# Compatibility between Differentiated Networks

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## 1. Introduction

- **Objective:** understand economic forces behind interconnection in the Internet

- **Early years of Internet**
  - ‘bill-and-keep’ system
  - flows were symmetric

- **Transition of Internet from academic to commercial**
  - large increases in traffic volumes,
  - unequal development of networks
  - 1997: U.S.’s 4 largest networks carry 85-95% of backbone traffic
  - rest carried by 40 networks

- **Recent developments**
  - 1996: Commercial Internet Exchange (CIX) starts to dissolve
  - 1997: UUNet leaves CIX, and attempts to cancel peering with 15 smaller ISPs
  - MCI and BBN leave CIX
  - larger networks continue to peer between themselves
  - growing fear of anti-competitive behaviour by large networks

- **Ideally, would like a dynamic model of this situation**

- **Difficult; instead, a dynamic interpretation of a static model**

- **Basic setting:**
  - network size ≡ quality
  - networks 'horizontally' differentiated (e.g. offer different content)

- ◦ heterogeneous consumer preferences for network size and 'location'

- **Central question:** what are networks' incentives to be compatible?

- **Compatibility has two effects**
  - ◦ decreases degree of vertical differentiation between networks of different sizes
  - ⇒ increases competition
  - ◦ makes market share less important for horizontally differentiated networks
  - ⇒ decreases competition

- **Structure of talk**
  - ◦ describe model and its interpretation
  - ◦ illustrate dependence of equilibrium on parameter representing relative importance of vertical to horizontal aspects in consumers' utility
  - ◦ conclusions

## 2. The Model

- **2 networks compete to attract customers in a 1-period model**

- **Utility that a consumer gains from joining a network when networks are not compatible**

$$U_{NC}(\alpha, \theta, 1; \beta, \underline{\theta}) = V + \beta(1-\alpha) + (1-\beta)\theta Q_1 + \underline{\theta} Q_1 - p_1,$$

$$U_{NC}(\alpha, \theta, 2; \beta, \underline{\theta}) = V + \beta\alpha + (1-\beta)\theta Q_2 + \underline{\theta} Q_2 - p_2.$$

- **When networks are compatible**

$$U_C(\alpha, \theta, 1; \beta, \underline{\theta}) = V + \beta(1-\alpha) + (1-\beta)\theta + \underline{\theta} - p_1,$$

$$U_C(\alpha, \theta, 2; \beta, \underline{\theta}) = V + \beta\alpha + (1-\beta)\theta + \underline{\theta} - p_2.$$

- **Model interpretation**
  - $V$ is a constant term, independent of network joined
  - $\alpha$: consumers with $\alpha$ close to 0 (1) prefer to join network 1 (2)
  - $\theta$: consumers with high $\theta$ gain greater utility from joining a large network
  - $\theta$ and $\alpha$ jointly uniformly distributed over unit square
  - $\frac{1}{8} < \underline{\theta} < \frac{1}{3}$: all consumers gain some utility from network size
  - $p_i$ is price to join network $i$

- **Relative importance of horizontal and vertical terms: $\beta$**
  - $\beta = 0$: model is purely 'vertical'
  - $\beta = 1$: model is 'horizontal'
  - $0 \leq \beta \leq 1$: full range of models

- **Strategies**
  - *network*: choice of price, given other network's price and decisions of consumers
  - *consumer*: choice of network to join, given prices quoted by networks and decisions of other consumers
  - consumers are assumed to join 1 and only 1 network
  - look for Nash equilibrium in pure strategies

- **Compatibility:** a binary variable
  - *networks not compatible*: consumers' utilities from joining network $i$ depend only on size and location of network $i$
  - *networks compatible*: consumers' utilities from joining network $i$ depend on location of network $i$ and total market size
  - compatibility perfect, 2-way and costless

- **Start by working out extreme points:** $\beta = 0$ **and** $\beta = 1$

**A.** $\beta = 0$**: Pure Vertical**

- **Utilities of consumer** $\theta$ **joining network** $i$ **are**

$$U_{NC}(\alpha, \theta, i; \beta = 0, \underline{\theta}) \;=\; V + (\theta + \underline{\theta})Q_i - p_i,$$

$$U_C(\alpha, \theta, i; \beta = 0, \underline{\theta}) \;=\; V + \theta + \underline{\theta} - p_i.$$

