Universal Service Obligations and Competition with Asymmetric Information

Jean-Christophe Poudou*, Michel Roland† and Lionel Thomas‡

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Abstract

We take into account adverse selection in the implementation of universal service obligations (USOs) for a network industry with no bypass. The USO is characterized by a coverage constraint imposed on the network's owner. We show that a sufficiently high shadow cost of public funds can lead to a lower coverage with the USO than without it when firms turn out to be relatively inefficient. If the regulator is able to determine the industry structure by issuing licences to operate, the optimal number of firms reflects a trade-off between allocative efficiency and the industry capacity to finance internally the USO.

Keywords: universal service obligations, coverage constraints, asymmetric information, regulation

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*Corresponding author: LASER Université de Montpellier I, Montpellier, France. jpoudou@univ-montp1.fr

†GREEN, Département d'économique, Université Laval, Québec, Canada.

‡CRESE, Université de Franche-Comté, Besançon, France.

1 Introduction

In recent years, regulatory reforms of public utility sectors, such as telecommunications, electricity and postal services, have been implemented worldwide. In general, these reforms imply a move from franchised monopolies towards more open markets. With free entry and exit in markets, however, unprofitable markets are at risk of loosing service. As a result, the reforms often include a Universal Service Obligation (USO), i.e. an obligation to provide all consumers access to the public utility services. In most cases, the implementation of the USO is very simple: one firm has to serve some non-profitable segments of the market but receives a financial compensation for this obligation.[1]

The USO and its funding, however, interfere directly with the competitive market that regulatory reforms are meant to promote. The literature on USOs has thus focused on the distortions they entail. Valletti *et al.* [25], Anton *et al.* [1], Bourguignon and Ferrando [2] and Hoernig [12] have singled out the strategic linkages that USOs create among markets when pricing and/or coverage constraints are imposed. Distortions then come from the fact that, because of such linkages, the universal service provider can become more or less aggressive on a specific market than it would be without the USO. Mirabel and Poudou [19] and Illie and Losada [13] analyze the distortions created by the tax instruments imposed on taxpayers or industry competitors to fund compensations. As distortions are dependent on the specificities of the USO, some authors study in more details different aspects of implementations: the allocation method of the USO (auctions in Anton et al. [1], restricted entry and "pay-or-play"[2] in Chone et al. [5], [6] and Mirabel and Poudou [19]) or industry-specific implementations (postal service in Crew and Kleindorfer [8] and Fabra et al. [9], broadband in Foros and Kind [10]).

Although asymmetry of information is as pervasive in universal service implementations as in any form of regulation, none of these papers has considered its impact on the efficiency of universal service. Because the cost of providing services is better known by the universal service provider than the regulator, an adverse selection problem is likely to arise when designing the USO. In this paper, we derive optimal incentive contracts between a universal service provider and the regulator. We consider a network industry where the network is an essential input, in the sense that it cannot be bypassed by suppliers.[3] The network is owned by the incumbent and covers a continuum of markets that

[1] A USO can also bring benefits to its provider. For instance, in UK, the telecommunications regulator has identified "brand enhancement and corporate reputation" as one benefit of the USO (see Cremer et al. [7]). For this reason, the compensation can in principle be non-positive if benefits are greater than or equal to the costs.

[2] "Pay-or-play" allocation allows the entrant to choose between paying the taxes that fund the USO or entering unprofitable markets. This is contrasted to "restricted entry" where the USO is allocated to the incumbent in exclusivity.

[3] Electricity and natural gas are prime examples of such industries.

differ in terms of their fixed costs. The incumbent must provide access to the network to competitors. Firms, including the incumbent, compete *à la Cournot* on the final market. This is to represent a reduced form of a capacity-constrained price game, as in Kreps and Scheinkman [15], since competitors' supply is generally limited by the incumbent's network capacity.[4]

The USO is modelled as a coverage constraint imposed on the incumbent. The regulator compensates the incumbent for the USO through monetary transfers which are financed by taxpayers (public funding)[5] as well as a lump-sum tax on entrants (internal industry funding).[6] We develop fully the model for a welfare-maximizing coverage constraint when firms have no outside opportunities. We also discuss two adaptations that reflect real implementations of USOs but that do not modify basic results. First, we consider a full coverage constraint instead of the welfare-maximizing one. Full coverage is known as the "ubiquity constraint" in the USO literature and it represents what is usually meant by universal service. Second, we take the unregulated coverage profits as the outside opportunities of firms. This follows the practice of compensating firms for the profit loss due to the USO.

