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Universal Service Obligations: The Role of Subsidization Schemes and the Consequences of Accounting Separation

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Abstract

This paper (*i*) highlights the role that unit subsidies can play in the compensation scheme of a Universal Service Obligation (USO), and (*ii*) shows that welfare may be reduced when regulation requires accounting separation of network activities for vertically integrated USO providers. This suggests that accounting separation should be avoided when a USO is implemented.

JEL Classification: L43, L51, L52

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1 Introduction

In recent years, many countries have implemented regulatory reforms of network industries, such as telecommunications, electricity and postal services. The general orientation of these reforms is to move away from franchised monopolies toward more open markets by removing some or all existing barriers of entry. With free entry and exit in markets, however, unprofitable markets are bound to loose service. As a result, governments often include in the regulatory reforms programs ensuring that all consumers keep access to the public utility services. A common way of doing this is to prescibe a Universal Service Obligation (USO) to one firm and to compensate financially this "USO provider".

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The USO mandate can impose either one or both of the following constraints: the ubiquity constraint, which states that all consumers should be connected to the network, and the uniform price constraint, which states that the same tariff should be proposed to all consumers. As is often the case in practice, we assume in this paper that both constraints are imposed and that the USO provider obtains a franchised monopoly on formerly unprofitable markets. These markets are consequently referred to as *reserved*.

The economics literature has focused on two aspects of the USOs: (*i*) the way that the uniform price constraint creates strategic links between reserved and competitive markets (Hoernig and Valletti [5]; Valletti et al. [8]), and (*ii*) the efficiency properties of methods to allocate USO to a firm as well as methods to fund the associated compensation (Anton et al. [1]; Chone et al. [2] and [3]; Illie and Losada [6]; Mirabel and Poudou [7]). The main results are that the price constraint makes the USO provider less aggressive on competitive markets and that the exact magnitude of efficiency loss associated to this behavior depends on the funding mechanism used. This is explained by the fact that the USO provider, when choosing its uniform price, must trade off monopoly power on the reserved market with competitiveness on other markets and that the exact terms of this trade-off depends on the funding mechanism.

In contrast to the focus on the funding mechanism, no paper has fully analyzed the compensation scheme used to transfer the funds to the USO provider: the compensation scheme generally considered is a simple lump-sum subsidy. This is surprising as compensation payments have in principle the same distortive (or incentive) powers than the tax instruments used to fund them.

In this paper, we show that, if the USO provider is vertically integrated to the network, a mix of unit and lump-sum subsidies can be used as instruments to counter the inefficiencies that the uniform price constraint creates. The reason is that the unit subsidy incites the USO provider to reduce price, mitigating the market power that its reserved market provides. However, if the reserved market is small compared to aggregate demand, unit subsidy could well make the USO provider too aggressive on the competitive market. The regulator thus needs both unit and lump-sum subsidy instruments to raise the exact fund needed, while fine-tuning the USO provider reaction. We also show that the power of a mix of subsidies to decouple price reduction incentives from pure compensation payment is reduced when accounting separation of network activities is imposed on the vertically integrated firm.

To make these points, we use a very simple model. As USOs can be considered as a set of constraints on the USO provider's pricing policy, we adopt the standard model used in previous studies by considering a price game where the USO provider is the leader.[1] However, contrary to Chone et al. [2], [3] and Mirabel and Poudou [7], we do not assume that firms are able to practice perfect price competition, as this unrealistic assumption forecloses any role to subsidy incentives by construction. We rather follow Valletti et al. [8] in assuming that firms use linear pricing. Although real practice in network industries lies between perfect price discrimination and linear pricing, the assumption of linear pricing allows to highlight the fundamental role of a mix of subsidies in a simple framework. In the same spirit, in order to abstract from the impact of different funding mechanisms, which were fully analyzed in the literature, we assume that there is no possibility of bypassing the network. This makes unit taxes and network access surcharges as equivalent instruments (Cremer et al. [4]) and allows us to dispense with access price regulation.[2]

The next section presents the basic model for the case where the vertically integrated USO provider does not have to keep separate accounts of network and production/distribution activities. Section 3 presents results for this basic model while Section 4 explains how results vary when we impose accounting separation. Finally, the conclusion stresses the fundamental factors that underlie our results and that should remain in a more realistic environment. It also presents the policy implications of the paper.