- **Consider incompatibility**

- **Wlog, suppose that** $p_1 \geq p_2$

  $\Rightarrow Q_1 \geq Q_2$

  $\Rightarrow$ consumers with higher $\theta$ join network 1

- **Marginal consumer $\theta^*$ indifferent between 2 networks**

$$U_{NC}(\alpha, \theta^*, 1; \beta = 0, \underline{\theta}) = U_{NC}(\alpha, \theta^*, 2; \beta = 0, \underline{\theta}),$$

$$\Rightarrow \quad (\theta^* + \underline{\theta})(1 - 2\theta^*) = p_1 - p_2.$$

- **Nash equilibrium**

$$Q_1 = \frac{4 + 3\underline{\theta}}{5},$$

$$Q_2 = \frac{1 - 3\underline{\theta}}{5},$$

$$p_1 = \frac{(1 + 2\underline{\theta})(4 + 3\underline{\theta})}{25},$$

$$p_2 = \frac{(1 + 2\underline{\theta})(1 - 3\underline{\theta})}{25},$$

$$\pi_1 = \frac{(1 + 2\underline{\theta})(4 + 3\underline{\theta})^2}{125},$$

$$\pi_2 = \frac{(1 + 2\underline{\theta})(1 - 3\underline{\theta})^2}{125}.$$

- **Features of equilibrium**

    1. network 1 is larger
    2. when $\underline{\theta} = \frac{1}{8}$, $Q_1 = 7Q_2$
    3. when $\underline{\theta} = \frac{1}{3}$, network 1 is a monopolist
    4. both networks earn positive profits when $\underline{\theta} < \frac{1}{3}$
    5. network 1 is more profitable

- **Now consider compatibility equilibrium**

    - each consumer $\theta$ receives same gross utility regardless of network joined
    - consequently, networks are pure Bertrand competitors
    - earn zero profits in equilibrium

$\Rightarrow$ **Profits decrease through compatibility**

**B. $\beta = 1$: Horizontal**

- **Utilities of consumer $\alpha$ joining network 1 are**

$$U_{NC}(\alpha, \theta, 1; \beta = 1, \underline{\theta}) = V + 1 - \alpha + \underline{\theta} Q_1 - p_1,$$

$$U_C(\alpha, \theta, 1; \beta = 1, \underline{\theta}) = V + 1 - \alpha + \underline{\theta} - p_1,$$

- **Utilities of consumer $\alpha$ joining network 2 are**

$$U_{NC}(\alpha, \theta, 2; \beta = 1, \underline{\theta}) = V + \alpha + \underline{\theta} Q_2 - p_2,$$

$$U_C(\alpha, \theta, 2; \beta = 1, \underline{\theta}) = V + \alpha + \underline{\theta} - p_2.$$

- **Incompatibility**

  - marginal consumer $\alpha^*$, indifferent between 2 networks:

$$U_{NC}(\alpha^*, \theta, 1; \beta = 1, \underline{\theta}) = U_{NC}(\alpha^*, \theta, 2; \beta = 1, \underline{\theta}),$$

$$(1 - \underline{\theta})(2\alpha^* - 1) = p_1 - p_2.$$

- equilibrium

$$Q = \frac{1}{2},$$

$$p = 1 - \underline{\theta},$$

$$\pi = \frac{1-\underline{\theta}}{2}.$$

- **Compatibility**
  - model is standard Hotelling
  - equilibrium

$$Q = \frac{1}{2},$$

$$p = 1 \quad > \quad 1 - \underline{\theta},$$

$$\pi = \frac{1}{2} \quad > \quad \frac{1-\underline{\theta}}{2},$$

⇒ **Profits increase through compatibility**

- **Three cases arise, depending on $\beta$**

$\beta < \beta_1$: both networks prefer not to be compatible

$\beta_1 \leq \beta < \beta_2$: smaller network prefers to be compatible, larger network does not

