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Process innovation, application compatibility, and welfare☆

Masayoshi Maruyama*, Yusuke Zennyo

Graduate School of Business Administration, Kobe University, Japan

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ABSTRACT

We analyze a model of cost-reducing R&D and compatibility decisions by two platforms. After an exogenous improvement in the efficiency of R&D, each platform has a heightened incentive to make its software incompatible with the rival's hardware device to avoid being dominated in the hardware market. This can lead to an inefficient market structure. The increase in the efficiency of R&D not only has a positive direct effect of reducing costs through process innovations but also a negative indirect effect through the change of the compatibility decisions. We show that due to this indirect effect, an increased efficiency of R&D can be harmful to the profit of a large platform and harmful to social welfare.

1. Introduction

The hardware–software systems that comprise a digital-content industry are competing platforms. Examples of such hardware–software systems include smartphones and their application software (apps), digital playback devices and their music, and digital readers and their e-books. The aim of this paper is to model the process innovations of cost-reducing R&D between competing platforms, where the pattern of compatibility between hardware and software is the outcome of private choices by the platforms. In the platform competition on which we focus, platforms have two sources of revenue: the revenue from selling their hardware to consumers through retail channels, and the royalties from selling their software (i.e. digital content) to consumers through their online marketplaces. Compatibility of hardware and software across platforms affects both revenue streams. When a platform chooses application compatibility—making its own-supplied software compatible with the rival's hardware—it widens the demand for its software, but also narrows the demand for its hardware (by increasing the attractiveness of the rival's hardware), which means it eventually has less incentive to invest in its hardware device.

Our main result is that choosing application compatibility interacts with the incentive for the process innovations (cost-reducing R&D investment) in a way that can adversely affect social welfare. We show that there exists a parameter range in which two platforms are apt to choose differing application compatibility strategies. For instance, in the market for e-books, Amazon has adopted the principle of application compatibility and made it possible for users of Apple's iPad to purchase e-books from the Amazon Kindle Store. In contrast, Apple has chosen incompatibility, and the users of Amazon Kindle cannot purchase e-books at the Apple iTunes Store. In this case, the platform that has chosen incompatibility, say Apple, can get more demand for its hardware because it has more usable content compared with a competing platform, say Amazon, that has chosen compatibility. Then the marginal benefit from cost-reducing R&D is larger for Apple. Hence it is more aggressive in process innovations of its cost-reducing R&D investment, which may make it possible to capture the entire market for hardware devices when the efficiency of R&D is increased to higher levels (henceforth, we refer to this monopolization as *tip-*

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* Correspoding author.
E-mail addresses: mmaru@kobe-u.ac.jp (M. Maruyama), xyzennyo@b.kobe-u.ac.jp (Y. Zennyo).

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ping[1]). In this case, platform 2 has two alternatives: (i) maintaining compatibility, letting the market for hardware devices be monopolized by platform 1, and earning only the royalty revenue from selling content at its marketplace, or (ii) changing to incompatibility and competing in the market for hardware devices with platform 1. We show that when the royalties from selling content are small, the degree of hardware differentiation is large, and the efficiency of R&D is high enough, platform 2 will deviate to incompatibility in order to defend the market for its hardware. In other words, the improvement in the efficiency of R&D can lead to reduced compatibility across platforms. The reduced compatibility diminishes the availability of content for consumers, which in turn worsens 'social' welfare depending on the parameter. Policymakers should take account of this effect when evaluating process innovations.

2. Related literature

This paper relates to two bodies of research. One is on strategic R&D competition and the other is on compatibility in two-sided markets. The literature on strategic R&D competition has established that technology licensing may reduce welfare if it induces competitors to exit the market (Kabiraj and Marjit, 1992; Lin, 1996), facilitates collusion (Fauli-Oller and Sandonis, 2002), changes R&D organization (Mukherjee, 2005), or induces excessive entry (Mukherjee and Mukherjee, 2008). In a piece that is related to ours, Chang et al. (2013) consider a three-stage (R&D, technology licensing, and output) oligopoly game in a traditional market in which only one of the firms undertakes cost-reducing R&D. They find that the availability of licensing leads to lower social surplus, if the "efficiency of R&D investment" is high. In this paper, we also explore the possibility of welfare-reducing innovation but in the inherently different setting in which the welfare effect of innovation is mediated by compatibility decisions.

