International Journal of Industrial Organization 37 (2014) 99–108

Contents lists available at ScienceDirect

International Journal of Industrial Organization

journal homepage: www.elsevier.com/locate/ijio

Indirect network effects and the quality dimension: A look at the gaming industry

Jin-Hyuk Kim [a,1], Jeffrey Prince [b,*], Calvin Qiu [c,2]

[a] Department of Economics, University of Colorado at Boulder, 256 UCB, Boulder, CO 80309, USA
[b] Kelley School of Business, Indiana University, 1309 E. Tenth Street, Bloomington, IN 47405, USA
[c] ICF International, 19/F Heng Shan Centre, 145 Queen's Road East, Wan Chai, Hong Kong

ARTICLE INFO

Article history:
Received 8 April 2014
Received in revised form 28 July 2014
Accepted 16 August 2014
Available online 23 August 2014

JEL classification:
L14
L82
M21

Keywords:
Network effects
Superstar software
Game console
Killer applications

ABSTRACT

Two-sided markets consist of platforms that need to bring both retail consumers and complementary goods producers on board to be successful. Consumer adoption of these platforms can often hinge on the presence and magnitude of indirect network effects — the positive feedback loop where a larger base of adopters of a primary product ("hardware") creates a larger market for complementary goods ("software"), which in turn increases the value of the primary good. Prior work attempting to measure indirect network effects often uses aggregate counts of software variety to do so. In this paper, we illustrate the importance of accounting for variation in software quality — a feature present in many markets — when conducting this measurement, and provide the conditions under which not doing so results in over- or underestimation of the actual indirect network effect. We apply our framework to the 7th-generation video game console market with quality-differentiated titles and show that in this market the use of aggregate software measures underestimates the indirect network effects by approximately 30%.

1. Introduction

Two-sided markets span a large segment of fast-growing, high-tech industries. The conceptual definition of a two-sided market is one in which platforms need to bring both retail consumers and complementary goods producers on board to be successful (e.g., Rochet and Tirole, 2006). Examples of such platforms include video game consoles, software operating systems, and various web portals, to name a few. One of the central issues in two-sided markets is known as the 'chicken-and-egg' paradox that "consumers wait to adopt the hardware until enough software is available, and software manufacturers delay releasing software until enough consumers have adopted the hardware" (Stremersch et al., 2007; see also Caillaud and Jullien, 2003).

Practitioners and researchers have tried to understand the chicken-and-egg paradox through the concept of network effects, a catch-all phrase that could represent a variety of advantages accruing to the platform with a larger number of users (Ratchford et al., 2009). In particular, the literature has developed the concept of indirect network effects, roughly defined as the positive feedback loop where a larger user base of a primary product ("hardware") attracts more complementary goods ("software"), which in turn increases the value of the primary good. Such effects can play an important role in the diffusion and survival of hardware (e.g., HD DVD vs. Blu-ray).

Our primary contribution in this paper is to raise an important measurement issue and provide a more accurate framework to measure indirect network effects as proposed by the classical, static models of two-sided markets. It is in these markets where both the identification and the measurement of indirect network effects have been regarded as the most challenging. In particular, aggregate counts of software titles have traditionally been used to measure indirect network effects (e.g., Clements and Ohashi, 2005; Corts and Lederman, 2009; Gandal et al., 2000). While these authors generally found significant indirect network effects in video game console markets, Stremersch et al. (2007) show, drawing on historical data from nine markets, that indirect network effects estimated using aggregate counts are generally weaker than what the prior literature has suggested.

The reason is that software quality rather than quantity matters. That is, "in some cases (e.g., Tetris in the case of Game Boy), quantity does not matter, but the presence of killer applications does […] the entire catalog of software may not be relevant to consumers" (Stremersch et al., 2007). In the 7th-generation console market, Nintendo's Wii has dominated Microsoft's Xbox 360 and Sony's PlayStation 3, and

* Corresponding author. Tel.: +1 812 856 2692.
E-mail addresses: jinhyuk.kim@colorado.edu (J.-H. Kim), jeffprin@indiana.edu (J. Prince), calvin.qiu@cantab.net (C. Qiu).
[1] Tel.: +1 303 492 3827.
[2] Tel.: +852 9669 8736.

http://dx.doi.org/10.1016/j.ijindorg.2014.08.005
0167-7187/

Table 1
Conditions under which indirect network effects are mis-measured.

	Condition 1	Condition 2
Correlation between marginal utility of software and…	Response of software supply to an increase in installed base	Conditional variation in software availability
Negative correlations means misalignment where, e.g.….	Hardware demand responds mostly to high-quality software, but it is primarily low-quality software that responds to hardware installed base	Hardware demand responds mostly to high-quality software, but most of the variation in software supplied in the data is among low-quality software
If negatively correlated, estimating indirect network effects with aggregate counts…	Overestimates the effects (*and* vice *versa for positive correlation*)	Underestimate the effects (*and vice* versa *for positive correlation*)

practitioners say motion-sensor games pioneered by Wii were 'game-changers' that contributed to the console's success (Gaudiosi, 2007). Similarly, even though Sony's PlayStation was the late entrant to the 5th-generation console market, the console had on board a large number of so-called killer applications, and dominated both the 5th-generation and the next. While these specific cases are intuitive and plausible, to our knowledge, few formal analyses of quality-differentiated titles exist.

