European Journal of Operational Research 240 (2015) 904–911

Contents lists available at ScienceDirect

European Journal of Operational Research

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

Interfaces with Other Disciplines

Welfare implications of piracy with dynamic pricing and heterogeneous consumers

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ARTICLE INFO

Article history:
Received 27 June 2013
Accepted 14 August 2014
Available online 26 August 2014

Keywords:
OR in marketing
Dynamic programming
Piracy
Welfare
Pricing

ABSTRACT

We present an information good pricing model with persistently heterogeneous consumers and a rising marginal propensity for them to pirate. The dynamic pricing problem faced by a legal seller is solved using a flexible numerical procedure with demand discretisation and sales tracking. Three offsetting pricing mechanisms occur: skimming, compressing price changes, and delaying product launch. A novel trade-off in piracy's effect on welfare is identified. We find that piracy quickens sales times and raises welfare in fixed size markets, and does the opposite in growing markets. In our model, consumers benefit from very high rates of piracy, legal sellers always dislike it, and pirate providers like moderate but not very high rates.

1. Introduction

Piracy can involve extraction of profits by pirate providers from legal producers, as pirate copies may be offered at prices as or more attractive than those of legal goods. Companies may attempt to avoid piracy's effects by various means, including using price reductions to capture a larger share of the market. Such a strategy involves lowering prices below those which would be optimal in the absence of piracy. Legal sellers can avoid some of the wealth loss associated with piracy, but their price reductions can transfer surplus to consumers.

Skimming on the other hand is a means by which companies can increase profits through successive price reductions. It involves selling at prices equal to the marginal valuations of consumers, first by setting prices to sell only to the highest valuing consumers, then reducing prices to sell only to the next highest valuing consumers, and so on. Companies can thereby extract all surplus from consumers. The surplus transfers due to skimming and piracy prevention can thus go in different directions.

In this paper we examine the welfare trade-offs between the two pricing strategies. We address three main questions. Firstly, does piracy raise or lower aggregate welfare when these countervailing strategies operate? Secondly, how does welfare divide between legal sellers, pirate providers, and consumers? Thirdly, how does market growth affect these welfare outcomes?

We find that in markets with a fixed size, total welfare rises with the piracy rate. The best way for the legal seller to avoid piracy's rising impact is to reduce prices early, reducing the discounting on the value of the goods and limiting the extent of skimming. Consumers have a strong preference for high rates of piracy, while pirate providers like moderate rates that do not trigger price responses from legal sellers. Legal sellers are adverse to all piracy.

In growing markets, total welfare falls as the piracy rate rises. With higher rates, the legal seller best avoids piracy's effect by delaying product launch until the market is large. Although skimming becomes less important, the pricing strategy to avoid piracy results in greater delays in sales and incomplete satisfaction of market demand. Consumers benefit from high rates of piracy, but to a lesser extent than in fixed size markets. Pirate providers prefer moderate to moderately high rates, and legal sellers like low rates.

Section 2 describes related literature. Section 3 presents our model and Section 4 describes the numerical analysis method. Section 5 looks at pricing, sales time, and welfare in the presence of piracy when market size is fixed, while Section 6 does the same when the market is growing. Section 7 concludes.

2. Related literature

In this section we briefly look at theoretical literature relating to the main themes in our model. Prior work suggests that piracy may increase or decrease aggregate welfare. An early stream of analysis examines static mechanisms, involving the breaking of a legal seller's monopoly control by pirate providers and the relative productive efficiencies of legal and pirate sellers. Later writers extend

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http://dx.doi.org/10.1016/j.ejor.2014.08.022
0377-2217/

the models in various ways, including examination of the welfare effect of government or company interventions against piracy, and outcomes in dynamic settings. Other writers examine legal sellers' profits in the presence of piracy, suggesting various mechanisms by which piracy can increase profits. A small number of papers present dynamic models examining the contrasting effects on profits of piracy and intertemporal price discrimination.

The short run effect of piracy is analysed in Besen (1986). Production of a good can occur by legal means or pirate means, with their relative efficiencies determining which productive form gives welfare maximising outcomes. When legal sellers are capable of capturing some of the value of pirate resale, effectively making piracy an alternative production technology, piracy may also be profit maximising if it is the more efficient productive technology. Johnson (1985) notes the ambiguity in short run welfare effects due to piracy. Greater inefficiency of pirate production is offset by surplus generated when more agents acquire the good in response to the cost of pirate acquisition being lower than legal prices.

Ahn and Shin (2010) look at the welfare consequences of piracy prevention strategies. They find government enforcement of copyright law can be more welfare enhancing than technological protection measures for digital goods. Tsai and Chiou (2012) examine the effects of anti-counterfeiting enforcement on welfare, and find ambiguous outcomes. They decompose welfare into consumer surplus and legal profit, with counterfeiter profit assumed to be zero under a market entry condition.

