Free and Open-Source Software: Coordination and Competition

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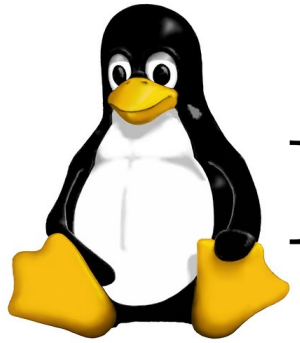

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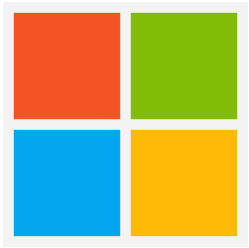
LATEX













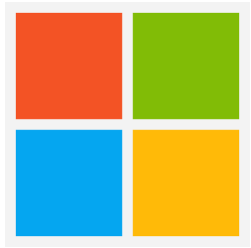


Software development

- Clear roadmap
- Minor changes between generations

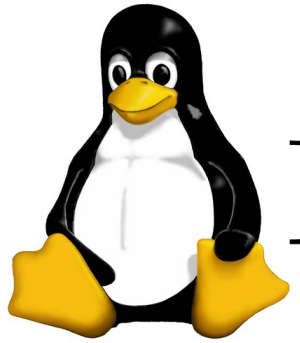















Developing FOSS

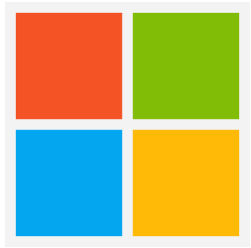
- Individuals collaborating
  - Voluntary basis
  - Non-material benefits
    - Personal use case
    - Honing skills

Coordinating FOSS

- Initial coordination by Founder
- Governing bodies/boards/user groups
- Firms – such as MS/Google/Intel

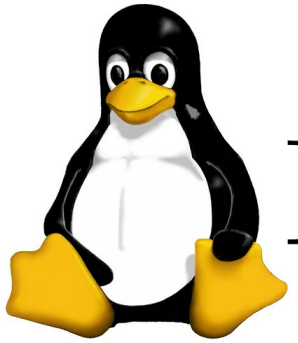






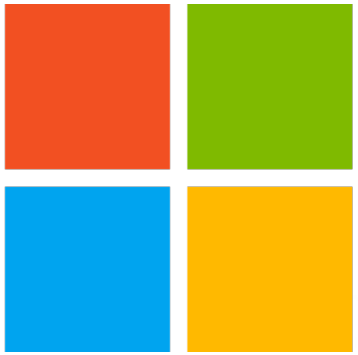











Microsoft









This Paper

Free and Open Source Software:

How are they coordinated?

How do they compete with proprietary software?

What role do software licenses play in promoting coordination/competition?

This Paper

Free and Open Source Software:

How are they coordinated?

- Better coordination → contributions are distinct (vertical improvement)
- Higher quality software → attract more developers
- But… contribute to different software features (horizontal dispersion)

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- Dual competitive nature of FOSS

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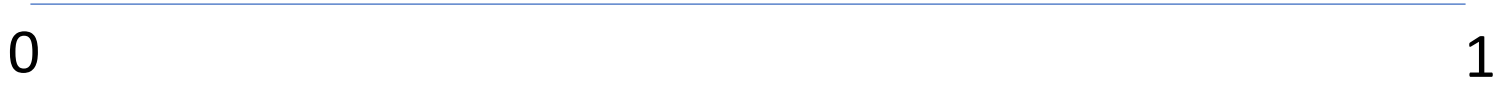
What role do software licenses play in promoting coordination/competition?

