The Effect of Piracy on Markets for Consumer Transmutation Rights

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Abstract

We have shown in a previous study that selling content-transmutation rights to consumers increases total surplus of both producers and consumers of digital products. Our results were conditional on the absence of piracy. There has been some research on the effect of online piracy in traditional content markets that do not consider consumer transmutation. Some claim that piracy damages producers’ surplus because it causes decline of music sales. At the same time, others claim that piracy, under certain conditions, has beneficial effects on production of digital products and increases profitability. The purpose of this study is to investigate whether piracy can damage the benefits related to the introduction and exchange of consumer modification rights. As a first step, we consider a market with a strong form of piracy and show that the presence of extreme piracy destroys the producers’ profit and that all surplus is transferred to consumers. In addition to causing lost sales piracy in markets with transmutation damages the market’s information and coordination function.

1. Introduction

Digital culture products – songs, movies, games, multimedia content etc. – are easily reproduced, easily distributed, and subject to endless transmutation [9]. The development of information technology enables nowadays’ consumers to modify and create products with handy toolkits. With this trend, some pioneering companies are reassigning some design aspects of product development to their customers [25]. The latest blockbuster video game, Halo 3, for example, provides a special toolkit for consumers to modify the game based on their preferences. In the music industry, some providers provide, instead of CDs, digital music tracks to consumers for them to modify and remix\(^1\). Both approaches increase the demand for and popularity of the products.

The present paper adds to the nascent literature on digital transmutation of information goods by examining the impact of piracy, which heretofore has not been considered within the context of transmutation. Secondly, we also contribute to the digital piracy literature, which has largely focused on piracy in the context of copying and sharing finished information goods among consumers. We introduce the concept of piracy in a different context, namely allowing consumers to share content for the purpose of reusing it to make it into new content rather than simply duplicating it for direct consumption. In other words, while the extant piracy literature treats piracy as a phenomenon that occurs only in the distribution process, we extend the piracy concept to affect the production process as well.

Consumers have acquired the technical means to effectively co-produce content, and increasingly do so, whether or not they have legal permission to modify and reuse content products, or parts of them, to create new product variants. In this paper, we extend previous work [15], where we investigated the effects of transmutation rights on markets in which consumers are allowed to modify products in the post purchase environment. We found that in such markets, both producers and consumers are better off in terms of producer profits and consumer welfare.

Our results, however, were predicated on assuming effective copyright enforcement policies and the absence of piracy. However, since piracy is a serious concern for producers of digital products, we relax this restrictive assumption in the present study

\(^1\) For example, the Grammy Award winning, bestselling rock band Nine Inch Nails has recently released a remix album that featured consumer-transmuted songs which were solicited through an accompanying interactive remix site with multi-track downloads encouraging fans to post remixes [cf http://www.remix.nin.com].
and design an experimental market with consumer transmutation that explicitly models piracy and allows us to study the question whether and to what extend piracy affects the production of digital content when consumers engage in transmutation activities. We apply a treatment that introduces a strong form of piracy while it keeps all previous experimental parameters the same. Under the new market rules, all consumers automatically share the products they buy from the market with other consumers who are interested in these products.

We examine the new market outcome and compare it to the market outcome without piracy. Our new experimental results suggest that piracy distorts the price signals and damages market transparency. In the presence of piracy, producers are confused about actual market demand for various products, which leads to a market coordination failure. Overproduction and misallocation of resources occur in every session of the new market treatment. In the short run consumers enjoy a substantial surplus increase which, however, is largely due to a wealth transfer away from producers. Producers are unable to cover costs and their production is unsustainable in the long run.

2. Related literature

Our paper investigates the impact of consumer transmutation and piracy on digital content markets. In this section, we will briefly review previous research on the key issues of digital piracy and transmutation.

Intellectual property rights regulate access and use of digital content [8]. Access to content for purposes of modification and reuse, on the other hand, is governed by contract law and is determined through negotiated business licensing arrangements between content owner and content user. The act of copying and distributing content for the purpose of sharing among consumers is typically referred to as digital piracy or online piracy. Piracy in terms of the various socio-economic benefits and harms has been thoroughly studied in the information economics literature. These studies, however, consider only piracy activities that refer to the use of content as a substitute for a legitimate copy of a product. They do not consider piracy activities that relate to the reuse and co-production (i.e., consumer transmutation) of content by consumers.

