Can Access Price Indexation Promote Efficient Investment in Next Generation Networks?

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Motivation: Trade-off between static and dynamic efficiency

It is essential to establish clear regulatory guidelines to encourage investment in next generation access networks, while ensuring that such networks remain open and competitive in the interest of consumers. *Neelie Kroes, European Commissioner for Digital Agenda.*

- Regulators face a trade-off between dynamic efficiency (ex-ante) and static efficiency (ex-post).
- Static efficiency: retail prices equal to marginal cost.
- Dynamic efficiency: equilibrium investment equals to socially optimal investment.

The Research Question

- This paper deals with a problem of underinvestment in shared infrastructures.
- How to encourage investment in shared network infrastructures without lessening downstream price competition?

The Main Result

- *An access price (per end-user) rule defined as function of investments, for example,*

$$a_i = xI_i - yI_j,\ i \neq j \tag{1}$$

can simultaneously (i) expand total investment in fibre coverage, (ii) expand the number of subscribers and (iii) enhance social welfare, vis-à-vis a fixed access price rule $a^* > 0$.

- The indexation approach, as compared to a fixed access price rule, rewards investors twofold by allowing them to: (i) charge higher access prices to accessing operators and, (ii) pay less to get access from other operators.
- Indexing access prices to investments enhances competition to the investment stage.

Assumptions (1): Networks

- Two operators denoted by 0 and 1 sell broadband (fibre) connection to subscribers.
- Investment expands the number of cities covered by fibre, where $I \equiv I_0 + I_1$, I_i is the number of cities covered by operator $i = 0, 1$, and I is the total number of cities covered by fibre.
- Operator i's cost of covering I_i cities by fibre is given by technology
$$C(I_i) = cI_i^2/2. \tag{2}$$
- Operator i's marginal cost of serving subscribers =
$$\begin{cases} 0, & \text{if subscriber in } i\text{'s area} \\ a_j, & \text{all other areas.} \end{cases}$$

Assumptions (2): Consumers

- Consumer Surplus

$$CS_{\tilde{x}} \equiv \begin{cases} v - t\tilde{x} - p_0 & \text{if operator } 0 \\ v - t\left(1 - \tilde{x}\right) - p_1 & \text{if operator } 1 \end{cases} \quad (3)$$

$$CS_{\tilde{y}} \equiv \begin{cases} v - \tau\tilde{y} - p_i & \text{if operator } i = 0, 1 \\ 0 & \text{if no service.} \end{cases} \quad (4)$$

- The representative city: mass one of consumers in the city centre; mass 0.5 in each hinterland, $v > t = \tau > 0$.

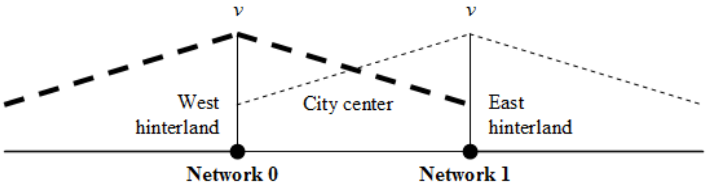


Figure 1: Hotelling model with hinterlands.

Assumptions (3): Consumer demand

From (3) and (4) we get the demand functions

$$x_i = \frac{1}{2} - \frac{p_i - p_j}{2t},\; z_i = \frac{v - p_i}{2v}. \tag{5}$$

Therefore,

$$q_i \equiv x_i + z_i = 1 - \frac{(v+t)\,p_i - vp_j}{2tv} \text{ and } Q \equiv q_0 + q_1 = 2 - \frac{p_0 + p_1}{2v}. \tag{6}$$

Timing of the Model

I. The regulator defines the access price rule per end-user, a_i, that operator i charges to j, $i \neq j$ and $i, j = 0, 1$.

II. Operators invest simultaneously and non-cooperatively in non-duplicable network infrastructures, which we interpret as NGNs infrastructures (FTTH). Immediately after, operators observe the investment outcome.

III. Operators compete simultaneously and non-cooperatively in retail prices in all cities regardless who has made the investment in each city.