- More permissive – more attractive to other developers
- But… reduce coordination incentives
- Cheaper proprietary software

Model

Users/Developers

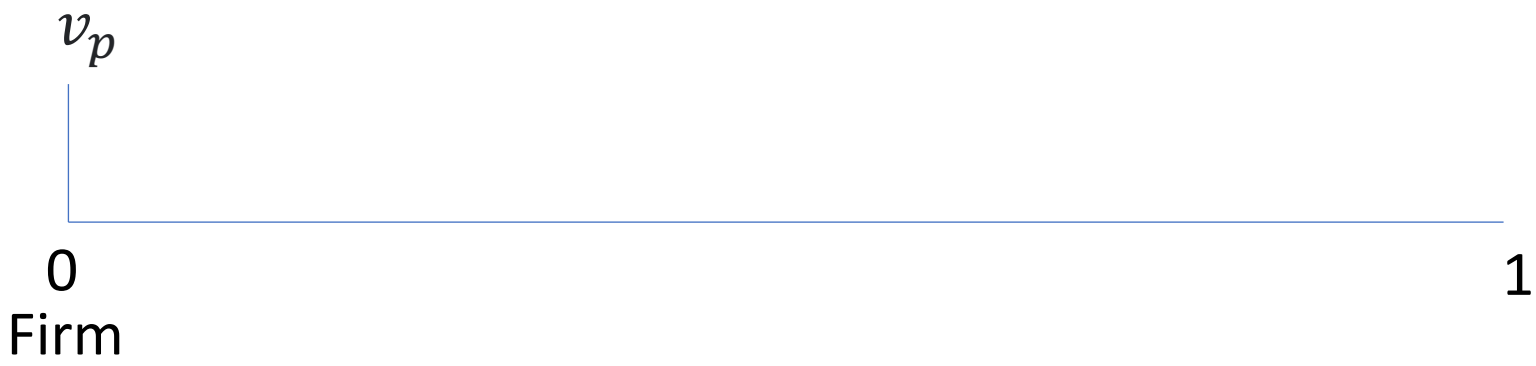
- Heterogeneous preference for product features
- Transport cost, $t > 0$
- $u_j = v_i - p_i - t|L_i - x_j|$



Model

Firm

- There exist a firm $i = p$
- Located at one end, $L_p = 0$
- Product quality v_p
- Maximising profits through price $\pi_p = p_p D_p$



Model

Free and Open Source Software

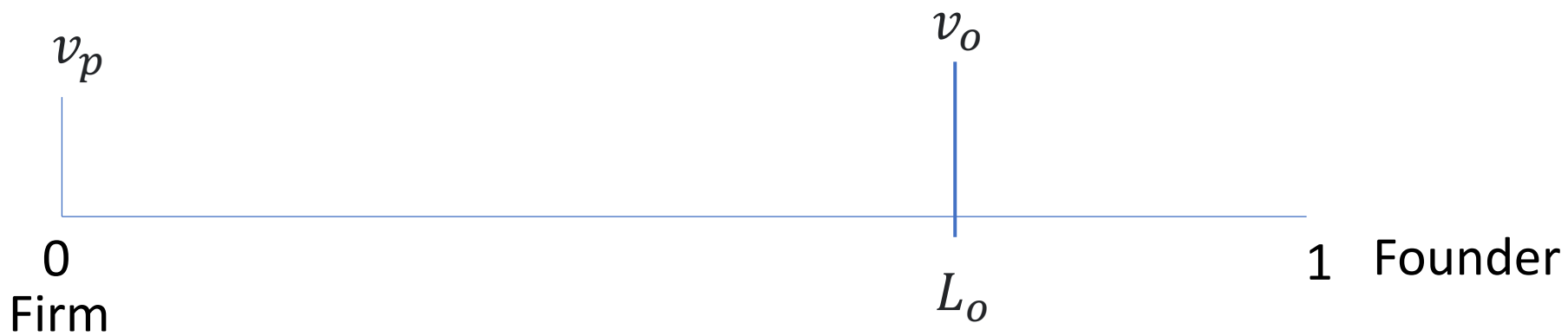
- There exist an FOSS $i = o$
- By definition, $p_o = 0$
- Product quality $v_o = \gamma D_o, \gamma \in [0,1]$
  - Probability of a unique contribution
- Location $L_o = 1 - lD_o, l \in (0,1)$
  - Ability to modify features
  - Proxy permissiveness of software license

