Shareware competition: Selling an experience*

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Abstract

A firm may allow customers to learn the value of its product prior to buying it. This increases their willingness to pay, even though it also leads some not to buy. That strategy may also be used as a competitive tool to increase its product's attractiveness.

This paper examines competition between ex-ante identical firms that sell horizontally differentiated and mutually exclusive experience goods. Customers incur set-up costs when buying a good, but those set-up costs are partly recoverable if they then decide to buy the product of a competitor.

The main conclusion from this paper is that while a firm that gives information about its product makes higher profits than a competing firm that chooses not to do so, a firm may however choose that last option in order to avoid being in direct competition with a firm that is more open about the value of its product.

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1 Introduction

> "Shareware is a marketing method, not a type of software or even strictly just a distribution method. When software is marketed through normal retail channels, you are forced to pay for the product before you've even seen it. The shareware marketing method lets you try a program before you buy. Since you've tried the program, you know whether it will meet your needs before you pay for it. A shareware program is just like a program you find in major stores, catalogs, and other places where software is purchased; except you get to use it, on your own computer, before paying for it."
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> Association of Shareware Professionals

There are two ways to sell software: The shareware marketing system ("SMS") lets customers learn the value of the product before incurring costs to install it, learn how it works and integrate it into their system ("set-up costs"). The shelfware marketing system requires customers to buy the product and incur set-up costs before knowing its value. Firms marketing their software as a shareware have to design two different products, one that will be the try-out version of the other. They therefore not only have to sell the software, but must distribute the try-out version and then sell to customers who decide to buy the full software. The Internet enlarged the type of settings where a SMS can be used profitably because the Internet lowers distribution costs for information goods; given low distribution and storage costs, policies that are based on distributing samples of a products or on accepting returns are less costly than before. There is also one other effect at work that makes SMS attractive: the rise in the software set-up costs. Indeed, more and more goods must be customized, fit to the specific needs of different types of customers, and it is the customers who must ask for, or make, the changes themselves - which result in additional buying costs. This makes customers reluctant to buy a new product and in order to overcome this reluctance, firms adopt policies that consist in offering a "light" version of the product. That one does not necessitate high set-up costs but allows to evaluate the quality of the "full" version. Allowing customers to try a product provides an alternative to advertising, as that method is less costly than traditional informative advertising. Indeed, advertising became less efficient in markets like those generated by the Internet, which doesn't provide for a way to reach each customers' categories at a low price while it encourages a fragmentation of customers' tastes. Finally, this marketing system alleviates the moral hazard problem of the firm, as it is difficult to misrepresent the value of your product when you let potential customers try it. This moral hazard problem is prominent on the Internet, which still is an unknown and dangerous territory to explore for most consumers.

Software marketing and book selling are two examples of the use of a SMS: A crippleware is a version of a software with reduced functionality. It can be used for a limited number of time or during a limited time period. Either you cannot continue to use it if you decide not to buy a license for the full version, or you can keep the crippled software for as long as you want. Examples of crippleware include WebExpert 2000 of Visicom Media, a website-designing software, Qualcomm's Eudora, a mail reader, Opera Software A/S's Opera, a web browser, and Fritz6Demo of Chessbase GmbH, a chess playing software. Firms usually set up a SMS to give the option to try the crippled version before buying the full product. They may be able to know which clients tried their products and which of them didn't by leaving a trace on the user's computer that, for most of them, is difficult to detect and erase, and thus segregate customers based on their behavior prior to purchasing. While many software firms choose to offer crippled version of their product, they constitute only a small part of the market; the big software makers such as Microsoft do not see the use of that marketing method. The crippleware are present in competitive markets with no big established player.

SMS are not limited to software of course: Barnes and Noble, an American bookseller, set up coffee-shops in its bookstores, so that customers can comfortably browse books they picked up and make their choice. This is in contrast to Fnac in France, where the customer is usually discouraged from staying too long in the bookstore. Even though a "reading room" may sometime be provided, customers who want to read a book usually have to stay up in the aisles in the middle of the crowd. In the first case, books are sold in a SMS (customers can "try" the books), in the second case, they are sold as a commodity. While the difference may be cultural, return policies and accommodations for readers may vary a lot among different bookstores in the same city. This shows how no marketing system can be said to truly dominate the other, and marketing systems are not only cultural. The second part of this paper will deal with the characteristics of competition between a "Barnes and Noble" bookseller and a "Fnac" bookstore, or between a "Microsoft's Outlook" and a "Qualcomm's Eudora".

The shareware industry and the motivations for selling software as shareware were studied from other perspectives. Shareware may be used as a market pre-emption device in a market with network externalities – if part of the value of the software is in the number of people who use it, then letting people try it for free will increase the number of people using it and thus the probability they will find its value to be high. For example, a basic version of Grisoft's AVG anti-virus software is distributed for free so as to protect Grisoft's paying customers from the viruses that may otherwise be sent by their unprotected correspondents. Shareware may also be used in standardization battles – this is the case in the battle between Microsoft's proprietary Windows Media digital content format and RealNetworks, Apple and others who support the open-standard MPEG4. Both sides distribute free readers for their formats, the stake being the control of the entertainment services over the Internet. Distributing shareware can also be an entry-facilitating strategy by a new entrant in a market with an established dominant player – Microsoft distributed its Internet Explorer web browser for free so as to displace Netscape which had been able previously to sell its software at higher and higher prices as it was becoming dominant on the market and benefited from network effects.

There are few studies on the shareware industry. The present paper focuses on 'crippleware' where the try-out version only allows to test the value of the software but is of no actual use. There are two types of crippleware: trial-versions of a product that are basically the same as the original version in all its aspects but expire in a limited period of time, and stripped-down versions with some functions disabled. Most crippleware is a combination of the two. This paper assimilates the two types of crippleware, even though the second type raises the issue of what the optimal quality of the stripped-down version should be; this has an effect on the probability of subsequent buying of the full version, but also on welfare as there is no time limit on its use. Heiman and Muller (2001) look at the effect of competition on the design of the shareware offering (length of the trial period, usage restrictions), and show how competition will tend to increase the duration and quality of the demonstration if that policy increases the probability that the software is tested. They also contrast industrial software products, where demonstration is personalized, with software distributed via the Internet, where personalization is not possible. Haruvy and Prasad (1998) study shareware as a product strategy in the presence of network externalities, and propose guidelines for using 'limited versions' strategies in the software markets. They underline the trade-off involved between the cannibalization of the commercial version of a software by its free version, and the possibility to raise price for the commercial version due to the positive effect of network externalities (the free versions of the software that are in circulation increase the value of the software to paying customers). They do not consider the benefit of encouraging customers in trying the software and learning their valuation for it, and focus instead on the optimal setting of the quality of the limited version product. It must be high enough to encourage customers who have a low valuation for the full product to use the free version, while it must be low enough to encourage high-valuation customers to purchase the commercial version. An example of differentiated quality is Adobe's Acrobat Reader which is distributed for free but only allows to read and print PDF files while Acrobat's full version allows to create PDF documents.

While the shareware market has been estimated as a $300 million industry (Foley, 1995), it has not been the subject of many economic studies because its model is not well understood; many software authors offer a fully featured product for free with an implicit agreement that if the user likes it he will pay a fee for it. That type of agreement does not readily enter in economic models. Takeyama (1994) sees shareware as a way for individual software authors to make money on a software they developed for individual use or as part of another project. It can also be a David's tactic when faced with the Goliath marketing resources of big software companies. She considers shareware as a cottage industry that provides a side revenue for professional programmers, and from her survey of shareware developers, very few shareware are successful and their price is about 4 times lower than comparable commercial software programs. Haruvy and Prasad (1998) mention that the quality of shareware is generally lower than that of their commercial versions because of a lack of documentation and technical support, lower reliability due to the lack of extensive debugging, and a higher possibility of virus infection. However, both Takeyama and Foley focus on a particular type of shareware, more commonly called 'freeware', where the incentive to pay are very low because the full version of the software does not differ from the try-out version except for giving right to support and upgrades. The studies that are cited above tend to discount the importance of shareware as a software marketing system, but they are a bit dated: the shareware marketing system has become more popular and used even by established, 'Goliath' software companies in recent years. The conclusion of this paper uses the terms of this model to explain that evolution.

Review of the literature The review of the literature is divided in three parts. A first part looks at the issue of information disclosure for a monopoly, another deals with the same issue for competing firms and the third part shows how the choice of a SMS may be motivated from other perspectives.

A SMS provides information to a consumer about the value of a product, and this paper thus deals with the well-known issue of voluntary information disclosure. Milgrom (1981) and Okuno-Fujiwara et alii (1990) look at the case where a firm has to choose whether to disclose information about its product to the consumer. The revelation of information influences the decision to buy not only because the consumer learns the value of the product, but also because the decision to reveal information itself acts as a signal about the value of the product. Grossman (1981) also looks at the dilemma faced by a seller who knows the value of his product and knows that buyers will attribute to it the lowest a-priori if he does not reveal it to them before selling. In the present paper, the value of the product to one specific customer is not known to the firm selling it and signaling problems thus play no role. Shavell (1994) studies the incentives for a firm to acquire information about the value of its own product but the cost to acquire such information is assumed to be prohibitively high in the present paper and the firm thus does not wish to acquire it. That cost is high because while the firm may know the average value of its product to consumers, each consumer attributes a different value to the product. Learning the value of the product to a customer may involve motivating him to reveal his valuation when there is no independent way to estimate it, and

this raises the cost of that information since the firm then faces incentive problems on the part of the customer. That information is however valuable to the customer because it allows him to decide whether to incur set-up costs in installing and learning how to use the product. If he is risk averse, that information is valuable even in the absence of set-up costs. It therefore makes sense for the firm to let customers learn their valuation for the product by themselves. This paper views the shareware pricing system as it is used on the Internet as a direct consequence of the prohibitive costs that would be involved in learning how each individual customers values the firm's product. Since the demonstration is not personalized, and the firm does not have direct contact with the customer prior to sale, the cost of revealing information about the product is relatively low too. Shavell (1994) analyzed the revelation of information as a way to prevent socially undesirable investment in the product (learning, installation cost, etc.). However, the conclusions of his model do not apply here; it is the firm which decides what is going to be the cost to the customer of acquiring the information – the firm designs the try-out version of the shareware and chooses its price – and there is therefore no independent decision on the part of the customer whether to learn the value of the product or not: either the firm allows him to do so before buying, or it does not offer him the possibility to learn the value of the product. Lewis and Sappington (1994) are closer to this paper as they study the incentive for a seller to allow potential buyers to acquire private information about their taste for the seller's product. They however do not determine at what price that information will be sold, while this model introduces such a price that is set by the seller. This is important because it will guide the design of the try-out version of a shareware: the price of that try-out version is most of the time not monetary, and consists in the cost of downloading it, the need to register it, or the user-friendliness of its design (see the discussion, part 5). The only choice in the present model is between providing perfect information about the product or no information at all. Lewis and Sappington show that the seller will choose either to provide full information or no information at all even when the seller can choose how informative its information about the product will be by varying the probability with which it will lead the customer to learn the value of the product. Che (1996) studies a monopoly's return policy and emphasizes screening as a rationale for using a SMS. In his model, screening is beneficial for the firms because it allows them to economize on retail costs by selling only to customers who are satisfied with the product. In the present paper, the focus is on buying costs, i.e. retail costs from the point of view of customers. Additionally, Che (1996) does not look at policies that would consist in allowing customers to buy a product and waive their option to return it if they are not satisfied. In this paper, customers may choose to buy the product directly without trying, even when trying is allowed. Crémer (1984) looks at a two period model where in a first period the customer learns the value of the product, and chooses whether to buy it in a second period. This model is quite similar to his in the case where the firm can discriminate in the second period between first time buyers and second time buyers. It differs when that type of discrimination is not possible. This is because in Crémer's model the firm is free to change the price of its good from periods to periods, so that customers do not face in a second period the same price for the good that they tried in a first period. In the present paper, customers have a choice between buying the good directly at a given price, or trying it and then buying it at the same given price, the price of the "full" version of the good.

Competition between two firms that have two marketing systems available introduces some complications compared to the existing literature. Bouckaert and Degryse (2000) look at competition between two firms, an "expert" and a "non-expert" that sell horizontally differentiated goods, and use a simple pricing system. The expert is guaranteed to fulfill your need if you decide to buy his product, while the product of the "non-expert" may not be satisfactory. The competition dynamics between those two types of firms is quite similar to that in this model. Their "expert" corresponds to the "shareware" and to their "non-expert" corresponds the "shelfware". Their search for an equilibrium of the competition game is however greatly facilitated by the fact that firms compete based on one instrument only, the price of the product sold. In the present model, the shareware has two instruments, the price of the light version, and the price of the full version of the product, which complicates the search for an equilibrium. Krishna and Winston (2000) study competition between two firms selling exclusive experience goods that require high personal investment. Their results apply to the competition between two shelfware – proposition 6 – and serves as a benchmark for the study of settings where one firm or both use a SMS – propositions 7, 8 and 9. Those proposition are extensions of Bertrand equilibrium to cases where firms do not use the same pricing systems, those pricing systems are not uni-dimensional, customers can switch between products, although at a cost, and learn their value along the way. Baye and Morgan (1999) also present that type of mixed-strategy Bertrand equilibrium, but this paper is original in that it presents differentiated equilibrium where one firm uses a classical, shelfware pricing system while the other uses a shareware pricing system. Its conclusions are interesting as it shows a shelfware is always bought first while the shareware is tried by consumers who are disappointed with the shelfware. This corresponds to stylized facts in the industry, where many software products are sold pre-packaged with hardware as default, and consumers only choose to try other products—most of them sold as shareware—when they are dissatisfied with what they bought originally.

This paper is original because it studies competition between firms that have a choice whether to reveal information about their product or not, and that choice is not a signal about the quality of their product. It introduces set-up costs as a motivation for revealing information about the product in the monopoly case, and looks at the influence of switching costs on the competition game. Many of the results in this paper depend critically on the assumption there are set-up costs when installing a product, and switching costs when choosing to buy another product. Set-up costs are assumed to be null for the try-out version of a shareware, while they are significant for the full-version of a shareware or for a shelfware. Additionally, it is assumed that the cost of installing a product is lower for a consumer who already installed and used a competing product than for one who did not; when you switch to a new product, you incur only a fraction of that product's set-up costs. While this second assumption does not pose problem – it is quite obvious that having learned how to use a product will facilitate your learning how to use a product in the same category later – the first assumption must be justified; it is important to understand that it is merely a way to convey the simple fact that set-up costs will be higher for a full-version with all its functionalities than for a light-version. That light version is easier to download, does not require registration, offers only limited functionalities and allows to test only a limited range of the product's capabilities. It is therefore much easier to learn, and anyway, no customer will incur high set-up costs to use it because either the trial period is too short to make it worth-wile, or they will soon realize they had better buy the full product because the light version is too limited. That assumption isn't even essential for the results in this paper to hold; set-up costs for the try-out version could be introduced.

