Economics of the Internet: A Policy Perspective

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Organization of the Talk

- Regulation on the Internet
- Introduction
- Model
- Sub-game Perfect Nash Equilibrium
- Numerical Results and Discussion

Regulation on the Internet in the US

- The communication act of 1996:
  - ⇒ Separated telephone and Information Services (IS).
  - ⇒ Relaxed regulation for IS's → investment on the Internet.
- In 2007, controversy over the Comcast limitation for BitTorrent.
  - ⇒ "Net-Neutrality" rules.
- Policies that mandate ISPs to treat all data equally, regardless of the source, destination, and type of the data.

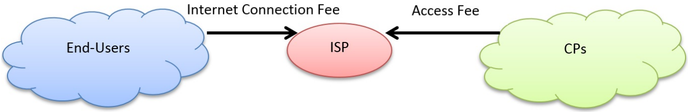
Net-Neutrality in the US: Now

- In January 2014, a federal appeals court struck down parts of the FCC's rules for Net-Neutrality.

- Comcast and Netflix signed an agreement in February 2014.
- AT&T sponsered data plans .

- February 2015: Broadband Internet Access listed as a public utility.
  - ⇒ Both wired and wireless.
  - ⇒ Ground for more neutrality regulations.

- Will not be the end, several lawsuits expected!



Net-Neutrality All Around the World

- Europe: In October 2015, the European parliament rejected legal amendments for strict net-neutrality rules.

  $\Rightarrow$ Allow for sponsored data plans and Internet fast lanes for specialized services.

- India: Controversy about Facebook's Internet.org.

- Iran: Examples of net-neutrality violations: cooperation of RighTel and Aparat.

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Our Work

- Intersection of engineering, economics, and public policy.
- Economic models for an Internet market, consists of:
  - Internet Serviced Providers (ISPs)
  - Content Providers (CPs)
  - End-Users (EUs)
- Problems considered:
  - Non-neutrality Adoption: (CISS'16)
    - How does the competition control the Internet market?
    - Social welfare analysis of the market.
    - Do we need regulation?
  - Different pricing frameworks in a non-neutral Internet: (TAC'16,WiOpt'15)
    - Which entity benefits more?
    - What is their effect on the market in the long-run?

Our Work

- Intersection of engineering, economics, and public policy.
- Economic models for an Internet market, consists of:
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- Problems considered:
  - **Non-neutrality Adoption without regulation:**
    - **How does the competition control the Internet market?**
    - **Social welfare analysis of the market.**
    - **Do we need regulation?**
  - Different pricing frameworks in a non-neutral Internet:
    - Which entity benefits more?
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Net-Neutrality Adoption

- One of the main factors in determining the regulation is competition.
- The leverage of CPs is one distinction of the Internet market.
  - CPs can control the equilibrium via differentiation between ISPs.
  - ISPs are afraid of non-neutrality by CPs!
- We model the framework with:
  - Some ISPs neutral, some non-neutral.
  - Asymmetric competition between ISPs.
  - CPs can differentiate between ISPs and their EUs.
- Goals:
  - Provide an insight for the new equilibrium of the Internet market.
  - How is each entity affected?
  - Do we need regulation?

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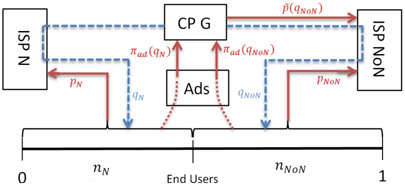
Model

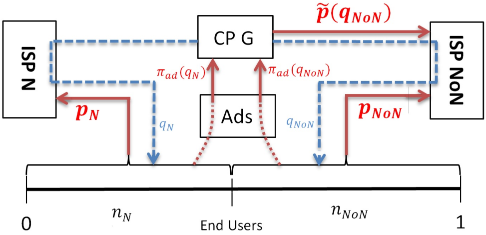
- Interactions between entities in the Internet market:
  - Internet Serviced Providers (ISPs)
    - 1 neutral offers:
      $\Rightarrow$ free (basic) quality
    - 1 non-neutral: offers:
      $\Rightarrow$ free quality
      $\Rightarrow$ premium quality
  - Content Providers (CPs)
    - 1 CP with high market power (e.g. Google)
  - End-Users (EUs)



- EUs decide between ISPs based on:
  - innate preference for ISPs (inertia)
  - Internet access fees
  - quality
- The payoff:

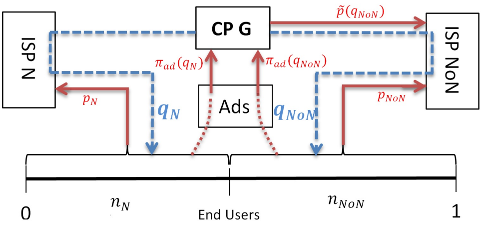
$$u_{EU,j}(x) = v^* + \kappa_{ad} q_j - t_j x_j - p_j \quad j \in \{\text{N}, \text{NoN}\}$$

  - t_j: transport cost
  - $t_j \uparrow \Rightarrow$ preference for ISP j $\downarrow$
  - Market power of ISP N: $\frac{t_{NoN}}{t_N + t_{NoN}}$
- n_N : fraction of EUs with neutral ISP.
- n_{NoN} : fraction of EUs with non-neutral ISP.



- Non-neutral decides on:
  - Internet access fee (p_{NoN})
  - side-payment ($\tilde{p}$)
- Neutral decides on:
  - Internet access fee (p_N)
- Payoffs:

$$\pi_N(p_N) = (p_N - c)n_N$$
$$\pi_{NoN}(p_{NoN}, \tilde{p}) = (p_{NoN} - c)n_{NoN} + \tilde{p}q_{NoN}n_{NoN}$$



- Decides on the qualities for EUs of neutral and non-neutral ISPs.
- Premium quality comes with a price.
- payoff:

$$\pi_G(q_N, q_{NoN}) = \begin{cases} \kappa_{ad} q_N n_N + \kappa_{ad} q_{NoN} n_{NoN} & \text{if } q_{NoN} = \tilde{q}_f \\ \kappa_{ad} q_N n_N + (\kappa_{ad} - \tilde{p}) q_{NoN} n_{NoN} & \text{if } q_{NoN} = \tilde{q}_p \end{cases}$$

Highlights of Model and Assumptions

- Highlights of the model:

  ⇒ Take into account the initial stages of migration to a non-neutral regime (some ISPs neutral, some non-neutral)

  ⇒ CPs can control the equilibrium outcome via quality choices.

  ⇒ Competition between neutral and non-neutral ISPs.

  ⇒ Asymmetric innate preferences (inertias) of EUs for ISPs.

- Modeled with a 4-stage sequential game:

  ⇒ Stage 1: ISPs decide on p_N and p_{NoN}.

  ⇒ Stage 2: ISP NoN decides on the side-payment, $\tilde{p}$.

  ⇒ Stage 3: CP decides on the qualities, q_N and q_{NoN}.

  ⇒ Stage 4: EUs decide.

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Sub-game Perfect Nash Equilibrium (SPNE)

- We show that if an SPNE exists, it is of the form of one of the four possible SPNE strategies:

1. (candidate strategy a:) Neutral ISP is driven out of the market:
   $\Rightarrow$ CP offers with premium quality ($\tilde{q}_p$) on ISP NoN.
   $\Rightarrow$ CP does not offer on ISP N.
2. (candidate strategy b:) Both ISPs active - 1:
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3. (candidate strategy c:) Both ISPs active - 2:
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SPNE: EUs not locked-in with ISPs (real competition)

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SPNE: Benchmark Case

- Both ISPs neutral.
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Equilibrium Outcome

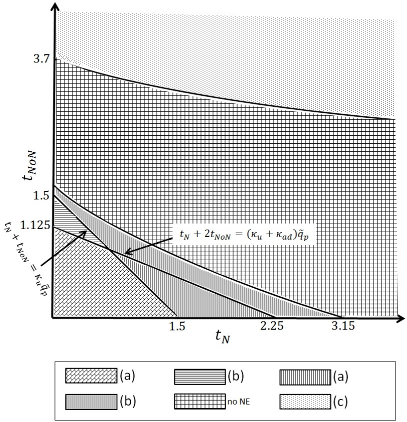
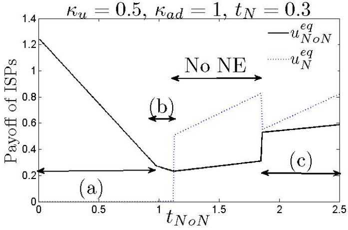
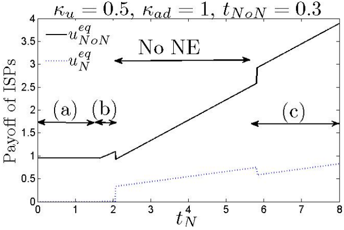


Figure: Equilibrium Outcome with $\kappa_u = 1$ and $\kappa_{ad} = 0.5$

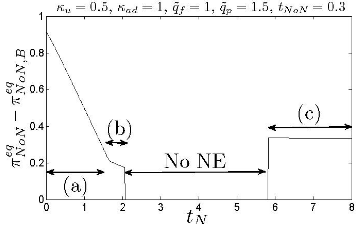
- The SPNE is unique (if it exists) for each parameter set.