It is widely accepted that piracy hurts sellers when consumers substitute legitimate with illegitimate products. It is also known that piracy can benefit sellers through increased product exposure which may generate new sales later on. The precise measurement of the impact of copying is complex and imprecise and the net effect of piracy remains inconclusive.

Clemons et al [6], for example, present a simulation model for the music industry that shows that large-scale consumer piracy destroys producers profits and threatens the entire industry in the long-run. Bakos, Brynjolfson and Lichtman [3], on the other hand, found that small-scale sharing of digital content within small social communities can actually increase seller profits. Liebowitz [18] argues that unauthorized copying of content products may not necessarily harm producers if they can offset lost direct sales with higher prices for legitimate purchasers. Oberholzer-Gee and Strumpf [20] report an econometric study that looked at the impact of illegitimate music downloads and CD sales. The authors could not establish a causal link between online piracy and sales. To the contrary, Liebowitz [19] presents evidence that file-sharing is indeed the principle reason for the decline of the music industry. Studying a large sample of college students Rob and Waldvogel [21] found that piracy reduces consumer expenditure on music while increasing consumer welfare (in the short term).

Khouja and Park (12) look at the impact of piracy on pricing strategies and find that lowering consumer prices can increase legitimate sales. On a macro-level, Chen and Png examine copyright enforcement regulation and suggest that the social welfare optimal government policy will combine a tax levy on copying media, a detection mechanism that will fine copyright infringers, and subsidies on legitimate content purchases [4].

Accessing content for the purpose of remaking it into something new and different constitutes a different form of piracy than copying just for sharing with other consumers. Copyright law protects content in both situations without differentiating between copying for sharing and sampling for reuse. A number of scholars are calling for reforms in patent and copyright law, which they see as currently too restrictive in terms of allowing effective knowledge sharing and content reuse [24]. In that sense, digital remix approaches are in fact similar to the re-use of artistic ideas, and should arguably not be prohibited by legal restrictions [19]. Some argue that allowing more openness to sharing and reusing cultural content through innovative licensing schemes may actually spur creativity and increase the supply of derivative
works [14, 18]. But overall, the literature on the effects of strong or weak protections remains inconclusive as well.

*Transmutation* describes generally activities that take one or several pieces of input, process it by applying methods of decomposition, modification and recombination, and generate a piece of output that derives from the original input. The new, derivative product differs from the original. The difference can be marginal or substantial. Digital transmutation, by extension, refers to the transmutation of digital content using digital manipulation with digital tools [9]. Terms like remix (in music), reuse (in software), mashup (in Web content), collage (in fine arts), cutup (in literature) are all specific examples of transmutation.

Research in information economics first addressed the economic potential of transmutability of digital content in terms of business risks. Choi et al [5], posit that firms may lose control of their product once it is released commercially. Using the software industry as their main case in point, they argue, however, that firms may take advantage of transmutability by quickly upgrading application programs in order to degrade the value of older versions and thereby regain and strengthen control over their content.

Hughes and Lang [9] extend the notion of transmutability beyond software to digital content products in general and identify specific transmutation activities that range from simple editing to complex remixing of content from multiple sources. They distinguish between producer and consumer-driven transmutation. The former refers to content creators who extend traditional firm-based production models to incorporate transmutation methods. The latter, on the other hand, describes the emergence of new forms of content creation that is based on co-production or social production models where consumers themselves engage in content transmutation. They argue that consumer-driven transmutation is best understood as a kind of technology affordance and emphasize that the increased IT endowment and IT efficacy among consumers generates the adoption and drives the development of transmutation activities outside the traditional boundary of the firm.

Arakji and Lang [2] analyze a new form of producer–consumer collaboration that is based on user participation in creating new game variants. They find that, under certain complementarity conditions, granting transmutation rights to gamers can increase quality and variety of game offerings.

Lang, Shang and Vragov [15] offer an experimental study that looks at markets for cultural content product. The consumers benefit from transmutation rights with free products generated from the transmutation of the product they buy. Therefore, they were willing to pay more for the products they demand. This increase in willingness to pay mostly affected the mainstream products. Such a transfer of value from specialized and niche products to mainstream products resulted in significantly higher prices for these products as compared to the prices in a market without transmutation rights. While most of the surplus increase is transferred to the consumer side, producers also benefited from the consumer transmutation rights by being able to charge higher prices. These new product prices in effect include a premium for offering a product format that lets consumers freely access and modify the content source. This result suggests that bundling content products with transmutation rights will benefit both consumers and producers.