Model

Coordinator

- A self-interested Founder
  - Located at 1
  - Selecting γ
  - Maximising his own utility

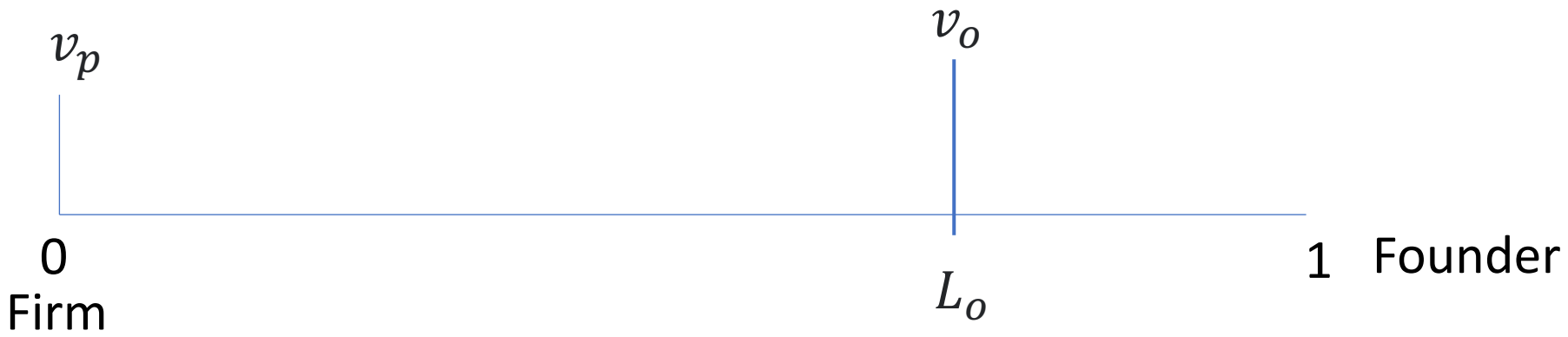
$$\pi_o = v_o - p_o - t|L_o - 1| = \gamma D_o - tlD_o$$



Model

Sequence of Events

- Choice of coordination level, γ
- Choice of price, p_p
- Users decide on which software to use

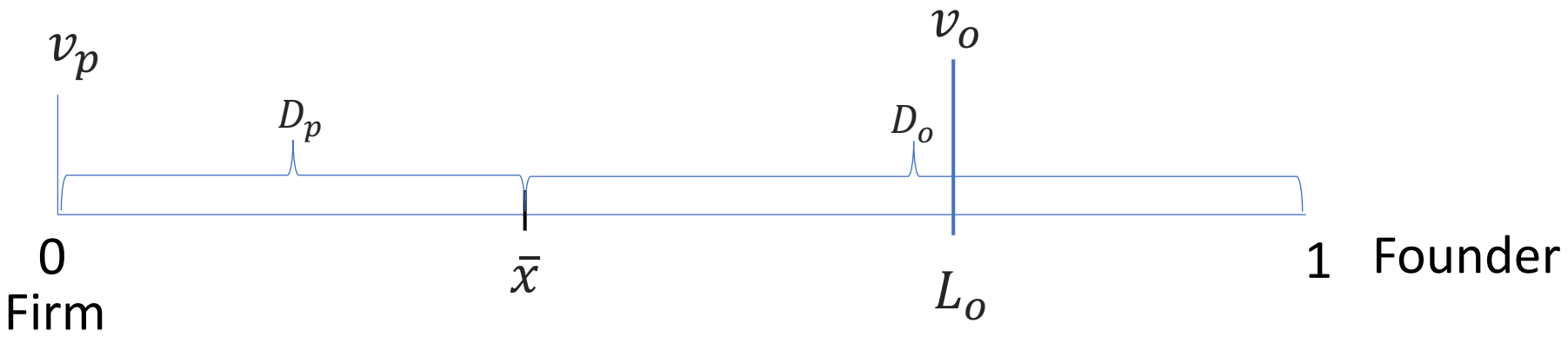


Equilibrium

Restrictions

- Covered market:
  - all users use something
  - exists an indifferent user $\bar{x}$
- Duopoly: firm and FOSS exist together