2 Model

A network industry supplies a homogeneous good that is not storable. The network covers two geographical areas characterized by their costs: a low-cost market, denoted L, has a fixed cost normalized to zero, while a high-cost market, denoted H, has a fixed cost $F > 0$. Proportions of consumers in markets L and H are α_L and α_H, respectively, with $\alpha_L + \alpha_H = 1$. For simplicity, we assume that the marginal cost of producing the good and using the network is zero.

Consumers have identical preferences and their demand function is $q(p)$, where p is the consumer price. This demand function is twice differentiable and is such that marginal revenue is always decreasing with quantity. Demand of market $\mu \in \{L, H\}$ is $\alpha_\mu q(\cdot)$.

Market H fixed cost is so high compared to willingness to pay that it is not profitable to serve this market without some form of subsidy:

$$p\alpha_H q(p) - F < 0, \quad \forall p > 0 \tag{1}$$

[1] An exception is Illie et al. [6], who assume Cournot competition in the second stage of a game where USO is auctionned in the first stage.

[2] Furthermore, our model will be constructed so that lump-sum and unit taxes are also equivalent in terms of welfare.

However, a single supplier can make a non-negative profit by serving both markets at a uniform price:

$$\bar{p}q\left(\bar{p}\right) - F \geq 0 \tag{2}$$

where $\bar{p}$ is the "monopoly price". Denoting the price elasticity of demand by $\eta(p) = -\frac{q'(p)p}{q(p)}$, $\bar{p}$ is such that $\eta(\bar{p}) = 1$.

We assume that there are two distributors, I and E, that compete on market L. Moreover, distributor I is vertically integrated to the network and is mandated to fulfill the USO on market H. For convenience, firm I is called the incumbent and firm E, the (potential) entrant. In the following, we develop the basic model for the case where regulation does not require accounting separation of production/distribution and network activities. Section 4 discusses how the model and its results are modified when such accounting separation is required.

The USO is modeled as a set of two constraints imposed on firm I: uniform pricing and ubiquity. The first constraint means that firm I must propose its service to both markets at the same price; the second, that it cannot deny service at that price to any consumer. In return, firm I receives a lump-sum subsidy S as well as a unit subsidy s on market H output. The couple (s, S) is called the *subsidy mix*.

Subsidies are funded by a lump-sum tax T on market L.[3] We constrain the USO to be "self-financed" by the industry in the sense that total subsidy payments must not exceed total tax receipts from market L:[4]

$$B \equiv T - S - s\alpha_H q(p_H) \geq 0 \tag{3}$$

Under this universal service scheme, market L profits are:

$$\pi_L \equiv p_L \alpha_L q(p_L) - T \tag{4}$$

These profits are obtained by either firm I or E depending on which firm posts the lowest price. Market H profits are necessarily obtained by firm I and are given by:

$$\pi_H \equiv (p_H + s)\alpha_H q(p_H) + S - F \tag{5}$$

We assume that the government wishes (i) that the incumbent be fully compensated for market H service and (ii) that competition on market L be effective, in the sense that

[3] The lump-sum tax is used to simplify presentation. Results are robust to the introduction of a unit tax t on market L used in conjunction to, or instead of, the lump-sum tax. When both types of taxes are used simultaneously, we obtain multiple solutions on taxes with the total amount of taxes raised being the same as the one derived here. All other variables have the same equilibrium values. Note also that, with no possibility of network bypass, a unit tax could be interpreted as an access surcharge.

