The Effects of Market Size, Wealth, and Network Effects on Digital Piracy and Profit

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Digital Piracy

- Digital goods can be copied and distributed by practically anyone with a copy at practically zero cost
- Piracy rates in developing countries are especially high: 81 percent in Vietnam, 85 percent in Pakistan, 88 percent in Venezuela (as of 2011)
- Evidence suggests that piracy usually displaces sales
- Empirical literature suggests that piracy has displaces more sales for popular works
- Lesser-known works are less affected, and in some cases might see an increase in sales due to piracy

Effects of Piracy

- How might piracy increase sales?
- Sampling: users experience software before purchasing it, which might increase their willingness to subsequently purchase a legitimate copy
- Modern Internet: reviews, trailers, demonstrations, trial versions, and sample footage for virtually any type of digital product, even without illicit copying
- Network effects: the more people using the software, pirate or otherwise, the more attractive the software

Network Effects and Piracy

- Typical conclusion in theoretical literature: strong network effects make piracy beneficial
- Strong network effects + pirate users make software more attractive, so developer can charge higher price to those who purchase
- I argue that these results can be refined in a meaningful way
- The market size is empirically relevant, but overlooked in theory
- Consumer budgets is empirically relevant, but overlooked in theory
- Development cycle often overlooked in theory, but developers presumably anticipate the effects of piracy when developing

General Setup

- Developer chooses development expenditure $\implies$ software quality q
- Developer then chooses market price p
- Let μ denote the wealthiest consumer, let $\sigma \sim \text{Uniform}[0, 1]$, so consumer σ has budget $\sigma\mu$
- Consumers can purchase software if they can afford it ($p \leq \sigma\mu$); they can pirate the software; or they can abstain altogether
- N is the market size, $C(p, q)$ is the proportion of the market using the software, $\eta \geq 0$ is the strength of network effects
- Utility of software given by $q + C(p, q)N\eta$

A World Without Piracy: Consumers

- If user σ can purchase software, then receives payoff of

$$U_B(p, q) = q + C(p, q)N\eta - p + \sigma\mu$$

- Purchase is made when

$$p \leq \sigma\mu \quad \text{and} \quad p \leq q + C(p, q)N\eta$$

- Assuming a purchase is desirable, the proportion of buyers is $1 - p/\mu$

A World Without Piracy: Developers

- Zero marginal cost of copies (physical media exceedingly rare)
- Non-zero marginal cost of quality (quadratic cost of quality)
- Fixed cost assumed sunk already
- Developer chooses p and q to maximize

$$\Pi(p,q) = \left(1 - \frac{p}{\mu}\right) Np - \frac{q^2}{2} \quad \text{subject to } p \leq q + \left(1 - \frac{p}{\mu}\right) N\eta$$

A World Without Piracy: Solution 1

- Solution is

$$p^* = \frac{N\mu(N\eta^2 + \mu\eta + \mu)}{N^2\eta^2 + 2N\eta\mu + 2N\mu + \mu^2}$$

$$q^* = \frac{N\mu(\mu - N\eta)}{N^2\eta^2 + 2N\eta\mu + 2N\mu + \mu^2}$$

$$\Pi^* = \frac{N^2}{2}\frac{\mu^2(1 + 2\eta)}{N^2\eta^2 + 2N\eta\mu + 2N\mu + \mu^2}$$

  provided $\eta < \mu/N$ so that q^* remains positive

- p^* higher when N larger, μ larger, η larger; q^* higher when μ larger
- q^* decreasing in η: more utility derived from network effects? Less need for inherently high-quality software
- Π^* higher when N larger, μ larger, η larger

A World Without Piracy: Solution 2

- If $\eta \geq \mu/N$, then $q^* = 0$ and

$$\Pi(p, q) = \left(1 - \frac{p}{\mu}\right) Np \quad \text{subject to } p \leq \left(1 - \frac{p}{\mu}\right) N\eta,$$

  which has a solution of

$$p^* = \frac{\mu}{2}, \quad q^* = 0, \quad \Pi^* = \frac{N\mu}{4}.$$

- p^* and Π^* higher when μ larger
- Stronger network effects no longer impart any benefit to developers (although consumers benefit)