The importance of set-up costs is another matter for debate; do people care much about set-up costs when considering buying a piece of software? People seem quite ready to download software on the Internet, even when that software responds only to transient needs, and therefore set-up costs must be pretty low. That observation stems from a confusion between downloading a software and actually using it. Most software is not used to the full extent of its capacities because the investment in learning to do so is too high. People care about set-up costs, and this is why most do not incur them. The full value of the software product can be extracted only if those set-up costs are incurred. In this paper, the choice is binary: either you incur set-up costs and get the full value of the product, or you don't and get no utility from the product. This is a simplification from the reality where the value of the product depends on how much you invest in learning how to use it. In summary, this model assumes people download the try-out version of a shareware merely to test whether it fits their needs and can work with their current computer system, but will choose to really learn how to use it only if that test is satisfactory, in which case they buy the full version of the software: learning comes after buying. There are two reasons for this: one is of practicality – the full version usually comes with better support for learning – the other one is of necessity – the crippled version of the software does not give access to all the features that could be learned by the user, it is usually not very powerful and thus does not require much learning.

While previous model consider the price of the information about the product's value to be a redundant variable, and set it at zero, this model introduces it as a variable – the price of the try-out version of shareware – and determines in what range it can be set. The discussion at the end of this paper gives an interpretation of that price: it is the utility of the try-out version of the shareware, which is a function of its design and availability more than of its monetary price. This model thus provides guidelines on how the try-out version of a shareware, but also the shareware distribution system, must be designed to provide the required utility to customers; a try-out version is not necessarily free.

Outline The first part of this paper examines a monopoly's mechanism choice, the second part deals with the features of the competition between firms depending on their choice of marketing mechanisms, and the third part is a study of how they will choose what marketing mechanism to adopt. The first part shows that a rationale for using a shareware marketing system is to enhance the marketability of horizontally differentiated experience goods that require significant unrecoverable investments from the part of the buyer. This means that a SMS will be used when customers must incur high search, installation, and learning costs ("set-up costs") before getting to know the value of a product. Following the study of monopoly is a study of duopoly competition between different marketing systems, one of them leading the agent to become informed on the value of the product before buying. The degree of compatibility, or similarities between competing products then becomes important as it facilitates switching from one product to another. That switching can be relatively inexpensive, because having used one product helps in learning how to use the other. This part on duopoly competition leads to some counter-intuitive insights into how a firm that lets people get information about its product will compete with a firm that sells to uninformed clients. Firms that choose a shareware marketing system may end up being a second choice and having a smaller market share than the firms that choose a shelfware marketing system but they will make higher profits. The last part on the choice of marketing systems shows how two firms may choose different marketing systems; the equilibrium of a two stage game where firms choose the marketing mechanism and then the prices of their products may exhibit endogenous differentiation in terms of marketing systems, even though the firms are ex-ante symmetric. No marketing system can be said to strictly dominate the other, in the sense that it will not always be used by both firms under every circumstances.

2 A Shareware monopoly

2.1 The Model

Consider a single firm developing a software. Customers have to buy or, when that is possible, try the software before knowing its value. That value is not known to the firm, and is not the same to each customer. The firm plays a two stage game. In a first stage, the firm chooses a marketing method for its product, either the shareware marketing system or the shelfware marketing system. A firm that chooses the shareware marketing system will develop at no cost a new product (the "light version") that will reveal to customers the value of its product (the "full version"). It can decide that the customer must buy the light version before the full version, or that customers can buy the full version directly without having bought the light version before. A firm that chooses the shelfware marketing system has nothing to do. In a second stage, the firm chooses its price. If it chose the shareware marketing system, it sets a price w on the light version and a price p on the full version. The choice of p and w is made at the same time. If it chose the shelfware marketing system, it sets a price P on its product ("shelfware"). There is a mass 1 of undifferentiated customers. Customers learn the firm's choice of marketing system choice and its price(s). All customers have the same a-priori on the product: The customers' prior on the value of the product follows a simple distribution function : There are a-priori two possible values for the product, $\overline{v}$ with probability π and $\underline{v}$ with probability $1-\pi$. Denote $Ev = \pi\overline{v} + (1-\pi)\underline{v}$. If the firm chose the shareware marketing system, the customers buy the light version at price w, and learn the value $v \in (\overline{v}, \underline{v})$ of the full version. They incur no set-up cost in so doing but the value of the light version is zero. They can then choose to buy the full version at price p, incur set-up cost φ and get value v from the product. If the firm chose the shelfware marketing system, customers pay P, incur set-up cost φ and then learn and obtain value v from the product. Set-up costs φ are known and identical for all customers.

Assumption 1 $Ev - \varphi > 0$

The graph below illustrates the chronology of the trying and buying process depending on the firm's marketing system:

(Graph 1 p. 10)

2.2 Preliminary analysis and outline

When the firm chooses a shelfware marketing system, the customer's expected value for the product is $Ev - \varphi - P$, while if the firm chooses a shareware marketing system, the customer will buy the light version at price w, and then, knowing the value of the product, decide whether to spend p and incur set-up costs φ on the full version.

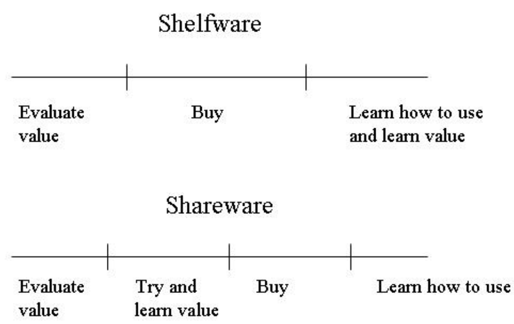

Figure 1: The trying and buying process.

In the following discussion of a shareware monopoly, there are two cases: In one case the customer must buy the light version before the full version; the firm can prevent the customer from buying its product without having tried it. In the other case, the customers are free to decide whether to buy the full version directly or buy the light version before buying the full version. That distinction reflects different assumptions about the ability of the firm to maintain strict control on the distribution of the try-out version of its product. It cannot maintain control when for example the available technology makes it unaffordable to require from customers that they register the light version, or when the firm out-sources the distribution of the try-out version to a firm like ZdNet, which aggregates shareware offerings on a single marketplace, reaching many more customers than individual firms could.

One remark is in order: the firm decides first whether to use a shareware or a shelfware marketing system, and then sets its prices, (P) if a shelfware marketing system is chosen, (w, p) if a shareware marketing system is chosen. This is in fact equivalent to another modeling option that would consist in setting prices (P, p, w) where P would be the price of the software if it is bought without trying, and p its price if w was paid before and the product tried. The firm does indeed have the same a-priori on all customers, so that it cannot segregate between those who will want to try before buying and those who buy directly. All customers face the same (P, p, w) triplet and take the same decisions. In case the firm can make sure a customer who tried the product will pay p to buy the full version, the customer must choose to either pay (P) or (w, p). In case the firm cannot monitor customers and they are free to buy the full product at price p or P, then the customer is faced with the choice to pay (P) or $(w, \min(p, P))$. Both options will be considered. The fact that both modeling options are equivalent will translate into the competitive case as long as the firms are not able to segregate between customers who tried or bought the other company's software and those who didn't.

2.3 A discriminatory monopolist

Suppose the monopolist is able to discriminate, when selling the software, between a customer who tried his product and one who did not. He can therefore prevent a customer who did not buy the light version from buying the full version. The monopoly will set up a SMS if, by letting customer try the product through the light version, he increases its expected willingness to pay for the full product by an amount sufficient to make up for the potential loss of sale from customers deciding not to buy the product after having learned its value. This may occur if there is some probability that the value of the product does not cover the set-up cost φ. Marketing this product as a shareware then allows the customer to avoid spending set-up costs in cases where the value of the software is too low to make this expense worthwhile. The following proposition draws from this intuition:

Proposition 1 *A discriminatory monopolist will use a SMS if an only if* $\underline{v} - \varphi \leq 0$*. He will set* $p \in [\underline{v} - \varphi, \overline{v} - \varphi]$ *and* $\pi p + w = \pi(\overline{v} - \varphi)$*. If* $\underline{v} - \varphi \geq 0$*, he will sell his software as a shelfware and set* $P = Ev - \varphi$*.*

Proof. If a SMS is used, and $p \leq \underline{v} - \varphi$, then, the shareware is always bought and the SMS is equivalent to a shelfware marketing system. If $p \geq \overline{v} - \varphi$, then, it is never bought. Now, if $p \in [\underline{v} - \varphi, \overline{v} - \varphi]$, the customer's expected value for the software is $\pi(\overline{v} - \varphi) - \pi p - w$ so that the firm will set $\pi p + w = \pi(\overline{v} - \varphi)$ so as extract all the surplus of the customer.

If a shelfware marketing system is used, the firm sets $P = Ev - \varphi$ which is the expected value of the software.

A SMS will thus be used if $\pi(\overline{v} - \varphi) \geq Ev - \varphi$, or $\underline{v} - \varphi \leq 0$. ■

2.4 A non-discriminatory monopolist

A monopolist may find it technically impossible or economically unviable to discriminate between customers who tried his product beforehand and those who did not. Alternatively, proposing different prices to people who tried the product and those who didn't may be illegal. The non-discriminating monopoly, when setting up a SMS, must therefore set the price of its product so as to get customers to naturally try its product before buying.

Proposition 2 *A non-discriminating monopolist will use a SMS if an only if* $\underline{v} - \varphi \leq 0$*. He will set* $p \in [Ev - \varphi, \overline{v} - \varphi]$ *and* $\pi p + w = \pi(\overline{v} - \varphi)$*. If* $\underline{v} - \varphi \geq 0$*, he will sell his software as a shelfware and set* $P = Ev - \varphi$*.*

Proof. p must be set such that the customer, when faced with a SMS, prefers to try the software before buying it, instead of just buying it directly:

$$Ev - \varphi - p \leq \pi(\overline{v} - \varphi - p) - w$$

Since $\pi p + w = \pi(\overline{v} - \varphi)$ so as to extract all the surplus, then, this condition translates in

$$p \geq Ev - \varphi$$

Then buying the shareware without trying it is not a valuable alternative for customers. Comparing profits in the SMS case and when a shelfware marketing system is used, the same conditions apply for the use of a SMS than in the case of a discriminating monopoly. ■

2.5 Continuum of valuations

The very simple value distribution of the previous part does not allow to predict the value of p and w, but only a range for them. With a more general continuous distribution of values, there comes a difference between the case where customers' ex-ante expectations on the value of the good follow a continuous distribution function ex-ante and they receive either $\overline{v}$ or $\underline{v}$ ex-post, and the case where customers all

have the same expectation on the value of the good ex-ante, but their valuation follow a continuous distribution function ex-post.

2.5.1 Uncertainty over the prior of customers

Customers have different a-priori on the product, which is expressed via an a priori probability π that the product has value $\overline{v}$, and $1 - \pi$ that it has value $\underline{v}$. The a-priori π is distributed in the population according to the density function $f(\pi)$ and π takes its values over $[\underline{\pi}, \overline{\pi}] \subset [0, 1]$. The expectations of customers are rational; a customer who has a-priori π will get value $\overline{v}$ from the good with probability π.

The firm will set $w = 0$ so as to maximize the number of people trying its product.

Proposition 3 *When customers have different a-priori valuations for the product, the monopoly that uses a SMS - whether he can discriminate between customers or not - will set $w = 0$ and $p = \overline{v} - \varphi$.*

A SMS will be chosen iif

$$E\pi(\overline{v} - \varphi) \geq \max_{\pi}[(1 - F(\pi))(\pi\overline{v} + (1 - \pi)\underline{v} - \varphi)]$$

Proof. If the firm chooses a shelfware marketing system, then, for a given price P, it sells to all customers who have an a-priori π s.t. $\pi\overline{v} + (1 - \pi)\underline{v} - \varphi \geq P$. There is a proportion $1 - F(\pi)$ of such customers. Profit is therefore $(1 - F(\pi))(\pi\overline{v} + (1 - \pi)\underline{v} - \varphi)$ when $P = \pi\overline{v} + (1 - \pi)\underline{v} - \varphi$. The firm will choose π such as to maximize this expression.

If the firm chooses a SMS, any $w > 0$ results in some customers not trying the product. Setting $w = 0$ ensures all customers try the product, which increases the profit of the firm, since each customer has a probability $\pi > 0$ of finding the product has value $\overline{v}$ - and therefore buy it if $p \leq \overline{v} - \varphi$. p will be set at $\overline{v} - \varphi$, and when $w = 0$, the question of discrimination does not enter into account, since no customer will want to buy the product directly without trying it. The profit of the firm will be $E\pi(\overline{v} - \varphi)$, or the average probability that the product is bought after having been tried, times the price of the shareware. ■

2.5.2 Uncertainty over the ex-post value of the good

Suppose now that ex-ante, all customers are alike. They all have the same a-priori f on the value v of the product. f is the density function of the cumulative distribution function F. Each customer's ex-post value is independent from that gotten by another one, and the overall distribution of values gotten by the customers is distributed according to f.

A discriminatory monopoly Suppose the monopolist can discriminate between the consumers who tried the product and those who did not, and can prevent those last ones from buying the product.

Proposition 4 *When customers have different a-posteriori valuations for the product, the discriminating monopoly will choose a SMS if and only if the support of the consumer's prior on the net value $v - \varphi$ of the software includes negative values, or* $\Pr\{v - \varphi < 0\} > 0$

The monopolist will set $p = 0$ (or marginal cost) and $w = E\{\max[v - \varphi, 0]\}$

Proof. Appendix A ■

The monopolist sets p at its marginal cost, and w so as to extract the surplus from the consumer. Profit will be

$$\pi^* = w = \int_{\varphi}^{\overline{v}} (v - \varphi) f(v) dv$$

Indeed, all customers try the product at that price if $p = 0$, as they know

they will not endear to learn how to use the product if its value doesn't cover its set-up costs. The monopoly extracts the customers' expected surplus in the try-out period and then sells his product at its marginal cost, which maximizes total surplus from trade. The result is quite intuitive: getting a negative net value from the product is an event which probability can be reduced by setting up a SMS. This result is similar to Crémer (1984) where firms price at marginal cost in a second period after consumers learned their taste in a first period of buying. The price of the light version is high while going over to the full version is free. This result runs counter to the pricing policy of most shareware but may however be applied in other similar settings: many products are offered with a guarantee, after-sale service and support, which can be seen as products in their own right. The "physical" good can be seen as a "light version", while support, after-sale service and guarantee can be seen as a "full version" that comes free when needed.

