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Regulation, free-riding incentives, and investment in R&D with spillovers[☆]

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ABSTRACT

In this paper, we analyze a duopoly market with investment in abatement technology under environmental regulation. We use a three-stage game where firms invest in a green technology with spillover effects in the first stage, the regulator sets the emission fee in the second stage, and production of the polluting good occurs in the third stage. We analyze two different regulatory regimes: (1) each firm faces the same emission fee (uniform fee), and (2) each firm faces an emission fee dependent on the investment in green technology (type-dependent fee). Firms can differ through their costs of investing in the abatement technology (asymmetric efficiency). We obtain that social welfare is unambiguously higher under the type-dependent regime than otherwise. In addition, we find that the asymmetry in efficiency of investment affects firms' profits, identifying that efficient (inefficient) firms favor type-dependent (uniform) policy regimes.

1. Introduction

Firms' investment in clean (or environmentally friendly) research and development (R&D) has increased over time, from less than $30 billion in 2005 to $159 billion in 2012 worldwide.[3] Given its large scale, several authors analyzed firms' free-riding incentives in their R&D decisions, as well as how these incentives are affected by emission fees.[4] These papers show that, in the absence of spillovers, every firm under-invests relative to the social optimum since its investment reduces

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3 National Science Foundation's Science and Engineering Indicators (2014), Chapter 6 (https://www.nsf.gov/statistics/seind14/index.cfm/chapter-6).

4 Katsoulacos and Xepapadeas (1996) consider an emission fee and simultaneous R&D subsidy; Montero (2002a) examines emissions standards, fees, tradeable permits, and auctioned permits; Poyago-Theotoky (2007) and Strandholm and Española-Arredondo (2016) analyze emission fees allowing for spillovers, whereby a firm's investment in R&D not only reduces its own emissions but also helps its rivals decrease a proportion of their own. The following papers consider emission fees without R&D spillovers: Biglaiser and Horowitz (1995), Denicolo (1999), Conrad (2000), and Montero (2002b). Griliches (1992), Cameron (1998), and Weiser (2005) report an average private rate of return to R&D around 20–30%, and an estimated spillover of 40–60%. While

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environmental damages which induces a laxer emission fee thus benefiting all firms. In the presence of spillovers, this free-riding incentive is emphasized, since firms also benefit from the investment in R&D of their rivals.

The aforementioned literature assumes that all firms are subject to uniform environmental policies. However, when firms are asymmetric, they may invest different amounts in clean R&D, generating a distinct amount of pollution. This asymmetry calls for a type-dependent environmental policy that takes into account the different marginal environmental damage each firm generates (first-best policy),[5] whereas a uniform regulation, that sets the same emission fee to all firms, represents a second best policy in this context. Our model considers these two regulatory regimes and focuses on settings where the regulator can accurately observe each firm's pollution before choosing emission fees (point pollution) or, alternatively, contexts in which R&D is observable thus helping the regulator infer the reduction in pollution.[6] We show that a type-dependent policy can ameliorate the above free-riding problem, thus providing firms with more incentives to invest in clean R&D, ultimately helping regulators more rapidly achieve the emission targets set in international environmental agreements. Intuitively, under no spillovers, every firm's investment is completely appropriated by itself, since it faces a laxer environmental policy, which is different from its rival's. When spillover effects are present, firms face free-riding incentives, although smaller than under a uniform regulation.

Our model considers a three-stage game where, in the first stage, two firms invest in green technology (where we allow for spillover effects); in the second stage, the regulator sets the emission fee (we separately analyze uniform and type-dependent policy regimes); and in the third stage, firms compete à la Cournot in the product market. In addition, we examine the case where firms jointly maximize profits by choosing their levels of investment in R&D in the first stage, commonly known as an environmental research cartel (ERC). In this setting, every firm internalizes both positive externalities that its investment produces on other firms: the reduction in emission fees and the spillovers. Therefore, the ERC does not exhibit free-riding incentives. Comparing investment levels in the ERC against the above non-cooperative game, we evaluate firms' free-riding incentives in both regimes.

We demonstrate that emission fees are more stringent under uniform than type-dependent policies, as the regulator considers the aggregate marginal environmental damage thus ignoring firms' asymmetry in R&D investment during the first stage. However, the difference in emission fees across policy regimes diminishes as spillovers increase. Intuitively, when spillovers are small, firms exhibit different marginal environmental damages, yielding distinct emission fees in each regime. However, when spillover effects are large, all firms benefit from each other's investment, and thus marginal environmental damages coincide. In this context, the use of either policy regime yields the same emission fees, investment in R&D, and welfare. Therefore, when regulating industries with small spillovers, the use of type-dependent policies becomes more relevant since they promote further investment in R&D and larger welfare. However, when spillovers are significant both policy regimes yield similar outcomes, such as in clustered industries, where several authors find large spillovers; see Jaffe et al. (1993), Audretsch and Feldman (1996), Almeida and Kogut (1997), Jaffe and Trajtenberg (2002), and Liu et al. (2010). When firms are located far from other competitors in the same industry, however, spillover effects are generally small, and our results would indicate that it is precisely in this type of industry where the choice of policy regime matters the most.

Our findings also suggest that profits are larger when firms operate under a type-dependent than a uniform regime when a firm is significantly more efficient in investing in R&D than its rival, as the former can appropriate a large portion of its investment. An increase in environmental damage expands the region of parameters for which the type-dependent policy yields larger profits than the uniform regime. This means that the most efficient firm has further incentives to lobby for a type-dependent policy since its investment in R&D entails a more significant reduction in its own emission fee which its rival cannot benefit from. We also find that the profit difference across regimes diminishes as spillovers increase since, as described above, firms face the same emission fees. In this setting, firms are not critically affected by the policy regime that regulators use to curb externalities. In contrast, when spillovers are small, the profit difference is substantial, leading efficient (inefficient) firms to favor type-dependent (uniform, respectively) policies. For instance, Exxon-Mobil has openly claimed on its website that, in the context of climate policies, "We believe that effective policies will be those that ensure a uniform [...] cost of greenhouse gas emissions across the economy." According to our findings, this type of statements suggests that Exxon-Mobil would be less efficient in clean R&D than its industry rivals, and thus prefers a uniform policy. However, this needs to be empirically analyzed.

Finally, we use our previous welfare ranking across policy regimes to identify a preference alignment between regulator and firms. This occurs when a firm is efficient at investing in R&D and where both welfare and profits are larger in the type-dependent than uniform regime. Intuitively, not only profits are larger in this regime, but also investment, yielding a smaller environmental damage. In this context both regulator and firm would favor a similar policy regime. In contrast, when a firm

Comin (2004) identified omitted variable bias in some of these estimates, thus reducing their size, most of the literature still finds significant spillovers from R&D.

[5] For instance, nuclear and coal-fired power plants are subject to different regulations, as they use distinct inputs to produce electricity. Carbon-fired power plants face federal carbon limits on electricity generation. In contrast, nuclear plant operations are subject to the Clean Water Act, which regulates thermal discharges; cooling water intake location, design, construction, and capacity; storm water discharges; dredging, filling, and wetlands impacts; see EPA (2008). In addition, under the Clean Air Act, the EPA has the authority to list hazardous air pollutants and develop and enforce emission limits for each of them. Last, the EPA has also the authority to issue generally applicable environmental radiation standards.

[6] Several papers have looked at the effects of such fine-tuned environmental policy, but do not consider investment in clean R&D, see Tietenberg (1974), Henderson (1977), Hochman et al. (1977), Hochman and Ofek (1979), and Munoz-Garcia and Akhundjanov (2016).