Market Equilibrium under Fixed Access Price (1)

STAGE III: RETAIL PRICE COMPETITION

Operator i's problem,

$$\max_{p_i} \Pi_i = (l_0 + l_1) \times p_i q_i + a q_j l_i - a q_i l_j - c \frac{l_i^2}{2} \tag{7}$$

In equilibrium,

$$\begin{cases} \frac{\partial \Pi_i(a)}{\partial p_i} = 0 \\ \frac{\partial \Pi_j(a)}{\partial p_j} = 0. \end{cases} \tag{8}$$

Market Equilibrium under Fixed Access Price (2)

STAGE II: INVESTMENTS

$$\max_{I_i} \Pi_i^* = (I_0 + I_1) \times p_i^* q_i^* + a q_j^* I_i - a q_i^* I_j - c\frac{I_i^2}{2} \qquad (9)$$

In equilibrium,

$$\begin{cases} \frac{\partial \Pi_i^*\left(p_i^*, p_j^*\right)}{\partial I_i} = 0 \\ \frac{\partial \Pi_j^*\left(p_j^*, p_i^*\right)}{\partial I_j} = 0. \end{cases} \qquad (10)$$

Market Equilibrium under Fixed Access Price (3)

STAGE I: REGULATOR'S CHOICE

The benevolent regulator solves

$$\max_{a} W^* = \left(l_0^* + l_1^*\right) U - c \left(\frac{\left(l_0^*\right)^2}{2} + \frac{\left(l_1^*\right)^2}{2} \right)$$

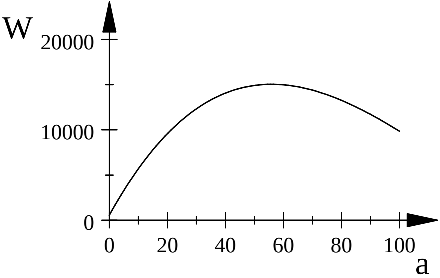


Figure 2: Welfare function for $v/100 = t = \tau = c = 1$. Solution is $a^* = 55.921$.

The First-Best Solution VS Market Equilibrium under Fixed Access Price

- In the first-best the regulator solves

$$\max_{x_0,z_0,x_1,z_1,I_0,I_1} W \equiv (I_0 + I_1)\,U - c\left(\frac{I_0^2}{2} + \frac{I_1^2}{2}\right) \quad (11)$$

$$\text{subject to } x_0 + x_1 = 1.$$

- Numerical example for $v/100 = t = \tau = c = 1$:

$$I_i^* = 80.79 < 149.75 = I_i^{opt}, \quad (12)$$

$$p_i^* = 57.06 > 0 = p_i^{opt}, \quad (13)$$

$$q_i^* = 0.715 < 1 = q_i^{opt}, \quad (14)$$

$$U^* = 133.47 < 149.75 = U^{opt}, \quad (15)$$

$$W^* = 15039 < 22425 = W^{opt}. \quad (16)$$

Market Equilibrium under the Indexation Approach (1)

- Let the access price charged by operator i, per j's subscriber using i's infrastructure, be defined by

$$a_i \equiv xI_i - yI_j,$$

where $(x, y) \in \mathbb{R}^2$ is the pair of regulatory parameters.

Market Equilibrium under the Indexation Approach (2)

STAGE III: RETAIL PRICE COMPETITION

Operator i's problem,

$$\max_{p_i} \Pi_i = I \times p_i q_i + a_i q_j I_i - a_j q_i I_j - c\frac{I_i^2}{2}. \tag{17}$$

In equilibrium,

$$\begin{cases} \frac{\partial \Pi_i(a_i,a_j)}{\partial p_i} = 0 \\ \frac{\partial \Pi_j(a_j,a_i)}{\partial p_j} = 0. \end{cases} \tag{18}$$

where

$$a_i \equiv xI_i - yI_j.$$

Market Equilibrium under the Indexation Approach (3)

STAGE II: INVESTMENTS

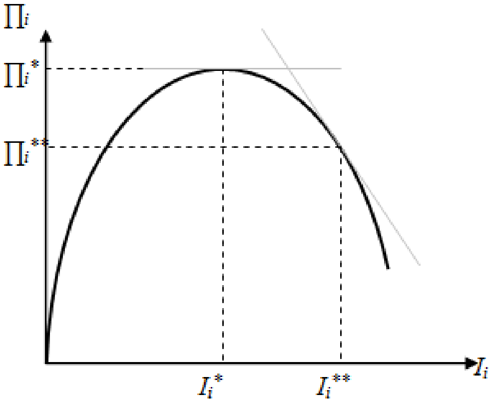
$$\max_{I_i} \Pi_i^{**} = I \times p_i^{**} q_i^{**} + a_i q_j^{**} I_i - a_j q_i^{**} I_j - c \frac{I_i^2}{2},$$