A non-discriminatory monopoly Suppose now that the monopolist cannot prevent the customers from buying the product without trying it. If the SMS is chosen, the customer can then choose to pay w before buying, or buy directly at p. The non-discriminatory monopoly has two marketing options: either sell his product to all customers as a shelfware at price $P = Ev - \varphi$, and make profit $\pi_0 = Ev - \varphi$, or sell it as a shareware at a price $p \leq Ev - \varphi$ with $w = E\{\max[p - v + \varphi, 0]\}$ and make profit $\pi_1 = p - \int_{\underline{v}}^{p+\varphi} (v - \varphi) f(v) dv$.

Selling the shareware at a price $p > Ev - \varphi$ does of course prevent the customer from buying the shareware without trying it, but $p = Ev - \varphi$ achieves the same purpose without incurring the same loss of efficiency in extracting the surplus from the consumer; the lower is p, the more there are customers who buy after having tried, and the higher is the total welfare that the shareware can appropriate. This is why $p \leq Ev - \varphi$.

Proposition 5 *When customers have different a-posteriori valuations for the product and the firm cannot discriminate between customers, the SMS is preferred to the shelfware marketing method iif* $E(v|v \leq E(v)) \leq \varphi$ *as long as the a-posteriori value distribution* f *is a logconcave distribution function*

p *will be equal to* $Ev - \varphi$ *and* w *will be more than* 0.

Proof. Appendix B ■

The condition for using the SMS when discrimination is not possible is more stringent than the condition for using a shareware marketing system when discrimination is possible. In that last case, the condition could translate as $\varphi \geq \underline{v}$, while now the condition is that $\varphi \geq E(v|v \leq E(v)) \geq \underline{v}$. When the firm is able to discriminate, it will use a SMS more frequently than if it is not able to do so. Since the price p is positive, there will always be less customers buying the shareware when no discrimination is possible than when it is possible. Therefore, total welfare is less when there is no discrimination.

Example f is an uniform distribution over $[\underline{v}, \overline{v}]$ When discrimination is not possible, a SMS is used when $\frac{\overline{v}+3\underline{v}}{4} \leq \varphi \leq \frac{3\overline{v}+\underline{v}}{4}$. The product cannot be sold for $\varphi \geq \frac{3\overline{v}+\underline{v}}{4}$.If the firm is able to discriminate, then a SMS is used for all $\underline{v} \leq \varphi \leq \overline{v}$. The graph below compares profits of the firm as a function of φ, when using discriminatory power (π^*) and without using it $(\max(\pi_0, \pi_1))$. The case with no discrimination is a lower envelope to the case with discrimination. This last one is therefore always more efficient.

(Graph 2 p. 15)

The pricing choice of a firm is dependent on the prior of the customers about the value of its product, and on the firm's ability to discriminate between those who try the product, and those who do not. Since the try-out version of a shareware is usually free, while its price is higher than that of a comparable software, the assumptions of the part 2.5.1 of this paper seem to be the ones that

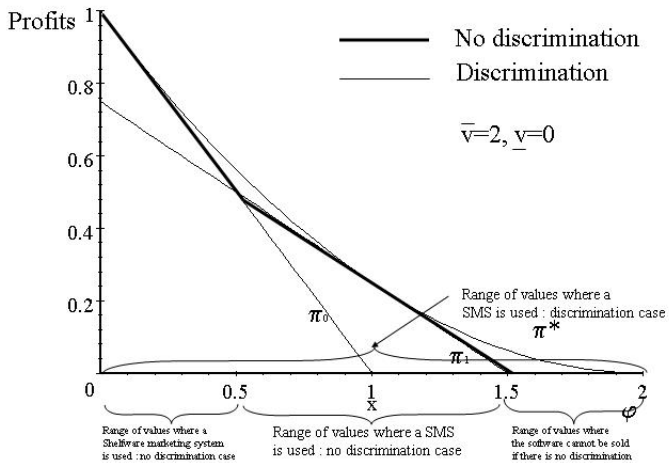

Figure 2: Monopoly shareware profits.

are verified on the software market: the customers' priors vary, while the value of the product is perceived as binary, either useful or useless.

3 Competition between marketing systems

3.1 The model

Two firms each developed a software. The two software are indistinguishable ex-ante, and customers have to buy or try them before knowing what is their value. That value is not known to the firm, and is not the same to each customer. Firms play a two stage game. In a first stage, firms independently choose a marketing method for their product, either the shareware marketing system or the shelfware marketing system. A firm that chooses the shareware marketing system will develop a new product at no cost (the "light version"), which if bought reveals to customers the value of its product (the "full version"). In order to simplify the analysis, assume that the firm is able to require customers to try its product before buying (Corollary 1 will show the results of this part can be extended to the case where it is not able.) This corresponds to the "discrimination case" of the previous part. A firm that chooses the shelfware marketing system has nothing to do. In a second stage, firms choose their prices, knowing what choice the other firm made. A firm that chose the shareware marketing system has to set a price w on the light version and a price p on the full version. A firm that chose the shelfware marketing system sets a price P on its product (the "shelfware"). The choice of prices is made at the same time by both firms. There is a mass 1 of undifferentiated customers. Customers learn the choice of systems by both firms and their prices. All customers have the same a-priori on both products. The customers' prior on the value of the products follows a simple distribution function: There are two possible a-priori values for the product, $\overline{v}$ with probability π and $\underline{v}$ with probability $1-\pi$. For each products, each customer's ex-post value is independent from that gotten by another one, and this value is independent of the value he gets from the other product. A customer who bought the two products (full version and shelfware) obtains an utility equal to the maximum of the two ex-post values. In other words, using the two products at the same time does not provide any additional utility.

As a matter of example, look at the case where one firm chose the shareware marketing system and the other the shelfware marketing system. In a first stage, the customer decides which of the product to choose first: the light version of the shareware or the shelfware. If the customer chooses the light version, he pays w, and learns the value of the full version. If he chooses the shelfware, he pays P, incurs set-up cost φ and learns its value.

In a second stage:

- If the light version of the shareware was bought in the first stage, the customer can decide to buy the full version of the shareware or to buy the shelfware. If he buys the full version in the second stage he pays p and incurs set up cost φ. If he buys the shelfware, he pays P, incurs set-up cost φ and learns its value.
- If the shelfware was bought in the first stage, the customer can try the light version, pay w, and learn the value of the full version, or he can stay with the shelfware. Trying the shareware does not allow you to recover any set-up costs in buying the other software. This assumption reflects the extreme point of view that the try-out version of the shareware only allows you to evaluate its quality, without allowing you to learn how that kind of software works. You cannot fit it to your needs and it does not necessitate any changes in your system that may also be useful when using another software. The try-out version of the shareware may be a read-only version of the product, that allows you to see what kind of documents you could create with the full version, but does not allow you to create such documents. (Realplayer by RealNetworks). On the other hand, the shelfware is designed in a way that forces you to incur those set-up costs φ before being able to use it, but those costs are partly recoverable in using another product of the same family. The shelfware will be designed in a way that makes the full φ expense necessary: since the shelfware chose this marketing system, it will design its product so that buying it only to learn its value without actually installing it properly will be prohibitively costly.

In a third stage, if both the light version and the shelfware were bought and the customer decides to buy the full version of the shareware, his set up cost is $\psi < \varphi$ because he already incurred setup cost of φ for the shelfware. ψ is lower than φ because software are usually built on open standards and switching costs consist mainly of establishing a new commercial relationship with the software developer (query, download, register, pay) and setting the parameters of the software. The customer avoids "higher levels" of learning. For example, if you learnt the terminology of mail reading

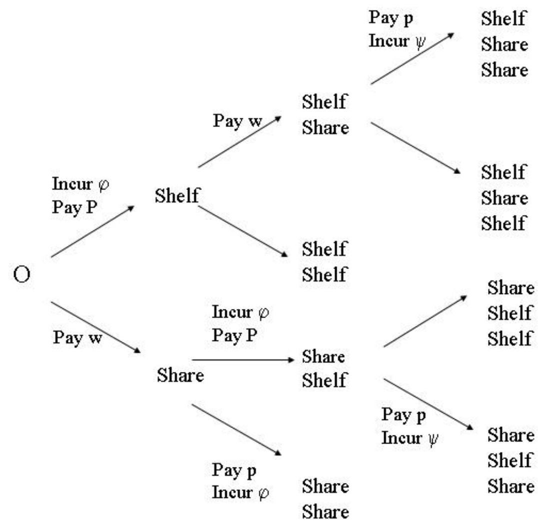

Figure 3: The buying process when a shareware and a shelfware compete.

systems with Outlook, then it will be easy to use Eudora. Set-up costs φ and ψ are known and identical for all customers.

All this is summarized in the following diagram :

(Graph 3 p. 17)

This graph shows what set-up costs and prices the customer faces according to his decision process. $Origin$ is the initial stage, $Shelf$ is the stage after having chosen the shelfware first, $ShelfShare$ is the stage where the shareware was tried after the shelfware was bought, etc... Similar processes of choice can be detailed when both firms chose a shareware marketing system or both chose a shelfware marketing system. As mentioned, ex-ante, all products look identical to each customers, and all customers are alike.

Assumption 2 $\underline{v} \leq \varphi - \psi \leq \overline{v}$.

3.2 Shelfware competition

The two firms chose a shelfware marketing system. For a given price, a shelfware prefers being bought first than second, because he will get more clients this way. A customer will choose the lower priced shelfware first, so that there is a tendency for a shelfware to undercut its competitor's. However, since even if a shelfware was not chosen first, it can still be chosen second at a positive price, prices will not be led to 0 as in Bertrand competition.

Notation 1 $\Delta = \overline{v} - \underline{v}$ *and* $g = \pi\Delta - \psi$.

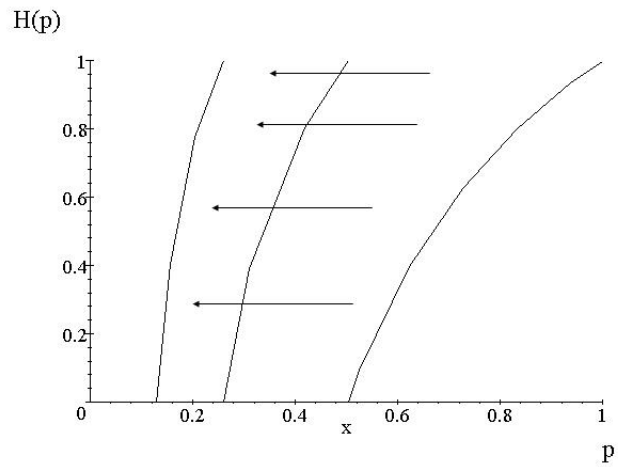

Figure 4: The convergence to a Bertrand equilibrium.

$g = \pi\Delta - \psi$ is the surplus value that can be gained from buying the second shelfware after having bought a first one and found its value to be $\underline{v}$. This is because the expected value of the second tried is $Ev - \psi$ and it will be bought only if $Ev - \psi - p \geq \underline{v}$, $\underline{v}$ being the alternative. If a first firm sets a low price and the other a high price, the first firm will sell first, but if the customer finds it to be of value $\underline{v}$, the other firm, as long as its price is less than g, will be chosen second. In an hypothetical dynamic setting, the first firm is then tempted to raise its price up to the level of the other one. If the other firm then lowers its price below the first one's price, it will be chosen first, which increases its profits. This shows there is no pure strategy equilibrium. A symmetric mixed strategy equilibrium must therefore be constructed. This strategy must guarantee expected payoff of at least $(1 - \pi)g$ because this payoff is always attainable by setting $p = g$. Firms thus choose prices according to a cumulative distribution function $H(.)$ such that $p(1 - H(p)) + (1 - \pi)pH(p) = (1 - \pi)g$. The term on the left is the expected payoff of the competitor. The strategy followed must guarantee him a payoff of $(1 - \pi)g$ so that he is willing to himself follow that same mixed strategy.

Proposition 6 *There is no pure strategy equilibrium of a pricing game between competing shelfware. There exists a symmetric mixed strategy equilibrium which guarantees profits of* $(1 - \pi)g$ *for each firms.*

Proof. Appendix C ■

(Graph 4 p. 18)

The graph above shows how this result is a generalization of a Bertrand equilibrium to cases where the value of the product is not known before buying and customers can switch between products. The arrows show the direction of the effect of an increase in π on the price distribution function $H(.)$. At the limit, when $\pi = 1$, firms set price $p = 0$ with probability 1. This corresponds to a Bertrand equilibrium.

3.3 Shareware vs Shelfware competition

One firm is a shelfware, which has to choose a price P, the other is a shareware, with two choice variables, the price w for the light version and the price p for the full version. When people buy the shelfware, they are guaranteed at least value $\underline{v}$ from the shelfware, but they incur learning costs φ. When they buy the light version of the shareware, they get no value from it, but do not need to incur set up costs. When people buy the shelfware first, there are two contradictory effects on the subsequent perceived value of the shareware: the first one is that the set up cost of the shareware will be lowered to ψ, the second one is that consumers have at least a $\underline{v}$ option to trying the shareware. When people try the shareware first, there are the same kind of contradictory effect on the subsequent perceived value of the shelfware, except that the set up cost φ is high for both software, and the option value is lower at $\max[\underline{v} - \varphi - p, 0]$. A balance must be struck between those effects. The first part of this section defines a (π, ψ) domain where an unique equilibrium in pure strategies ("PSE") exists. The second part shows that there exists a mixed strategy equilibrium ("MSE") for (π, ψ) outside the PSE domain.

Preliminary remark Any couple (w, p) with $w > 0$ and $p > 0$ is weakly dominated by a couple (w', p') with $w' = 0$ and $\pi p' = \pi p + w$. Indeed, since $\psi > 0$, if $p > 0$, the customer will never buy the shareware if $v_{Share} = \underline{v}$ – If he bought the shelfware before, he is better off using it even if its value is low rather than incur expense $\psi > 0$. If he didn't buy it before, he prefers buying the shelfware now, which has positive expectation of utility, rather than learning how to use the shareware, which would provides utility of $\underline{v} - \varphi$, a negative number by assumption 2. Because $w > 0$, the customer will try the shareware only if he is sure to buy it when $v_{Share} = \overline{v}$. Therefore, $w > 0$ and $p > 0$ means that the decision of the customer to test the shareware is equivalent to a decision to buy it if $v_{Share} = \overline{v}$. $\pi p + w$ is therefore the only parameter that enters in the decision of the customer when looking at the couple of prices (w, p). This couple (w, p) is weakly dominated by (w', p'), because $\pi p' + w' = \pi p + w$ (same profit) and $w > w'$, which means there are potentially more customers who try the shareware under the couple (w', p') than under the couple (w, p). This concept of weak dominance is repeatedly used to simplify the exposition of the proofs of the following lemmas and propositions.

