the right but not the obligation to buy an asset at some future time of its choosing.

    cf. Dixit and Pindyck, 1994

  - Implicitly: Modigliani-Miller-Theorem (1958)

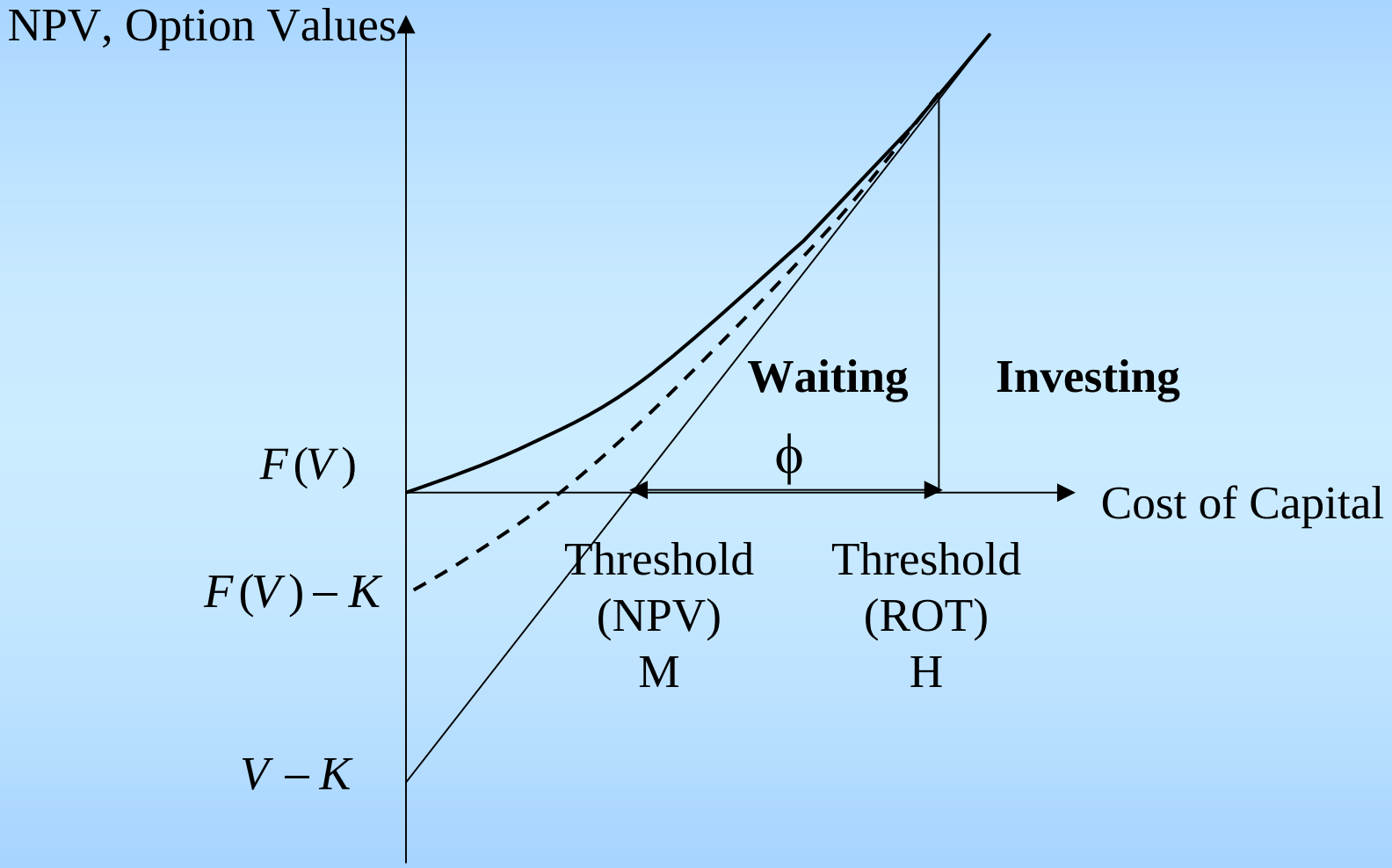
    Independence of investment and funding decisions
  - Degree of irreversibility of capital:

    Option multiple is the ratio H / M

Table: Option Multiple for different degrees of reversibility and expandability of capital (cf. Dixit and Pindyck, 1998)

Capital	**Totally expandable**	**Partially expandable**	**Totally non expandable**
Totally reversible	$\phi = ?$	$\phi = ?$	$\phi < 1$
Partially reversible	$\phi = ?$	$\phi = ?$	$\phi < 1$
Totally irreversible	$\phi > 1$	$\phi > 1$	$\phi = 1$

- Illustration:



- Trade-Off Theory: Interdependence of investment and funding decisions

  The levered project value:

$$V(p_t,C)= V(p_t,0)+TB(p_t,C)-BC(p_t,C)=D(p_t,C)+E(p_t,C)$$

$V(p_t,C)$ is the levered project value;
$V(p_t,0)$ is the unlevered project value;
$TB(p_t,C)$ is the value of tax benefits;
$BC(p_t,C)$ is the value of bankruptcy cost;
$D(p_t,C)$ is the debt value;
$E(p_t,C)$ is the equity value;
C is the debt coupon.