[4] For ease of presentation, we omit arguments of functions defined below whenever this does not create confusion.

entry on market L is not blockaded because of the USO. Taxes and subsidies must then be set so that:

$$\pi_\mu \geq 0, \ \mu \in \{L, H\} \tag{6}$$

We consider a three-stage game. In the first stage, the government chooses universal service parameters (s, S, T) in order to maximize welfare. In the second stage, the incumbent chooses the price of output, acting as a leader vis-à-vis the entrant.[5] In the third stage, the entrant sets its price. The equilibrium concept used is sub-game perfection.

3 Equilibrium and the Role of the Subsidy Mix

This section brings out the capacity of the subsidy mix to insure the feasibility of USO implementation and to reduce the market power of the USO provider. To show these facts, we proceed to the determination of the sub-game perfect equilibrium by doing backward induction.

At the third stage, the entrant chooses its price p_E for its service on market L, knowing that the incumbent posts price p_I on this market. Since goods from both firms are homogeneous, the firm that announces the lowest price serves the market. We assume that the entrant wins if it exactly matches the incumbent's price.[6] Then, the entrant's payoff function is:

$$\Pi_E = \begin{cases} p_E \alpha_L q(p_E) - T & \text{if } \ p_E \leq p_I \\ 0 & \text{if } \ p_E > p_I \end{cases} \tag{7}$$

The entrant chooses p_E in order to maximize Π_E. Its reaction function, R^E, is then given by:

$$R^E(p_I, T) = \begin{cases} \bar{p} & \text{if } \ p_I \geq \bar{p} \text{ and } T \leq \bar{p}\alpha_L q(\bar{p}) \\ p_I & \text{if } \ p_I < \bar{p} \text{ and } T \leq p_I \alpha_L q(p_I) \\ p_E \in (p_I, \infty) & \text{if } \ T > p_I \alpha_L q(p_I) \end{cases} \tag{8}$$

This reaction function is interpreted as follows. In the first two cases, entry is profitable at the incumbent's price. In the upper case, the incumbent's price is greater or equal

[5] This is a usual assumption in the literature. Chone et al.([2], p. 252) mention that it "can be justified by the fact that the incumbent served all consumers before liberalisation. This provides him an historical advantage."

[6] This assumption is made to avoid the "open set problem" of the entrant trying to price epsilon below the incumbent. If we rather consider that, under a price tie, the market is served by the incumbent or is shared between firms, the same equilibrium results are obtained for consumption, prices and welfare, but at the cost of a much more complicated model.

to the monopoly price, so that the entrant acts as if it were a monopoly. In the middle case, the incumbent's price is below monopoly price but allows a profit to the entrant, so that the entrant matches the incumbent's price. Finally, in the lower case, entry cannot be profitable given the incumbent's price and the level of tax, so that the entrant prices itself out of the market.

In the second stage, the incumbent's payoff is:

$$\Pi_I = \begin{cases} (p_I + s)\alpha_H q(p_I) + S - F & \text{if} \quad p_I \geq R^E(p_I, T) \\ (p_I + s)\alpha_H q(p_I) + p_I \alpha_L q(p_I) - F + S - T & \text{if} \quad p_I < R^E(p_I, T) \end{cases} \tag{9}$$

The incumbent maximizes Π_I with respect to p_I. To derive its reaction function, denoted R^I, it is useful to introduce the function $p^*(x) \equiv \arg\max(p-x)q(p)$, which is the monopoly price with a marginal cost equal to x.[7] Substituting (8) into (9) then leads to:[8]

$$R^I(s,T) = \begin{cases} p^b(s) & \text{if } T > p^b(s)\alpha_L q(p^b(s)) \\ p^f(s) & \text{if } T \leq p^b(s)\alpha_L q(p^b(s)) \end{cases} \tag{10}$$