SPNE



Equilibrium: Indifferent User

$$v_p - p_p - t\bar{x} = (1 - \bar{x})(\gamma - t(1 - l))$$

Proprietary Software = FOSS

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$$v_p - p_p - t\bar{x} \quad = \quad (1-\bar{x})(\gamma - t(1-l))$$

Proprietary Software = FOSS

$$\bar{x} = \frac{v_p - p_p - \gamma + t(1-l)}{t(2-l) - \gamma}$$

Dual role of network effects

- FOSS demand increases in permissive license
- FOSS demand increases in unique contributions

Equilibrium: Firm Pricing

$$\pi_p = p_p \bar{x}$$

$$\bar{x} = \frac{v_p - p_p - \gamma + t(1-l)}{t(2-l) - \gamma}$$

$$p_p^* = \frac{v_p - \gamma + t(1-l)}{2}$$

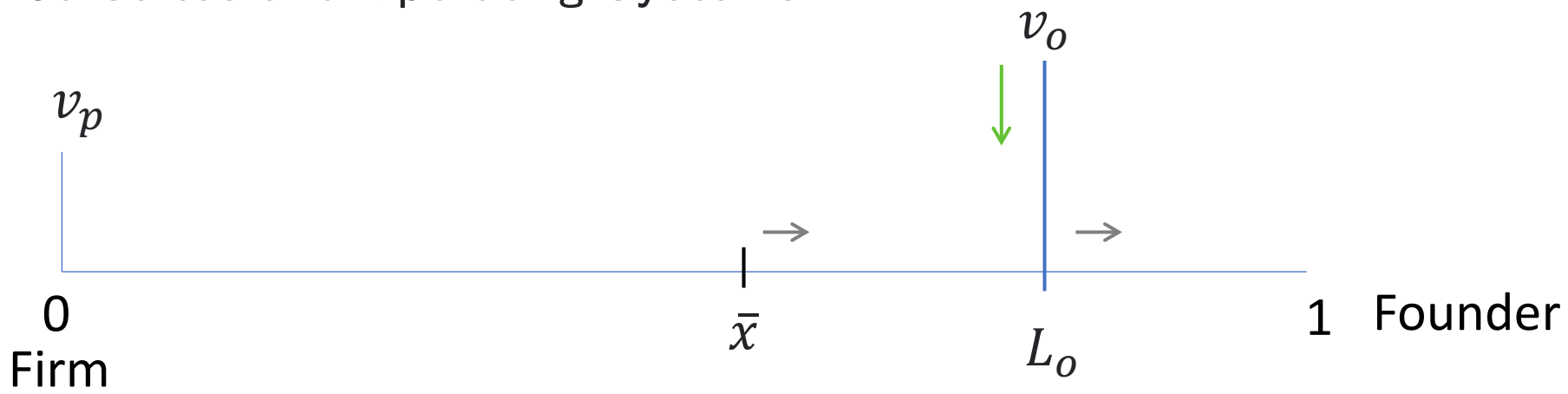
Dual role of network effects

- Proprietary price decrease in permissive license
- Proprietary price decrease in unique contributions

Founder: Competition

- Proprietary Firm
  - Lower prices allows recapture of market share
  - Able to diminish competition in both dimensions
    - But lower profits

- Existence of Niche/small FOSS can stimulate competition
  - Market share as a poor measure of market power
  - E.g. Office Suites and Operating Systems



Equilibrium: Founder

$$\pi_o = \gamma D_o - tlD_o$$

- Choice of γ balances
  - Positive quality effect – raising own utility
    - Diminishing in γ due to competition
  - Negative characteristic effect – raising own mismatch cost

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$$\gamma^* = t(2-l) - \sqrt{2t(v_p - t)(1-l)}$$

Proposition

Level of coordination decreases when FOSS license is more permissive.