3.3.1 Pure strategy equilibrium in shareware vs. shelfware competition

The graph below outlines the customer's choice process. This graph shows the final payoffs of a customer according to his pattern of choice and the results of his product samplings.

(Graph 5 p. 20)

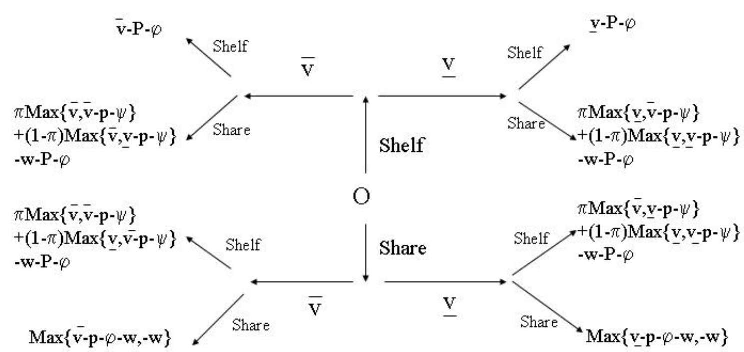

Figure 5: The customer's payoff, depending on his strategy and sampling results.

Successive lemmas will allow a simplification of this graph. Proposition 4 gives the conditions that ensure a PSE of the game of shareware vs. shelfware competition exists. It is then shown that under those conditions, it is unique.

From the shelfware vs. shelfware competition analysis, a firm can always choose to be chosen second at a positive price if the other is chosen first. The same reasoning can be applied here: both firms will make positive profits in a pure strategy equilibrium. Neither the shareware nor the shelfware can eliminate the other firm by choosing one or the other pricing system.

Lemma 1 *In any pure strategy equilibrium, both firms sell with positive probability.*

Proof. Appendix $D.1$ ■

Denote $U(Shelf)$ the consumer's expected utility from buying the shelfware first, and $U(Share)$ the consumer's expected utility from trying the shareware first. Suppose that $U(Shelf) < U(Share)$. Then the shareware will increase its prices until $U(Shelf) = U(Share)$ so as to make higher profits. Now, suppose $U(Share) = U(Shelf)$. Then the shareware can lower its price P by ε so as to be bought first and make profits of $P - \varepsilon$ – instead of $\frac{1}{2}(1 + (1 - \pi))P$ when the customer was indifferent between choosing one of the product first or second – unless when $U(Share) = U(Shelf)$, the shelfware is bought with probability 1. Therefore, in any pure equilibrium, either $U(Shelf) > U(Share)$ or $U(Shelf) = U(Share)$ and the shelfware is bought with probability 1. This means that, while from a welfare point of view, it is better that the shareware be tried first, this cannot be the case in a pure strategy equilibrium: you will first buy the shelfware and then try the shareware.

Lemma 2 *There are no pure strategy equilibria where the shelfware is bought with probability less than* 1.

Proof. Appendix $D.2$. ■

Contrary to what could be expected, a firm that lets consumers try its product does not subsidize their trying. This is because it is not necessary to lower w below 0 as it would only lower profits without gaining customers.

Lemma 3 *There are no pure strategy equilibrium with* $w < 0$.

Proof. Appendix $D.3$. ■

The proposition below builds on the previous lemmas. From those lemmas, the search is restricted to branches of graph 5 where the shelfware is bought with probability 1, $w \geq 0$, and both products are sold. There remains only to study the optimal choice of the shareware when that type of choice pattern is followed, and determine under what conditions the shareware will not deviate, so that a pure equilibrium exists.

Some intuitions: $\underline{v}$ is the minimum alternative to trying the shareware when the shelfware has been bought, and $\varphi - \psi$ is the difference between the set up costs ψ for the shareware when it is bought after the shelfware, and the set up cost φ for the shareware when it is bought first. As $\underline{v} \leq \varphi - \psi$ by assumption 2, and if π is relatively low, the shareware accepts being tried second by a proportion $1 - \pi$ of customers – the people who got value $\underline{v}$ from the shelfware. $\underline{v}$ is sufficiently low to make the shelfware look like a bad alternative compared to buying the shareware when the value of the shareware is high, while $\varphi - \psi$ – the reduction in shareware set-up costs – is high enough for the shareware to prefer being bought after the shelfware.

Proposition 7 *There exists a pure strategy equilibrium iff* $\pi \leq \sqrt{\frac{\varphi - \underline{v} - \psi}{\Delta - \psi}}$. *The shelfware sells with probability one while the shareware is tried by the consumers who were disappointed by the shelfware.*

w *is positive and* $p \in [-\psi, \Delta - \psi]$, *while* $\pi p + w = \pi(\Delta - \psi)$ *and* $P = Ev - \varphi$

The shareware makes profit of $V_{Share} = (1 - \pi)\pi(\Delta - \psi)$ *while the shelfware makes profit of* $V_{Shelf} = Ev - \varphi$.

This PSE is the unique PSE of the competition game.

Proof. Appendix $D.4$. ■

Despite competition, all welfare goes to the firms. The shelfware is bought first with probability one if $w > 0$, while if $w = 0$, the consumer is indifferent between buying the shelfware first, or trying the shareware first and then buying the shelfware. The shareware is tried with probability $1 - \pi$ but is bought only with probability $\pi(1 - \pi)$, when its value is found to be high and the value of the shelfware is found to be low. Given that $\pi \leq \sqrt{\frac{\varphi-\underline{v}-\psi}{\Delta-\psi}}$, profit of the shareware is strictly higher than the shelfware's profit; the shareware has two pricing instruments, compared with only one for the shelfware, and this allows it to make higher profits in equilibrium than the shelfware. The shareware will have a lower market share than the shelfware, but will sell only to customers who think it has a high value, while the shelfware is sold to everybody. Customers who own a shareware will therefore be satisfied by it, while there will be a proportion $(1-\pi)^2$ of people who use the shelfware that will be dissatisfied with it, but will keep using it because they also found the shareware to be of low value. The shelfware has no incentive to choose a mixed strategy over its price P, as $P = Ev - \varphi$ is the highest price it can ask for any possible choice of prices by the shareware. Given that $P = Ev - \varphi$, the shareware cannot get higher profits than what it makes under this pure equilibrium; choosing a mixed strategy would make sense only if that resulted in the shareware before chosen first in some instances, but in the domain where the PSE holds, being chosen first results in less profits for the shareware, so that it has no incentive to choose a mixed strategy over prices.

Suppose now that the shareware cannot require its customers to buy the try-out version of the shareware before buying the full version.

Corollary 1 *The results of proposition* 7 *remain valid when the shareware cannot require people to try its product before buying.*

Proof. The shareware can set $w = 0$ and $p = \Delta - \psi$. Then, customers are at least better of trying the shareware before buying it, since trying is free and it may result in not having to pay $p > 0$. ■

Suppose that a customer could buy the shelfware, choose to incur cost C to learn its value, and then install it at cost φ.

Corollary 2 *The results of proposition* 7 *remain valid when* C, *the cost of learning the value of the shelfware, is more than* $(1-\pi)(\varphi - \underline{v} - \pi(\varphi - \psi))$

Proof. The expected utility for the customer when conforming to the equilibrium strategy is $Ev - \varphi - P + (1-\pi)\pi(\overline{v} - p - \psi) - w$ while if he chooses to incur cost C for testing the shelfware to know its value before deciding to invest φ in set up costs, then his expected utility is $\pi(\overline{v} - \varphi) - P + (1-\pi)\pi(\overline{v} - p - \varphi) - w - C$. The former is higher than the later if $C \geq (1-\pi)(\varphi - \underline{v} - \pi(\varphi - \psi))$ ■

The cost of learning the value of the shelfware does not need to be high for the customer to prefer to incur full set up costs directly. If C is sufficiently high, the customer will not treat the shelfware like he would treat the try-out version of a shareware; a quick review of the characteristics of the shelfware before installing it increases total set-up costs by too much for this review to be made.

3.3.2 Mixed strategy equilibrium in shareware vs. shelfware competition

A pure strategy equilibrium in shelfware vs shareware competition was found, and it has some counter intuitive characteristics. A mixed strategy equilibrium of this game is difficult to find because of the asymmetric nature of the game played. The MSE is found by assuming that the mixed strategy equilibrium will exhibit some properties of the pure equilibrium strategy, and by building from those premises to find a MSE that verifies those properties. The important properties of the PSE that will simplify the search for a MSE are that when the shareware is tried, it is bought only if its quality is high, and for any realization of p, P and w, any one of the product is bought with a positive probability. In other terms, $\forall[p, P] \in$ [Support of p] $\times$ [Support of P], $0 < pr$[shelfware sells] and $0 < pr$[shareware sells]. Under those conditions, what matters for the competition game is the comparison of $\pi p + w$ with P. For further simplification, and without loss of generality (See the preliminary remark to 3.3.1), assume $w = 0$ and $p \in [0, \Delta - \psi]$, so that the only choice variable of the shareware is p.

Proposition 8 *There exists a mixed strategy equilibrium iff* $\pi \geq \sqrt{\frac{\varphi-\underline{v}-\psi}{\Delta-\psi}}$.

For $\frac{\varphi-\underline{v}-\psi}{\psi} \geq \pi \geq \sqrt{\frac{\varphi-\underline{v}-\psi}{\Delta-\psi}}$, *the expected payoff of the shelfware is* $V_{Shelf} = \pi(1-\pi)(\Delta - \psi) - (1-\pi)\psi$ *while the expected payoff of the shareware is* $V_{Share} = \pi(1-\pi)(\Delta-\psi)$.

For $\pi \geq \frac{\varphi-\underline{v}-\psi}{\psi}$, *the expected payoff of the shelfware is* $V_{Shelf} = (1-\pi)(Ev-\varphi)$ *while the expected payoff of the shareware is* $V_{Share} = (1-\pi)(Ev-\varphi) + (1-\pi)\psi$.

Proof. Appendix E ■

The three different domains $\pi \leq \sqrt{\frac{\varphi-\underline{v}-\psi}{\Delta-\psi}}$, $\pi \in [\sqrt{\frac{\varphi-\underline{v}-\psi}{\Delta-\psi}}, \frac{\varphi-\underline{v}-\psi}{\psi}]$ and $\pi \geq \frac{\varphi-\underline{v}-\psi}{\psi}$ are mutually exclusive because $Ev - \varphi \geq 0$. There is a continuity of the payoffs on the whole (π, ψ) domain (Figure 7)

The following graph shows the domains of definition of the equilibria,

(Graph 6 p. 24)

while this graph shows the payoffs of the shareware and the shelfware when ψ varies.

(Graph 7 p. 24)

When ψ reaches a certain level, its increase actually increases the payoffs of the shareware. This is because while for ψ low, the shareware keeps on putting some probability on setting its price high ($p = \Delta - \psi$) so as to be chosen second, that strategy is not anymore profitable when ψ becomes high. The shareware then prefers trying to be chosen first, and this strategy becomes more credible vis-a-vis the shelfware when ψ increases; the shelfware chooses a low price with higher probability.

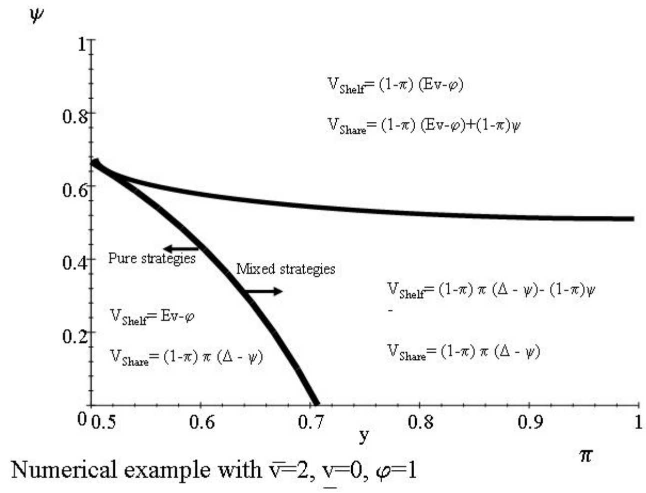

Figure 6: The payoffs of competing shareware and shelfware when ψ and π vary.

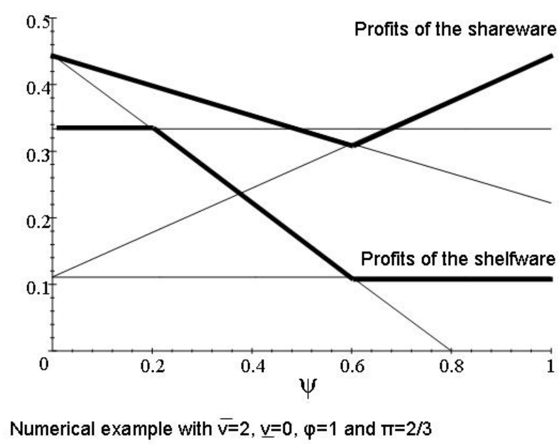

Figure 7: The payoffs of competing shareware and shelfware when ψ varies.

The shelfware is in a worse competitive position in a mixed strategy equilibrium than in a pure equilibrium as it will not always be chosen first. This is apparent from the fact that the pure equilibrium corresponds to the best case scenario for the shelfware: the shelfware is always bought at its monopoly price. It was however not straightforward that the shareware would be better off in a MSE than in a PSE: while in a PSE it is indeed bought with the lowest possible probability, this is at the highest possible price. It is only for π high that the shareware stops putting some probability to set p at its highest possible level $\Delta - \psi$, and can make higher profits than $(1-\pi)\pi(\Delta - \psi)$.

This mixed strategy equilibrium does not anymore allow the firms to jointly extract all surplus from the market, but the shareware still is able to make strictly higher profits than the shelfware. In this mixed strategy equilibrium, when P increases, and depending on the realization of $\pi p + w$, the probability for the shelfware to be bought may be lowered from 1 to $1-\pi$, and the probability for the shareware to be bought may increase from $\pi(1-\pi)$ to π. Depending on $\pi p + w$ and P, what varies is the probability to try the shareware, 1 or $1-\pi$, but for any realization of p, P and w, there is a positive probability that the shareware or the shelfware will be bought. This MSE therefore verifies the desirable properties that were assumed to hold when trying to find it. It was not possible to find other types of MSE where there would be a positive probability that none of the product is bought, or one of the products is not bought. That does not mean the MSE presented here is the unique one.

