Managing Digital Piracy: Pricing and Protection Strategies

Arun Sundararajan
New York University

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Digital goods are easy to pirate

- Software piracy rates are still very high
  - Eastern Europe: 71%
  - Latin America: 55%
  - Asia/Pacific: 55%
  - Middle East/Africa: 49%
  - Western Europe: 35%
  - North America: 24%
- Music, digital video, electronic textbooks, research, artwork,..

Piracy is impossible to eliminate

- Digital goods are easily replicated, distributed, stored
- Inferior substitutes can always be created
- It is hard to enforce legal deterrents
- Technological deterrents are eventually hacked (at least partially)

Digital piracy needs to be effectively **managed** through a combination of **pricing** and time-varying **technological deterrence**

Research agenda

Price screening in the presence of digital piracy

- Structure of optimal nonlinear pricing schedule
- Variation in structure of schedule at different levels of piracy
- Effects of piracy on seller profits, consumer surplus and total surplus

Appropriate levels of technology (DRM) protection

- Profit-maximizing protection levels with/without price discrimination
- Optimal pricing and technology responses to DRM hacking

Summary of key results

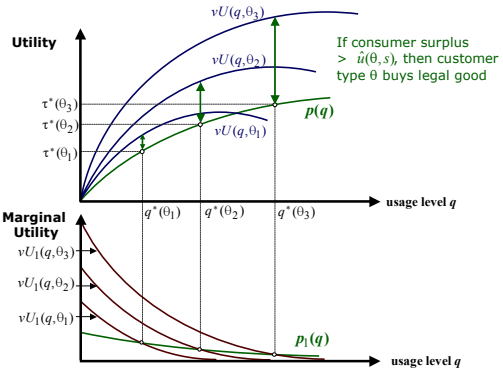
Price screening in the presence of digital piracy

- Optimal pricing schedule is a combination of two simpler schedules:
  (a) Zero-piracy pricing schedule (adjusted downward)
  (b) Piracy-indifferent pricing schedule
- Piracy can induce short-term increases in total surplus from *legal* usage

Choice of appropriate levels of technology-based protection

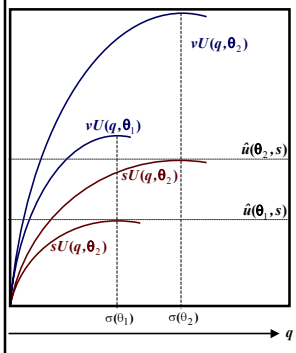
- In the absence of price-discrimination: technologically-maximal level
- When price discriminating: strictly lower
  - Trade-off between deterrence and ability to price-discriminate
- Responses to weakening of underlying protection technology can be
  - Increase protection level, reduce prices
  - Reduce protection level, sometimes increase prices
  - Suggests need to preemptively over/under protect

Recap: Nonlinear pricing



If consumer surplus > $\hat{u}(\theta, s)$, then customer type θ buys legal good

Seller, products and customers



Monopoly seller of information good, used in varying quantities

- Legal good: quality v, pricing chosen by seller
- Pirated good: quality s, free

Heterogeneous customers

- Indexed by type $\theta \in [\alpha,\beta]$ distributed as $F(\theta)$ with $f(\theta) > 0$, non-increasing inverse hazard rate
- Value from legal good: $vU(q,\theta)$
- Value from pirated good: $sU(q,\theta)$

$$U(q,\theta) = \theta q - \tfrac{1}{2}q^2$$

- Therefore, reservation utility

$$\hat{u}(\theta,s) = \max_q sU(q,\theta) = sU(\sigma(\theta),\theta)$$

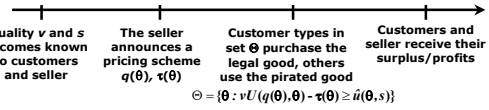
Pricing schedule, timeline

Structure of pricing schedule

- Menu of quantity-price pairs $q(t),\tau(t),\ t \in [\alpha,\beta]$
- Incentive-compatible: $\theta = \arg\max_t vU(q(t),\theta) - \tau(t)$
  - $q(\theta)$: Usage of customer type θ
  - $\tau(\theta)$: Total price paid by customer type θ for usage

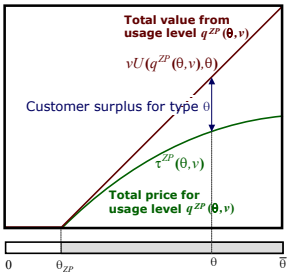
$$h(\theta) = \frac{1-F(\theta)}{f(\theta)}; \qquad H(\theta) = \int_\alpha^\theta h(\theta)d\theta$$

Timeline



$$\Theta = \{\theta : vU(q(\theta),\theta) - \tau(\theta) \geq \hat{u}(\theta,s)\}$$