$$\frac{d\Pi_i^{**}}{dI_i} \equiv \underbrace{\frac{\partial \Pi_i^{**}}{\partial I_i}}_{\text{“direct effect”}} + \underbrace{\sum_{k=0}^{1} \frac{\partial \Pi_i^{**}}{\partial a_k} \frac{\partial a_k}{\partial I_i}}_{\text{“indexation effect”}} = 0,$$

$$\text{where} \quad \underbrace{\frac{\partial \Pi_i^{**}}{\partial a_i}}_{(+)} \underbrace{\frac{\partial a_i}{\partial I_i}}_{(+)} + \underbrace{\frac{\partial \Pi_i^{**}}{\partial a_j}}_{(-)} \underbrace{\frac{\partial a_j}{\partial I_i}}_{(-)} > 0$$

Market Equilibrium under the Indexation Approach (4)

STAGE II: INVESTMENTS



Market Equilibrium under the Indexation Approach (5)

STAGE I: REGULATOR'S CHOICE

- The regulator solves

$$\max_{x,y} W \equiv (I_0 + I_1)\, U - c\left(\frac{I_0^2}{2} + \frac{I_1^2}{2}\right) \text{ subject to}$$

$$\begin{aligned} x_i^{**}(I_0, I_1, x, y) &= x_i^{**},\ \ z_i^{**}(I_0, I_1, x, y) = z_i^{**} \text{ (Stage III)} \\ q_i^{**}(I_0, I_1, x, y) &= q_i^{**},\ \ p_i^{**}(I_0, I_1, x, y) = p_i^{**} \text{ (Stage III)} \\ d\Pi_i^{**}/dI_i &= 0,\ \ d^2\Pi_i^{**}/dI_i^2 < 0 \text{ (Stage II)} \\ \Pi_i^{**} &\geq 0 \text{ (PC)} \end{aligned}$$

Access Price Indexation VS Fixed Access Price

Proposition 2 (indexation vs fixed): *A linear access pricing rule depending on investments with* $(x, y) \in \mathbb{R}^2_+$ *can simultaneously (i) expand total investment in fibre coverage, (ii) expand the mass of subscribers in each city and (iii) enhance social welfare, as compared to a fixed access price* $a^* > 0$.

- Numerical example (cont. for $v/100 = t = \tau = c = 1$):

$$
\begin{aligned}
(x, y) &= (0.352;\ 0.0537) \Rightarrow a_i = 0.352 I_i - 0.0537 I_j \\
I_i^{SB} &= 124 > 80.79 = I_i^*, \quad a_i^{SB} = 36.94 < 55.92 = a^*, \\
p_i^{SB} &= 38.36 < 57.059 = p_i^*, \quad q_i^{SB} = 0.808 > 0.715 = q_i^*, \\
\Pi_i^{SB} &= 0 < 3325.8 = \Pi_i^*, \\
W^{SB} &= 19938 > 15039 = W^*.
\end{aligned}
$$

Access Price Indexation VS Regulatory Holidays

Proposition 4 (regulatory holidays): *A linear access pricing rule depending on investments can simultaneously decrease retail prices and increase investment and social welfare levels as compared to regulatory holiday regime (i.e., local monopolies).*

The monopolist i solves

$$\max_{p_i, I_i} \Pi_i^{mon} = I_i p_i q_i - c\frac{I_i^2}{2}. \tag{19}$$

- Numerical example (cont. for $v/100 = t = \tau = c = 1$):

$$\begin{aligned} I_i^{mon} &= 100 < 124 = I_i^{SB}, & (20)\\ p_i^{mon} &= 99.5 > 38.356 = p_i^{SB}, & (21)\\ Q^{mon} &= 1.005 < 1.6164 = Q^{SB}, & (22)\\ W^{mon} &= 10050 < 19938 = W^{SB}. & (23) \end{aligned}$$

Takeaway: an idea for regulation

- The contribution of this paper lies in the new access price formulation.
- Under the indexation approach, investors are rewarded with a competitive advantage when competing in prices in the downstream market. This pushes operators to compete in investment (fibre coverage), what does not happen under the fixed access price approach.
- Don't give holidays to operators, give them incentives to compete!

Time for questions and suggestions. Thank you!

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