In the same study the authors also examined other market performance measures, including the number of products acquired by consumers. We found that in the presence of transmutation rights it was significantly higher than without. Furthermore, we examined in detail the product selection made available to consumers by product category. The niche category (the low tail) is usually less profitable for producers in content industries, so many of these products were not produced when transmutation is not possible. Significantly more niche products were made available to consumers when transmutation was available. This was especially true for niche products for which the production costs were higher than the demand for those products. The study, however, did not consider the possibility that consumers could use pirate copies of content as input to the transmutation process.

3. Experimental market design

Using experiments with economically motivated human subjects has been accepted as a legitimate research method to evaluate alternative market designs [10]. In this study, we follow the same experimental research approach described in [15] and summarized above.

3.1 The experimental environment
A transmutation process consists of three major elements: transmutable content, transmutation methods, and transmutation tools. As transmutable content, we chose to use a set of words from the English language, the simplest and most common content product we can think of, to represent the content products. Each word comprises of three letters which serve as content components. A simple form of character processing – copying words, decomposing words into letters, and recombinating letters – was used to create new words (of three letters). The transmutation tools used in the experiment were automated with software and included the need character processing functions and a decision aid that helped users identifying transmutation possibilities and performing the transmutation steps. The words that are traded in our experimental economy represent content products. This design setting makes transmutation more understandable to the experimental subjects and puts the experimental environment in a context of digital content manipulation.

All producers incur a relatively high fixed production cost for developing the new product and making the first copy of it. Assuming digital reproduction, there is a zero marginal cost for making additional copies of a product. There are ten consumers and four producers of digital content in our design model, which is considered sufficient to simulate equilibrium market in the laboratory [23].

We introduce product heterogeneity by distinguishing three categories of word products that are based on degree of specialization. The products in the first category (mainstream) are of general interest and are demanded by all consumers in the economy, although willingness to pay for them varies considerably across individual consumers. The products in the second category (specialized) exhibit some level of specialization and are demanded by a specific consumer segment only. Finally, products in the last category (niche) are highly specialized and target only a single consumer in our experiment. The sixteen particular product designs that our lab economy can produce are represented by the following set of words: {“and”, “bad”, “bat”, “bee”, “bet”, “bit”, “boa”, “dad”, “end”, “net”, “one”, “sea”, “sin”, “sit”, “sob”, “ten”}.

Our demand configuration with three product categories is derived from Anderson who reports on market studies across various content industries that express the long tail of content products, largely following a power law distribution [1]. As shown in figure 2 and figure 3, the mainstream products (“boa”, “end”, “sit”) in our experimental setting are the most popular and the most profitable to producers. The second category (“net”, “and”, “bit”) represent the middle of the product spectrum while the remaining ten are niche products that make up the long tail. However, even though the niche products are the least popular and least profitable, the sum of the demand for them can rival the total demand for mainstream products.

**Figure 1. Consumer demand for product “boa”**

On the demand side we allow different valuations (and thus willingness to pay) across consumers and products. As prescribed by induced value theory, we assign heterogeneous values, randomly drawn from a uniform distribution, to each buyer for each product. For example, the utility values of the content product “boa” to the different buyers are shown in figure 1. The consumer valuations were randomly drawn from a uniform distribution and rounded to the nearest ten. Unlike most theoretical work, this modeling choice assumes neither linear demand curves nor homogeneous valuations and is therefore more realistic.
There are four content producers in our experimental economy. Each has been granted the exclusive right to produce and trade a different set of four, specific words chosen from those shown in Table 1. The seller incurs the fixed cost at the moment the first copy of the product is produced. The fixed costs were randomly drawn from a uniform distribution and rounded to the nearest ten. Once the first copy is produced, the seller can make an unlimited number of additional copies and sell as many as consumers are willing to buy. In addition to the four producers, there are ten consumers. Each consumer has a non-zero demand for a different set of five of the sixteen traded words.