where $p^b(s) \equiv \max\{p^*(-\alpha_H s), 0\} \leq \bar{p}$ and $p^f(s) \equiv \max\{p^*(-s), 0\}$. Price $p^b(s)$ is the "blockaded entry" price, i.e. the monopoly price that the incumbent can charge without considering the threat of entry because the USO scheme parameters make the entrant unprofitable even at this price. It is based on a marginal cost equal to $-\alpha_H s$, as this is the effective marginal cost that the incumbent faces when it is a monopoly on both markets. Whenever entry is not blockaded, i.e. whenever $T \leq p^b(s)\alpha_L q(p^b(s))$, the incumbent would have to incur a loss on market L in order to avoid entry. Entry then takes place and price p^f is the "free-entry" price. It is based on a marginal cost equal to $-s$, as this is the effective marginal cost that the incumbent faces when it is a monopoly on market H only.[9]

Lemma 1 $p^b(s) \geq p^f(s)$, $\forall s \geq 0$

Proof. This results directly from the facts that p^* is increasing and that $-\alpha_H s \geq -s$. ■

In the first stage, the government chooses USO parameters in order to maximize welfare under constraints (3) and (6). The following observation helps to simplify the problem.

[7] $p^*(x)$ is thus such that $q(p^*) + (p^* - x)\, q'(p^*) = 0$. Second order condition $2q' + (p-x)q'' < 0$ insures that $\frac{dp^*}{dx} > 0, \forall x$. Note that $\bar{p} = p^*(0)$.

[8] Note that we consider that the incumbent has an obligation to serve in the second stage even though its profit is negative. Regulation in the first stage will however be done under constraints $\pi_L \geq 0$ and $\pi_H \geq 0$, which insures that $\Pi_I \geq 0$ at equilibrium.

[9] When the incumbent serves only market H, any increase of 1 unit of its output is sold exclusively on market H : this brings an additionnal subsidy of amount s.

Lemma 2 *Let* $\tilde{p}_H \equiv R^I(s,T)$ *and* $\tilde{p}_L \equiv \min\left\{R^I(s,T), R^E(R^I(s,T),T)\right\}$ *be equilibrium prices from second and third stages. Then, at game equilibrium, firm E is the market L supplier and prices are* $\tilde{p}_L = \tilde{p}_H = p^*(-s)$.

Proof. Assume that $\tilde{p}_L = \tilde{p}_H = p^b(s)$. It must then be the case that $T > p^b(s)\alpha_L q(p^b(s))$, in contradiction with constraint $\pi_L \geq 0$. We must then have $\tilde{p}_L = \tilde{p}_H = p^f(s)$. Since constraints (3) and (6) imply that the optimal prices are positive, we get $\tilde{p}_L = \tilde{p}_H = p^*(-s)$. ■

Let $W(p, s, S, T) = \int_p q(x)dx + pq(p) + s\alpha_H q(p) + S - T - F$ be the welfare function under USO, given that prices are the same on both markets. The government's problem can then be written as:

$$\max_{s,S,T} \quad W(p^*(-s), s, S, T) \tag{11}$$

s.t.

$$T - S - s\alpha_H q(p^*(-s)) \geq 0 \tag{12}$$

$$p^*(-s)\alpha_L q(p^*(-s)) - T \geq 0 \tag{13}$$

$$(p^*(-s) + s)\alpha_H q(p^*(-s)) + S - F \geq 0 \tag{14}$$

This problem can be solved through economic reasoning with the help of four preliminary observations.[10] First, constraints (12) and (13) must be binding at optimum: if one of them were slack, unit subsidy s could be increased and this would allow a price decrease, and thus a welfare increase, without violating constraint (14). Second, the unit subsidy instrument has the advantage over the lump-sum subsidy of inciting the incumbent to decrease price, i.e. to bring price closer to the first-best price, $p = 0$. Third, under the constraints, the lowest price feasible is $\hat{p} \equiv \inf\left\{p \,\middle|\, p = \frac{F}{q(p)}\right\}$, which corresponds to average-cost pricing. Finally, at the second stage, the incumbent chooses p_I, taking s as given, in order to maximize profit. Its marginal revenue is then given by:

$$MR(q(p_I), s) \equiv (p_I + s)\alpha_H q'(p_I) + \alpha_H q(p_I)$$

Acknowledging these facts, let us assume initially that government sets $S = 0$, while keeping in mind that it must be checked later whether this is feasible or not. With binding constraints (12) and (13), this implies that $p_I = p^*(-s) = \frac{\alpha_H}{\alpha_L}s$. Marginal revenue at second stage then becomes:

$$MR\left(q(p^*), \frac{\alpha_L}{\alpha_H}p^*\right) = p^*q'(p^*) + \alpha_H q(p^*) = q(p^*)(\alpha_H - \eta(p^*))$$

The middle term reflects the fact that, because of the unit subsidy that turns over market L profit to the incumbent, a 1$ price decrease allows the incumbent to grab additional

[10] The Appendix presents a formal derivation of the solution.

revenue from the increase in quantity demanded in both markets but to incur losses on inframarginal units exclusively on market H. The incumbent thus chooses the price p^* such that its marginal revenue is zero, which, from the RHS, implies that p^* is such that $\eta(p^*) = \alpha_H$. If $p^* \geq \hat{p}$, this is the best that government can obtain given the monopoly power that the incumbent acquires with USO. If $p^* < \hat{p}$, the solution is infeasible as it incites the incumbent to price below average cost. Government must then decrease unit subsidy s until $p^*(-s) = \hat{p}$. The lump-sum subsidy must concomitantly be increased in order to meet constraint (14). We thus get the following results.

Proposition 1 *Let $p_\eta = \{p \,|\eta(p) = \alpha_H\}$ and let equilibrium values be marked by an asterisk. Then:*

1. $B^* = 0$, $\pi^*_L = 0$
2. *If* $\alpha_H > \eta(\hat{p})$, $p^* = p_\eta > \hat{p}$, $s^* = \frac{\alpha_L}{\alpha_H} p_\eta$, $S^* = 0$ *and* $\pi^*_H > 0$
3. *If* $\alpha_H \leq \eta(\hat{p})$, $p^* = \hat{p}$, s^* *is such that* $\frac{\hat{p}+s^*}{\hat{p}} = \frac{1}{\eta(\hat{p})}$, $S^* = \alpha_L F - s\alpha_H q$, *and* $\pi^*_H = 0$

Proof. See Appendix. ■

Note that if $\alpha_H > \eta(\hat{p})$, the price turns out to be independent of the fixed cost. This is because the USO makes the incumbent acts as a monopolist, which, as usual, ignores fixed cost when making its choice. With a sufficiently high α_H,[11] market H is large enough to support such a monopoly strategy. However, if $\alpha_H \leq \eta(\hat{p})$, market H is too thin for having $S = 0$, so that it is the competitive market that dominates and the second-best solution (average cost pricing) is reached.

This model highlights the fact that the subsidy instruments used matter. If government used only a unit subsidy, it is clear from the discussion above that USO could not be implemented for low α_H (precisely for $\alpha_H < \eta(\hat{p})$). Now, using exclusively a lump-sum instrument would result in monopoly pricing since the incumbent knows that it gets the whole market profit without having incentives to reduce price in the second stage:

Corollary *If the government provides a compensation to the incumbent only through a lump-sum subsidy, then the equilibrium price is the monopoly price $\bar{p}$.*

Proof. Impose the additional constraint $s = 0$ in problem (11)-(14). Then in second stage, the incumbent chooses $p^*(0) = \bar{p}$. In order to complete the proof, we must show that there exists at least one feasible solution (S, T) in the first stage when price $\bar{p}$ is substituted into the constraints. This is the case for $S = T = \bar{p}\alpha_L q(\bar{p})$. ■

In brief, the subsidy mix (i) insures that USO can be implemented, and (ii) avoids full exercise of monopoly power by the USO provider.

[11] When $\alpha_H > \eta(\hat{p})$, the incumbent's marginal revenue is positive at $\hat{p}$.

