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The year of the cat: Taxing nuclear risk with the help of capital markets

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HIGHLIGHTS

- Limited liability leads to excessive risk-taking in nuclear power companies.
- Current regulation does not address this issue sufficiently.
- We evaluate five regulatory instruments and explain their shortcomings.
- We propose a market-based nuclear risk tax as a new regulatory instrument.

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ABSTRACT

This paper proposes new regulation for nuclear power reactors aimed at increasing their safety. We begin by describing how limited liability leads to risk-loving behaviour in nuclear power companies and unsafe nuclear power reactors. By reviewing current regulatory regimes, we show that this issue is not being sufficiently addressed today. Therefore, we evaluate five regulatory instruments: (1) safety regulation, (2) minimum equity requirements, (3) mandatory insurance, (4) risk-sharing pools, and (5) catastrophe bonds. We conclude that any of these instruments either cannot be recommended in its pure form or is infeasible in reality. We therefore propose a new approach that, in its core, consists of a two-stage procedure. In the first stage, capital markets assess the risk stemming from each nuclear reactor via catastrophe bonds. In the second step, the regulator uses this private risk assessment and intervenes by charging an actuarially fair premium in the form of a Pigouvian risk tax. Society ultimately acts as an explicit insurer for nuclear risk and is, on average, fairly compensated for the risk it is taking over.

1. Introduction

According to the Vietnamese zodiac, it was the year of the cat when in March 2011 the Fukushima catastrophe occurred. While this was pure coincidence, the need for improved regulation of the nuclear industry has never been greater and catastrophe (cat) bonds could become a cornerstone of it, as we argue in this paper.

The Three Mile Island, Chernobyl, and Fukushima catastrophes are terrifying events in the history of civilian nuclear power use, which goes back to the 1950s. The probability of a severe accident occurring at a nuclear power plant on a randomly chosen day is microscopically small, yet, many people are afraid of this risk. Nuclear power is still being used after those catastrophes because energy is essential for the functioning of modern societies and an alternative way of generating a continuous supply of energy using other climate-friendly technologies at reasonable costs has not yet been found. It is important, however, its risks are properly addressed as long as a society decides to use nuclear power.

Many countries around the world are currently expanding their civilian nuclear programs. The list of countries with the most nuclear power plants under construction is headed by China, Russia and India, but plants are also currently being built in the European Union. The fact that nuclear fission will remain an important source of energy in the future is also the content of the Energy Roadmap 2050, published by the European Commission (EC) in December 2011. It emphasises the current and future role of nuclear energy as an 'important part of Europe's power generation mix' and considers it to be 'needed to provide a significant contribution in the energy transformation process' (see EC, 2011). Thus, despite a general reassessment of nuclear risk after the Fukushima catastrophe, nuclear power is likely to become or remain a significant determinant of many countries' electricity supply. On the downside, the Fukushima accident, with only clean-up costs that could reach or exceed JPY 20 trillion over the next ten years (cf. JCER, 2011), has shown how strongly a society can be affected by the use of nuclear power while also

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Table 1
De facto vs. de jure limited liability, selected countries/NPCs.

Selection of countries with de jure limited liability[a]		Countries with de facto limited liability[b]		
China	RMB 300 million	Germany	E.ON	EUR 39.6 billion
Czech Republic	CZK 8 billion		RWE	EUR 9.9 billion
France	EUR 91 million		EnBW	EUR 6.1 billion
India	INR 5 billion		Vattenfall	SEK 138.9 billion
United Kingdom	GBP 140 million	Japan	TEPCO	JPY 2.47 trillion[c]
United States	USD 375 million	Switzerland	Axpo	CHF 7.6 billion

[a] Right column: de jure national liability limitation.
[b] Right column: NPCs' equity capital in 2011.
[c] As of March 2010.

sensitising people to the reality that many nuclear reactors may be carrying a substantial risk.

We argue in this paper that the problem at heart is the existence of de facto (through the amount of equity capital) or de jure (by law) limited liability of nuclear power companies (NPCs). The basic mechanism is the fact that an NPC cannot lose more than the legally defined liability capital or, in the worst case, its equity capital, even if the damage of a nuclear accident is much higher. This reduces the incentive to invest in costly nuclear safety and leads to an inefficient safety level in nuclear reactors. For example, the Tokyo Electric Power Company (TEPCO) reported equity capital in the amount of JPY 2.47 trillion for 2010 (see TEPCO, 2011). This does not seem small at first glance; however, this amount only constitutes a small proportion of the actual costs of the Fukushima catastrophe, the remainder of which cannot be borne by TEPCO and must therefore eventually be absorbed by Japanese society. Similarly, the liability of other NPCs around the world is, in the case of catastrophic accidents, limited de jure or de facto (see Table 1 for a brief overview and Section 3 for a more detailed discussion).