Several previous papers address strategic R&D competition in two-sided markets. Casadesus-Masanell and Llanes (2013) is the seminal article on the incentives to invest in platform quality in proprietary and open-source two-sided markets. They study a two-sided monopoly platform and show conditions under which an open source platform may lead to higher investment in platform quality than a proprietary platform. Still other papers, including Musacchio et al. (2009), Choi and Kim (2010), Economides and Hermalin (2012), and Bourreau et al. (2015), consider how network neutrality affects investment incentives. Bourreau and Verdier (2014) consider the impact of cooperation on R&D investment in the framework of a two-sided market. They extend the work of d'Aspremont and Jacquemin (1988), who showed that cooperation on R&D investment facilitates firms' investment when the degree of spillover is sufficiently high. They show that the results in d'Aspremont and Jacquemin (1988) still hold in the setting of a two-sided market. Our focus is how compatibility interacts with investment incentives.

The other body of research related to this paper is on compatibility between platforms in two-sided markets. Previous literature on this topic, including Doganoglu and Wright (2006), Miao (2009), Casadesus-Masanell and Ruiz-Aliseda (2008), and Viecens (2011), treats compatibility as exogenous to the choices of individual platforms, determined either by public policy or by joint agreement across platforms. Maruyama and Zennyo (2013, 2015) focus instead on the structure of compatibility that arises endogenously from the unilateral choice by each platform whether to make its own software compatible with rival's hardware–application compatibility.[2] They find that, depending on the parameters, asymmetric equilibria exist with regard to other content, where one platform chooses incompatibility while the other platform chooses compatibility. However, they do not address R&D investment by platforms. Viecens (2011) demonstrates how a parametric change in the degree of compatibility affects incentives to invest in innovation. That is, as the result of comparative statics, she examines the relationship between the degree of compatibility and investment in its stand-alone value.

From our reading of the literature, the strategic relationship between compatibility and process innovation (R&D investment) is one of the increasingly relevant open issues. In this respect, the unique contribution of this paper lies in examining the welfare effects of process innovation in a model which endogenizes the determination of compatibility structure across platforms. To the best our knowledge, this is the first paper which explores the profit and social welfare implications of process innovation mediated by the strategic compatibility decisions of platforms.

3. Model

3.1. Platforms

We suppose that there are two platforms, $i = 1, 2$, each selling a differentiated hardware device i at a price p_i $(i = 1, 2)$ and operating its marketplace i that distributes content for its own hardware device. Both platforms initially have the same marginal cost c per unit of hardware device, and each platform expenses R&D expenditure ky_i^2 to reduce marginal costs to $c - y_i$. Here, the variable y_i is a process innovation, and the parameter k expresses the efficiency of cost-reducing R&D. A reduction in k is an improvement in the efficiency of R&D that is likely to encourage firms to achieve greater process innovations. There are two content providers, $i = 1, 2$, and they exclusively supply content i to marketplace i at its price ρ_i. Each platform charges a content provider a royalty rate r $(0 \leq r \leq 1)$ for each unit of content sold at its marketplace. The unit of content has the same benefit for consumers, and we assume that the price of content is same for all content, $\rho_i = \rho$ $(i = 1, 2)$. In this paper, we treat the royalty rate r and the content price ρ as exogenous parameters.[3] Thus, the decisions by content providers are not considered in this model. Furthermore, we assume an exogenous, equal, and fixed number of applications on each platform in our model. That is, this paper does not consider endogenous affiliation by content providers. This may be problematic because we ignore some of the main features of two-sided markets such as indirect network effects in pricing. However, we consider that each platform chooses whether to make its content compatible with the rival's hardware device which we refer to as "application compatibility." Application compatibility enables the users of other hardware devices to use content (application software) that it supplies in its marketplace.[4] Application compatibility is a way to gain more royalties but it also makes the rival's hardware more attractive to consumers. In our model, even though the compatibility decision of

[1] The term *tipping* is used in the sense that one system pulled away from its rivals in popularity once it gained an initial edge (Katz and Shapiro, 1994, p. 106). There exist a number of previous studies that follow this definition of tipping (e.g., Dubé et al., 2010; Lee, 2014; Gold and Hogendorn, 2016).

[2] Endogenous choices of compatibility have been studied in the mix-and-match literature (Matutes and Regibeau, 1988, 1992; Economides, 1989; Economides and Salop, 1992), but, little has been reported on endogenous compatibility in two-sided markets.

[3] There is a real-life example of a common fixed royalty rate r in the e-book industry (see, for example, Jiang, 2012; Knowledge@Wharton, 2012). Similarly, about the fixed content price, in the iTunes Store almost all music is sold for $1.29 per track.

[4] For example, "a platform can choose application compatibility by providing a specific app that enables users of hardware devices operating on other standards to purchase and use content that the platform supplies in its marketplace" (Maruyama and Zennyo, 2015, p. 39)