4 Consequences of Accounting Separation

When the USO provider is vertically integrated as it is the case in this model, the regulator often requires that it keeps separate accounts of network and production/distribution activities.[12] We now discuss the impact of accounting separation on the subsidy mix and on welfare.

Assume that the incumbent still owns the network but that regulation requires accounting separation. As USO must compensate the "network division" of the incumbent, irrespective of profits of the production/distribution division, this is equivalent to require that the government pays subsidies S and s such that

$$A \equiv S + s\alpha_H q(p) - F \geq 0 \tag{15}$$

instead of meeting constraint (14). Since it is vertically integrated, we assume that the incumbent acknowledges the impact of its price decision on network revenue despite accounting separation. In other words, the incumbent rationally takes into account overall profit π_H even though these profits are now split in different accounts. Then, firms' behavior in the third and second stages are not modified by this separation of accounts. The first stage problem stays the same, except that constraint (15) replaces constraint (14). One can state the following result where superscript a marks equilibrium values under accounting separation and where $\breve{p} \equiv \inf \left\{ p \,\middle|\, p = \frac{F}{\alpha_L q(p)} \right\}$

Proposition 2 *With accounting separation,*

1. *if $\alpha_H > \eta(\breve{p})$, $p^a = p^* > \breve{p}$, $s^a = s^*$, $S^a = 0$ and $A > 0$;*
2. *if $\alpha_H \leq \eta(\breve{p})$, $p^* = \breve{p}$, s^a is such that $\frac{\breve{p}+s^a}{\breve{p}} = \frac{1}{\eta(\breve{p})}$ with $s^a > s^*$, $S^a = F - s^a \alpha_H q(\breve{p})$, and $A = 0$;*
3. *welfare is less than or equal to welfare under integrated accounts and price is greater than or equal to price under integrated accounts.*

In brief, accounting separation is weakly dominated in terms of welfare by integrated accounts. This is because constraint (15) cannot be less restrictive than constraint (14): by forcing itself to reimburse network cost in full, the regulator does not take into account the fact that the monopoly rent related to market H is itself a compensation to the USO provider. When market H is so large that it allows enough monopoly power to

[12] On European energy markets, accounting separation has been imposed for two main reasons. First, it would promote transparent and non discriminatory access to network. Second, it would eliminate cross-subsidization between regulated and competitive activities.

charge a price higher than market-L average cost, equilibrium is the same than under integrated accounts. However, whenever monopoly power induced by market H does not allow to cover network cost, compensation of this cost under separated accounts is made strictly from market L profit, so that unit subsidies cannot bring price below market L average cost. In contrast, with integrated accounts, both market profits contribute to the compensation, so that price can be brought as low as overall market average cost. In other words, integrated accounts allow for a more flexible way to fund the USO.

5 Conclusion

Although the implementation of USO is generally done in environments much more complex than the one considered here, our model stresses the fundamental tendency of USOs to create market power and to a concomitant output incentive role for the compensation scheme, which is to be added to its transfer role. The compensation scheme becomes less efficient with accounting separation than without it because the government is prevented from seizing the monopoly rent related to the supply of the reserved market.

In practice, several factors, such as product differentiation and network bypassing, will tend to modify the extent of USO-induced market power. However, as long as the industry oligopolistic structure and the USO leave some room for market power, there should be a role for the compensation scheme to counter it. Although this was not treated here, the same would be true for the distortions produced by the USO funding methods (taxes). These facts have been neglected in the literature.

An extension to our analysis will be to compare a vertically integrated USO provider to a structurally separated industry where the network is owned and operated independently from distribution and production activities. Structural separation is of course a natural policy option when markets are liberalized. By removing residual rights that the USO provider has on subsidized inputs (network), structural separation could eliminate the market power associated to USO and thus, eliminate the incentive role of the compensation scheme. But structural separation cannot be analyzed directly with our model and is thus beyond the scope of this paper. Our results nevertheless maintain their relevance because, for institutional and/or political reasons, a number of countries do not perform network divestiture from the incumbent operator at the moment of liberalization. At best, accounting separation is then presented as an improvement over full vertical integration for a temporary period before structural separation or, at worst, as a permanent reform equivalent to structural separation. Our model suggests that the middle way of accounting separation, whether temporary or permanent, should be avoided.