A small number of researchers have looked at how piracy affects welfare in a dynamic framework. In a simulated model, Khouja, Hadzikadic, Rajagopalan, and Tsay (2008) observe that the total number of sales for any level of piracy is close to the total market size, so pirate sales compensate for restrictions on acquisitions due to legal prices. The authors do not calculate discounted welfare although their model allows it, which would be informative about the welfare effects of piracy. In Herings, Peeters, and Yang (2009), the cost of pirate copying declines directly with the number of copiers. Discouraging piracy by increasing its cost reduces welfare. The authors do not present the dynamic patterns of emergence.

The effect of piracy on legal sellers' profits has been studied in the literature, with various mechanisms proposed by which piracy can be profit enhancing. Minniti and Vergari (2010) suggest that if piracy of one good increases the utility derived from purchase of another good, then profits can be increased by it. Banerjee (2013) notes that profits may rise as piracy goes up if network externalities are simultaneously present and sufficiently strong. A number of papers (Givon, Mahajan, & Muller, 1995, 1997; Haruvy, Mahajan, & Prasad, 2004; Liu, Cheng, Tang, & Eryarsoy, 2011; Prasad & Mahajan, 2003) use dynamic analyses to suggest that piracy can benefit legal sellers. A common theme is that piracy can act as a control on diffusion, either to reach a certain diffusion rate or network size. The analyses also generally include assumptions to stop piracy getting out of hand, and have absent or transient consumer heterogeneity.

By contrast, Khouja and Smith (2007) present a dynamic model of piracy where consumers exhibit persistent heterogeneity and intertemporal price discrimination can occur. They show that piracy leads to departure from skimming and reductions in profit. In Khouja et al. (2008)'s dynamic analysis, the market for a product consists of a number of individuals each of whom may make a pirate copy from a fixed number of neighbours if the latter have the product. Skimming by the legal seller is profit maximising for low numbers of neighbours (when piracy is less extensive), but is not optimal as the numbers of neighbours rises.

In modelling skimming and departures from it in the presence of piracy, Khouja et al. (2008) and Khouja and Smith (2007) overlap with our model and results. However, whereas Khouja et al. (2008) use simulation and Khouja and Smith (2007) use algebraic solution for pricing, we use a flexible numeric solution to solve our dynamic programming model. Their primary concern is not welfare, and Khouja et al. (2008) consider a fixed size market and Khouja and Smith (2007) examine a contracting one, compared with the expanding market we examine and that leads to our dynamic welfare trade-off.

3. Model

In this section, we describe our model of information good pricing in the presence of piracy. Diffusion is divided into acquisitions from a legal seller and pirate providers. The split is decided by competition between the two groups. Potential buyers are heterogeneous in their valuation of the good, so that price acts as a control variable on diffusion. The number of pirate providers rises with the number of previous buyers. Aside from pirate entry, additional dynamics in the model are induced by market growth. The legal seller performs dynamic optimisation over pricing, taking into account the dynamics within the model.

There is a single legal producer of an information good. The legal producer is profit maximising and possesses the ability to produce the information good developed from their own research and development. The legal producer can instantly produce copies of the good at a constant unit cost. As the cost of production can be absorbed into net price, we without loss of generality set the cost to zero.

At time t, there are k_t pirate providers of the good. Pirate providers produce copies of the good innovated by a legal seller. They initially get the production technology by acquiring a copy of the good from a legal seller or pirate provider. The technology may be as little as computer software and a DVD burner. Pirate providers are a subset of current good users, so as the number of past acquisitions rises, the number of pirate providers may increase too. We assume that the number of pirate providers is related to the number of goods previously sold by the equation $k_t = s\left(\sum_{\tau=1}^{t-1} S_\tau\right)^h$ for $t > 1, s > 0$, and $h > 0$ (and $k_0 = 0$) where S_τ is all goods sold at time τ. Fractional numbers of pirate providers are allowed, representing providers who are less active than average. h is the elasticity of the number of pirate providers with respect to past sales. Its precise value does not change the main pricing mechanisms of interest here, so we take it to be one and term the coefficient of proportionality s as the piracy rate (see Khouja & Smith (2007), who present a model where the number of copies pirated in a period is a fixed proportion of past sales). The modifying effects of different values of h are described in the conclusion. The unit cost of pirate production is constant and we absorb it into the net price charged by pirate providers, so again we can without loss of generality set production cost at zero.

The population who could have acquired the good by time t is denoted $N(t)$. $N(t)$ includes people who have already acquired the good and those who have not. We term this population as market size, as they are people who will acquire the good if they are offered it at a price below their valuation, but may not yet have been offered at such a price and prior to the product launch may not even be aware of it. $N(t)$ can vary over time, for example with a rise in the number of owners of a technology necessary for the information good's usage, such as DVD players or computers. A similar approach to growth in market size is used in Givon et al. (1995), and models the number of people who could potentially own the good because they meet the necessary criteria (like DVD player ownership) whether or not they have yet purchased the good (like a DVD). The market size can thus grow independently of the actual market availability of the good. Once the potential adopter has acquired the good, they will not acquire it for a second time.