3.4 Shareware competition

Both firms chose a SMS. Like in shelfware competition, firms' marketing system are the same, so that no pure equilibrium will be found. However, after having tried one shareware, the option is 0 instead of $\underline{v}$, since you do not own the product. On the other hand, you will have to incur expense φ only if you decide to buy one of the product. Therefore, the maximum value that a shareware can extract from the consumer if it is chosen second is $\pi(\overline{v} - \varphi)$, instead of $g = \pi\Delta - \psi$ in shelfware competition. The proposition below shows there exists a mixed strategy equilibrium that guarantees to each shareware at least the profit it could make if it was always chosen second.

Proposition 9 *There is no pure strategy equilibrium when two shareware compete. There exists a mixed strategy that guarantees expected payoff of* $(1-\pi)\pi(\overline{v} - \varphi)$ *for both firms.*

Proof. Appendix F. ■

The proof is very similar to the one made in the "shelfware competition" section. $\pi p + w$ is the expected price of the shareware, and it plays exactly the same role as P in shelfware competition. The proof also borrows from the proof of the existence of a MSE in shareware vs. shelfware competition, as it builds on the intuition that a MSE with some desirable characteristics exists, and then shows that a MSE can be found which exhibits those characteristics.

Payoffs in pure strategies

		Firm 2: Share	Firm 2: Shelf
Firm 1	Share	$(1-\pi)\,\pi\,(\bar{v}-\varphi)$, $(1-\pi)\,\pi\,(\underline{v}-\varphi)$	$(1-\pi)\,\pi\,(\Delta-\psi)$, $Ev-\varphi$
	Shelf	$Ev-\varphi$, $(1-\pi)\,\pi\,(\Delta-\psi)$	$(1-\pi)(\pi\,\Delta-\psi)$, $(1-\pi)(\pi\,\Delta-\psi)$

Figure 8: The payoffs of competing software depending on their pricing systems' choice.

4 Competing firms' choice of marketing systems

Knowing the expected profits of firms under the different pricing choice they and their competitor make, the equilibrium chosen will depend on the relationship between their payoffs. Firm's payoffs can be represented in a 2×2 game matrix according to the choice of pricing systems. The matrix below represents the case where there is a pure equilibrium in shareware vs. shelfware competition.

(Graph 8 p. 26)

The following proposition indicates what kind of pricing systems will coexist for various levels of π and ψ. π 'low' means $\pi \leq \frac{\underline{v}-\varphi+\sqrt{(\underline{v}-\varphi)^2-4(\underline{v}-\varphi)(\overline{v}-\varphi)}}{2(\overline{v}-\varphi)}$.

Proposition 10 *When $\pi \leq \sqrt{\frac{\varphi-\underline{v}-\psi}{\Delta-\psi}}$ and π low, firms both choose a SMS with probability 1, while for π high, firms will choose a SMS with probability $\alpha_1 < 1$.*

For $\frac{\varphi-\underline{v}-\psi}{\psi} \geq \pi \geq \sqrt{\frac{\varphi-\underline{v}-\psi}{\Delta-\psi}}$, firms will choose a SMS with probability $\alpha_2 < \alpha_1$ and for $\pi \geq \frac{\varphi-\underline{v}-\psi}{\psi}$, firms choose a SMS.

Proof. Appendix G. ■

The graph below shows a generic case, and indicates which types of competition equilibrium will emerge depending on the (π, ψ) characteristics of the products sold.

(Graph 9 p. 27)

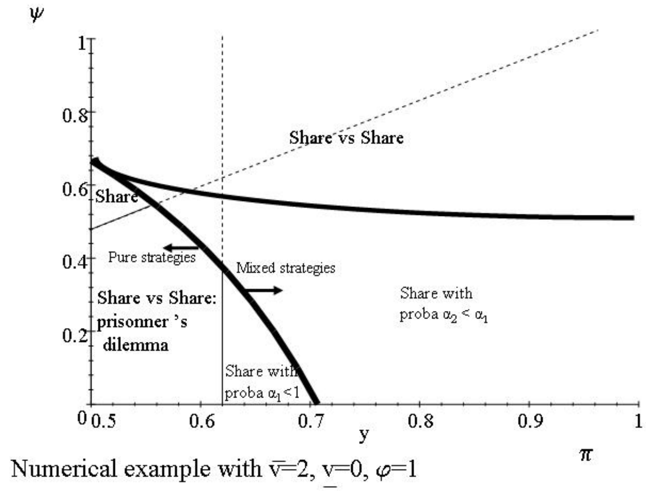

Figure 9: The software's equilibrium choices of pricing strategies.

In most cases, a SMS will be chosen when there is competition. There are however cases where firms may end up choosing different marketing systems. Equilibrium configurations exhibits endogenous differentiation between the firms. Unlike in the paper by Krishna and Winston (2000), that differentiation is not mediated through a choice of different levels of quality, but through a choice of different marketing systems. Firms get a high benefit from differentiation, one firm serving customers who were disappointed with the other, while the other sells as a "generalist". The benefits of such differentiation are high enough that a firm may settle for the "inferior" shelfware marketing system instead of adopting a SMS that would put it into a more direct competition with the other firm.

From a welfare point of view, the product selection process in shareware vs shelfware competition is suboptimal. Indeed, it is possible that the shareware be bought only as a second choice in equilibrium, while from a social welfare point of view, having it tried first, and bought whenever its value is high is always more efficient. The total welfare is indeed higher in that case:

$$\pi(\overline{v} - \varphi) + (1 - \pi)(Ev - \varphi) \geq Ev - \varphi + (1 - \pi)\pi(\Delta - \psi)$$

It was quite straightforward from the outset that a SMS was more efficient from a welfare point of view than a shelfware pricing system. This is because under a SMS customers incur set-up costs only when it is efficient to do so. However, it is now possible to discuss how much of that welfare goes to the customers and the firms, depending on the equilibrium that surfaces.

Proposition 11 *The higher the probability that firms use a SMS, the higher is the total welfare. Consumers benefit from the SMS only if both firms adopt it.*

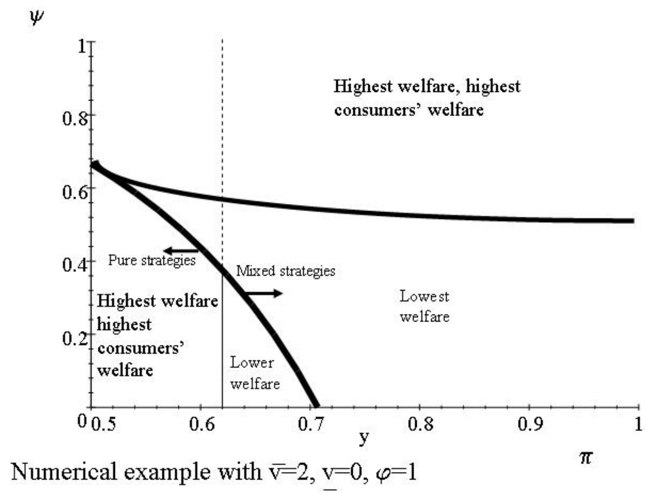

Figure 10: The welfare results of software firms' pricing strategies.

Proof. Appendix H ■

The worst situation for the consumers is when shareware vs shelfware competition occurs in the domain where a pure equilibrium exists ($\pi \leq \sqrt{\frac{\varphi - \underline{v} - \psi}{\Delta - \psi}}$) and firms choose a SMS with probability 1 ('π low'). Firms are then able to extract all surplus from the customer by differentiating based on pricing systems. Consumer welfare is highest when there is shareware competition. The SMS always enhances total welfare, as welfare is higher when there are two shareware than when there is only one, and it is higher when there is only one than when there is none. The proposition allows to draw the graph below which outlines the regions where consumer welfare will be highest.

(Graph 10 p. 28)

From this graph, total welfare will be the lowest when ψ is low and π is high, which means that welfare may be lowered when the probability to get a high value from the product is increased and it is not very costly to switch from one product to the other. This paradoxical result arises because when ψ is low, the shelfware marketing system may be used, as it becomes an attractive marketing system against a SMS. Indeed, the difference in profits the two type of marketing systems allow to obtain becomes small. Welfare, and more specifically consumer's welfare, is then decreased as the shelfware marketing system is suboptimal from a welfare point of view.

5 Discussion

Interpretation of the price w for the light version w is the utility, positive or negative, of the try-out version of the shareware. However, it is usually not monetary, and the flow of utility from the firm to the customer may not correspond exactly to the flow of utility from the customer to the firm. w is difficult to evaluate empirically: From the point of view of the consumer, w includes the utility of the try-out product, its set-up cost, and the monetary exchange between the customer and the firm. From the point of view of the firm, w includes the cost of producing and distributing the try-out product, the monetary exchange between the customer and the firm, and all revenues that the firm can derive from distributing the try-out version. Those revenues can come directly from advertising that is distributed via the try-out version of the shareware (advertising sponsored version of Eudora or Opera), or indirectly from network effects: the more there are try-out version around, the higher is the utility of the full version of the shareware, and thus the higher the price it can be sold. That effect is quite evident in the case of reader vs. developers' versions of RealPlayer, a shelfware that comes in two forms: a version that can only read audio and video files created using RealPlayer,

and another that allows people to create those audio and video files. That last one is all the more valuable the higher is the number of people who can read those files. The effect is more subtle when a firm wants to promote its own standards. For example, Internet Explorer, a web browser, has gained such a dominant position that web site designers write their web pages with IE in mind and the users of other web browser find it difficult to read those pages. In order to force Microsoft and web site developers to care about those compatibility issues, a firm like Opera switched to a SMS so as to have more Opera users around. Web site developers then begin to design their web pages with Opera users in mind, which increases the value of Opera to its users.

Analyzing the role of each components of w did not change the basic insights of the model. Having a dissymmetry between what customers and firms get from the shareware did not change much either. Therefore it does not really matter if w is seen as a monetary exchange between the firm and the customer, as the utility of the try-out version of the shareware for the customer, or as the profit or loss made by the firm when distributing it. The approach taken in this paper is therefore justified; all components of w can be summarized into a single term and treated as a monetary exchange between the firm and the consumers.

Some comparative static Suppose firms committed to a pricing system and have to design their product in terms of set-up and switching costs, as well as in terms of the distribution function of the valuations they offer to the customer. In shareware vs. shelfware competition, the profits made by the shareware is $(1-\pi_{shelf})\pi_{share}(\overline{v}_{share}-\underline{v}_{shelf}-\psi_{share})$ while profits of the shelfware is $Ev_{shelf}-\varphi_{shelf}$. A firm that has chosen a shelfware pricing system will try to maximize the value of its product to the average consumer, and minimize set-up costs. A firm that intends to use a SMS will not care about the average value of its product, but only about its value to some customers. It will also try to make it compatible with the shelfware (i.e. "imitate" the shelfware's choice of interface, standards and procedures). In a dynamic setting, differentiation between the two product should occur. Put another way, the choice by firms of a pricing system will depend on how firms think they compare with the other firms in terms of set up costs, target customers and design innovation (which increase ψ). However, cases where firms are not symmetric are an extension of this model which was not specifically studied. The reasoning made here may therefore be valid only when products remain relatively similar in terms of their f, φ and ψ characteristics.

The strategies of Internet providers in France are interesting to study from that point of view : Firms compete on the basis of their free introductory offers (w), quality of service (π) and choice of interface, that may be standard (Liberty Surf) or proprietary (AOL). The choice of the interface determines the level of set-up costs customers have to incur when changing ISP. An user of AOL has to install a proprietary software to connect to the internet, but then, the AOL interface is very special, and is incompatible with standard ones, since it uses different protocols. It would therefore be interesting to study if and how the choice of the interface influences the terms of Internet providers' offerings.

Variations on the basic model When w is a parameter that is not under the control of the firm, or when w is set before p, there is a wider area where a pure equilibrium exists in shareware vs. shelfware competition. Indeed, the shareware has less strategic freedom, and can therefore more easily be reduced to being a second choice, like in the pure equilibrium.

The model assumes there is no correlation between the values of competing software. This means that a customer is not supposed to update his a-priori on one software after having tried the other. Relaxing this assumption does not change the basic insights of the model, though it may reduce or augment the value of the second chosen product, and therefore change the expression of profits. It also introduces a free-riding problem for the shareware, as its try-out version not only provides information about the value of its own product, but also about the other one's value. The competition between Opera and Internet Explorer provides such an example of free-riding. Opera not only allows a free download of its light version, but uses it to convey information about its rival: Opera advertises the fact that its software is very light and provides links to Netscape or Internet Explorer's download sites, not without warning them that downloading those will be lengthy! This is a way for Opera to change the a-priori of consumers who try its own product, by making them less willing to try the other product. Firms may thus want to introduce a negative correlation between the perceived value of their product and that of the others'. Those issues are discussed in a model by Meurer and Stahl (1994).

6 Extensions

Two types of customers The model can be extended to a setting with two types of customers who have different a-priori on the mean value of each product, or different a-priori on the distribution of their possible values. Firms would try to discriminate between them, by having some try the products and others not. Courty and Hao (2000) study the problem in the case of a monopoly. This one will offer a menu of advance payments (p) and partial refunds $(w - p)$ contracts. Bouckaert and Degryse (2000) model the differences in customers' a-priori valuations for the software by using a parameter t representing the type of the customer on a line with origin one product and end the other. The utility function then includes a term $\alpha(1-t)$ for one product and αt for the other. Two schedules of prices would possibly be offered by one firm for the same product under its two versions, a shelfware version with price P, and a shareware version with prices p and w. Setting p different from P would require setting up a discriminative mechanism between those who tried the product and those who did not. This could be done through the use of coupons and rebates that would come with the try-out version of the shareware, as that strategy is frequently used out of the Internet. Internet firms usually find it easier to install a piece of software on the computer of the customer who downloaded the try-out version of the shareware, and thus identify them thereafter. That type of system can take the form of "cookies" that are used to identify returning website customers. Many shareware vendors hide a marker in the consumer's computer that forbids them to use their try-out version beyond its try-out period.