A World With Piracy

- Suppose poor enforcement of copyright protection: pirate copies are available practically immediately after release
- Empirical research suggests that accessibility of piracy is important factor in consumer behavior, e.g. search costs, probability of malware
- Each consumer faces a common piracy cost κ, yielding pirate utility

$$U_P(p, q) = q + C(p, q)N\eta - \kappa + \sigma\mu$$

- To make sales, developer must satisfy

$$p \leq \kappa \quad \text{and} \quad p \leq \sigma\mu \quad \text{and} \quad p \leq q + C(p, q)N\eta$$

- Assuming a purchase is desirable, the proportion of buyers is $1 - p/\mu$

Denying Piracy

- If budget-unconstrained consumers purchase and budget-constrained consumers pirate, then all N consumers will be users, so software generates utility $q + N\eta$
- No one will pirate if $q + N\eta < \kappa$
- Making sales and denying piracy requires

$$p \leq q + \left(1 - \frac{p}{\mu}\right) N\eta < q + N\eta < \kappa$$

- If κ is sufficiently large, then developer can behave as if there is no piracy: solutions same as before
- If κ is sufficiently small, then developer is constrained ($q^* + N\eta < \kappa$ is not possible), and without any network effect benefits of piracy
- So the threat of piracy is weakly harmful to developers if they try to deny piracy

Exploiting Piracy

- Perhaps the developer could try to exploit piracy instead of denying it
- Incentivizing piracy requires $q + N\eta \geq \kappa$, which requires more development expenditure relative to denying piracy, all else equal

$$p \leq \kappa \leq q + N\eta$$

- But the potential benefit is that the developer can charge a higher price to those who purchase up to $p = \kappa$
- Cost minimization implies $\hat{q} = \kappa - N\eta$
- Two distinct solutions for p depending on κ relative to μ

Exploiting Piracy: Budget-Poor Consumers

- The consumer base is *budget-poor* when $\mu/2 \leq \kappa$
- Developer maximizes

$$\Pi(p) = \left(1 - \frac{p}{\mu}\right) Np - \frac{(\kappa - N\eta)^2}{2} \quad \text{s.t. } p \leq \kappa$$

- The optimal unconstrained price is $\hat{p} = \mu/2$, so $p \leq \kappa$ is non-binding

$$\hat{\Pi} = \begin{cases} \dfrac{N\mu}{4} - \dfrac{(\kappa - N\eta)^2}{2} & \text{if } \eta < \dfrac{\kappa}{N} \text{ and } \kappa \geq \dfrac{\mu}{2} \\ \dfrac{N\mu}{4} & \text{if } \eta \geq \dfrac{\kappa}{N} \text{ and } \kappa \geq \dfrac{\mu}{2} \end{cases}$$

- Development expenditure has floor at zero, price is unaffected by network effects

Exploiting Piracy: Budget-Rich Consumers

- The consumer base is *budget-rich* when $\mu/2 > \kappa$
- Developer maximizes

$$\Pi(p) = \left(1 - \frac{p}{\mu}\right) Np - \frac{(\kappa - N\eta)^2}{2} \quad \text{s.t. } p \leq \kappa$$

- Optimal unconstrained price is $p = \mu/2$, but $p \leq \kappa < \mu/2$ requires binding solution of $\hat{p} = \kappa$

$$\hat{\Pi} = \begin{cases} \left(1 - \frac{\kappa}{\mu}\right) N\kappa - \frac{(\kappa - N\eta)^2}{2} & \text{if } \eta < \frac{\kappa}{N} \text{ and } \kappa < \frac{\mu}{2} \\ \left(1 - \frac{\kappa}{\mu}\right) N\kappa & \text{if } \eta \geq \frac{\kappa}{N} \text{ and } \kappa < \frac{\mu}{2} \end{cases}$$

- Development expenditure has floor at zero, price is unaffected by network effects

Exploiting Piracy: When?

- For piracy to be beneficial to developers, there must be enough room for price to increase – it has a ceiling – relative to piracy-free counterfactual
- Or enough room for quality/development expenditure to fall – it has a floor – relative to piracy-free counterfactual

Proposition

Piracy cannot be beneficial to developers when network effects are very weak or very strong.