Table 1: Fixed cost schedule and units demanded

<table>
<thead>
<tr>
<th>Product</th>
<th>Cost</th>
<th>Units</th>
<th>Demand</th>
<th>Producer ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>and</td>
<td>200</td>
<td>3</td>
<td>4</td>
<td>dad</td>
</tr>
<tr>
<td>bad</td>
<td>370</td>
<td>1</td>
<td>2</td>
<td>end</td>
</tr>
<tr>
<td>bit</td>
<td>490</td>
<td>3</td>
<td>1</td>
<td>one</td>
</tr>
<tr>
<td>net</td>
<td>320</td>
<td>4</td>
<td>1</td>
<td>sea</td>
</tr>
<tr>
<td>bat</td>
<td>400</td>
<td>1</td>
<td>3</td>
<td>sin</td>
</tr>
<tr>
<td>bee</td>
<td>270</td>
<td>1</td>
<td>3</td>
<td>sit</td>
</tr>
<tr>
<td>bet</td>
<td>490</td>
<td>1</td>
<td>1</td>
<td>sob</td>
</tr>
<tr>
<td>boa</td>
<td>270</td>
<td>10</td>
<td>3</td>
<td>ten</td>
</tr>
</tbody>
</table>

The economy’s trading institution is a version of the continuous double auction. Most digital products are offered at posted prices. However, it has been shown in previous experimental studies that markets with posted prices converge very slowly to competitive equilibrium. Since the experiment has a much limited time-frame, we followed common practice and chose a double auction mechanism to speed up convergence [7]. Producers can submit asks or accept bids. They can lower ask prices, but they are not allowed to increase them. Consumers can submit bids or accept asks. Similarly, they can change bids, but not decrease them. These trading rules are widely used in experimental economics to speed up the convergence of market prices to equilibrium levels. They are identical, in particular, to those used by Smith [22] in his classical market experiments. Bids and asks at the same price are matched automatically by the trading system. This market institution allows producers to sell the same product at different prices to different consumers.

3.2 Market for consumer transmutation rights (CT treatment)

In this treatment the consumers are allowed to modify a word in the post-purchase environment. The basic market structure is the same as shown in Figure 4. Consumers now also acquire transmutation rights as part of their user license when they buy a product. Consumers have complete access to the digital content, which gives them the freedom to alter the content they bought. In the process there are opportunities for making new words from those they already got that are either not offered in the market or are too expensive for them to buy directly. All products in this treatment are transmutable and, assuming the availability of low-cost digital transmutation tools, the direct transmutation costs are zero. However, it is important to note that only those recombinations that yield words the consumer needs accrue value.

Let’s take the product “sit”, for example. It is made of the three components “s”, “i”, and “t.” Similarly, the product “bad” comprises of the components “b”, “a”, and “d.” Now let’s assume a consumer has already bought those two but needs “bat”, too. She has the choice either to buy it in the marketplace or to reuse components from the other two products. In this case, she could disassemble the two words and then recombine component “t” from “sit” with components “b” and “a” from “bad” and make “bat” herself. However, consumers cannot sell words they make themselves to others.

In our current design, subjects cannot bid on all possible combinations of words. We allow consumer subjects to bid only on individual words, for which the consumer already had been given utility values. This limitation is reasonable because of the simply overwhelming complexity if the experimental subjects were to consider a combinatorial auction with all possible product combinations.

3.3 Market for consumer transmutation rights with piracy (P treatment)
As the flowchart (in Figure 6) indicates, buyers (consumers) begin each round with receiving their demand schedule, which tells them which words they need to acquire in the present round and what their valuations are. Each buyer will receive a different set of five words with different valuations. The allocation of words and values to consumers changes from round to round. Buyers monitor the market for available products and ask prices. They may accept asks or place and change bids for words they need.

<table>
<thead>
<tr>
<th>Ask Price</th>
<th>Bid now</th>
<th>Product(Rawts)</th>
<th>My Rs</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>0.5</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>0.50</td>
<td>0.5</td>
<td>0.50</td>
<td>0.50</td>
</tr>
<tr>
<td>1.00</td>
<td>0.5</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>0.00</td>
<td>0.5</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>2.00</td>
<td>0.5</td>
<td>2.00</td>
<td>2.00</td>
</tr>
</tbody>
</table>

Figure 7. Buyer screen (partial view)

Figure 7 shows an instance of a buyer screen in a particular round of the experiment. Buyers can see which words they need and what they are worth to them, they also can see ask prices of words currently available in the market. They can enter new bids into the system at any time. They also get instant feedback when they complete transactions and can monitor the cash dollar winnings they accumulate during the session.