Our main contribution is to compare the socially optimal coverage under asymmetry of information to the unregulated coverage, where the incumbent chooses freely the extent of the network. As the incumbent does not take into account consumers' surplus when it chooses coverage, the socially optimal coverage under complete information is always greater than the unregulated one. Under asymmetry of information, however, the USO automatically raises a new cost in the form of information rents. As usual, controlling this cost entails a reduction of coverage, which is the more important the less efficient the firm is. The choice of coverage thus involves a trade-off between surplus and information rents and the terms of this trade-off is set by the shadow cost of public funds. We show that, if the shadow cost of public funds is relatively high, coverage under the USO can be lower than the unregulated coverage when the firm turns out to be relatively inefficient. In other words, the regulation aimed at extending service can have the perverse effect of reducing it.

Because of the essential input assumption, this paper can be related to the literature on the regulation of infrastructure. Caillaud and Tirole [4] analyze the funding of an

[4] For instance, entrants may have to reserve capacity on the incumbent's network prior to the downstream production stage as mentioned by Foros and Kind [10]: "The suppliers of access to Internet typically have long term contracts with suppliers of connectivity to the global backbone".

[5] Examples of USOs that are financed publicly are the rural post office network in the UK (Oxera [21]) and broadband services to isolated communities in Canada (ITU [14]).

[6] This lump-sum tax can be considered as a fixed access charge, as used in the Spanish telecommunications sector for interconnection circuits (Calzada [3]). A companion paper (Poudou et al. [22]) extends this model to take into account a unit access charge, as this is a common instrument to finance universal service. Results on the impact of asymmetry of information are not modified by such an extension.

infrastructure project when an incumbent operator has private information about market profitability. An open access policy raises welfare, but can make the project non-viable since funding must be provided by operators' capital contributions. In Gautier and Mitra [11], a vertically integrated firm owns an essential input and faces a potential entrant on the downstream market. When the regulator's objectives are to ensure financing of the essential input and to generate competition in the downstream market, the optimal regulatory mechanism generates inefficient entry: it is possible that a cost efficient entrant stays out of the market or that a cost inefficient entrant gets in. Both papers thus feature the trade-off between efficiency and financing in the context of infrastructure funding that we capture in our model of USO funding.

The following section presents the basic elements of the model, while Section 3 derives and analyzes its results. Section 4 discusses the two extensions to the model, i.e. the imposition of an ubiquity constraint rather than welfare maximizing coverage and the integration of unregulated market profit opportunities in the firms' participation constraints. Section 5 concludes.

2 Model

A network industry supplies a homogeneous good on a continuum of locations $\mu \in [0,1]$. At each location, there is a mass 1 of identical consumers that are represented by the differentiable and strictly decreasing demand function $q(p)$, where p is the price and $q(0) < \infty$. We denote by $\eta(p) \equiv -\frac{pq'(p)}{q(p)}$, the price elasticity of demand, by $S(p) \equiv \int_p^{q^{-1}(0)} q(x)dx$, $\forall p \in [0, q^{-1}(0)]$, the consumers' surplus, and by $r(p) \equiv pq(p)$, the consumers' expenditure for the good.

Reaching consumers at location μ requires the connection to an essential network. The network is owned and operated by a vertically integrated incumbent firm. Locations are ordered by increasing fixed connection costs $K(\mu,\theta) = \theta\mu$, where $\theta \in [\underline{\theta}, \bar{\theta}]$ represents an efficiency parameter that is privately known by the incumbent. Ordered locations are distributed according to density and distribution functions g and G respectively. We say that location μ is covered if the incumbent has incurred its fixed connection cost.