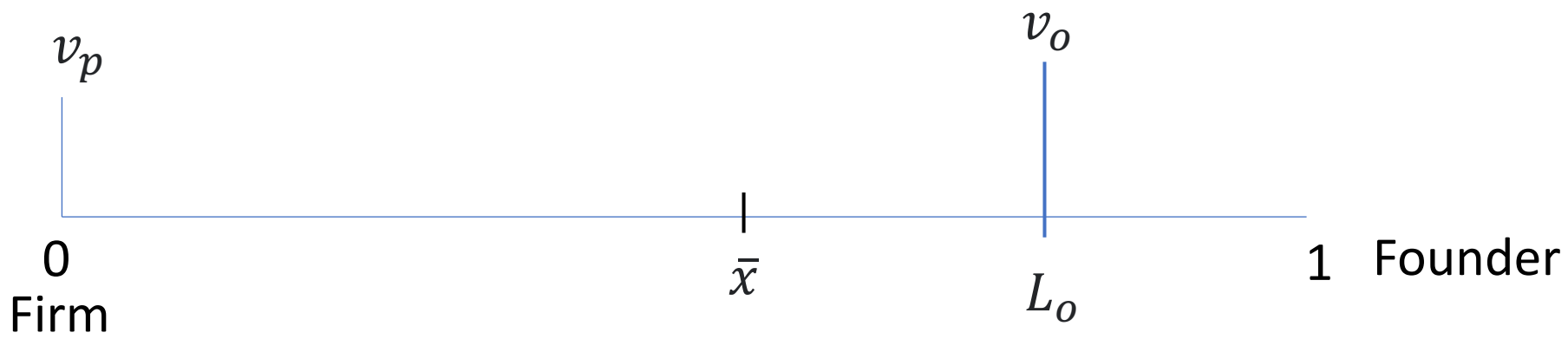
Founder: License

- Suppose we begin with $l \to 0$, $L_o \to 1$
  - Some γ^*, $p_p^*$and $\bar{x}$

- Represents:
  - Full control – closed license (Proprietary/Freeware)

Founder: License

- Permissive licenses, $l \uparrow$, $L_o = 1 - lD_o \downarrow$
- Lower total cost for indifferent user
- As more users join, $L_o \downarrow$