$\beta \geq \beta_2$: both networks prefer to be compatible

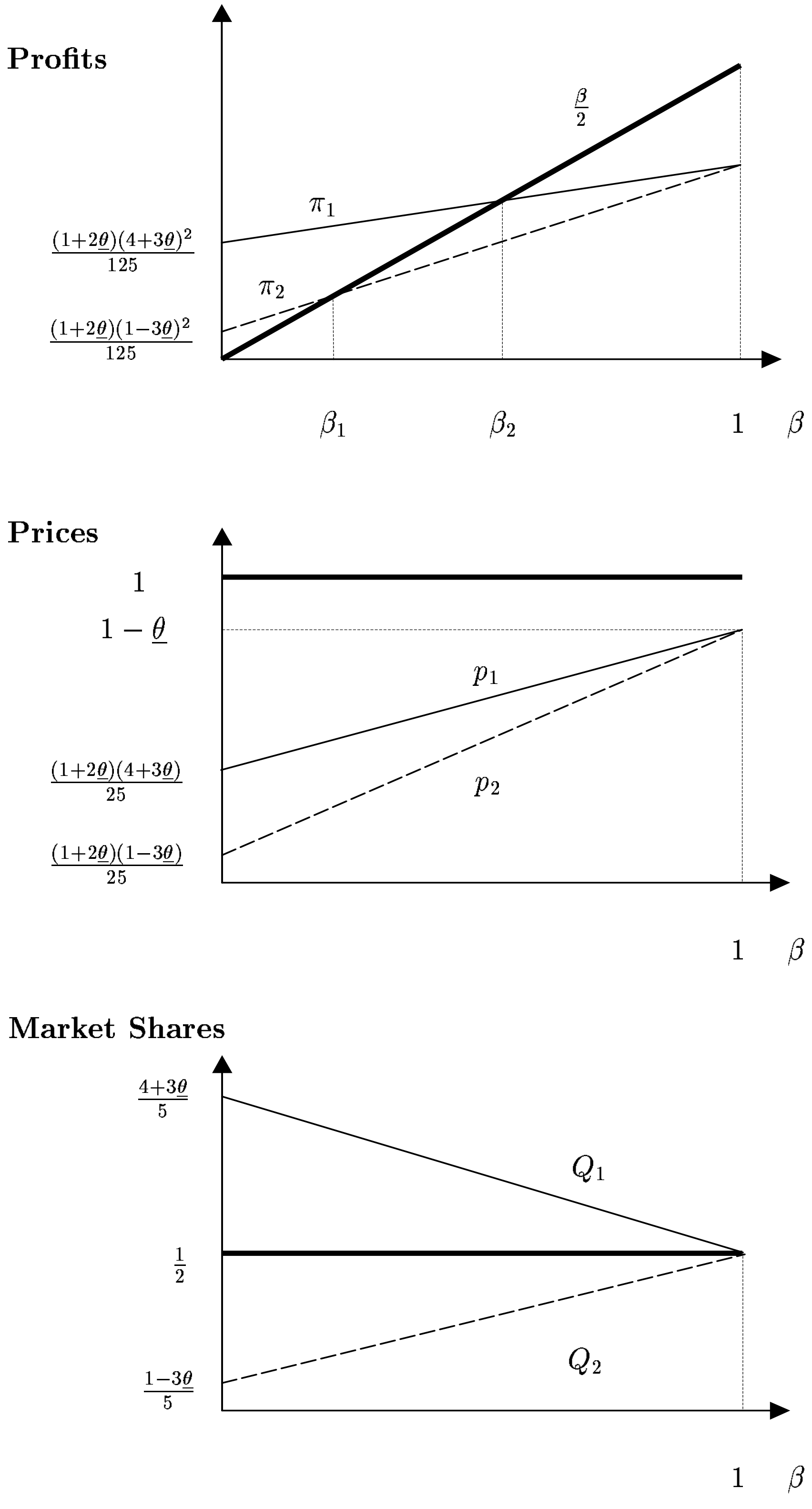




Figure 1: Illustrative Network Profits, Prices and Size

- **Low number of Internet users**
  - vertical aspects less important
  - $\beta$ high
  - networks symmetric
  - interconnection preferred by all networks

- **Growth in use of Internet**
  - vertical term increases in size
  - equivalent to a decrease in $\beta$
  - networks diverge
  - interconnection preferred by small network, not by large

## 3. Conclusions

- **Developed a generalised model of network competition**
  - consumers vary in their preferences for network size and location
  - networks are endogenously vertically and exogenously horizontally differentiated