The industry is composed of the incumbent and n competitors, called entrants. Entrants cannot bypass the incumbent's network but have open access to it. All firms produce under the same constant variable cost, normalized to zero. Entrants and the incumbent compete *à la Cournot* at each location where the incumbent incurs the connection cost. We denote by p_n the price at the symmetric Cournot equilibrium when there exist n entrants.[7] The entrant's and incumbent's equilibrium profits at a covered location

[7] Then, p_0 represents the incumbent's monopoly price and $\lim_{n\to\infty} p_n$ is the price under perfect com-

μ are $\pi^E \equiv \frac{r(p_n)}{n+1}$ and $\pi^I(\mu, \theta) \equiv \pi^E - \theta\mu$, respectively. The following Lemma presents properties of this equilibrium.[8]

Lemma 1 *At the symmetric Cournot equilibrium of a covered location μ,*

(a) p_n is such that $\eta(p_n) = \frac{1}{n+1}$

(b) p_n is a decreasing function of n i.e.[9] $\dot{p}_n < 0$

(c) Each firm equilibrium gross revenue is $\frac{r(p_n)}{n+1}$.

By a slight abuse of language, we say that the coverage is μ whenever the firms serve all locations of the interval $[0, \mu]$. Agregate profits are then $\Pi^E(\mu) = \int_0^\mu g(z)\pi^E dz = G(\mu)\pi^E$ for an entrant, and $\Pi^I(\mu, \theta) = \Pi^E(\mu) - \theta H(\mu)$, where $H(\mu) \equiv \int_0^\mu zg(z)dz$, for the incumbent. Accordingly, $\mu^I(\theta)$ is referred to the unregulated coverage.

We define the USO as a coverage constraint $\mu \neq \mu^I$ imposed by the regulator on the incumbent.[10] This constraint forces the incumbent to get away from its profit maximizing coverage. For cases where the firm cannot make a positive profit, a compensation is given to the incumbent. This compensation is financed through a lump-sum tax t on each entrant and a transfer T from taxpayers.[11] Transfer T is raised at a unit shadow cost of public funds equal to $\lambda > 0$. The regulator sets coverage and taxes with the aim of maximizing welfare. As it does not have knowledge of parameter θ, it must then design a type contingent contract. This can be viewed as a regulatory game for which the timing is:

1. Nature chooses $\theta \in [\underline{\theta}, \bar{\theta}]$.

petition.

[8]Proofs of Lemmas and Propositions are found in Appendix. Note that statement (a) is a simple application of the standard symmetric Cournot equilibrium $\frac{p_n - C'}{p_n} = \frac{1}{(n+1)\eta}$ with a marginal cost C' equal to zero.

[9]Hereafter, a dot denotes the first partial derivative with respect to n.

[10]In practice, USOs also include the "uniform pricing" constraint, which forces the incumbent to supply its service at the same price across locations. The Cournot symmetric equilibrium satisfies *de facto* this constraint.

[11]For simplicity, we allow the transfer to be negative if the incumbent makes a positive profit, i.e. any profit is taxed away by the regulator. In Section 4, we consider the more realistic case where the regulator can take only profit that exceeds the one obtained under unregulated coverage. Note that negative transfers are sometimes encountered in cases where the incumbent is a publicly-owned enterprise. For instance, the province of Quebec (Canada) annually sets a dividend target for its publicly-owned electric utility and this dividend is integrated in the general provincial budget. Cases where no negative transfers are allowed are easily dealt with by adding the constraint $T(\theta) \geq 0$. This would imply that internal funding is "used" first, so that public funds are raised only when internal transfers are insufficient to cover the USO cost.

2. The incumbent learns its type.

3. The regulator offers a USO contract $\mathcal{C}(\theta) = \langle \mu(\theta), T(\theta), t(\theta) \rangle$.

4. The incumbent refuses or selects a contract.

5. All markets $\mu \in [0, \mu(\theta)]$ clear *à la Cournot.*

The regulator has a *a priori* distribution and density functions F and f, respectively, which display an increasing inverse hazard rate $\varphi(\theta) \equiv \frac{F(\theta)}{f(\theta)}$. We also assume that $\varphi(\theta)$ is convex in θ: as θ increases, the regulator becomes more and more concerned about the rents left below θ at the margin.[12]

Two benchmarks will serve to assess the USO.