- Weak network effects do not have enough impact to be of net benefit
- Strong network effects do not leave enough room for impact to be of net benefit

Exploiting Piracy: Budget-Poor Consumers, Redux

- When $\mu/2 \leq \kappa < \mu$, a consumer base is *moderately* budget-poor
- When $\mu \leq \kappa$, a consumer base is *extremely* budget-poor

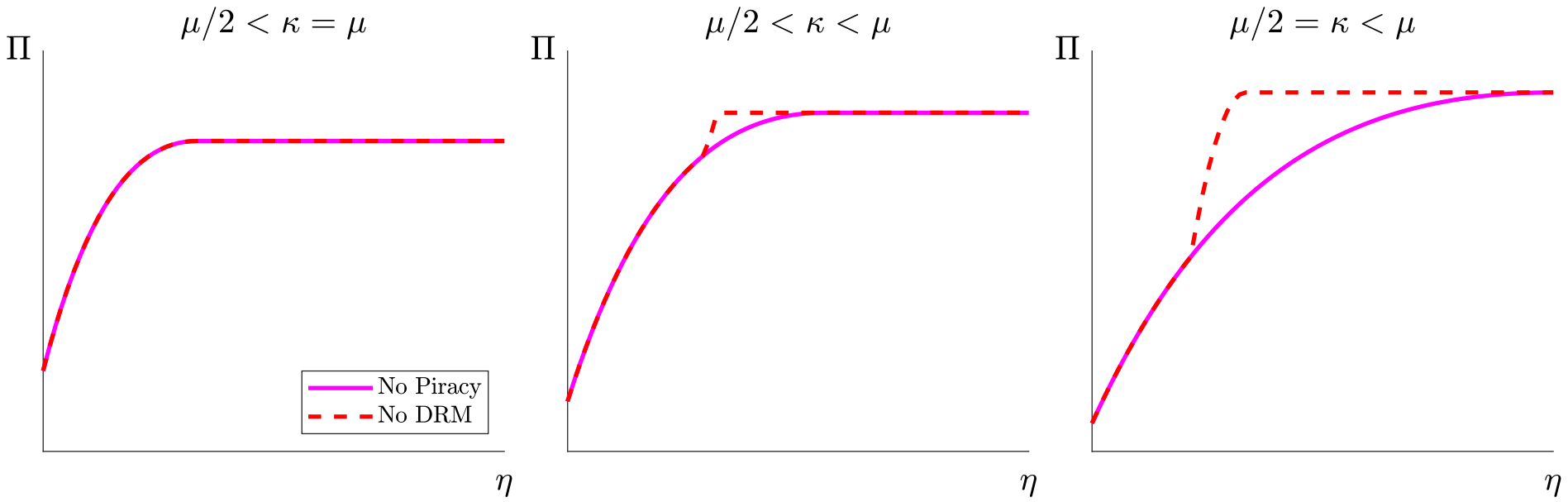
Proposition

If a consumer base is moderately budget-poor, then a range of network effects exists such that piracy is beneficial to developers.

But if a consumer base is extremely budget-poor, then no strength of network effects exists such that piracy is beneficial to developers.

- When $\mu \leq \kappa$, very costly to inducing budget-constrained consumers to pirate (big jump to satisfy $q + N\eta \geq \kappa$); consumers struggle to afford price increase
- When $\mu/2 \leq \kappa < \mu$, smaller jump in quality needed to induce pirates; more likely that consumers can afford price increase