Appendix: Proof of Propositions 1 and 2

As problems considered in Propositions 1 and 2 differ only in one of their constraints, we provide a generic proof for both propositions. Proof of Proposition 1 is read by setting $\lambda_A = 0$ below, while proof of Proposition 2 is read by setting $\lambda_H = 0$. Let

$$\begin{aligned}\mathcal{L} &= W(p^*(-s), s, S, T) + \lambda_B[T - S - s\alpha_H q(p^*)] + \lambda_L[p^*\alpha_L q(p^*) - T] \\ &\quad + \lambda_H[(p^* + s)\alpha_H q(p^*) + S - F] + \lambda_A[S + s\alpha_H q(p^*) - F]\end{aligned}$$

be the Lagrangian function associated to (generic) problem (11)-(14), (15). The FOC are then:[13]

$$\begin{aligned}&\mathcal{L}_s = -\dot{p}^*p^*q' + (1 - \lambda_B)[\alpha_H q - s\alpha_H q'\dot{p}^*] - \lambda_L\alpha_L[\dot{p}^*q + p^*q'\dot{p}^*] \\ &\qquad -\lambda_H\alpha_H[\dot{p}^*q - q + (p^* + s)q'\dot{p}^*] - \lambda_A\alpha_H[-q + sq'\dot{p}^*] \leq 0 \qquad \mathcal{L}_s \cdot s = 0 \qquad s \geq 0\end{aligned}$$

$$\mathcal{L}_S = 1 - \lambda_B + \lambda_H + \lambda_A \leq 0 \qquad \mathcal{L}_S \cdot S = 0 \qquad S \geq 0$$

$$\mathcal{L}_T = -1 + \lambda_B - \lambda_L \leq 0 \qquad \mathcal{L}_T \cdot T = 0 \qquad T \geq 0$$

$$\mathcal{L}_{\lambda_i} \geq 0 \qquad \mathcal{L}_{\lambda_i} \cdot \lambda_i = 0 \qquad \lambda_i \geq 0, \qquad i \in \{B, H, L, A\}$$

For the proof of Proposition 1, let us consider that (15) is always ignored, so that $\lambda_A = 0$. Simple observation of these FOC leads to the following properties of the optimal solution.

Lemma 3 *At the optimal solution,* $T > 0$, $\lambda_L = \lambda_B - 1 > 0$ *and* $\pi_L = 0$.

Proof. (i) Assume that $T = 0$. Then constraint (12) implies that $s = S = 0$. Since $p^*\alpha_H q(p^*) - F$ is necessarily negative by assumption (1), constraint (14) is then violated. We thus have $T > 0$. From FOC on $\mathcal{L}_T$, this in turn implies that $\lambda_L = \lambda_B - 1$. (ii) Assume now that $\lambda_L = \lambda_B - 1 = 0$. Since, from second stage equilibrium, $q + (p^* + s)q' = 0$, we get $\mathcal{L}_s = -\dot{p}^*p^*q' + \lambda_H\alpha_H q > 0$ in contradiction with condition $\mathcal{L}_s \leq 0$. We thus have that $\lambda_L > 0$. From FOC on $\mathcal{L}_{\lambda_L}$, this in turn implies that $\pi_L = p^*\alpha_L q(p^*) - T = 0$. ■

Two cases must then be considered.