- *Complete information*

  This is the Cournot equilibrium described in Lemma 1 when the regulator offers contract $C(\theta)$ with full knowledge of θ. The regulator's problem is to maximize welfare under the participation constraints of the firms:

$$\max_{\mu(\theta),T(\theta),t(\theta)} \quad G(\mu(\theta))\left[S(p_n) + r(p_n)\right] - \theta H(\mu(\theta)) - \lambda T(\theta)$$
$$\text{s.t. } \Pi^I(\mu(\theta),\theta) + nt(\theta) + T(\theta) \geq 0,\ \Pi^E(\mu(\theta)) - t(\theta) \geq 0$$

  The entrants' participation constraint guarantees that the n firms are active whenever the contract is accepted by the incumbent, so that the market equilibrium is given by Lemma 1. As constraints are necessarily binding at optimum, the problem can be rewritten as:

$$\max_{\mu(\theta),T(\theta),t(\theta)} G(\mu(\theta))\, S(p_n) + (1+\lambda)[G(\mu(\theta))\, r(p_n) - \theta H(\mu(\theta))]$$

  which makes clear that \$1 of industry profit is socially valued at \$$(1+\lambda)$, as such a dollar allows a saving of λ in terms of the cost of public funds. Letting $\mu^C(\theta)$ represent the welfare-maximizing coverage under complete information, we obtain from the FOC on coverage:

$$\mu^C(\theta) = \begin{cases} 1 & \text{if } \theta \leq \theta_n^\lambda \\ \frac{S(p_n)+(1+\lambda)r(p_n)}{(1+\lambda)\theta} & \text{if } \theta > \theta_n^\lambda \end{cases} \tag{1}$$

[12] Rochet and Stole [23] use this assumption in a nonlinear pricing model. For instance, it is satisfied with uniform, exponential, Pareto and normal distributions. It mainly implies that $\frac{d(\varphi(\theta)/\theta)}{d\theta} \geq 0$, i.e. the mean inverse hazard rate is also increasing. Under this assumption our solution is uniquely characterized.

where $\theta_n^\lambda \equiv \frac{S(p_n)+(1+\lambda)r(p_n)}{(1+\lambda)}$. To interpret this solution, note that the marginal social benefit of coverage is $[S(p_n) + (1+\lambda)(r(p_n) - \theta\mu)]g(\mu)$ while its marginal cost is $(1+\lambda)\theta\mu g(\mu)$. If $\theta \leq \theta_n^\lambda$, marginal benefit exceeds marginal cost at all locations so that there is full coverage. If $\theta > \theta_n^\lambda$, $\mu^C(\theta)$ is the value that equalizes marginal benefit to marginal cost.

- *Unregulated coverage*

  This is the Cournot equilibrium described in Lemma 1 when the regulator does not impose a USO, so that coverage is chosen by the profit-maximizing incumbent. Unregulated coverage with n entrants is then:

$$\mu^I(\theta) \equiv \frac{r(p_n)}{(n+1)\theta} > 0$$

  In order to ensure that the USO will become a constraint to the incumbent, we assume that it is never profitable for the incumbent to serve the costliest location $\mu = 1$, even when it is the most efficient monopoly:

$$r(p_0) < \underline{\theta}$$

  This assumption implies that, without USO, there is never full coverage.

3 Optimal Policy

We consider first the case where the number of firms is exogenous. We then allow the regulator to choose the optimal industry structure.

3.1 Coverage and Taxes

Given a contract $\mathcal{C}(\theta)$, the incumbent's utility when it announces to be of type τ is:

$$U(\theta,\tau) \equiv \Pi^I(\mu(\tau),\theta) + T(\tau) + nt(\tau) \tag{2}$$

For any entrant, the net profit is:

$$u(\tau) \equiv \Pi^E(\mu(\tau)) - t(\tau) \tag{3}$$

Contract $\mathcal{C}(\theta)$ must then satisfy the following participation and incentive compatibility constraints:

$$\forall\theta \in [\underline{\theta},\bar{\theta}] : U(\theta) = U(\theta,\theta) \geq 0 \text{ and } u(\theta) \geq 0 \tag{4}$$

$$\forall\theta,\tau \in [\underline{\theta},\bar{\theta}] : U(\theta,\theta) \geq U(\theta,\tau) \tag{5}$$