Exploiting Piracy: Budget-Poor Consumers, Comparison



Exploiting Piracy: Budget-Rich Consumers, Redux

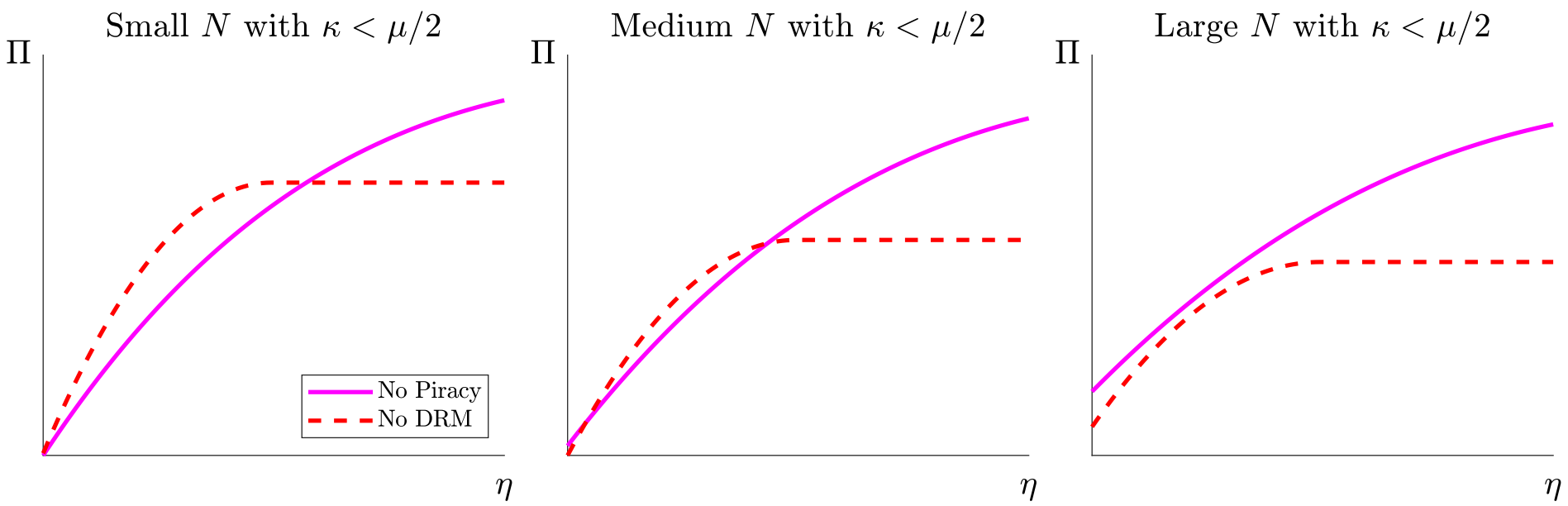
Proposition

Suppose the consumer base is budget-rich. If either the cost of piracy is sufficiently small or the market size is sufficiently large, then no range of network effects exists that makes piracy beneficial to developers.

But if the cost of piracy is sufficiently large and the size of the market is sufficiently small, then a range of network effects exists that makes piracy beneficial to developers.

- Budget-rich consumers mean μ is no longer suppressing price: need something else to provide room for price increase
- A small market implies a low piracy-free price, and therefore room for price to increase with piracy-driven network effects
- Also need κ to be sufficiently large so price has room