- **Analysed effect of compatibility on degree of competition**

- **Compatibility**
  - decreases vertical differentiation, and hence increases competition
  - decreases importance of market share, and hence decreases competition

- **Which effect dominates depends on relative importance of horizontal and vertical aspects in consumers' utilities**

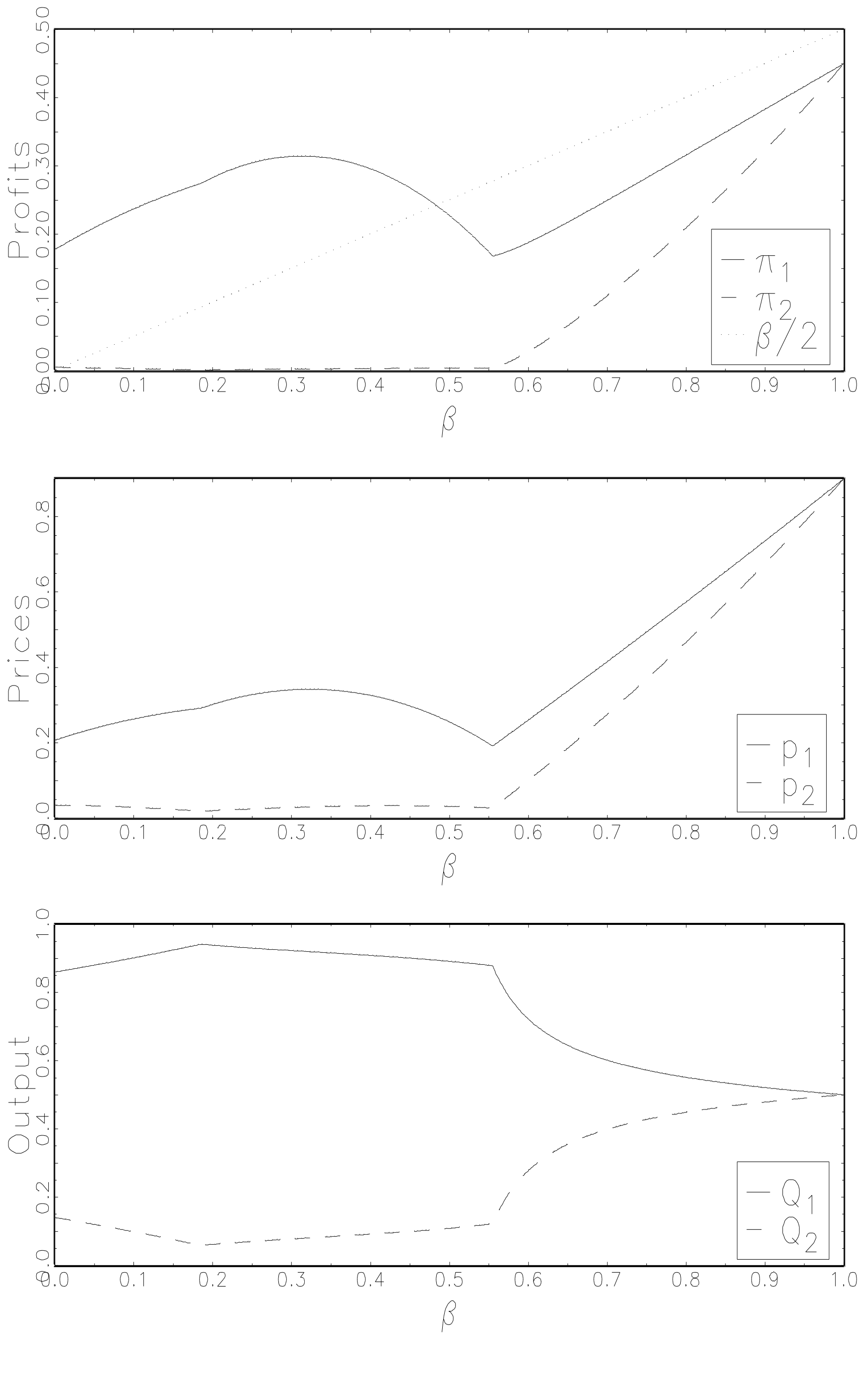


Figure 2: Equilibrium across all Cases