The incumbent's participation constraint now includes an information rent. The incentive constraint ensures truth-telling by the incumbent. The regulator's problem is then to maximize expected welfare $\mathcal{E}W$ under constraints (4) and (5), where:

$$\mathcal{E}W = \int_{\underline{\theta}}^{\bar{\theta}} \left[G\left(\mu(\theta)\right) S\left(p_n\right) + U\left(\theta\right) + nu(\theta) - \left(1+\lambda\right) T(\theta)\right] f(\theta) d\theta \tag{6}$$

It is shown in the Appendix that incentive compatibility for the mechanism is obtained if and only if $\mu'\left(\theta\right) \leq 0$ and $U\left(\theta\right) = \int_{\theta}^{\bar{\theta}} H\left(\mu\left(z\right)\right) dz$. The regulator's problem then becomes:

$$\max_{\mu(\theta)\leq 1, u(\theta)} \mathcal{E}W \text{ s.t. } u(\theta) \geq 0 \text{ and } \mu'\left(\theta\right) \leq 0 \tag{7}$$

where expected welfare (6) is rewritten as:

$$\mathcal{E}W = \int_{\underline{\theta}}^{\bar{\theta}} \{G\left(\mu(\theta)\right) S\left(p_n\right) - n\lambda u(\theta) + (1+\lambda)[G\left(\mu(\theta)\right) r(p_n) - (\theta + \alpha\varphi\left(\theta\right))H(\mu(\theta))]\} f(\theta) d\theta \tag{8}$$

with $\alpha \equiv \frac{\lambda}{1+\lambda}$.

We solve the relaxed problem where the monotonicity constraint $\mu'\left(\theta\right) \leq 0$ is initially ignored and we will check afterwards whether this constraint is met or not. Pointwise optimization for the problem (7) then leads to:

$$u^*(\theta) = 0 \text{ and } \mu^*(\theta) = \begin{cases} 1 & \text{if } \theta \leq \hat{\theta}_n^{\lambda} \\ \frac{S(p_n)+(1+\lambda)r(p_n)}{(1+\lambda)\theta+\lambda\varphi(\theta)} & \text{if } \theta > \hat{\theta}_n^{\lambda} \end{cases} \tag{9}$$

where $\hat{\theta}_n^{\lambda} \equiv \{\theta\left|(1+\lambda)\theta + \lambda\varphi\left(\theta\right) = S(p_n) + (1+\lambda)r(p_n)\right.\}$.[13] Comparison with the complete information coverage (1) shows that μ^* balances the same marginal social benefit of coverage to a marginal social cost of coverage that now takes into account the increase in information rent of a unit increase of coverage, $\lambda\varphi\left(\theta\right)$, in addition to $\left(1+\lambda\right)\theta$.

Turning to optimal taxes, we substitute (9) into (2) and (3) to obtain:

$$t^*(\theta) = \Pi^E(\mu^*(\theta)) \text{ and } T^*(\theta) = U(\theta) - \Pi^I(\mu^*(\theta), \theta) - n\Pi^E(\mu^*(\theta))$$

where $U(\theta)$ is the incumbent's rent. Entrants profits are entirely taxed away and transferred to the incumbent since this profit transfer is made at no cost and is a substitute to the costly transfer from public funds. If the sum of incumbent profit and transfers from entrants is greater than the incumbent's rent, the difference is "returned" to government in order to save on the cost of public funds. If this sum is less than the incumbent's rent, the transfer from public funds eliminates the gap in order to meet the incentive compatibility constraint.

[13] We have that $\theta_n^{\lambda} = \hat{\theta}_n^{\lambda} + \alpha\varphi(\hat{\theta}_n^{\lambda}) \geq \hat{\theta}_n^{\lambda}$. Note that nothing prevents $\hat{\theta}_n^{\lambda}$ from being greater than $\bar{\theta}$ or less than $\underline{\theta}$. In the first case, coverage would always be full, while there would never have full coverage in the second case.