Pricing in the absence of piracy



- 'Standard' nonlinear schedule of prices and usage
- Prices are concave in quantity
- All customer types with $q^{ZP}(\theta,v) > 0$ get positive surplus

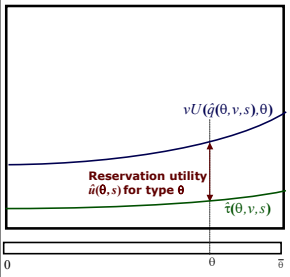
For $\theta \leq \theta_{ZP}$

$$q^{ZP}(\theta,v) = 0$$
$$\tau^{ZP}(\theta,v) = 0$$

For $\theta \geq \theta_{ZP}$

$$q^{ZP}(\theta,v) = \theta - h(\theta)$$
$$\tau^{ZP}(\theta,v) = \frac{v[h(\theta_{ZP})^2 - h(\theta)^2]}{2} + v[H(\theta) - H(\theta_{ZP})]$$

Piracy-indifferent pricing schedule



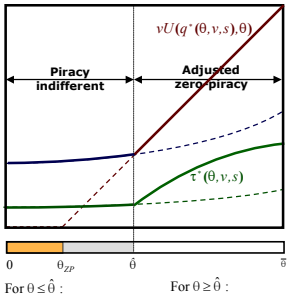
Building block for optimal contract

Pricing schedule which is:

- incentive-compatible
- affordable to all customer types
- provides every customer type with surplus equal to exactly their value from the pirated good: $\hat{u}(\theta,s)$
- always profitable for the seller, for any segment of customers, if $v > s$

$$q^{PI}(\theta,v,s) = \frac{s\theta}{v}$$
$$\tau^{PI}(\theta,v,s) = \frac{s(v-s)\theta^2}{2v}$$

Optimal pricing with digital piracy



When $s \geq \frac{v[\alpha - h(\alpha)]}{\alpha}$

- Pricing schedule is comprised of two distinct segments
  - piracy-indifferent (lower)
  - adjusted zero-piracy (higher)
- Customers who were priced out of the market are now included
- At a higher level of piracy s:
  - piracy-indifferent segment expands to include more types
  - prices fall for higher segment

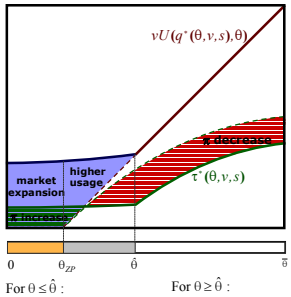
For $\theta \leq \hat{\theta}$:

$$q^*(\theta,v,s) = q^{PI}(\theta,v,s)$$
$$\tau^*(\theta,v,s) = \tau^{PI}(\theta,v,s)$$

For $\theta \geq \hat{\theta}$:

$$q^*(\theta,v,s) = q^{ZP}(\theta,v)$$
$$\tau^*(\theta,v,s) = \tau^{ZP}(\theta,v) - \left(vH(\theta) - \frac{[v-s]\hat{\theta}^2}{2} + \frac{v\alpha^2}{2}\right)$$

Optimal pricing with digital piracy



The presence of digital piracy:

- decreases seller profits
- increases total surplus
- increases consumer surplus

Each of these effects is higher at higher levels of piracy

For $\theta \leq \hat{\theta}$:

$$q^*(\theta,v,s) = q^{PI}(\theta,v,s)$$
$$\tau^*(\theta,v,s) = \tau^{PI}(\theta,v,s)$$

For $\theta \geq \hat{\theta}$:

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Digital rights management (DRM)

Premise:

- DRM allows sellers to control the level of piracy s, to some extent
- Implementing DRM always involves some form of degradation of the quality of the legal good

Endogenous protection:

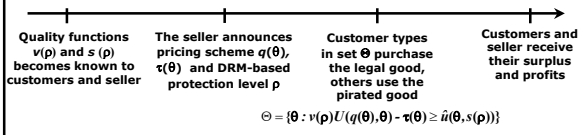
- ρ : Level of DRM-based protection that the seller chooses
- $v(\rho)$: Quality of **legal** good at level of protection ρ
- $s(\rho)$: Quality of **pirated** good at level of protection ρ

Digital rights management

Assumptions about $v(\rho)$ and $s(\rho)$

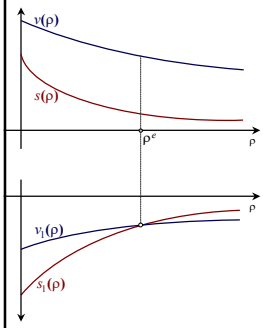
- $v(\rho) > s(\rho)$: The seller can make a profit
- $v_1(\rho) < 0, s_1(\rho) < 0$: DRM 'manages' rights by restricting them
- $s_1(0) < v_1(0)$: The DRM technology is effective, at least initially
- $v_{11}(0) < s_{11}(0)$: The DRM technology has diminishing returns