Exploiting Piracy: Budget-Rich Consumers, Comparison

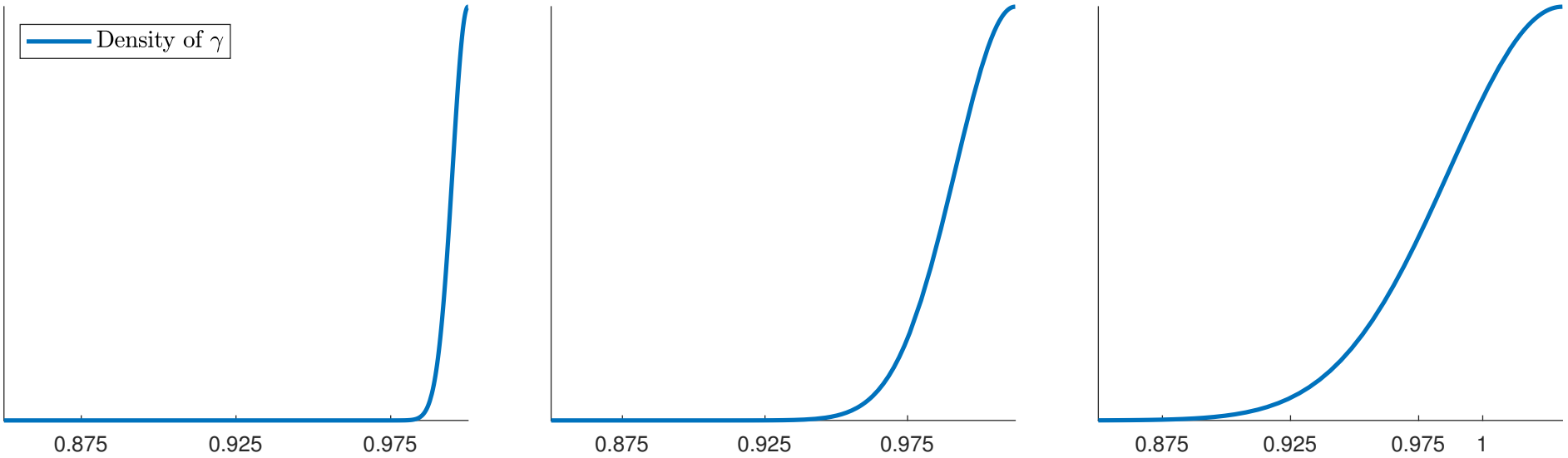


Conditions for Exploiting Piracy

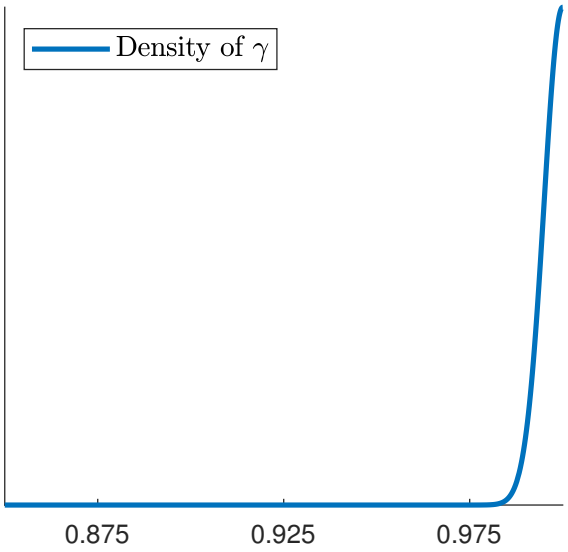
	Rich	Moderately Poor	Extremely Poor
small η	no benefit	no benefit	no benefit
large η	no benefit	no benefit	no benefit
medium η	benefit for some η small N, large κ	benefit for some η	no benefit
κ	vanishes with small κ	vanishes with large κ	no benefit
N	vanishes with large N	benefit for some η	no benefit

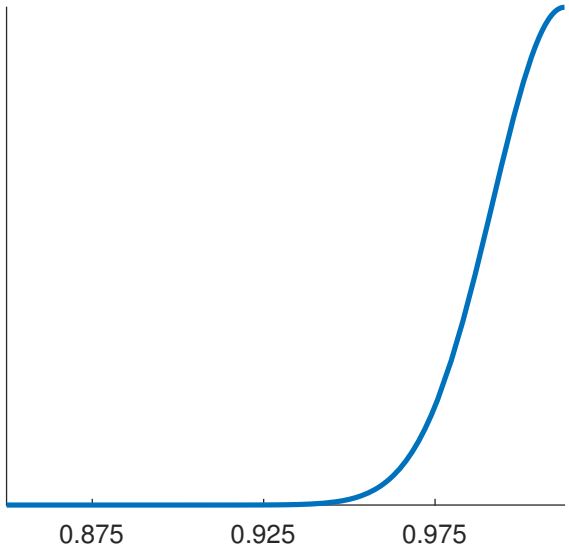
Heterogeneous Piracy Cost

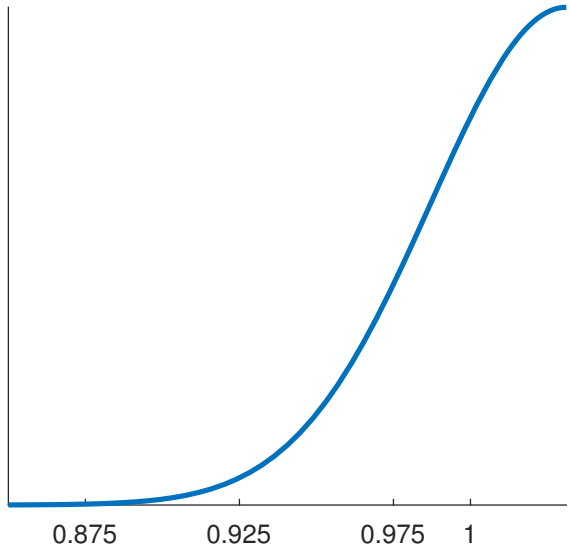
- Model is generous towards possibility that piracy is beneficial: everyone who can't afford will pirate if developer exploits piracy
- Heterogeneous cost of piracy could imply otherwise: some consumers who can't afford might not pirate either
- Try truncated normal distribution to $\gamma\kappa$, alter shape via σ_γ
- If $\sigma_\gamma = 0$, homogeneous; if $\sigma_\gamma \to \infty$, uniform