Case 1. $\pi_H > 0$ $(\Rightarrow \lambda_H = 0)$
Then, from Lemma , $\mathcal{L}_S = 1 - \lambda_B < 0$, which implies that $S = 0$. From (12) and (13), we have that

$$s = \frac{\alpha_L}{\alpha_H}p^*$$

[13] Hereafter, $\dot{p}(x) \equiv \frac{dp(x)}{dx} > 0$. For ease of presentation, we omit arguments of functions.

which implies from second stage equilibrium that $\eta(p^*) = \alpha_H$ or, equivalently, that $p^* = p_\eta$. This solution is feasible only if $\pi_H > 0$, that is if $p^* q(p^*) > F$. This implies that $p_\eta > \hat{p}$, i.e. $\alpha_H > \eta(\hat{p})$.

Case 2. $\pi_H = 0$ ($\Rightarrow \lambda_H \geq 0$)
Then we have from the three constraints that p^* must be equal to $\hat{p}$. To get this price in the second stage, s^* must be such that $q(\hat{p}) + (\hat{p} + s^*)\, q'(\hat{p}) = 0$ or

$$\frac{\hat{p} + s^*}{\hat{p}} = \frac{1}{\eta(\hat{p})} \tag{A.1}$$

i.e. the subsidy is such that average cost pricing is "felt" as monopoly pricing for the incumbent. We then have $S^* = F - (\hat{p} + s^*)\alpha_H q(\hat{p}) = \alpha_L F - s^* \alpha_H q(\hat{p})$. Moreover $S^* \geq 0$ if and only if $s^* \leq \frac{\alpha_L}{\alpha_H}\hat{p}$. Using (A.1), this leads to the condition $\alpha_H \leq \eta(\hat{p})$. Using FOC's, one can easily show that $\lambda_H = \frac{\eta(\hat{p})}{1-\eta(\hat{p})} > 0$.

For the proof of Proposition 2, let us consider that (12) is ignored, so that $\lambda_H = 0$. It can easily be seen that Lemma 3 still holds. Two cases must then be considered. The case where the accounting constraint (15) is slack ($A > 0$) implies again that $S^a = 0$ and $\eta(p^*(-s^a)) = \alpha_H$ so $s^a = s^*$, i.e. $p^a = p^*(-s^a) = p_\eta$ but now with the condition that $p_\eta > \breve{p} = \inf\left\{p | p = \frac{F}{\alpha_L q(p)}\right\} > \hat{p}$. Hence this solution is optimal only if $\alpha_H > \eta(\breve{p}) > \eta(\hat{p})$. When the accounting constraint (15) is binding ($A = 0$) then $p^a = \breve{p}$, s^a is such that $\frac{\breve{p}+s^a}{\breve{p}} = \frac{1}{\eta(\breve{p})}$ and $S^a = F - s^a \alpha_H q(\breve{p})$, which is optimal if and only if $\alpha_H \leq \eta(\breve{p})$. Since $\frac{dp^*(-s)}{ds} < 0$ and $\breve{p} > \hat{p}$, it follows that $s^a < s^*$.
Finally, equilibrium social welfare levels are:

$$W^* = \begin{cases} \int_{\hat{p}} q(x)dx & \text{if } \alpha_H \leq \eta(\hat{p}) \\ \int_{p_\eta} q(x)dx + p_\eta q(p_\eta) - F & \alpha_H > \eta(\hat{p}) \end{cases} \text{ and } W^a = \begin{cases} \int_{\breve{p}} q(x)dx + \frac{\alpha_H}{\alpha_L} F & \text{if } \alpha_H \leq \eta(\breve{p}) \\ W^* & \alpha_H > \eta(\breve{p}) \end{cases}$$

For $\alpha_H \leq \eta(\hat{p})$, W^* is invariant whereas W^a is a stricly decreasing function of α_H :

$$\frac{dW^a}{d\alpha_H} = -q(\breve{p})\frac{d\breve{p}}{d\alpha_H} + \frac{F}{(1-\alpha_H)^2} = -\frac{\eta(\breve{p})}{1-\eta(\breve{p})}\frac{F}{(1-\alpha_H)^2} < 0$$

which proves that $W^a \leq W^*$ for all $\alpha_H \in [0, 1]$.

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