Two periods In a two period settings, a poaching problem emerges: a firm may be tempted to discriminate between people who tried the other's product, and new customers. It would become possible for the shareware to attract some customers of the software in a second period without having to reduce its price for those it locked in a first period. However, customers would anticipate this effect. There are examples of such two period pricing strategies : an anti-virus software, InnoculateIT by Computer Associates International Inc., was long proposed as a shareware with a free try-out version. That policy was then discontinued while preferential pricing was offered to users of the try-out version. Fudenberg and Tirole (2000) look at those types of strategies where the SMS is used as a screening device in a two-stage game.

Intermediated informative advertising A system that is similar to a SMS in some ways, intermediated informative advertising as a way to market special-interest goods, is the subject of another paper, Gaudeul (2002). Newsletters and other "free" information services may be seen as part of a SMS. Subscribing to a mailing list, or another information service, exposes you to targeted advertising. Based on personal information that you gave for obtaining the service, the intermediary will inform you on potentially interesting product. Using such information provides you with a free benefit and with the option to get informed at a low personal cost on products that otherwise would require high search costs. This service therefore shares some characteristics of a SMS. However, firms that manage information services are usually not the same than those that get their products advertised. This is why this example requires a new model to study the incentives of such intermediaries. Some aspects of the activity of Amazon or ZDNet make of them examples of such intermediated informative advertisers. Amazon lets people read excerpts of some books, and exploits the feedback from its customers to provide objective recommendations. ZDNet has developed an efficient web interface that guides customers in their choice of electronic products.

7 Conclusion

The differentiation between firms that arises in this model is solely the outcome of an equilibrium in pricing system choices. It is based on the choice of a pricing systems, and is not due to any differences in the quality of the products both firms offer, or to the use of different ways to manufacture the product or service the customer. Even though a mechanism (the SMS) may be deemed superior to the other by all accounts, as it generates higher profits for the firm using it and higher total welfare, an inferior mechanism (the shelfware marketing system) may be preferred in equilibrium. More interestingly, an inferior mechanism may coexist with a superior one.

When both firms are shareware, they do not care at all about whether their products are easy to learn for people who used other products. This may help explain the existence of a wide variety of shareware that fulfill the same needs; developers are freer to innovate. Shelfware, and shareware that compete with shelfware, will have to worry about making their products easy to learn for previous users of the other's product, because those will be more likely to try their own product if the switch is easy. This may be a reason for the features' inflation and complexity of dominant shelfware, and the frequent minor changes they incur. It makes it more difficult for a competitor to keep up and it ensures that consumers will find it difficult to switch to the competitor's product.

Distribution costs were assumed to be low, which allow easy distribution of a light version of a shareware. In reality, distribution costs for the light version of a software are still significant because of the cost to advertise their availability (See Ilan (2001)).

Customers were assumed to share the same a-priori on both products. In fact, some firms enjoy a better a-priori than others, through reputation effects for example (Microsoft). However, in the context of the Internet, distribution costs for software decrease and the playing field is leveled, so that the analysis made in this paper is relevant.

As software are increasingly developed based on open standards (reduction in ψ), and customers become more sophisticated and diverse in their needs (reduction in π), shareware as a distribution method should gain prominence. There is indeed a tendency for software firms to increasingly use a SMS to market their product. However, this paper shows that there needs to be a reduction in both ψ and π for a transition to a shareware marketing system to occur: For example, when ψ and π are high, simply reducing ψ while keeping π high results in a possible transition to a shelfware marketing system by one firm or both. A reduction in switching costs (also called friction costs) may thus lead to a decrease in the welfare, and this to the detriment of consumers.

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A Proof of proposition 4

If the monopoly sets-up a one price system, he can sell his product at $p = Ev - \varphi$ and make corresponding profits. If he sets up a shareware pricing system, his program is

$$\max_{p,w}[w + \int_{p+\varphi}^{\overline{v}} pf(v)dv]$$

subject to

$$\int_{p+\varphi}^{\overline{v}} (v - \varphi - p)f(v)dv - w \geq 0$$

The first expression is the profit of the firm, while the constraint is that the consumer gets positive expected value from the product. The first order conditions of the Lagrangian are

$$\frac{\partial L}{\partial w} = 1 + \lambda = 0$$

$$\frac{\partial L}{\partial p} = -(1 + \lambda)F(p + \varphi) - pf(p + \varphi) = 0$$

There are therefore three possibilities, either $p \leq \underline{v} - \varphi$ but that means the product will be bought whatever happens so that the expected value of the product cannot be higher by being sold via a SMS, or $p \geq \overline{v} - \varphi$ but that means the shareware will never be bought, or finally $p = 0$, which is a distinct possibility iif $\varphi \in [\underline{v}, \overline{v}]$, or put another way, if $\Pr\{v - \varphi \geq 0\} \neq 1$. Comparing the result of such a maximization program with the profits a software could make, the monopoly will set up a SMS only if $\Pr\{v - \varphi \geq 0\} \neq 1$ by setting a price $p = 0$ and extracting surplus *via* w.

B Proof of proposition 5

$p > Ev - \varphi$ was shown not to be optimal. Therefore, $p \leq Ev - \varphi$ and profit is

$$\pi_1 = p - \int_{\underline{v}}^{p+\varphi} (v - \varphi) f(v) dv$$

Make a change of variable, $z = p + \varphi$. Compare

$$\pi_1 = z - \varphi - \int_{\underline{v}}^{z} (v - \varphi) f(v) dv$$

with $Ev - \varphi$, the profit if a shelfware marketing system is used. The function to study is therefore

$$g = z - E(v) - \int_{\underline{v}}^{z} v f(v) dv + \varphi F(z)$$

which is increasing in φ. Denote $E(v|v \leq E(v)) = \varphi^*$ and make a change of variable, $\varphi = \varphi^* + \lambda$. Rewrite g as

$$g = z - E(v) - \int_{\underline{v}}^{z} v f(v) dv + \int_{\underline{v}}^{Ev} v f(v) dv \frac{F(z)}{F(Ev)} + \lambda F(z)$$

Multiplying this by $F(Ev)$:

$$F(Ev) * g = F(Ev)[z - E(v)] - F(Ev) \int_{\underline{v}}^{z} v f(v) dv + F(z) \int_{\underline{v}}^{Ev} v f(v) dv + \lambda F(z) F(Ev)$$

Integrating by parts:

$$F(Ev) * g = F(Ev)[z - E(v)][1 - F(z)] + \{F(Ev) \int_{\underline{v}}^{z} F(v) dv - F(z) \int_{\underline{v}}^{Ev} F(v) dv\} + \lambda F(z) F(Ev)$$

The first part of the expression is increasing in z and is less than 0. The third part is negative for $\lambda \leq 0$ and positive and increasing with z for $\lambda \geq 0$. The derivative of the second part is

$$\int_{\underline{v}}^{Ev} F(v) dv F(z) [\frac{F(Ev)}{\int_{\underline{v}}^{Ev} F(v) dv} - \frac{f(z)}{F(z)}]$$

which is increasing in z as f is logconcave [Bagnoli-Bergstrom (1989)]. The second part is therefore a quasi-concave function. It is equal to 0 for $z = \underline{v}$ and $z = Ev$, and it is therefore negative for any $z \in [0, Ev]$. Therefore, g can be positive only for $\lambda \geq 0$. Since the third and first parts are increasing with z,and the second part is maximum for $z = E(v)$, and I must have $z \leq E(v)$, I will have $z = E(v)$.

C Proof of Proposition 6

"1" denotes the first chosen and "2" the second chosen. Consider any couple of prices $[p_1, p_2]$. Suppose that $p_1 < p_2$. 1 is chosen first, and $p_2 \leq \pi\Delta - \psi$ is necessary for 2 to be sold as a second choice. $U_1 = \pi\overline{v} - \varphi - p_1 + (1-\pi)(Ev - \psi - p_2) > \pi\overline{v} - \varphi - p_2 + (1-\pi)(Ev - \psi - p_1) = U_2$ so that 1 can raise p_1 until $p_1 = \min[p_2, Ev - \varphi]$. Suppose now that $p_1 = \min[p_2, Ev - \varphi] \geq 0$. Firm 2 has an incentive to slightly lower its price unless $p_1 = 0$ or $Ev - \varphi \leq (1-\pi)p_2$. Suppose $p_1 = 0$. If $p_1 = p_2 = 0$, then profit is 0 for both firms. This is not an equilibrium because $g > 0$ and therefore, firm 2 has an incentive to increase its price to g so as to make profits $(1-\pi)g > 0$. Suppose now that $p_1 = Ev - \varphi < p_2$ and $Ev - \varphi \geq (1-\pi)p_2$. 2 is tempted to lower its price under p_1. Each firm then needs to lower its price only by a small amount in order to be chosen first, and increase its profit, so that this is not a pure equilibrium. Finally, if $p_1 = Ev - \varphi < p_2$ and $Ev - \varphi \leq (1-\pi)p_2$ then firm 1 has an incentive to increase its price to $max[p_2, g]$ so as to be chosen second and make higher profit than if it was a first choice. However, that results in $0 > U_2 > U_1$ and no product is bought, so that profit is 0 for both firms. Therefore, in that situation, firm are in a prisoner's dilemma and choose a mixed strategy over the pair $[Ev - \varphi, g]$. There is therefore no pure equilibrium strategy for this game as for any couple of prices $[p_1, p_2]$ one of the firms has an incentive to change its price.

Look now at a strategy that consists in putting a probability on setting a price according to the distribution f with support $[x, X]$. Suppose that parameters are such that $X \geq \pi\Delta - \psi \geq x$. M is the probability mass that is put on value g by the other shelfware. ε being the smallest monetary unit, denote $g^+ = g + \varepsilon$ and $g^- = g - \varepsilon$. One firm follows the strategy f, x_1, X_1 and the other the strategy h, x_2, X_2. x, X, f and h are such that the strategies form a Nash equilibrium. One firm can set price g and get payoff g if the price of the other is higher than g, which happens with probability $H(X_2) - H(g^+)$, payoff $\frac{g+(1-\pi)g}{2}$ if the price of the other is g, which happens with probability M, and payoff $(1-\pi)g$ if the price of the other is lower than g which happens with probability $H(g^-) - H(x_2)$. The strategy h, x_2, X_2. is a Nash equilibrium if the other firm is indifferent between setting price g and any other price in its support. Therefore, on the support $[x_1, X_1]$: For $p < g$,

$$\begin{aligned}
& p(H(X_2) - H(p)) + (1-\pi)p(H(p) - H(x_2)) \\
= \quad & g(H(X_2) - H(g^+)) + M\frac{g + (1-\pi)g}{2} + (1-\pi)g(H(g^-) - H(x_2))
\end{aligned}$$

and for $p > g$,

$$\begin{aligned}
& p(H(X_2) - H(p)) \\
= \quad & g(H(X_2) - H(g^+)) + M\frac{g + (1-\pi)g}{2} + (1-\pi)g(H(g^-) - H(x_2))
\end{aligned}$$

because if $p > g$, then you have no chance to sell as a second choice. The shelfware will set a price $p \leq g$ because that allows it to get higher expected payoffs given a strategy of the other shelfware that has support on $[x_2, X_2]$ with $X_2 > g > x_2$. More precisely, if $X_1 > X_2$, then it is straightforward to see that firm 1 has an interest in lowering X_1 since it has no chance to sell. By symmetry, $X_2 = X_1$. Now, if $X_1 > g$, then lowering X_1 by ε and increasing the mass M on g proportionally increases the profits of the firm as

$$\varepsilon(H(X_2) - H(X_2 - \varepsilon)) \leq (F(X_1) - F(X_1 - \varepsilon))\frac{g + (1-\pi)g}{2}$$

X_1 will therefore be lowered to g and by symmetry $X_2 = g$. Our condition then becomes:

$$p(1 - H(p)) + (1-\pi)pH(p) = M\frac{g + (1-\pi)g}{2} + (1-M)(1-\pi)g$$

The maximum price that the shelfware will set is a price $p = g - \varepsilon$ if there is a mass M on g by the other shelfware, because that gives it expected return of

$$g^{-}(1 - (1-M)) + (1-\pi)g^{-}(1-M) \geq M\frac{g + (1-\pi)g}{2} + (1-M)(1-\pi)g$$

By symmetry, $M = 0$. Our condition then become that

$$p(1 - H(p)) + (1-\pi)pH(p) = (1-\pi)g$$

and

$$H(p) = \frac{p - (1-\pi)g}{\pi p}$$

for p belonging to the interval $[(1-\pi)g, g]$.

D Proof of proposition 7

D.1 Proof of Lemma 1

If one product is chosen first, the other firm can set prices that give it positive profits by being chosen second. To prove this, it is sufficient to show that it will be bought if the first sampling by the customer gives a bad result, because this is easier done than if the first sampling gave a good result. Look at both cases, one where the customer bought the shelfware first and got value $\underline{v}$, and one where the customer tried the shareware first and realized it had value $\underline{v}$.

If the customer buys the shelfware first, and gets value $\underline{v}$, then the shareware will be tried if

$$\pi \max\{\underline{v}, \overline{v} - p - \psi\} + (1-\pi)\max\{\underline{v}, \underline{v} - p - \psi\} - w \geq \underline{v}$$

and bought with probability π if $p \leq \Delta - \psi$ and probability 1 if $p \leq -\psi$. If $p \leq -\psi$ then profits $p + w$ must be less than g while if $-\psi \leq p \leq \Delta - \psi$ then profits $\pi p + w$ must be less than

$\pi(\Delta-\psi)$ therefore the shareware will choose $-\psi \le p \le \Delta-\psi$ and $\pi p+w \le \pi(\Delta-\psi)$ and will be bought with probability $(1-\pi)\pi$.

If the customer tries the shareware first, and finds its value to be $\underline{v}$, then the shelfware is bought if

$$\pi \max\{\overline{v}, \underline{v}-p-\psi\} + (1-\pi)\max\{\underline{v}, \underline{v}-p-\psi\} - P - \varphi \ge \max\{\underline{v}-p-\varphi, 0\}$$

Suppose that $p \le -\Delta-\psi$. Then that would mean the shelfware is not bought. But if $p \le -\Delta-\psi$, then profit of the shareware is $p+w$ which must be more than 0. Suppose that $p+w=0$, then $E(Share) = Ev-\varphi$ but $E(Shelf) = \pi\overline{v}-\varphi+(1-\pi)(Ev-\psi)-P$ so that for $P \le \pi(1-\pi)g$ then $E(Shelf) > E(Share)$. Since $g > 0$ and the alternative for the shelfware is not selling at all, the price P will be set lower than $\pi(1-\pi)g$, so that the shareware is not tried first. Suppose then that $-\Delta-\psi \le p \le \underline{v}-\varphi$. Then $P \le Ev - \pi(\underline{v}-p)$ is necessary for the shelfware to be bought. Suppose now that $-\Delta-\psi \le p \le \underline{v}-\frac{Ev}{\pi}$. Then for P sufficiently low, it would be the shelfware that would be bought first. Therefore, $p \ge \underline{v}-\frac{Ev}{\pi}$ and the shelfware is bought with some probability after the shareware is tried with $P > 0$. Suppose now that $-\psi \ge p \ge \underline{v}-\varphi$. Then $Ev-\varphi-P \ge (1-\pi)(p+\psi)$ is necessary for the shelfware to be bought. This is true for any $P \le Ev-\varphi$ since p belongs to $[\underline{v}-\varphi, -\psi]$. Finally, if $p \ge -\psi$, then if $P \le Ev-\varphi$ the shelfware will be bought with probability $(1-\pi)$ when the shareware is chosen first.