As the flowchart (in Figure 6) indicates, at the beginning of each round, sellers (producers) receive their production schedule and learn the fixed costs for making each of the four word products for which they own the rights. Throughout the round they monitor the market and check the bids that buyers who are interested in their products are posting. Taking into account market signals about consumer demand and the known production cost, producers decide if and when to produce a word and offer it in the market. Producers may decide to offer only those words they expect to make money with. Given the incomplete market information and the high fixed cost that a decision to develop a new product entails there is considerable uncertainty about the profitability of the different products. Once producers choose to offer a product, they need to set an ask price. During the course of a round, they continue to monitor bids and at any point in time they can accept bids for words that are already offered or change ask prices.

2 The box with the dashed border line highlights the difference between the two treatments of the experiment. The box is activated in the treatment with piracy and deactivated without piracy.
During the experiment producers are working with a trading screen as depicted in Figure 8. Producers can see the fixed production cost of the words they control and monitor bids as they are posted in the market. When they decide to produce a word and post an ask price, and thus make it available in the market, the information is broadcast to buyers. Producer decisions are entered to the trading system interactively through a number of specifically designed information fields and action buttons (not shown in the figure). The profits of the current round as well as the accumulated total profits over all completed rounds are shown to the subject in both experimental currency and real cash dollars. This again provides participants with instant real-economic feedback on their decisions and performance in the experiment.

### 4. Experimental procedures

Forty-two subjects were recruited randomly from the undergraduate student population and grouped into three groups of fourteen participants, four producers and ten consumers each. The subjects were paid a ten dollar show up fee plus a performance-based payoff. After the volunteering subjects came to the experimental laboratory, they were randomly assigned to the roles of a producer or a consumer. They were asked to read a primer and a set of computerized instructions and then participated in a test and a short simulation that were designed to teach them the market rules and the use of the trading system that we developed for the experiment.

The subjects participated in a preliminary practice round that lasted 10 minutes. Subsequently 10 rounds of the experimental market were conducted. The length of each round was determined randomly to last anywhere between 5 and 6 minutes with equal probability. This was done with the intention to remove explosions of activity that typically occur, when the closing time is known, during the last seconds before the market is closed. The times resulting from the random draws during the first session of previous experiment were recorded and used in all following sessions. Thus, the same number of rounds with the same length was run under all treatments. The software was implemented as a real-time client/server application and programmed in Visual Basic .NET. The server software is in charge of starting each round and recording all transactions and activities in the experiments.

### 5. Results and discussion

The individual consumer surplus (CS) of each round depends on how many products they were able to get and how much they paid for them. If a buyer has a value $v$ for a product and buys that product at price $p$, then her profit of the product will be $v - p$. Her surplus CS of a round will be the sum of the profits of all her five products. The total consumer surplus (TSC) of the round is the sum of individual consumer surplus of all ten consumers. The same calculation is performed for every round and over all three sessions.

\[
\overline{\text{TCS}} = \frac{1}{RS} \sum_{i=1}^{S} \sum_{r=1}^{R} \sum_{j=1}^{1} CS_{irs}
\]

\[
CS_i = \sum_{n=1}^{N} (V_{in} - P_{in})B_{in}
\]

$CS_i$: individual consumer surplus in each round.

$V_{in}$: valuation for product $n$ of consumer $i$.

$P_{in}$: transaction price for product $n$ of consumer $i$.

$i = \text{consumer 1, 2, ..., } I; I = 10$

$r = \text{round 1, 2, ..., } R; R = 10$

$s = \text{session 1, 2, ..., } S; S = 3$

$n = \text{product 1, 2, ..., } N; N = 5$

$B_{in}$: dummy variable; 1 if consumer $i$ bought product $n$ in the market, 0 otherwise.