Proposition 1 *Let* $\hat{\lambda}_n(\theta) = \theta \frac{(n+1)S(p_n)+nr(p_n)}{r(p_n)(\varphi(\theta)-n\theta)}$ *be the shadow cost of public funds for which* $\mu^*(\theta) = \mu^I(\theta)$*. Then,*

(a) $\mu^*(\theta) \leq \mu^C(\theta)$, $\forall\theta \in [\underline{\theta}, \bar{\theta}], \forall\lambda \geq 0$

(b) $\mu^*(\theta)$ *is non increasing in* θ

(c) $\mu^*(\theta)$ *is non increasing in* λ

(d) If $n \geq \frac{\varphi(\bar{\theta})}{\bar{\theta}}$ *or if* $n < \frac{\varphi(\bar{\theta})}{\bar{\theta}}$ *and* $\lambda \leq \hat{\lambda}_n(\bar{\theta})$*, then* $\mu^*(\theta) > \mu^I(\theta)$, $\forall\theta$

(e) If $n < \frac{\varphi(\bar{\theta})}{\bar{\theta}}$ *and* $\lambda > \hat{\lambda}_n(\bar{\theta})$*, there exists a unique* $\tilde{\theta} \in (\underline{\theta}, \bar{\theta}]$ *such that* $\mu^*(\theta) < \mu^I(\theta)$, $\forall\theta \in [\tilde{\theta}, \bar{\theta}]$.

The first three statements recall that, compared to complete information, asymmetry of information introduces a trade-off between efficiency[14] and rent extraction that creates (a) a downward coverage[15] distortion (b) which is the greater the more inefficient is the firm and (c) which is the more important the greater is the shadow cost of public funds. Statement (c) in particular, highlights the traditional role of λ in determining the terms of the efficiency rent trade-off.

Statements (d) and (e) reveal the impact of market structure on coverage *via* internal industry funding. If the number of firms is relatively high, the private marginal benefit $\frac{r(p_n)}{n+1}g(\mu)$ is so low compared to social marginal benefit $(S(p_n) + (1+\lambda)r(p_n))g(\mu)$ that even the highest information rent does not justify a lower coverage than the unregulated one. However, a welfare maximizing coverage lower than unregulated coverage can occur for relatively inefficient firms when *(i)* there is a low number of firms, so that private marginal benefit is relatively high and *(ii)* the shadow cost of public funds is sufficiently high, so that the information rent is high. In such a case, the imposition of the USO, which aims to extend coverage, has the perverse effect of reducing it.[16]

3.2 Licensing

Assume now that the regulator can choose the number of firms, for instance, through the emission of licenses. This choice allows to minimize allocative distortions given the

[14] Since asymmetry of information is about fixed cost, this is productive efficiency.

[15] Note that it is possible that μ^* be equal to the complete information coverage for $\theta > \underline{\theta}$ because both μ^* and μ^C are equal to 1 when $\theta < \hat{\theta}_n^{\lambda}$.

[16] Note that because the marginal information rent is low for efficient firms, there is always a range of relatively efficient firms for which optimal coverage is greater than the unregulated one.

shadow cost of public funds.[17] Substituting $\langle \mu^*(\theta), u^*(\theta)\rangle$ into (8) leads to the following expected welfare function:

$$\begin{aligned}\mathcal{E}W &= \int_{\underline{\theta}}^{\hat{\theta}_n^{\lambda}} \{S(p_n) + (1+\lambda)[r(p_n) - (\theta + \alpha\varphi(\theta))H(1)]\} dF \\ &+ \int_{\hat{\theta}_n^{\lambda}}^{\bar{\theta}} (1+\lambda)(\theta+\alpha\varphi(\theta))[G(\mu^*(\theta))\mu^*(\theta) - H(\mu^*(\theta))]dF \end{aligned} \qquad (10)$$

Proposition 2 *The welfare-maximizing number of firms is given by* $n^*(\lambda) = \frac{1}{\lambda}$.