One of the original goals of nuclear power liability regulation was to protect NPCs against potentially ruinous claims by setting a limit to their liability. In this way, regulators increased the profitability of the industry and contributed to its development. Currently, the countries using nuclear power can be broken down into two groups. The first group of countries – Germany, Japan, and Switzerland – do not limit the NPCs' liability by law; thus, NPCs enjoy a de facto limited liability. The second group, comprising all other countries, impose strong de jure liability limitations.

A body of literature has analysed how limited liability affects individuals' decision making, generally finding that it induces a distortion towards risk-loving behaviour (see, Sinn, 1980, 1983, for the first discussion; see also Shavell, 1986). The literature on NPCs' risk choice similarly emphasises that it might be too excessive owing to limited liability (see Sinn, 1983; Tyran and Zweifel, 1993; Strand, 1994; Trebilcock and Winter, 1997; Van't Veld and Hutchinson, 2009, who also provide a review of other related literature). Further literature discusses both conventional and innovative remedies for overcoming this problem (see, for example, Tyran and Zweifel, 1993; Trebilcock and Winter, 1997; Radetzki and Radetzki, 2000; Faure, 2004; Cummins and Weiss, 2009). Particularly closely related to our work are Tyran and Zweifel (1993) and Radetzki and Radetzki (2000), who elaborate on the possibility of using capital markets to deal with limited liability and cover the potential damages from nuclear accidents.

We contribute to this literature in three ways: First, we explain how limited liability affects the risk-taking behaviour of NPCs and illustrate its relevance by reviewing current regulation. Second, we consider various regulatory instruments and evaluate their ability to set the desired incentives such that NPCs choose the optimal level of risk. We conclude that any of them either cannot be recommended in its pure form or is infeasible in reality. Third, we propose a new approach and emphasise its advantages compared with other instruments. The core of our proposal consists of a two-stage approach, in the first of which capital markets evaluate the risk stemming from each reactor via catastrophe bonds; in the second step, the regulator uses this private risk assessment and intervenes by charging an actuarially fair premium, thereby (under ideal conditions) inducing the optimal level of risk-taking. Society then acts as an explicit insurer for nuclear risk but is, on average, fairly compensated. While we are aware that our proposal faces a couple of difficulties when applied in a world that is not ideal, we discuss these issues and explain how their impact can be reduced.

The remainder of this paper is structured as follows: in Section 2, we outline an aspect of the theory of limited liability that is important for our argument and define the negative externality stemming from excessive risk-taking. In Section 3, nuclear power liability regulation around the world is briefly summarised, serving as a framework within which to evaluate several regulatory instruments on their ability to internalise excessive risk-taking in the nuclear industry in Section 4. In Section 5, we elaborate a new regulatory proposal, a market-based nuclear risk tax and Section 6 offers some conclusions.

2. Limited liability and risk-taking by an NPC

This section develops a theoretical argument about how the limited liability of NPCs affects their risk-taking behaviour. According to Sinn (1982, 1983), the existence of limited liability generates a kink and hence, a de facto convexity in a firm's profit or an individual's utility function, as all losses beyond the factual or legal liability are truncated and thus not taken care of.[2] This also applies to both risk-averse and risk-neutral NPCs, which are liable, at most, with their equity capital. As nuclear catastrophes imply extremely large economic losses, and as the equity capital of NPCs is comparatively tiny (see Table 1), the nuclear industry is a prime example of firms operating under limited liability. This is intensified when the liability is de jure limited to an even smaller amount.

Because of limited liability, an NPC's incentives to engage in measures that lower the probability of catastrophic accidents are reduced. The socially inefficient excessive risk-taking resulting

[2] Although the behaviour of a firm is studied, we write 'utility function' in the following. It could be replaced with 'profit function' if we considered the case of risk neutrality. The use of the term utility function enables us to study the case of risk-aversion, which would be appropriate and more general if the NPC is owned by a risk-averse individual.