Sequence of events



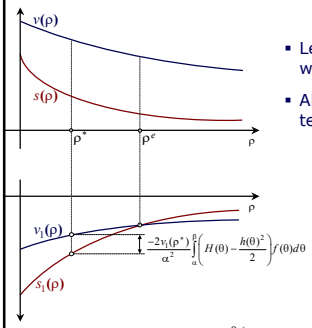
$$\Theta = \{\boldsymbol{\theta} : v(\boldsymbol{\rho})U(q(\boldsymbol{\theta}),\boldsymbol{\theta}) - \tau(\boldsymbol{\theta}) \geq \hat{u}(\boldsymbol{\theta}, s(\boldsymbol{\rho}))\}$$

DRM: Technologically-maximal protection



- Level of DRM protection which maximizes $v(\rho) - s(\rho)$
- Maximizes the 'effectiveness' of the DRM technology
- Optimal level of protection when seller cannot price-discriminate

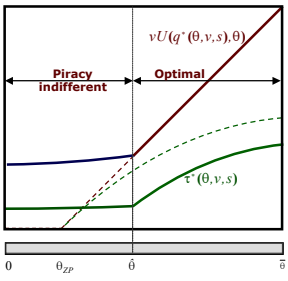
DRM: Profit-maximizing protection



- Level of DRM protection $\boldsymbol{\rho^*}$ at which profits are maximized
- Always **strictly lower** than the technologically-maximal level $\boldsymbol{\rho^e}$

$$v_1(\rho^*) - s_1(\rho^*) = \frac{-2v_1(\rho^*)}{\alpha^2}\int_{\alpha}^{\beta}\left(H(\theta) - \frac{h(\theta)^2}{2}\right)f(\theta)d\theta > 0$$

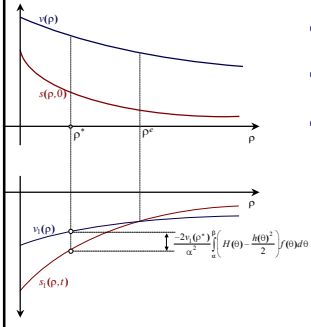
DRM: Profit-maximizing protection



Why is $\rho^* < \rho^e$?

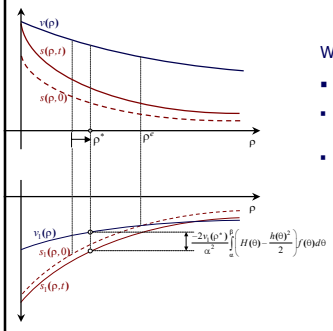
- A marginal decrease in the quality of the pirated good:
  - increases total price across all customer types
- A marginal decrease in the quality of the legal good
  - decreases total price across all customer types
  - …and decreases the seller's ability to price discriminate in the higher (optimal) segment
- The negative effect of a marginal decrease in $v(\rho)$ outweighs the positive effect of an identical marginal decrease in $s(\rho)$

Responding to weakening DRM technology



- As a DRM technology gets hacked, $s(\rho)$ increases over time
- This is modeled as a continuous variation: $s(\rho,t)$, with $s_2(\rho,t) > 0$
- Sign of $s_{12}(\rho,t)$ influences direction of technological and pricing responses

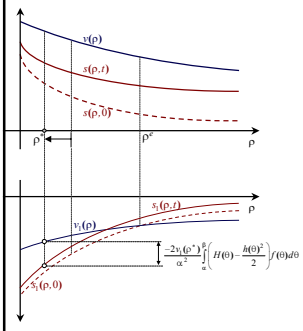
Responding to weakening DRM technology



When $s_{12}(\rho,t) < 0$

- ρ^* increases over time
- Total prices reduce across all customer types
- There may be reason to preemptively *overprotect*

Responding to weakening DRM technology



When $s_{12}(\rho,t) > 0$

- ρ^* *reduces* over time
- Total prices may either increase or reduce
- There may be reason to preemptively *underprotect*

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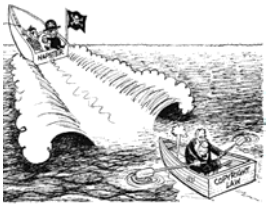
Moving ahead…



- Legal responses to piracy lag technology in a disturbingly significant way
- Technology determines the effective behavior of users as well as creators
- Modeling technology as the determinant of behavior is realistic but has potentially negative policy implications

Open issues

- Long-term effects on innovation and quality of legal goods
- The effect of piracy-induced usage externalities
- The impact of network effects