From Lemma 1, the choice of the number of firms amounts to controlling the price. Accordingly, Proposition 2 results from the trade-off between industry profit and consumers' surplus that a change in price entails. The price p_{n^*} must then be such that the marginal consumers' surplus[18], q, equals the marginal social value of increased profit, $(1+\lambda)r'$, i.e. $q = (1+\lambda)r'$. Since $r' = (1+\eta)$, it follows, from the Cournot equilibrium $\eta = \frac{1}{n+1}$, that $n^* = \frac{1}{\lambda}$.

The shadow cost of public funds thus plays a dual role. First, it determines the number of firms or, equivalently, the allocative distortions on covered locations, from the trade-off between internal industry funding and allocative efficiency. Second, it determines optimal coverage by setting the relative social value of consumer surplus compared to profit. For a given efficiency parameter θ, a high λ means that the cost of funding consumption is high, so that coverage is reduced.

In brief, the choice of optimal policy involves two independent trade-offs: the (productive) efficiency / information rent trade-off and the (allocative) efficiency / internal funding trade-off. The first corresponds to the usual trade-off emphasized in adverse selection models. The second appears from the necessity to fund a fixed cost. Both trade-offs are determined by the shadow cost of public funds.

4 Extensions

4.1 Ubiquity Constraint

In practice, the USO generally requires that the incumbent insures full coverage $\mu(\theta) = 1$, $\forall\theta$, rather than the welfare maximizing one. This is known as the ubiquity constraint. Compared to an optimal coverage policy, the ubiquity policy initially does not take into account the cost of service. This implies that it is possible that universal service turns

[17] Note that these distortions are independent of market coverage.
[18] We omit arguments of functions for brevity.

out to be socially too costly and has to be abandoned.[19] Consequently, the choice that the regulator makes when imposing an ubiquity constraint is the probability of shutdown $x \in [0,1]$. It thus offers a USO contract $\mathcal{C}(\theta) = \langle x(\theta), T(\theta), t(\theta)\rangle$.

The problem then boils down to the choice of the optimal cutoff type $\breve{\theta}_n^{\lambda}$, so that service is supplied if the firm is found to be of type $\theta \leq \breve{\theta}_n^{\lambda}$ and abandoned if $\theta > \breve{\theta}_n^{\lambda}$, implying an *ex ante* probability of shutdown of $1 - F(\breve{\theta}_n^{\lambda})$. This problem has a similar structure to problem (7) and thus yields similar results. In particular, (i) asymmetric information increases the probability of shutdown compared to a complete information benchmark because of the costs of information rents. (ii) The probability of shutdown is increasing with the shadow cost of public funds. (iii) If there is a small number of firms ($n < \frac{\varphi(\bar{\theta}_n)}{\bar{\theta}_n}$) while the cost of public funds exceeds a given threshold, there is a greater probability of shutdown if the incumbent is compensated for the USO rather than being forced to full coverage without compensation. This is because the payment of the information rent makes the service socially too costly even for relatively efficient firms. Then it would be socially advantageous to just impose ubiquity without funding USO. (iv) The optimal number firms is still $\frac{1}{\lambda}$ as this still depends only on demand and not on the exact implementation of the USO. In other words, $\frac{1}{\lambda}$ is the optimal structure to fund the USO whatever are the funding requirements.

4.2 Unregulated Market Profit as Outside Opportunity

We have considered that the reservation utility of firms was zero. In practice, however, financial compensation for the USO is generally meant to cover the loss in profits incurred because of the USO. In other words, implementations of USO takes unregulated market profit as the outside opportunity. Within our framework, this translates into the following participation constraints:[20]

$$\forall\theta \in [\underline{\theta}, \bar{\theta}] : U(\theta) \geq \Pi^I(\mu^I(\theta), \theta) \text{ and } u(\theta) \geq \Pi^E(\mu^I(\theta))$$

This comes down to consider only Pareto-superior improvements to the unregulated market outcome when implementing the USO.