D.2 Proof of Lemma 2

The method of resolution is as follows: There are various thresholds for p from the diagram of choices. Since $\underline{v} \le \varphi-\psi \le \overline{v}$ different diagrams are obtained according to whether $p \le -\Delta-\psi$, $p \in [-\Delta-\psi, \underline{v}-\varphi]$ or $[\underline{v}-\varphi, -\psi]$ or $[-\psi, \overline{v}-\varphi]$ or $[\overline{v}-\varphi, \Delta-\psi]$ or $p \ge \Delta-\psi$. To simplify the demonstration, note that either the firm is indifferent between setting p at one extreme or the other of the interval, and then p can be set at one of those extremes, or the firm is not indifferent, but then, that means it is optimal to set it at one or the other extreme, since this is a linear maximization problem. Therefore, without loss of generality, p can be set at each extreme of the interval, and then the choice of w studied. In each of the relevant intervals for p, there are conditions that ensure that, after choosing to buy or try one product first, the other product will be tried or bought. Looking at each combination of the conditions found above, there are conditions that ensure that one product or the other will be chosen first. I look below at each combination of conditions for any choice of p and prove that if the shareware is chosen first, then $U(Share) = U(Shelf)$ i.e. the shareware will saturate the constraint that ensures it is chosen first. But then the shelfware will deviate by lowering P a bit so as to be chosen first. Therefore, this will prove that there is no pure strategy equilibrium where the shareware is chosen first, as that would mean either that the shareware could raise its profits by increasing its prices, or that the shelfware could lower its price and increase its profits.

For $p \le -\Delta-\psi$, if the shareware was chosen first, then the shelfware would make no sale, which is not compatible with lemma 1.

For $p \in [-\Delta - \psi, \underline{v} - \varphi]$, rewriting the diagram 4 , and computing conditions that ensure one product will be bought after the other, if the shareware is to be chosen first (i.e. $U(Share) > U(Shelf)$) then that means $P \leq \pi\Delta - \psi + \pi(p + \psi)$ is necessary for the shelfware to sell. If $p + w \leq \pi\Delta - \psi$, then $\pi p + w \leq P + (1 - \pi)\psi$ is necessary for the shareware to be chosen first. Combining $P \leq \pi\Delta - \psi + \pi(p + \psi)$ and $\pi p + w \leq P + (1 - \pi)\psi$ together, this means that $w \leq \pi\Delta$, and since $p < -\psi$ then it is the constraint that the shareware be chosen first that is the most binding, and it will therefore be saturated. Check that if $p + w \geq \pi\Delta - \psi$, one gets an incompatibility with the condition that the shareware be chosen first.

For $p \in [\underline{v} - \varphi, -\psi]$, look at the case where $p = -\psi$ - the other extreme where $p = \underline{v} - \varphi$ was studied above - If $p + w \leq \pi\Delta - \psi$ and $P \leq Ev - \varphi$, the shareware is chosen first if $P \geq \pi p + w - (1 - \pi)\psi$. Since $\underline{v} \leq \varphi - \psi$, once again, of the constraint that $w \leq \pi\Delta$ and $w \leq P + \psi \leq Ev - \varphi + \psi$, it is the last one that is binding, and therefore it will be saturated.

For $p \in [-\psi, \overline{v} - \varphi]$, look only one extreme of the interval, or $p = \overline{v} - \varphi$. $w \geq 0$, as setting $w \leq 0$ can only increase the value of the "shelfware first" alternative, and therefore cannot allow to make the shareware bought first. If $\pi p + w \leq \pi(\Delta - \psi)$ and $P \leq \pi p - (1 - \pi)\psi$ then $E(Share) \leq E(Shelf)$ as $w \geq 0$ and therefore the shareware is chosen second and the shelfware always bought. If $\pi p + w \leq \pi(\Delta - \psi)$ and $P \geq \pi p - (1 - \pi)\psi$ then the shareware is chosen first if $\pi p + w \leq P + (1 - \pi)\psi$. The shelfware will set its price at the maximum it can get as a second choice, or $Ev - \varphi$, and the shareware will set its price at the maximum such that it is chosen first, or $Ev - \varphi + (1 - \pi)\psi$, as this is less than $\pi(\Delta - \psi)$ since $\underline{v} \leq \varphi - \psi$. If $\pi p + w \geq \pi(\Delta - \psi)$ and $P \geq \pi p - (1 - \pi)\psi$ then in order to sell, which is a necessary condition according to Lemma 1, the shareware must set $\pi p + w \leq (1 - \pi)\pi\Delta + \pi P$, which is compatible with the condition that $\pi p + w \geq \pi(\Delta - \psi)$ iff $P \geq g$. But then, as $\underline{v} \leq \varphi - \psi$, $g \geq Ev - \varphi$ and the shelfware would not make any sale, which contradicts lemma 1. If $\pi p + w \geq \pi(\Delta - \psi)$ and $P \leq \pi p - (1 - \pi)\psi$ then as above, the shareware must be chosen first to make any sales, and this translates into $\pi(1 - \pi)p + w \leq \pi(1 - \pi)(\Delta - \psi)$. But $\pi(\Delta - \psi) \geq \pi(1 - \pi)(\Delta - \psi) + \pi^2 p$ as $p \leq \Delta - \psi$. Therefore there is a contradiction between $\pi p + w \geq \pi(\Delta - \psi)$ and $\pi p + w \leq \pi(1 - \pi)(\Delta - \psi) + \pi^2 p$.

For $p \in [\overline{v} - \varphi, \Delta - \psi]$, let us again study only the case where $p = \Delta - \psi$. Then, when the shareware is tried first, the shelfware is always bought if $P \leq \min[Ev - \varphi, \overline{v} - \varphi - (1 - \pi)(p + \psi)]$ but both elements are equal when $p = \Delta - \psi$. Therefore, the condition that the shelfware is bought with some probability (lemma 1) and that this probability is 1 (lemma 2), are equivalent. Here, lemma 2 is a consequence of lemma 1.

Finally, $p > \Delta - \psi$ would mean that the shareware is never bought, which would contradict lemma 1.

D.3 Proof of Lemma 3

Suppose that $w < 0$. Then the shareware is always tried. Since $P \geq 0$, the shareware is tried before the shelfware is bought, since trying it may make the P expense not necessary, in case the value of the shareware is found to be high. According to lemma 1, the shareware cannot be bought when its value is found to be low, because that would mean the shelfware would never be bought. According to lemma 2, it is not possible that the shareware be bought whenever its value is high, because that would mean that the shelfware would be bought with probability less than $1-$ Note that it is not possible that the shareware is bought whenever its value is high and the shelfware is also bought in that case, because since $w < 0$, $p > 0$ if the shareware is to make positive profits. Therefore, the customer will not buy the shareware first and then buy the shelfware whatever happens. He will prefer buying the shareware only after having bought the shelfware and found its value to be low, because that saves him the expense p in some cases. Therefore, since it is not possible that the shareware be bought whenever its value is high, and since the shareware must however sometimes be bought, that means the shareware will be bought only if its value is found to be high and the value of the shelfware is found to be low. $\underline{v} \leq \overline{v} - p - \psi$ is also necessary, otherwise the shareware would not be bought even in the above case. This means that by setting $w < 0$, the shareware cannot make higher profits than $w + (1-\pi)\pi(\overline{v} - \underline{v} - \psi)$. It will therefore increase w up to 0.

D.4 Proof of proposition 7

The formal proof will go like this : Either the shareware is chosen second, or it could be chosen first when $w = 0$. Without loss of generality, the shareware is chosen second - this also includes the special case where $w = 0$ as the customer is then indifferent between trying it before or after buying the shelfware: He knows he will in any cases try the shareware and buy the shelfware.

The shareware, as it is chosen second, can set its price $p \leq -\psi$ such as to be bought whenever $v_{Shelf} = \underline{v}$. Then $\underline{v} \leq Ev - \psi - \pi p - w$ is necessary. He can also set its price $p \geq -\psi$ such that it is bought only if $v_{Shelf} = \underline{v}$ and $v_{Share} = \overline{v}$. Then $\pi(\overline{v} - p - \psi) - w + (1-\pi)\underline{v} \geq \underline{v}$ is necessary. The shareware will set $p \geq -\psi$ as this gives profits $\pi(\Delta - \psi)$, which is more than $\pi\Delta - \psi$, the maximum profit if $p \leq -\psi$.

Given this, the shelfware will set its price at the highest such that it is chosen first and customers get positive utility. Whatever the choice of p in the allowed interval, P cannot be raised higher than $Ev - \varphi$, which is the stand alone value of the shelfware. But it is also not necessary to lower P below this value.

This value for P guarantees that $U(Shelf) > U(Share)$ but also that $U(Shelf) \geq 0$,so that customer do enter the process of choice.

The shelfware will not deviate as this can only lower its profits. The shareware can deviate by changing its price so as to be chosen first - or in the case where $w = 0$, so that it is bought whenever $v_{Shelf} = \underline{v}$ - The expected value of choosing the shelfware first when $P = Ev - \varphi$ is $(1-\pi)(\pi(\Delta - \psi) - \pi p - w)$ while the expected value of choosing the shareware first is $\pi(\overline{v} - \varphi - p) - w$. The latter is

higher than the former if $\pi p + w \leq Ev - \varphi + (1-\pi)\psi$. The shareware will therefore not deviate iff $(1-\pi)\pi(\Delta - \psi) \geq Ev - \varphi + (1-\pi)\psi$, or $\pi \leq \sqrt{\frac{\varphi - \underline{v} - \psi}{\Delta - \psi}}$.

Formal proof From preceding lemmas I only have to worry about the conditions that ensure that the shareware is tried and bought after the shelfware is bought and found to be of value $\underline{v}$. I showed in the outline of the proff above that the shareware will set $p \geq -\psi$ because then the shareware will be bought only if its value is found to be high, which increases the surplus it gives to customers - they spend ψ only if the value of the shareware is found to be high - Therefore choosing $p \geq -\psi$ maximizes the profit of the shareware.

Whatever $p \in [-\psi, \Delta - \psi]$, and given that $\pi p + w = \pi(\Delta - \psi)$, the shelfware will set $P = Ev - \varphi$ and has no incentive to deviate from that price. Given this price P, I look at the best deviation for the shareware, i.e. the deviation that gives it the highest profit. Comparing that deviation profit to the profit without deviation, the condition that ensure this last profit is higher than the deviation profit is sufficient to have a pure equilibrium strategy.

Suppose that $p = -\psi$. Then $w = \pi\Delta$. P cannot be raised higher than $Ev - \varphi$ in an equilibrium where the shelfware is chosen first, because that would mean that $U(Shelf) < 0$. The shelfware will not deviate by setting a price lower than $Ev - \varphi$, because as long as $P > -\psi$, it would anyway be bought only $1 - \pi$ times if the shareware was tried first. Given a price $P = Ev - \varphi$, $U(Share) < 0$, so that indeed the shelfware is bought first. This reasoning can be replicated for $p = \overline{v} - \varphi$ and $p = \Delta - \psi$.

Now, given a price $P = Ev - \varphi$, what is the deviation that gives the highest profit for the shareware? Intuitively, this deviation must maximize $U(Share)$. $U(Share)$ is highest when prices p and w are chosen such that the shareware is bought whenever it is found to be of value $\overline{v}$, but not in any other cases, while the shelfware is bought whenever the value of the shareware is found to be of value $\underline{v}$. In that case, $U(Share) = \pi(\overline{v} - p - \varphi) - w$ while $U(Shelf) = (1 - \pi)(\pi(\Delta - \psi) - \pi p - w)$ and $U(Share) \geq U(Shelf)$ iff $\pi p + w \leq \overline{v} - \varphi - (1 - \pi)(\Delta - \psi)$. Comparing this with $(1 - \pi)\pi(\Delta - \psi)$, the later is higher than the former if $\pi \leq \sqrt{\frac{\varphi - \psi - \underline{v}}{\Delta - \psi}}$.

The intuition above is proven by showing that for any choice of p and w the shareware will not be able to make a higher profit than $\overline{v} - \varphi - (1 - \pi)(\Delta - \psi)$ when $P = Ev - \varphi$. For example, if the shareware deviates by setting a price $p \leq -\Delta - \psi$, then $U(Share) = Ev - \varphi - p - w$ while $U(Shelf) = (1 - \pi)(\pi\Delta - \psi - p - w)$ and $U(Share) \geq U(Shelf)$ iff $p + w \leq \frac{Ev - \varphi - (1-\pi)(\pi\Delta - \psi)}{\pi}$. This later expression which is the highest profit the shareware can make if it deviates by setting $p \leq -\Delta - \psi$, is lower than $\overline{v} - \varphi - (1 - \pi)(\Delta - \psi)$, the maximum profit found before. Replicating that reasoning for each choice of p, the condition on π that is in the proposition is found to be the most stringent for an equilibrium to exist.

E Proof of proposition 8

$G(p)$ denotes the strategy of the shareware. The strategy of the shareware depends only on p because $w = 0$. $G(p)$ is the cumulative probability to set a price lower than p. This strategy must make the shelfware indifferent between various levels of prices. $H(P)$ denotes the strategy of the shelfware.

Since $w = 0$, I can safely assume the first thing the customer does is buy the light version of the shareware. Then, the shareware can set a price p such that it is bought whenever its value is found to be high, or bought only when its value is high <u>and</u> the value of the shelfware is found to be low. The first case obtains if

$$\overline{v} - p - \varphi \geq \pi\overline{v} + (1-\pi)(\overline{v} - p - \psi) - P - \varphi$$

or

$$p \leq \frac{P + (1-\pi)\psi}{\pi}$$

Then profit of the shareware is πp and that of the shelfware is $(1-\pi)P$.