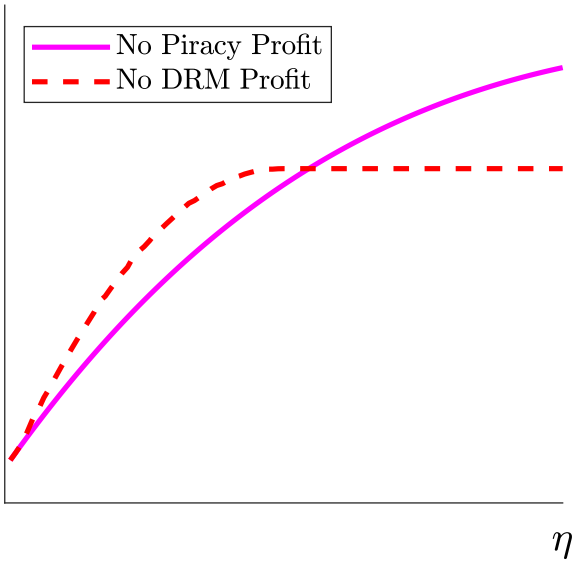


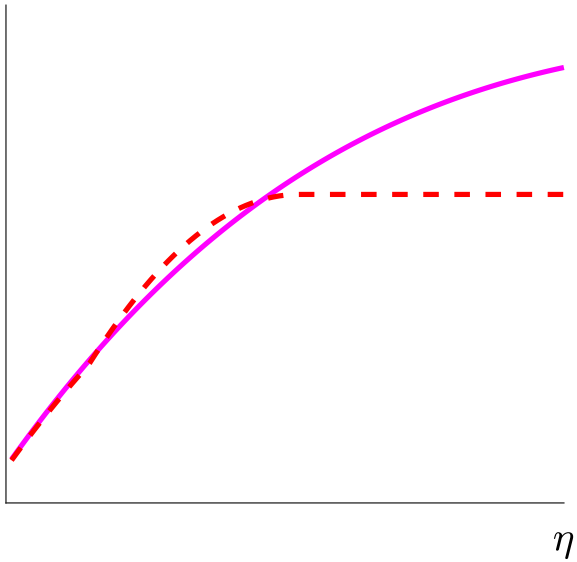
Heterogeneous Piracy Cost, Declining Profit

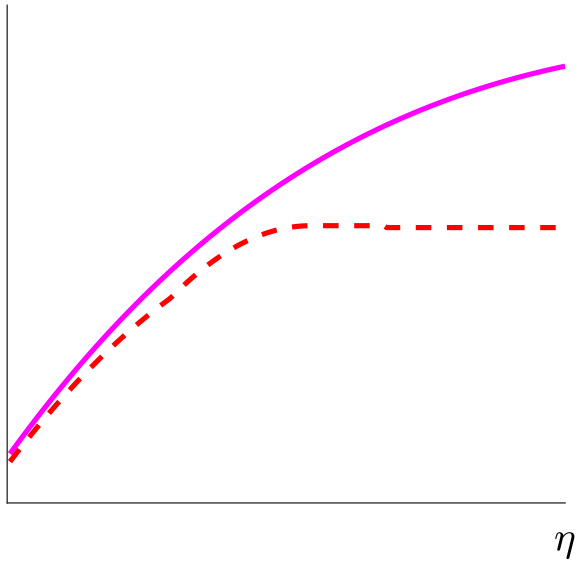












Heterogeneous Piracy Cost, Tentative Conclusion

- Piracy is never beneficial when distribution of κ is uniform
- I don't explore this further (closed-form solutions elusive with multiple sources of heterogeneity)
- But it's another suggestion that piracy is less likely to beneficial to developers than argued in previous literature

Conclusion

- The size of the market and the budgets of consumers are empirically important, but previously overlooked theoretically
- Refines conclusions of previous literature, implies piracy less likely to benefit developers through network effects
- Piracy less likely to be beneficial to developers in large markets
- Piracy less likely to be beneficial when the consumer base is extremely poor
- Piracy less likely to be beneficial when network effects are very weak or very strong
- Piracy less likely to be beneficial when piracy costs are more heterogeneous