Founder: License

- Permissive licenses, $l \uparrow$, $L_o = 1 - lD_o \downarrow$
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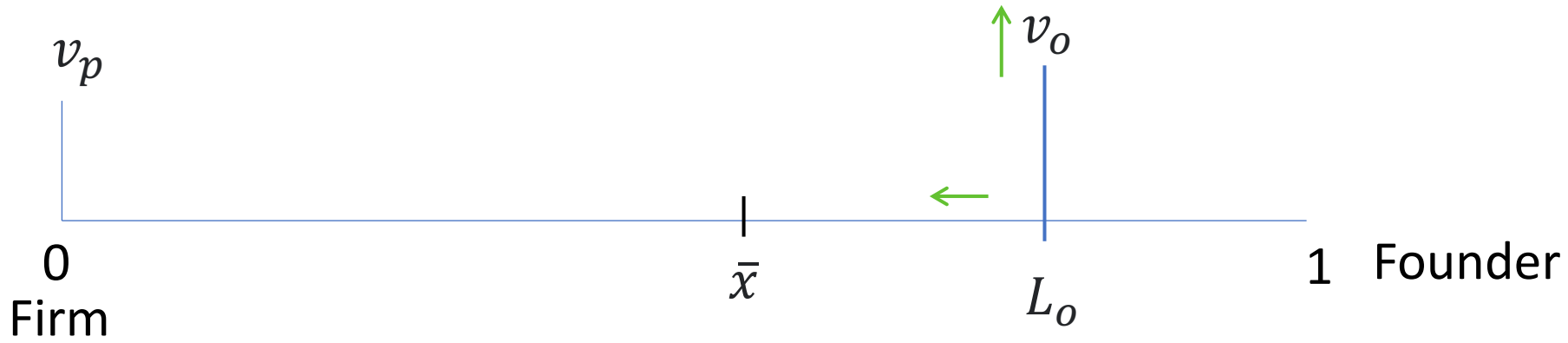
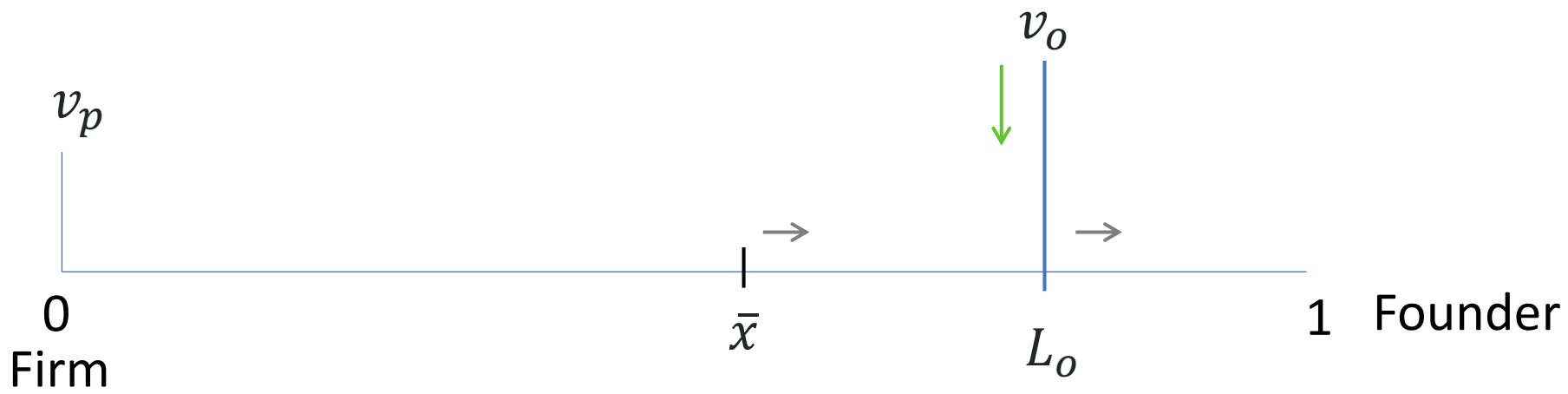
- As more users join, $L_o \downarrow$

- More users → quality improvements
- More users → further from Founder



Founder: License

- Keeping personal transport cost down
  - Reducing coordination, $\gamma \downarrow$
  - Existence of niche FOSS
  - Founders are only active if licenses are sufficiently restrictive



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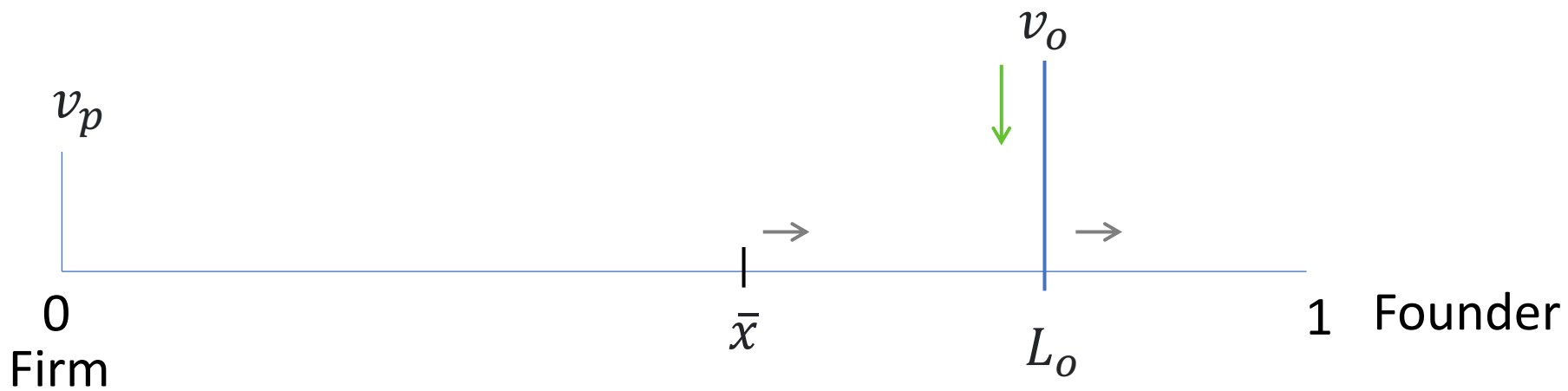
FOSS Consumer Surplus