In this paper, we provide a theoretical and empirical framework that explains the relationship between indirect network effects and software quality, and we identify the conditions under which the traditional approach of using aggregate counts yields upward- or downward-biased estimates of the indirect network effects. We enrich the prior work such as that of Binken and Stremersch (2009) and Corts and Lederman (2009) by including a full spectrum of software quality and also the supply side of software. We demonstrate how our quality-adjusted measure of indirect network effects is different from the traditional measure in the 7th-generation console market. Our framework can be applied to many other two-sided markets.

We begin with an extension of the classical monopolistic competition model such as those considered by Chou and Shy (1990) and Church and Gandal (1992, 1993) to the introduction of quality-differentiated complementary goods. We show that the modified framework leads to the following predictions:

i. hardware sales may only increase low-quality software offerings, and
ii. only high-quality software offerings increase hardware sales.

Therefore, the multiplicative effect (or the positive feedback loop) between installed base (i.e., the number of users of a hardware platform) and software variety — the operational measure of indirect network effects in the literature — depends on a couple of correlations along the quality dimension. We show that the use of aggregate software counts in consumer utility can mis-measure indirect network effects when there are correlations between the marginal utility of software, and either:

i. the response of software supply to an increase in installed base, or
ii. conditional variation in software availability in the data.

The conceptual meaning of these correlations and the direction of mis-measurement are summarized in Table 1 below.

In our empirical exercise, both the above correlations exist and both turn out to be negative. However, the direction of mis-measurement using aggregate counts is dominated by the latter. We find that in the 7th-generation console market, the use of aggregate measures underestimates the indirect network effects by approximately 30%. In terms of the implied percentage increase in market share, this means that using aggregate measures underestimates the predicted increase in the market share of a console over a two-year period by roughly one third.

The literature on the quality dimension and network effects is nascent. Tellis et al. (2009) analyzed historical data in 19 markets and showed that while both quality and network effects matter, higher-quality products, rather than necessarily the first movers, tend to win the market after a short time lag. Their analysis and its implications were however limited to direct network effects.[3] Binken and Stremersch (2009) showed that superstar titles have a significant effect on video game console sales, but they did not use the full spectrum of quality or model the supply side. As emphasized by these authors, there is a clear need to further investigate the relationship between software availability and hardware sales even in a static framework.

Our work builds on the earlier literature on platform competition (e.g., Ackerberg and Gautam, 2006; Hogendorn and Yuen, 2009; Prieger and Hu, 2012; Rysman, 2004), where much of the focus is on aspects such as the effect of platform pricing, entry and exit, and exclusive contracts. For instance, Hogendorn and Yuen (2009) showed theoretically that the platform that has exclusive access to 'must-have' components would experience higher sales than platforms that do not have such access; this was empirically supported by the findings by Binken and Stremersch (2009). While we focus on the measurement issue, we also show separate estimation results for exclusive and non-exclusive titles, which links into this literature.

Recently, there has been notable progress on the dynamics of two-sided markets. That is, researchers started to investigate the effects of forward-looking consumer expectations and the firm's dynamic pricing in the presence of indirect network effects (e.g., Dubé et al., 2010; Lee, 2013; Liu, 2010). Specifically, these dynamic models use a single variable representing the software side — the expected utility of software — where high game sales imply high game quality, and high game quality affects expected utility essentially by construction. The main difference between our paper and these is that we analyze the relationship between hardware sales and game quality more directly. We utilize a static model, which has the benefit of being a simpler template for illustrating our main insights but at the cost of ignoring forward-looking behavior. Nevertheless, we believe our qualitative findings for the static model apply to dynamic models as well, but their relative importance is an open question. Lastly, as a byproduct of our main investigation, we show that our results render support for the specification used in the structural models.

The implications of our findings are straightforward but practical. For many markets, quality can be difficult to measure reliably. It is likely due to difficulty in measuring quality that many prior analyses of network effects have used aggregate rather than quality-differentiated counts for software. Our results show that, even if one is forced to use aggregate counts due to quality measurement difficulties, it is often possible to infer sign of the bias of the measured indirect network effects with just a qualitative understanding of the two correlations we have described. Suppose the market functions similarly to the 7th-generation console market where:

i. hardware demand (as a function of software availability) and software supply (as a function of installed base) are negatively correlated along quality dimension, and

[3] Direct network effects refer to the phenomenon where an increase in usage leads to a direct increase in value for other users (Katz and Shapiro, 1985). A primary example is the telephone network.