$\kappa_u = 0.5,\ \kappa_{ad} = 1,\ t_N = 0.3$
u_{NoN}^{eq}
u_N^{eq}
No NE
(a)
(b)
(c)
Payoff of ISPs
t_{NoN}

(a)

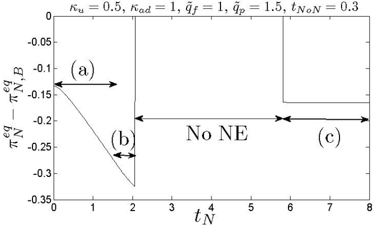

$\kappa_u = 0.5,\ \kappa_{ad} = 1,\ t_{NoN} = 0.3$
u_{NoN}^{eq}
u_N^{eq}
No NE
(a)
(b)
(c)
Payoff of ISPs
t_N

(b)



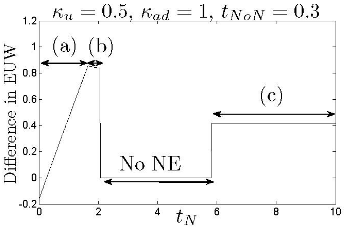
$\kappa_u = 0.5$, $\kappa_{ad} = 1$, $\tilde{q}_f = 1$, $\tilde{q}_p = 1.5$, $t_{NoN} = 0.3$
$\pi^{eq}_{NoN} - \pi^{eq}_{NoN,B}$
t_N
(a)
(b)
(c)
No NE

(c)

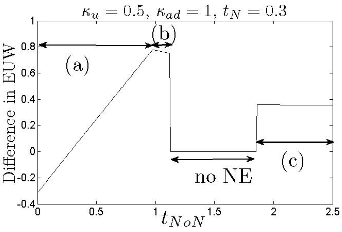


$\kappa_u = 0.5$, $\kappa_{ad} = 1$, $\tilde{q}_f = 1$, $\tilde{q}_p = 1.5$, $t_{NoN} = 0.3$
$\pi^{eq}_{N} - \pi^{eq}_{N,B}$
t_N
(a)
(b)
(c)
No NE

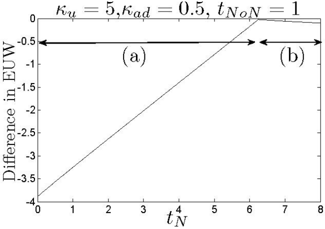
(d)


$\kappa_u = 0.5,\ \kappa_{ad} = 1,\ t_{NoN} = 0.3$
Difference in EUW
(a) (b)
(c)
No NE
t_N
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
0
2
4
6
8
10

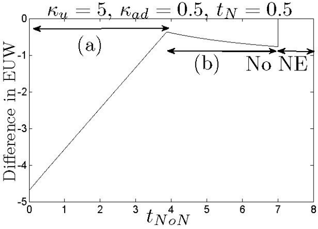
(e)


$\kappa_u = 0.5,\ \kappa_{ad} = 1,\ t_N = 0.3$
Difference in EUW
(b)
(a)
no NE
(c)
t_{NoN}
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
0
0.5
1
1.5
2
2.5

(f)


$\kappa_u = 5, \kappa_{ad} = 0.5,\ t_{NoN} = 1$
Difference in EUW
(a)
(b)
t_N

(g)


$\kappa_u = 5,\ \kappa_{ad} = 0.5,\ t_N = 0.5$
Difference in EUW
(a)
(b)
No NE
t_{NoN}

(h)

Summary of the Key Results - part I

- CP receives the same payoff in neutral and non-neutral regimes.
- Neutral ISP receives a lower payoff in a non-neutral regime.
- Non-neutral ISP receives a higher payoff (for most parameters).