In the second case, where $p \geq \frac{P+(1-\pi)\psi}{\pi}$, then profit of the shareware is $\pi(1-\pi)p$ and that of the shelfware is P.

Let us denote V_{Shelf} the expected profit of the shelfware under the mixed strategy equilibrium, and V_{Share} that of the shareware.

The shelfware puts a probability M on setting $P = Ev - \varphi$, while the shareware put a probability m on setting $p = \Delta - \psi$. The support of the G distribution is $[\underline{p}, \overline{p}] \times \Delta - \psi$. $\underline{p}$ is the lower limit of the G distribution, and $\overline{p}$ is the upper limit of the connected part of the G distribution's support. The support of the shelfware's H distribution is $[\underline{P}, Ev - \varphi]$ and is connected. H^{-} is the H distribution over $[\underline{P}, Ev - \varphi[$.

The strategy G of the shareware must be such that

$$P(1 - G(\frac{P + (1-\pi)\psi}{\pi})) + (1-\pi)PG(\frac{P + (1-\pi)\psi}{\pi}) = V_{Shelf}$$

The strategy H of the shelfware must be such that

$$\pi p(1 - H(\pi p - (1-\pi)\psi)) + \pi(1-\pi)pH(\pi p - (1-\pi)\psi) = V_{Share}$$

Suppose $m > 0$.

Then, $V_{Share} = \pi(1-\pi)(\Delta-\psi)$ since $H(\pi(\Delta-\psi)-(1-\pi)\psi) = H(\pi\Delta-\psi) \geq H(Ev-\varphi) = 1$.

Then,

$$H(\pi p - (1-\pi)\psi) = \frac{p - (1-\pi)(\Delta - \psi)}{\pi p}$$

This c.d.f must verify the two following conditions:

- $\underline{p} = (1-\pi)(\Delta - \psi)$ (the support of G must not include values lower than this, since this value already puts H to 0)
- $\overline{p} = \frac{Ev-\varphi+(1-\pi)\psi}{\pi}$ (since $H(\overline{P}) = H(Ev - \varphi) = 1$)

I must have $\underline{p} \leq \overline{p}$, which translates in $\pi \geq \sqrt{\frac{\varphi-\psi-v}{\Delta-\psi}}$.

M to belong to the interval $[0, 1]$ as:

$$1 - M = H^{-}(Ev - \varphi) = \frac{1}{\pi} - (1-\pi)\frac{\Delta - \psi}{Ev - \varphi + (1-\pi)\psi}$$

$\underline{v} \leq \varphi - \psi$ ensures $M \geq 0$ and $\pi \geq \sqrt{\frac{\varphi - \psi - \underline{v}}{\Delta - \psi}}$ ensures $M \leq 1$.
Now,

$$\begin{aligned} & P(1 - G(\frac{P + (1-\pi)\psi}{\pi})) + (1-\pi)PG(\frac{P + (1-\pi)\psi}{\pi}) \\ = \quad & (m + (1-\pi)(1-m))(Ev - \varphi) \end{aligned}$$

so that

$$G(\frac{P + (1-\pi)\psi}{\pi}) = \frac{P - (m + (1-\pi)(1-m))(Ev - \varphi)}{\pi P}$$

This c.d.f must verify the two following conditions:

- $\overline{P} = Ev - \varphi$ since $G(\overline{p}) = 1 - m$.
- $\underline{P} = (m + (1-\pi)(1-m))(Ev - \varphi)$ but since $\frac{\underline{P} + (1-\pi)\psi}{\pi} = \underline{p}$ and $\underline{p} = (1-\pi)(\Delta - \psi)$ then $\underline{P} = \pi(1-\pi)(\Delta - \psi) - (1-\pi)\psi$

I must have $\underline{P} \leq \overline{P}$, which translates in $\pi \geq \sqrt{\frac{\varphi - \psi - \underline{v}}{\Delta - \psi}}$. This also ensures that $m \leq 1$.
The other conditions is that $m \geq 0$ which translates in $\underline{v} \leq \varphi - \psi - \pi\psi$, or $\pi \leq \frac{\varphi - \psi - \underline{v}}{\psi}$.
If that is not the case, then $m = 0$. In that case,

$$V_{Shelf} = \underline{P} = (1-\pi)\overline{P}$$

Therefore, since $\underline{P} = (1-\pi)(Ev - \varphi)$ and $\frac{\underline{P} + (1-\pi)\psi}{\pi} = \underline{p}$

$$\underline{p} = \frac{1-\pi}{\pi}(Ev - \varphi + \psi)$$

while in the same fashion

$$\overline{p} = \frac{Ev - \varphi + (1-\pi)\psi}{\pi}$$

Since

$$V_{Share} = \pi\underline{p} = (M + (1-\pi)(1-M))\pi\overline{p}$$

then

$$M = \frac{(1-\pi)\psi}{Ev - \varphi + (1-\pi)\psi}$$

and M obviously belongs to the $[0, 1]$ interval. In the same obvious manner, $\overline{p} \geq \underline{p}$. Finally, the shareware will deviate by setting $m > 0$ because when $\underline{v} \geq \varphi - \psi - \pi\psi$, then V_{Share} under this equilibrium is more than $\pi(1-\pi)(\Delta-\psi)$, the shareware's profit under the equilibrium where $m > 0$.

This gives the payoffs of each firm and their equilibrium mixed strategy distribution.

It is easy to check that the bounds for p and P satisfy the requirement that for any realization of p and P, each product has a positive probability to be bought. When $[p, P] = [\overline{p}, \overline{P}]$, since $\overline{p} \leq \Delta - \psi$ and $\overline{P} = Ev - \varphi$, the situation cannot be worse than in the pure equilibrium, and indeed, the consumer may buy both products. When $[p, P] = [\overline{p}, \underline{P}]$, the consumer buys the shelfware first, but still will want to try the shareware if $v_{Shelf} = \underline{v}$. finally, if $[p, P] = [\underline{p}, \overline{P}]$, the consumer tries the shareware first, but will still want to buy the shelfware if $v_{Share} = \underline{v}$.

F Proof of Proposition 9

Prices are set such that both products have positive sales. A firm that is chosen second will not try to compete for customers who were satisfied with their first choice, but will set its price so as to attract customers who were disappointed with their first choice. It will therefore set $p \in [\underline{v} - \varphi, \overline{v} - \varphi]$ so that if no product is found of high quality by the customer, he buys none, and if it is found to be of high quality, he buys it.

In a first stage, either one product is chosen first or second, and the condition that $E(Share_1) \geq E(Share_2)$ translates in $\pi p_1 + w_1 \leq \pi p_2 + w_2$. In that case, 2 will set $\pi(\overline{v} - \varphi - p_2) - w_2 = 0$ and 1 will set $\pi(\overline{v} - \varphi - p_1) - w_1 = 0$. 1 makes higher profits than 2. Therefore, this is not a pure equilibrium strategy.

Firms adopt a MSE such that each product is tried with probability 1, and is bought with some probability, whatever the price choice of the other. Schematically, this limits strategies to those that keep (p_1, p_2, w_1, w_2) in the region outlined below.

(Graph 11 p. 45)

Intuitively, those MSE are optimal from a welfare point of view, which is a justification for concentrating on them. This does not mean they are the only ones to exist. Firms will compete based on the value $\pi p + w$ which is the total expected cost of a shareware. This makes the equilibrium found very similar to the one found in shelfware competition, with $\pi p + w$ replacing P. There remains to prove that if one firm sets its prices such that it is always tried and sometimes bought, e.g. $w_1 = 0$, $p_1 \leq \overline{v} - \varphi$, then the other one has no incentive to set its prices such that the other firm's product is sometimes not tried. Suppose that indeed $w_1 = 0$. Then 2 knows 1 will always be tried. Suppose it sets its prices (w_2, p_2) such that 2 is sometimes bought even if $v_1 = \overline{v}$ and $v_2 = \underline{v}$. The limit case where it can happen with the highest probability is when p_1 happens to be set at $\overline{v} - \varphi$ so that the condition is that with some probability $\underline{v} - \varphi - p_2 \geq 0$. But raising the lower limit for the distribution of p_2 above $\underline{v} - \varphi$ can only increase profits of 2. Therefore, $p_2 > \underline{v} - \varphi$ with probability 1. As for the setting of w_2, it is straightforward to see that the couple (w_2, p_2) will be set such as to guarantee the product is tried whatever the price choices of 1, i.e. $\pi p_2 + w_2 \leq \pi(\overline{v} - \varphi)$ with

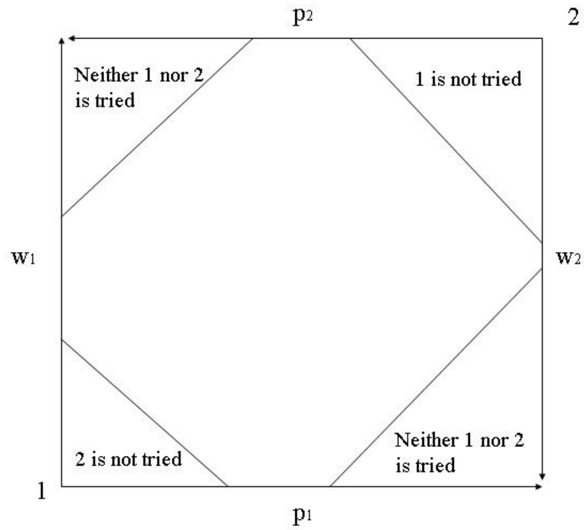

Figure 11: The limits on the variations on p and w when two shareware firms compete.

probability 1 so as to capture the possibility of being bought second - the same reasoning as that of the proof for the shelfware competition mixed equilibrium strategy is used. From the shelfware competition part, the support for $\pi p + w$ will be $[(1-\pi)(\pi(\overline{v}-\varphi)), \pi(\overline{v}-\varphi)]$ and the mixed strategy must guarantee $(1-\pi)(\pi(\overline{v}-\varphi))$. The density function for $\pi p + w$ is such that

$$G(\pi p + w) = \frac{\pi p + w - (1-\pi)(\pi(\overline{v}-\varphi))}{\pi(\pi p + w)}$$

G Proof of proposition 10

The proof is straightforward using the 2×2 payoff matrix and studying how the payoff compare under various situations, leading to different choices for equilibria.

Suppose $\pi \leq \sqrt{\frac{\varphi-\psi-\underline{v}}{\Delta-\psi}}$. Then when two shelfwares are competing, one will always be tempted to deviate as $(1-\pi)\pi(\Delta-\psi) > (1-\pi)(\pi\Delta-\psi)$.

When $\pi \geq \frac{\underline{v}-\varphi+\sqrt{(\underline{v}-\varphi)^2-4(\underline{v}-\varphi)(\overline{v}-\varphi)}}{2(\overline{v}-\varphi)}$, the profit of a shelfware in competition with a shareware, $\pi_{Shelf}(Shelf, Share)$, is higher than what it would make if it switched to a SMS, $\pi(Share, Share)$. Firms then choose a mixed strategy. Each one chooses a SMS with probability

$$\alpha_1 = (1 + \frac{Ev - \varphi - (1-\pi)\pi(\overline{v}-\varphi)}{(1-\pi)^2\psi})^{-1}$$

If $\pi_{Shelf}(Shelf, Share) \leq \pi(Share, Share)$ and $\pi(Share, Share) \geq \pi(Shelf, Shelf)$, then there will be shareware vs shareware competition : when a shelfware switches to a SMS then the other one will also switch, and the profits under shareware competition is higher than profit under shelfware competition.

If $\pi_{Shelf}(Shelf, Share) \leq \pi(Share, Share)$ and $\pi(Share, Share) \leq \pi(Shelf, Shelf)$, then firms are caught in a prisoner's dilemma. Even though a firm knows that the other one will imitate when it switches to a SMS and that the end result - shareware competition - is less profitable than shelfware competition, it still benefits from switching to a SMS if the other one does not.

Suppose now that $\frac{\varphi-\psi-\underline{v}}{\psi} \geq \pi \geq \sqrt{\frac{\varphi-\psi-\underline{v}}{\Delta-\psi}}$. When there is shareware competition, one firm will deviate whenever $\psi \leq \frac{\pi(\varphi-\underline{v})}{1+\pi}$, which is always true in this domain. However, when there is shareware vs shelfware competition, no firm wants to deviate. Each one chooses a SMS with probability

$$\alpha_2 = \frac{(1-\pi)\psi}{\pi(\varphi-\underline{v}-2\psi)} < \alpha_1$$

Suppose finally that $\pi \geq \frac{\varphi-\psi-\underline{v}}{\psi}$. When there is shareware competition, no firm wants to deviate, while if there is shelfware competiton, one firm will want to deviate if $\psi \geq \frac{\varphi-\underline{v}}{2}$, which is always true in this domain. Firms therefore choose the SMS.

H Proof of proposition 11

Expected social welfare under shelfware competition is $\pi\overline{v} - \varphi + (1-\pi)(Ev - \psi)$ of which firms get an expected payoff of $2(1-\pi)(\pi\Delta - \psi)$, which gives an expected welfare for consumers

of $Ev - \varphi - (1-\pi)(\pi\Delta - \psi)$. Expected social welfare under shareware competition is $\pi(\overline{v} - \varphi) + (1-\pi)\pi(\overline{v} - \varphi)$ of which firms get an expected payoff of $2\pi(1-\pi)(\overline{v} - \varphi)$, which gives an expected welfare for consumers of $\pi^2(\overline{v} - \varphi)$. Expected social welfare is higher under shareware competition: $\pi^2(\overline{v} - \varphi) \geq Ev - \varphi - (1-\pi)(\pi\Delta - \psi)$ since $\pi \geq \frac{\psi}{\varphi-\underline{v}} - 1$. Expected social welfare is higher under shareware competition than under shareware vs shelfware competition: $\pi(\overline{v} - \varphi) + (1-\pi)\pi(\overline{v} - \varphi) \geq Ev - \varphi + (1-\pi)\pi(\Delta - \psi)$ since $\pi \leq \frac{\varphi-\underline{v}}{\varphi-\underline{v}-\psi}$ while social welfare under shareware vs shelfware competition is higher than under shelfware competition: $Ev - \varphi + (1-\pi)\pi(\Delta - \psi) \geq \pi\overline{v} - \varphi + (1-\pi)(Ev - \psi))$

Shareware vs shelfware competition when π and ψ are such that a pure equilibrium exists, reduces consumers' welfare to 0.

When comparing welfare across the different (π, ψ) domains where the equilibrium payoffs of firms differ, it is when the probability for a firm to choose a SMS is the highest that the welfare will be the highest.