FOSS consumer surplus is decreasing in l.



MIT license: A problem

Corollary

Founder is only active if $l < \bar{l} = 1.5 - \frac{v_p}{2t}$

- License decision should be environment specific

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- License decision should be environment specific

- Pervasive use of extremely permissive MIT license
  - Default recommendation of the FOSS community
    - CS knowledge ≠ Legal understanding
  - But may lead to under development of FOSS

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Examples

- Paint.NET
- colors-js
- faker-js
- core-js

MIT license: A problem

- Problems with permissive licenses:
  - Lower FOSS surplus
  - Suboptimal coordination
  - Niche FOSS

- Why are permissive licenses the default?
  - Spirit of collaboration?
  - Social norms?

Profit-driven Manager: Model

- Services and products adjacent to the FOSS
  - Plug-ins
  - Advertising
  - Data

Users/Developers

- Heterogeneous preference for product features
- $u_j = v_i - p_i - t|L_i - x_j|$

Firm

- Located at one end, $L_p = 0$, with product quality v_p
- Maximising profits through price $\pi_p = p_p D_p$

Profit-driven Manager: Model

~~Free and~~ Open Source Software

- Product quality $v_o = \gamma D_o, \gamma \in [0,1]$
- Location $L_o = 1 - lD_o, l \in (0,1)$

Profit-driven Manager

$$\pi_o = p_o(1 - \bar{x})$$

- By selecting uniqueness of contributions, γ

Sequence of events

- Choice of coordination, γ^M
- Choice of prices, p_p, p_o
- Users decide on which software to use

Manager: Equilibrium

When are they active?

- Only if licenses are sufficiently permissive
  - $l \geq 1.5 - \frac{1}{2t}$
  - More permissive licenses entice more users

Manager: Equilibrium

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Preferred level of coordination?

- Binary levels of coordination
  - Maximal: $\gamma^M = 1$ when $v_p < t$
  - Minimal: $\gamma^M = \max\{t, t(1.5 - l)\}$ when $v_p > t$

- Transport cost matters
  - Low t → weak user preference → mismatch 'ok' for users
  - High t → mismatch 'hurts' → OSS benefit from location network effects

Manager: Welfare

Total Consumer Surplus

Total consumer surplus is decreasing in l.

Proprietary profit

Proprietary firm profit is decreasing in l.

Manager: Welfare

Total Consumer Surplus

Total consumer surplus is decreasing in l.

Proprietary profit

Proprietary firm profit is decreasing in l.

OSS Manager profit

Manager's profit is decreasing in l unless contributions are unique.

- Permissive licenses hurts users of (F)OSS
- What motivates permissive licenses?
  - Managers ensuring unique contributions may benefit – $v_p < t$.
  - Are firms contributing to OSS development dictating standards?