  $\Rightarrow$ By switching to non-neutrality, ISP losses payoff if:
  - EUs not sensitive to the quality of the content (small κ_u)
  - The CP is not sensitive to the quality users receive (small κ_{ad})
  - Not enough differentiation with free quality (small $\tilde{q}_p$)

Summary of the Key Results - part II

- Non-neutral regime yields a higher welfare for EUs than a neutral one if:

  ⇒ the market power of the ISP NoN is small,

  ⇒ the sensitivity of EUs (respectively, the CP) to the quality is low (respectively, high), OR,

  ⇒ a combinations of these factors.

Does the Market Need to be Regulated?

- It depends!
- Neutral ISPs are likely to forced out of the market.
  $\Rightarrow$ Regulator should provide incentives for the neutral ISPs (monetary subsidies or tax deductions).
- If non-neutral ISP losses profit by switching to non-neutrality:
  $\Rightarrow$ Non-neutrality is unlikely to emerge.
  $\Rightarrow$ No need for a government intervention.

Section 2.1:

Uncertain Price Competition in a Duopoly Internet Market

- Mohammad Hassan Lotfi and Saswati Sarkar,"*Uncertain price competition in a duopoly: Impact of heterogeneous availability of the commodity under sale*", 50th Annual Allerton Conference ,IEEE, 2012.

- Mohammad Hassan Lotfi and Saswati Sarkar," *Uncertain Price Competition in a Duopoly with Heterogeneous Availability*", Revised and Submitted to IEEE Transaction on Automatic Control

Introduction

- Previous works:
  - Uncertainty in competition when the availability level is either zero or one.
  - Sellers control the amount of units they produce- i.e. supply function auctions.

- In our work: Two ISPs, each selects the price based on:

  ⇒ number of units of resources available for sponsoring

  ⇒ statistics of the availability process for her competitor → uncertainty in competition

  ⇒ statistics of the demand of CPs → uncertainty in demand

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  $\Rightarrow$ statistics of the demand of CPs $\rightarrow$ uncertainty in demand

Model

- Mixed strategy of each ISP is a vector of probability distributions each element representing an availability level.

  $\Rightarrow$ For instance: ISP offers 3 units, strategy$=(\Phi_1(.), \Phi_2(.), \Phi_3(.))$.

- An integer number of CPs.
- CPs shop around for the lowest available prices.

- ISPs maximize the payff:

  Payoff = Price per Resource × Expected Number of Resources Sponsored

- Classic theorems for existence and uniqueness of NE cannot be used.

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Results

Theorem (Limited Necessary Conditions)

If demand is greater than the maximum possible number of available unit, then every NE satisfies a set of properties:

- ISPs select price using probability distributions whose support sets are mutually disjoint, contiguous and in decreasing order of the number of availability.

  $\Rightarrow$ The higher the availability level, the lower the price per unit.

  $\Rightarrow$ Algorithm to explicitly compute such strategies.

Theorem (General Necessary Conditions for a Symmetric Market)

The necessary properties are necessary conditions for a symmetric NE in a symmetric market, regardless of the demand.

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Every strategy that satisfies the necessary properties is an NE regardless of the demand.

- **Necessary and Sufficient:**
  - ⇒ Symmetric
  - ⇒ Asymmetric & demand>maximum availability
- **Only Sufficient:**
  - ⇒ Asymmetric & demand≤maximum availability
- **Unique NE:** symmetric setting
- **Multiple Nash equilibria:** asymmetric setting

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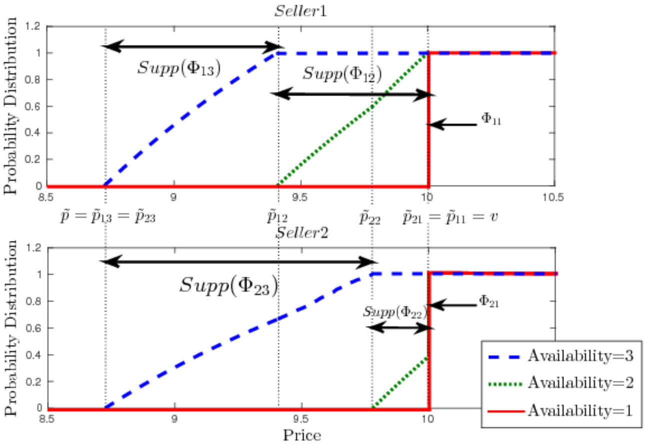
Results: An Example for an Asymmetric Market



Generalizations and Applications

- Proposed a heuristic set of strategies for sellers in a symmetric oligopoly, satisfying mentioned properties.
- Numerical results reveal that the strategy is a fairly good approximation of NE.
- Model can be also used in microgrid networks, primary/secondary markets.

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Thanks!