The firm optimizes its debt in order to maximize its value

4. Model

- Program:

$$F(p_t) = \max_t \xi \left\{ \left(V^*(p_t) - K \right) \; e^{-rt}; 0 \right\},$$

$F(p_t)$ is the value of the investment opportunity;

$V^*(p_t)$ is the value of the optimally levered project;

K is the initial cost of capital;

t is the future point in time when the investment is made;

r is the risk-free discount rate.

4.1 Hypotheses: Investment

- Evolution of the cost price p_t:
  - Certain in monopoly
  - Uncertain in competitive market
  - Negative drift
- Standardized equipment: initial cost of capital K
- Baseload operation: Constant production and exploitation costs equal to 0
- Infinite lifetime
- The value of the unlevered project is equal to the cost price

= a call option (an option to defer)

4.2 Hypotheses: Funding

- Project-company Principle to isolate financial risks
- The financial structure cannot vary – Lifetime of debt is infinite
- Submitted to a corporate tax and can file for bankruptcy
- The debt is risky: the bankruptcy price is endogenous

  The company cannot any more raise sufficient equity capital to meet its current obligations

- At bankruptcy:
  - The project value is equal to the debt value.
  - The project property is transferred from stockholders to debtholders:

    The stockholders have a limited responsibility
- Buying a put option on equity

  = addition of a put option (this financial option), which increases the project value (multiple interaction options)

4.3 Solution

- Value of the optimally levered project
  - Under uncertainty:

$$rV^*(p_t) = \frac{E[dV^*]}{dt} = \frac{dV^*}{dt}.$$

  - Under certainty (Dixit, 1982): volatility$\rightarrow$0
- Investment thresholds
  - In monopoly:

$$F(p_0) = \max\{V^*(p_0) - K; 0\}$$

  - In a competitive market:

$$rF(p_t) = \frac{E[dF]}{dt} = \frac{dF}{dt}.$$

5. Results

- *The monopolistic company invests if the initial cost price is superior to the price threshold. Its structure of capital corresponds then to the optimal leverage.*

  This price threshold is inferior to the initial cost of capital K, which is the price threshold for an unlevered project.

$$p^*_{NPV} = p^*_0 = \phi_M K < K, \quad \phi_M < 1.$$

- *In a competitive market, the company invests above a price threshold, which can be inferior, equal or superior to the one determined under certainty.*

$$p^* = \phi_C K,$$

ϕ_C *increases with the rise in volatility.*

Because the option multiple $\phi = \dfrac{\phi_C}{\phi_M}$

which is the ratio H / M, is not always superior to one, the optimally levered project is defined as partially reversible.

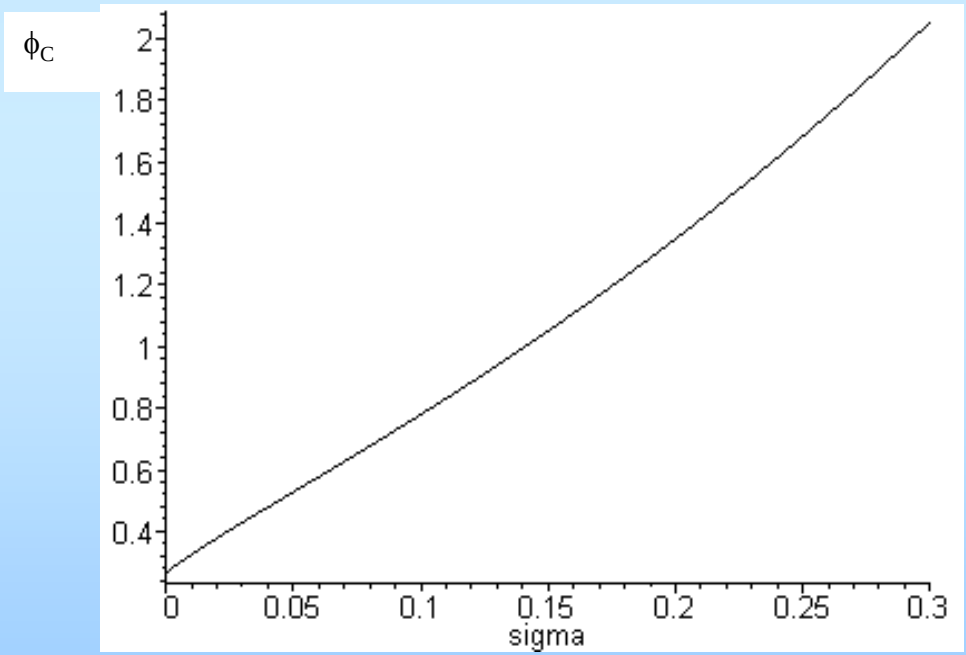
the risk-free discount rate r is equal to 8%

the corporate tax rate is set at the level of EdF: 37,77%

the bankruptcy cost here is equal to 62,23 (Jou, 2001)

the drift of the cost price evolution is assumed -6%

the volatility of the cost price evolution is assumed to evolve in a range of 0% at 30% (Jou, 2001)



6. Conclusion

- Energy policy insights include the following.

  In a competitive market, nuclear investment would not systematically be delayed. It depends on the cost price evolution, the corporate tax and the bankruptcy cost. The result shows that liberalisation does not necessarily lead to a reduction of long-term investment in NPPs.