Case Study: Permissive Licenses

Browser Wars 2.0 (2008)

- Internet Explorer as a leading browser
  - Frustrating, slow, outdated, $v_p < t$

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  - Preferences getting stronger, $t \uparrow$

- Code release of Chromium, $l \to 1$
- Explains Google's continued management

Other Results

Coordinator motivated by Altruism

- Maximising FOSS user surplus
- Lower γ than Founders, lower TS

Founder's license choice

- An initial FOSS decision?
- Binary decision: most restrictive or most permissive, depends on firm quality

Mutually exclusive users/developers

- Founder active if:
  - (i) firm quality low and FOSS license restrictive
  - (ii) firm quality high and FOSS permissive
- Founder prefer distinct contributions $\gamma = 1$

Skilled users

- Founder always prefer distinct contributions $\gamma = 1$

Related Literature

Motivations for contributing

Lerner and Tirole (2003, 2005); Agrawal, Catalini, and Goldfarb (2014); Hars and Ou (2002); Roberts, Hann, and Slaughter (2006); Gandal, Naftaliev, and Stettner (2017); Grewal, Lilien and Mallapragada (2006) ..... a very long and extensive literature.

- Incorporate types of people contribute to FOSS development
  - Intrinsic motivations, extreme preferences, highly skilled users
- And how they influence the outcome of the software
  - Own specialised needs

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Competing firms

Gauduel (2007); Morschheuser, Hamari, and Maedche (2019); Mustonen (2005); Casadesus-Massanell, and Llanes (2015); Casadesus-Masanell and Ghemawat (2006); Economides and Katsamakas (2005); Jaisingh, See-to, and Tam (2008); Mehra, Dewan and Freimer (2011) ..... another very long and extensive literature.

- Competition between FOSS and proprietary firms
  - Understanding the role of control / licenses
  - Describing profitable open source software

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Location-Quality trade-off

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- Coordination choice and network effects
  - Location-quality-price game

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Software Licenses

Fershtman and Gandal (2007); Stewart, Ammeter and Maruping (2006); Sen, Subramaniam and Nelson (2008); Gaudeul (2005, 2008); Lerner and Tirole (2005)

- License choice, motivations and outcomes
  - Less restrictive license leads to more contributors/users
  - Use of restrictive license to attract small highly skilled group

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Johnson (2002)

- Study FOSS accounting for developer private value of public good
  - Coordinators motivations
- Fixed notion of FOSS license
  - License permissiveness

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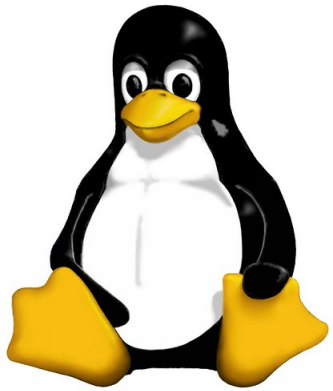
Other applications

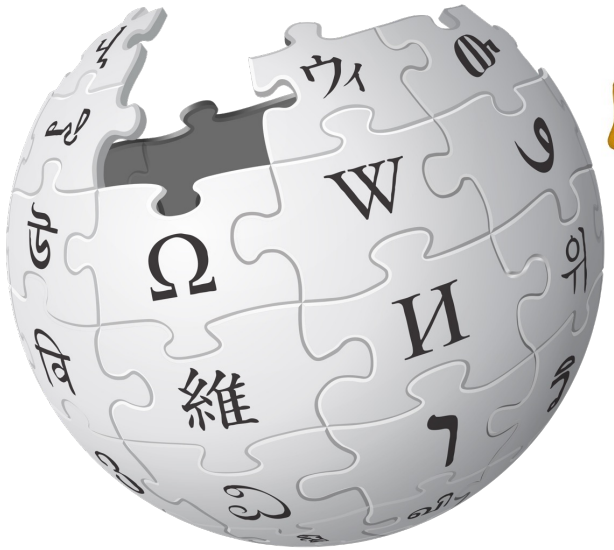
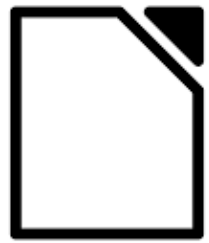
- Politics
- LLM
- Community







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