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IRREVERSIBILITIES AND TECHNOLOGICAL INNOVATIONS: INVESTMENTS FLEXIBILITY AS A CONDITION TO SECURE FUTURE NUCLEAR ENERGY

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Overview

For a few years, energy markets are into full change. Deregulation and new environmental requirements combined with the growing scarcity of fossil resources and the increasing world energy demand lead to a renewal of the debate on tomorrow's energies. Specifically, nuclear energy, which has undeniable assets, faces new constraints. Nuclear energy is competitive, efficient and harmless to greenhouse effect. However, its technology of production generates important risks for environment and health and in spite of dynamic efforts in R&D, it is still marked with scientific and technical uncertainties. Therefore, if nuclear energy is one of the most secured energy today, it still shows weaknesses. Since the environment of energy markets is muting and priorities are changing, nuclear operators must adapt, in order to secure even more nuclear energy. If they want to play a central role in the future world energy landscape, they have to cope with new challenges: the priority must be set on *flexibility*. Nuclear energy implies massive and heavy investments and a high-level technology. However, these infrastructures bring about structural rigidities and irreversibilities which imply great costs; irrecoverable and sunk for most of them. Nuclear investment is thus the source of a first form of irreversibility: *financial irreversibility*. Then, engaging in nuclear investment also means assuming environmental and sanitary risks this activity generates. These risks are all the more worrying that they are very difficult to evaluate and to foresee. In addition to this uncertainty, nuclear risks may have very serious consequences, sources of *environmental and sanitary irreversibilities*. The major part of the nuclear investment costs is due to the technology of production. The reactor is one of the most expensive equipment for an investor. In spite of a great evolution since the last fifty years, investing in a nuclear reactor still creates strong technological rigidities. Indeed, nuclear industry is subject to a *technological lock-in* which generates infrastructures inertia since it impedes technological change, and particularly the adoption of new technologies. It leads the production process on a specific technological trajectory, thus creating path dependencies. Consequently, old technologies remain in spite of their relative inefficiencies. This phenomenon is going against the competition behaviour required by the new economic context of energy markets. Nuclear investment is thus a third source of rigidity: *technological irreversibility*. In our view, this form of rigidity is the most important because it determines the two first ones: technological choices determine the equipment size, the costs magnitude and the environmental and sanitary impacts of the activity. To secure nuclear energy, operators must carry out *technological adjustments* to make their investments more flexible. What do these adjustments consist in?

Methods

This paper is based on the literature on *irreversibilities and investments under uncertainty* and on *technological change* (see references below). First, it aims at presenting the current state of nuclear industry and the irreversibilities it has to cope with. Secondly, this paper analyses the nuclear technological lock-in, which is the main factor of the other irreversibilities, and explains the causes and consequences of it, through the theories of *increasing returns to adoption* and *path dependencies*. Thirdly, it demonstrates how the flexibility of nuclear investments is likely to alleviate the irreversibilities and, thus, secure even more nuclear energy. This last section uses the literature on *modularity* and *innovation*.

Results

Why is investment flexibility so important? Irreversible forms of investment are relevant only in a stable environment with perfect information. However, energy markets are far from this framework. On the contrary, they are stamped by uncertainty and constant mutation. So, to secure and adjust nuclear industry, and more generally energy markets, with their new environment, decision-makers must favour adaptable and reversible investments, that is, prefer modularity. Modularity consists in two types of innovations. First, it consists in a **modular investment** which implies the successive construction of small size nuclear reactors on one single site. Secondly, it consists in the construction of a **modular** reactor, that is, a reactor composed of several modules technically independent from one another. This type of reactor satisfies to the decomposability criterion. This property makes the reactor structure reversible and adjustable at an accessible cost. Even if these two kinds of installations are initially often more expensive than traditional investments, they allow the investor to reconsider his technological and technical choices in an intertemporal manner. Indeed, if technical progress improves in the future, he will have the possibility to reverse and/or complete his production process.

Conclusions

To sum up, nuclear industry faces multiple mutations to which it must accommodate. It currently suffers from rigidities, particularly technological rigidities, which prevent the world-scale development of nuclear energy production and hinder the adaptability required by the current new context. To secure nuclear energy, the solution will come from a new configuration of nuclear investments which must focus on flexibility and thus unlock the lock-in.

References

Arthur B., 1989, "Competing technologies, increasing returns, and lock-in by historical events", *Economic Journal*, 99, 116-131.

Baldwin C.Y. and Clark K.B., 2000, *Design Rules: the Power of Modularity*, vol 1, MIT Press, Cambridge.

Buenstorf, G., 2005, "Sequential production, modularity and technological change", *Structural change and economic dynamics*, vol. 16, p. 221-241.

Cowan R., "Nuclear Power Reactors: A study in Technological Lock-in", *Journal of Economic History*, 50, 1990.

Dixit A. and Pindyck R., 1994, *Investment under uncertainty*, Princeton.

Gollier, C., Proult D., Thais F. and Walgenwitz, G., 2004, "Choice of nuclear power investments under price uncertainty: valuing modularity", World Energy Congress, Sydney, Australia.

Liebowitz S. J. and Margolis S. E, 1995, "Path dependence, lock-in and history", *Journal of Law, Economics and Organization*, 11(1), pp. 205-226.