The music industry is often seen as the primary victim of piracy. Its decline has been attributed to the large number of pirates whose actions harm both artists and their representatives. Still, the damage caused by this sort of activity is often ambiguous and hard to compute due to the fact that some artists chose to give their work for free, while others are quick to implement anti piracy measures. However, the cost of policing such individual behavior is often so high that it is longer profitable for firms to pursue such measures.

On a fundamental level, firms under the threat of piracy, have two main options, attempt to make their bought product more valuable, or increase the potential cost of pirating. The ability to differentiate the bought product from the pirated product is a challenge which requires balancing costs. An example of this strategy is already seen through limited edition sets that include various extra content such as conceptual art or more information on the development process. This added content is most often coveted by the consumers who have a higher willingness to pay.

The present situation can be framed as a choice between the relative level at which a firm will rely the stick versus the carrot. Firms with copyright claims on their products have in their arsenal both a carrot and a stick. The carrot, in this case, is the ability to attract consumers by offering a high value product. In contrast, the stick is the ability to increase the cost of piracy; this would incite pirates to switch to buying.

Conceptually, the carrot is the improvement of the product but also a decreased price and, while improving the product is often costly, changing the price is not. This means that there is automatically a built-in mechanism to incite firms to rely on the stick. Nevertheless, with regards to copyright, firms do incur some cost of chasing after individual consumers or distributor firms.

A company that decreases the cost of pirating can expect two types of effects. The first is that the consumers who would have bought the product will instead pirate it and similarly the consumers who would have neither pirated nor bought it may decide to obtain it through piracy. Data indicates that the consumer who will pirate will most likely be a consumer with a lower willingness to pay. The business software alliance estimates that the developing world has a much higher rate of piracy than the developed world, with countries like the United States, Japan, Luxembourg, New Zealand, Belgium, and Denmark having a piracy rate below $25$ per cent whilst countries like Bangladesh, Georgia, Armenia, Zimbabwe, Sri Lanka, Azerbaijan have rates exceeding $90$ per cent. \citep{BSA09}

In some domains these effects may be separate, that is, if there is an increase in the number of pirates, this has no effect on the number of people who will buy and vice versa. Under such a presumption, a firm would only be concerned with maximizing the number of buyers, meaning that it will set the cost of piracy as high as possible. However, we can imagine that there are some domains where an increase in the number of pirates has an indirect effect which increases the number of buyers.

To consider why it may be that an increase in the number of pirates may lead to an increase in the number of buyers we need only consider that the decision to purchase a good depends not only on the intrinsic value of the good but also on the number of consumers who are consuming it. This means that there is a secondary source of utility stemming from the communal aspect of a good. This can be interpreted as a sort of socialization utility.

If we gradually relax the assumption of utilities being independent we have what is called in the literature a 'network good'. It is possible to envision most goods as having an intrinsic value and an extrinsic value. This relative ratio of intrinsic to extrinsic value will likely vary substantially between cultures. The domain in which this is true is likely to extend much farther than what common intuition would entail. For instance, even perishable goods, such as food, are not necessarily exempt from this feedback process.

The intrinsic and extrinsic value of a product can radically change depending on what kind of goods we are observing. The common example of QWERTY keyboard is but one, where is it said the keyboard itself is inferior to other variants but because it the socially accepted one, a self fulfilling prophecy occurs. Spectator sports are another important example; much of the popularity comes from the social and community building elements. It is hard to imagine the World Cup attracting the number of viewers they do because the viewers are interested in the intricacies of a good match, such events are clearly network goods, communal events.

Of course network goods do not necessarily entail a single event, it may be a constant consumption of a good that gradually increases solidarity. News about current events or the weather can easily enter into this framework, where they are not merely useful in themselves but also in that they allow consumers to socialize with those around them.

Piracy is often dismissed as merely a clear loss for the firm. However, within the framework of network goods, stealing and not consuming are not worth the same to the company. An example of this could be a televised series; part of the value of such a good is in the socialization that follows it after every new episode. Often companies structure themselves in a way as to offer a free good of base value and giving an improved product to those who pay. In the case of football this usually means more pixels on pay per view programming as well as some functionality upgrades such as the ability to pause and rewind games.

Why might the value of socialization between these two approaches to consumption be different?

Accordingly, much of what can be deemed "group identity" can be represented within a network good framework.

Digital goods are the most intuitive, as they have a trivially low marginal cost to distribute and can essentially be distributed to everyone with a computer and access to the Internet. Traditional economic theory would imply that the company would just find the profit maximizing level, which depends on the distribution of consumers. In a world with perfect price discrimination, it is intuitive that every consumer would be charged exactly their marginal product and in a world with a single price, the profit maximizing level would depend on the distribution of valuations. However, this traditional logic is aggravated when people’s utilities are not independent. The aim of this paper is to capture piracy as a form of leakage that is between these two worlds.

The music industry has specifically been a vocal

The following paper focuses on cases where firms effectively have a monopoly on the network good in question. This may be for various reasons, ranging from intellectual property rights to geographical advantages.

Another example that may shed light is software. Everyone has their uses of it but one thing that enhances the product is how many packages the product has, something that often depends on the number of users. This is so for one of two reasons. For open source this is because the users themselves generate these packages and for proprietary software it is because the higher number of users leaves more money for product improvement. The willingness to pay for the product increases either by direct investment by the company into the product or by the creation of networks between consumers. Sometimes these networks are explicitly organized by the company, such as Stata where licensees are invited to events, or sometimes the organization is emergent as would be the case in Python or R.

The main contribution of this paper is a characterization of surplus and welfare properties of piracy equilibria as well as a closed form solutions for the optimal level of innovation and explicit characterization for the conditions under which the optimal level of product degradation is 0.

Note that for the remainder of this paper, we will be referring to the segment of "users" as the proportion of the population that is either pirating or purchasing.

**\section{Literature review}**

There exists a fairly rich literature on the pricing of network goods. The classic paper of networks in industrial organization by \citep{katz1986technology} where it is shown that under competitive paradigm, firms don't have an incentive to make their product comptibility but they do have one to standardize. \cite{fudenberg2000pricing} show that under a network good paradigm, the incumbent may decide to keep low prices even without a direct competitor as long as the threat of entry exists.

The \cite{neill2005cascade} who introduce a dynamic framework which has norm dependent utilities and norm independent utilities and shows how these utilities can induce cascade effects.

Similarly \cite{peitz2006music} use a sampling model to show that giving free samples to consumers may be profitable for firms.

Similar work on the effects of digital piracy also include \cite{jain2008comp}, without, who focus more explicitly on copying and show that stronger copyright may also act as a coordinating device between firms to collude.

Perhaps the closets model to our own is the model by \cite{reavis1991software} where they also have an intermediate option of piracy. However their model does not include a product improvement variable and does not give an explicit solution for a specific distribution. Other models of piracy which mimic our approach are, \cite{mach2017os}, whom mimic our demand approach but focus more on the competition with open source.