The profit a producer collects at the end of a round will depend on the number of copies sold for each product as well as the price points at which the sales were made. The individual surplus (PS) of a producer is calculated by adding up the prices of all sold copies minus all fixed costs incurred in the production process. It is possible that revenues do not recoup production cost. In such a case the round ends with a loss for the producer. The total producer surplus (TPS) is the sum of the profits of all four producers in a round. The same process is repeated for each round in each session.

\[
\overline{\text{TPS}} = \frac{1}{RS} \sum_{i=1}^{S} \sum_{r=1}^{R} \sum_{j=1}^{1} PS_{iirs}
\]
\[ PS_j = \sum_{m=1}^{M} (S_{jm} - C_{jm}) D_{jm} \]

- \( PS_j \): individual producer surplus in each round
- \( S_{jm} \): sales of product \( m \) of producer \( j \)
- \( C_{jm} \): production cost of product \( m \) of producer \( j \)
- \( j = \) producer \( 1,2,..,J; \) \( J = 4 \)
- \( m = \) product \( 1,2,...,M; \) \( M = 4 \)
- \( D_{jm} \): dummy variable; 1 if producer \( j \) developed and offered product \( m \), 0 otherwise

### Table 2. Experimental results in terms of surplus

<table>
<thead>
<tr>
<th>Findings</th>
<th>Realized Value</th>
<th>( P ) Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>( TS_P &gt; TS_CT )</td>
<td>( \overline{TS_{CT}} = 2590.5 ) ( \overline{TS_P} = 3722.5 )</td>
<td>( p = 0.05^* )</td>
</tr>
<tr>
<td>( TCS_P &gt; TCS_CT )</td>
<td>( \overline{TCS_{CT}} = 2672.8 ) ( \overline{TCS_P} = 4945.2 )</td>
<td>( p &lt; 0.001^* )</td>
</tr>
<tr>
<td>( TPS_{CT} &gt; TPS_P )</td>
<td>( \overline{TPS_{CT}} = -82.3 ) ( \overline{TPS_P} = -1222.7 )</td>
<td>( p &lt; 0.001^* )</td>
</tr>
</tbody>
</table>

Our findings related to surplus are reported in Table 2. We see that the resulting average total surplus (TS), the sum of average total consumer surplus (TCS) and average total producer surplus (TPS), in the consumer transmutation with piracy (P) treatment (3722.5) is significantly higher than the total surplus in the consumer transmutation without piracy (CT) treatment (2590.5). The consumer surplus (4945.2) almost doubles due to piracy which, at the same time, damages producer surplus (-1222.7). Because consumers share the products they bought, sales were falling with each round (\( p = 0.049 \)). The number of transactions per round in the piracy treatment (8.2) is significantly lower than the number of transactions per round without piracy (24.6).

In the CT treatment, consumers used the products’ transmutation capability and self-produced some products. Thus they were willing to pay more for the products they bought since they needed some of the embedded components for consumer-based transmutation. While most of the surplus increase is transferred to the consumer side in the CT treatment, producers also benefit from the consumer transmutation rights by being able to charge higher prices when the products they sell include transmutation rights. This result suggests that introducing the possibility for consumers to buy access and transmutation rights will benefit both consumers and producers. However, in the presence of piracy and absence of proper control of copyright of their products, producers cannot appropriate the value from consumer-based transmutation, as shown Table 2 indicates.

### Table 3. Product selection

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Avg Number of Products Acquired by Consumers (per Round)</th>
<th>Avg Number of Products Made by Producers (per Round)</th>
<th>Number of niche products acquired</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumer Transmutation Rights</td>
<td>33.6</td>
<td>7.4</td>
<td>6.5</td>
</tr>
<tr>
<td>Piracy</td>
<td>44.7</td>
<td>8.4</td>
<td>17.8</td>
</tr>
</tbody>
</table>

We also looked at product variety in terms of number of products acquired by consumers in each treatment. As shown in Table 3, we see that the number of products acquired by consumers in the P treatment is significantly higher than in the CT treatment. Out of the 44.7 product acquisitions that consumers made on average, 36.5 were shared among consumers. Examining the selection of products made available to consumers by product category, we find that consumers acquire significantly more products from a niche category (the low tail) whose total demand value is actually lower than its total production cost.

