



# Crowding-in of complementary contributions to public goods: Firm investment into open source software<sup>☆</sup>



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## ARTICLE INFO

### Article history:

Received 7 March 2013

Received in revised form 17 April 2014

Accepted 9 June 2014

Available online 2 July 2014

### JEL classification:

H44

L13

L86

### Keywords:

Investment crowding-in

Government contribution

Market entry

Open source software

## ABSTRACT

We present a fairly general model in which firms are competitors in a commercial market segment and can invest into a complementary public good like open source software. We show that, contrary to standard predictions, additional contribution to the public good by the government or a new market entrant can lead to higher investments of all incumbent firms, that is, a crowding-in effect. This result occurs if the investment cost function is superadditive. We find that government contribution leads to larger crowding-in effects than subsidizing market entry if the price elasticity of demand with respect to the private good is large relative to the one with respect to the public good. Our results are robust to extensions in the timing and the mode of competition.

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## 1. Introduction

There is a long-standing debate why firms voluntarily contribute to public goods by freely sharing their innovations and by engaging in R&D activities with beneficial spillovers to rivals. An example can be observed in the market for software where profit-maximizing firms privately contribute to the open source development. Since the source code of open source software can be copied, used and modified free of charge, these firms contribute to a non-excludable public good. This implies that they are not able to fully appropriate their investments, and conducting such contribution seems to contradict the economic rationale of free-riding.

An important reason why firms nevertheless contribute to open source software is that they offer goods and services in a complementary commercial market. Even though they cannot directly capture the value of their contribution, they benefit indirectly by selling more complementary private goods or services at a potentially higher price. The organization of these

<sup>☆</sup> A previous version of this paper by Schmidtke was titled “Private Provision of a Complementary Public Good”. We would like to thank two anonymous referees and the editor for very helpful comments and suggestions that greatly improved the paper. We also thank our discussant Patrick Rey as well as Paul Belleflamme, Achim Czerny, Monika Schnitzer, Jean Tirole, Christian Traxler, participants at the conference on the economics of ICT in Paris and seminar participants in Düsseldorf for many helpful comments and suggestions. Schmidtke is grateful for financial support from the “Kurt Fordan Förderverein”.

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firms is toward a business model that combines the supply of proprietary software, hardware or services with complementary open source software (see e.g., Lerner and Tirole (2002, 2005) and Bonaccorsi et al. (2006)). The most prominent example is probably IBM who invested huge amounts into several open-source projects, like adapting Linux and Apache to IBM's computer hardware.<sup>1</sup> As pointed out by West (2003), IBM especially gained strategic advantages from Linux by offering specialized (hardware and software) products to large corporate customers. A further example of a firm that significantly contributes to the Linux kernel and offers complementary services and products is Red Hat, whose business model centers around assembling and testing operating systems that are potentially merchantable.<sup>2</sup>

In addition to commercial firms, many government agencies aim to promote innovations in and contributions to open source software. As reported by Lerner and Schankerman (2010), in 2008 there were globally 275 open source public policy initiatives. For example, government agencies may directly employ programmers or subsidize market entry of contributing firms.<sup>3</sup> They may also fund R&D projects, which make use of and participate in the development of modules or extensions that make open source technologies suitable for e.g. embedded systems. A conclusion emerging from the literature on public good provision is that such government contribution will crowd-out private contribution (see e.g., Warr (1982, 1983); Bergstrom et al. (1986) and Bernheim (1986)). Incumbent firms will curb existing contributions due to the free-riding problem.<sup>4</sup>

However, recent papers caused doubts on the crowding-out hypothesis of public R&D spending. For example, David et al. (2000) provide a detailed survey of econometric studies whether or not public R&D spending crowds-out private R&D. Although their evidence in general is mixed, at the industry level they report that almost all studies find a significant complementarity between public and private R&D spending. Most notably, the study by Levin and Reiss (1984) uses a structural equation model (formulated by Dasgupta and Stiglitz (1980)) and find that one dollar increase in government spending leads to an increase in private R&D spending ranging from seven to seventy-four cents. Similarly, a case study conducted by Mansfield and Switzer (1984) finds a crowding-in effect of public R&D investment on private R&D investment.

The aim of our paper is to explore the question of crowding-out/in in more detail and to draw conclusions on the optimal decisions of contributing firms as well as for well-guided policy making. We first set up a fairly general model in which profit-maximizing firms compete in a commercial market and can invest into a complementary public good. In case of open source software, these investments represent contributions in a modularized development of a project. Firms simultaneously choose their quantities of the private good and their investments into the public good. Due to the complementarity, increased investments lead to an outward-shift in the demand curve for the private good and the benefits of public good investments fully spillover to all competitors in the commercial market. The investment cost function of each contributing firm is assumed to be convex, resulting in an aggregate cost function which is superadditive. We provide a detailed explanation for this assumption relying on specialization benefits and hierarchy costs, which are both important in the development of open source software.

We first address the question how a policy of direct government contribution affects firms' incentives to invest into the public good. We find that government contribution does not necessarily lead to a crowding-out of incumbent firms' investments but can induce a crowding-in. Firms benefit indirectly from the increased investment into the public good through an increased demand for their private products. This implies that they receive larger revenues and therefore raise the produced quantity. This in turn increases their incentive to contribute to the public good because additional contribution lets them benefit to a larger extent from the quantity increase in the commercial market segment. For the widely used case of linear demand, we demonstrate that a crowding-in effect always occurs.

We also show that the interaction between the private and the public good with respect to crowding-out/in effects crucially depends on the shape of the firms' cost functions of public good investments. In particular, a crowding-in effect can only occur if this cost function is strictly convex, such that the aggregate cost function is superadditive. By contrast, if the cost function is linear, a crowding-out effect always prevails although the public good is complementary to the private good. In addition, even if the cost function is convex but the choice of private good production is independent of the public good, a crowding-out effect occurs. Thus, it is the interplay of the complementarity between private and public good and the superadditivity of the cost function for public good investments that generates a crowding-in effect.

We then analyze market entry of a further firm, which also invests into the public good. As free-riding can now be assumed to be stronger, one would expect reduced incentives of incumbents to contribute to the public good. By contrast, we demonstrate that a similar effect as in the case of direct government contribution occurs. An entering firm, although being a competitor to incumbents in the commercial market, also contributes to the public good. This in turn leads to an increase in the market value of the incumbents' private products, which causes a crowding-in effect. Moreover, this effect

<sup>1</sup> Recently, IBM announced to make a \$1 billion investment to promote the development of Linux for cloud computing, see <http://www.linuxjournal.com/node/1160671>.

<sup>2</sup> For a more detailed description and for further examples, see e.g. Evans and Reddy (2003).

<sup>3</sup> An example for the former is the French government, which recently requested support for the use of Debian and Centos. The offered contracts are worth two million Euros and involve 16 of the country's 22 ministries (see: <http://joinup.ec.europa.eu/news/fr-government-procuring-two-million-euro-worth-opensource-support>). An example for the latter is the agreement between IBM and the Israeli Ministry of Industry, Trade and Labor in 2005 to offer grants of up to \$100,000 for open source start-ups (Center for Strategic and International Studies (2012)).

<sup>4</sup> Andreoni (1990) argues that in case of individuals, crowding-out might be incomplete because people are driven by impurely altruistic motives, so that they receive utility from the act of giving. This warm-glow hypothesis is supported by experimental tests conducted by Andreoni (1993) and Chan et al. (2002).

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