![Figure 9. Production allocation over rounds](image-url)

Looking at the market performance over the ten rounds of the experiment, reflected in Figure 9, we conclude that piracy damages the allocative efficiency of the market. The components of the mainstream products can be used to create all the products. Therefore, ideally, producers should focus on the producing and selling of those products if they know which these products are. In the CT treatment, the market displays high demand for mainstream products. Thus the market helps producers discover which products are mainstream. We can easily detect that in the CT treatment producers’ production set gradually converges to the set of mainstream products over rounds (\( p = 0.021 \)). In the piracy treatment, however, producers have problems identifying the correct set of mainstream products.
Market transactions do not reflect actual demand and carry misleading signals to producers. Hence, piracy damages the basic market function of providing precious value information to producers so that resources can be allocated in the most efficient way. In the P treatment, producers don’t focus their production on the mainstream products, relatively to the CT treatment (p<0.001). Instead they are trying to produce and sell all the words regardless to get a profit.

Piracy causes lost sales. Extreme piracy in our experiment limits sales to just one copy per product because consumers instantaneously share every product they buy legitimately with everyone else who wants it. Producers try to make profit by charging high prices for these single copies. The average price in the piracy treatment is significantly higher than in the CT treatment (p<0.001). However, since producers in piracy treatment can only sell one copy, the increase in price is not enough to compensate for the decrease in sales volume. This is why producer revenue in the piracy treatment is significantly lower than the one in the CT treatment.

Figure 10. Profit of mainstream products

Interestingly, as shown in figure 10, in both the CT and P treatments, the production of mainstream products can still be profitable for producers, if they discover the right products and prices. But the profit from selling mainstream products in the piracy treatment is significantly lower than in CT. This means that even though piracy seriously damages the surplus of producers, producers can still keep some profits as long as they focus on the production of mainstream products. But as mentioned earlier, the piracy damages the informational function of the market, which makes it hard for producers to discover the set of mainstream products. Niche products cannot sell at a profit in the market, so their production by producers is inefficient and leads to losses.

Piracy also offsets the monopoly power of the producers of mainstream products. In the CT treatment, consumers don’t have access to all combinations. With transmutation rights, they can home-make niche products through reusing and transmuting components of mainstream products, which increase the demands for mainstream products. However, in the piracy treatment, consumers have access to all combinations through sharing. In such a market environment producers are unable to charge prices that would be high enough to sustain the long-term supply of mainstream products, curtailing consumers’ transmutation possibilities in the long run, too. For example, if the price of "end" is too high, consumers in the piracy treatment can make "end" themselves by buying "one" and obtaining "dad" from sharing.

6. Conclusion and future research

Our study has shown that piracy might have much deeper repercussions in markets for transmutation rights than previously thought. The experiments we conducted show that piracy destroys the signaling power of market prices. Consumer’s market behavior does not help producers to accurately estimate demand. Thus piracy thwarts market coordination as it distorts the price mechanism and forces producers to make inefficient production decisions. We also find that piracy transfers wealth away from producers to consumers, thus hurting producers. While consumers enjoy more content in the short-term it is likely that the production of new original content by producers will decrease and reduce overall content selection in the long term. Unless, of course, consumers keep making new content themselves, using transmutation capabilities, that can offset dwindling production from tradition producers.

Our findings suggest that it is in the interest of both producers and consumers to cooperate and coordinate market prices that will let consumers engage effectively in transmutation while, at the same time, guaranteeing the producers’ ability to continue furnishing a steady supply of core products that serve as the basis for consumers wherefrom they can derive personalized versions and niche products that otherwise might not be available.

Our experimental design does not model the possibility that piracy could be leading to better product exposure. In our case the demand curves are fixed and only people with already existing demand are exposed to pirated copies. Increased exposure is often cited as a positive effect of piracy that can offset (some of) lost sales. We deliberately control for that effect in our case of extreme piracy in the present study. It will be interesting to consider the product exposure in future experiments.
Unlike most other piracy research, piracy in our case involves two forms: first, the conventional sharing of an illicit copy of a product that is consumed as is (sharing for replaying); second, a new form of piracy where consumers obtain pirate copies of content not for consumption but to use them as input material for transmutation to make a different product (sharing for reuse). In our study, consumers pirate the components that they need as inputs. Our experimental design models an extreme case of piracy where the first buyer of an original product shares it immediately and free of charge with everyone who wants it. Hence our results probably exaggerate the effects on lost sales. We have designed a third treatment that models a moderated level of piracy and prepare to run additional experiments to compare the effect of piracy at different levels.

7. References