Because the incumbent's outside opportunity becomes dependent on type θ, one has to check for potential countervailing incentives. But, following standard developments

[19] Of course, our model is a crude representation of reality since characteristics of the USO (other than coverage) are exogenously given. In practice, characteristics of the USO (e.g. days of delivery in postal services) can be redefined in order to reduce cost and insure ubiquity under the less stringent USO. To this respect, the Universal Postal Union [24] notes that "Universal service is defined politically, but the issue is inseperable from that of whether a country can afford it".

[20] One could think that the regulator can ignore outside opportunities for entrants. The results we state hereafter still hold if $u(\theta) \geq 0, \forall\theta$.

found in Maggi and Rodríguez-Clare [18] and Jullien [16], it turns out that countervailing incentives are possible only for cases where USO coverage would be less than unregulated coverage, cases that are unfeasible for the problem with the outside opportunity.[21] In other words, the incumbent is never incited to understate θ even though its outside opportunity is decreasing with θ and the solution technique used for the case of zero outside opportunity is still valid.

Results for market coverage are the same than those presented in Proposition 1 except for a minor amendment for cases where market coverage is less than unregulated coverage: coverage is then scaled up to unregulated coverage as it would otherwise become impossible to compensate for outside opportunities. For cases in Proposition 1 where market coverage is greater than unregulated coverage, coverage remains the same with the unregulated market outside opportunity as without it.

In brief, the motivation for the regulator to impose a lower coverage than the unregulated market coverage was to reduce the information rent. This cannot be done when it is not allowed to reduce the incumbent's rent below the unregulated profit. The regulator must then acquiesce the unregulated coverage, in which case no transfer is made to the incumbent ($T = 0$). For cases where optimal coverage was greater than the unregulated coverage, it is as if government lost a lump-sum revenue equal to unregulated market profit.

5 Conclusion

As mentioned in Laffont [17] (p. 510), "[r]egulators, whatever their objectives, are fundamentally constrained by their lack of information on the firms they are regulating". As universal service is a form of regulation whose efficiency depends on the costs of regulated firms, which is private information, taking into account information constraints is as important in characterizing optimal policy under USO as it was for the direct natural monopoly regulation that the imposition of the USO often replaces. In this paper, we have showed that the necessity to concede information rents leads to a lower USO coverage. We have also determined conditions under which asymmetry of information paradoxically makes coverage under a USO lower than the unregulated market outcome.

From a policy viewpoint, asymmetry of information provides an additional indictment of the net avoided cost (NAC)[22] approach used for implementing universal service. Cremer

[21] More precisely $\Pi^I(\mu^I(\theta), \theta)$ has a slightly convex profile in the sense of Maggi and Rodríguez-Clare. Hence the participation constraint is binding for some types, but the optimal contract is still fully separating.

[22] The NAC is "the total cost savings that the incumbent could get by withdrawing from the loss-making areas" (Valletti *et al.* [25]).

et al. [7] and Valletti et al. [25] have already observed that using the NAC as a measure of the profitability cost of a universal service is valid only when the market structure is stable. In our framework, even with a given market structure, using the NAC to compensate for a USO would incite the USO provider to overstate it (by announcing $\tau > \theta$). Optimal policy thus involves the payment of an information rent over and above the NAC.

A further contribution of the paper is to highlight the role of the shadow cost in determining the terms of a trade-off between internal industry funding and public funding of the USO. Because there is no asymmetry of information on variable costs in our model, allocative efficiency of served markets was independent of the adverse selection variable, so that the information rent/productive efficiency and the internal funding/public funding trade-offs are resolved recursively. An extension would be to introduce asymmetry of information on allocative efficiency[23] to analyze the interaction of both trade-offs in the determination of optimal coverage.

In this paper, quantity competition has been assumed so that the uniform pricing constraint is met *de facto*. Another extension would be to model price competition (*à la Bertrand*) in order to understand how this constraint can modify asymmetric information distortions.

Appendix

Proof of Lemma 1. Denote $P(Q)$ the inverse demand such that $q(P(Q)) = Q$ where Q is the total demand in each market $\mu \in [0,1]$. Let $\Xi \equiv \frac{P''(Q)Q}{P'(Q)}$ be the elasticity of the slope of the inverse demand and assume that $\Xi \geq -1$.Then a Cournot-Nash symmetric equilibrium exists and is unique (Novshek [20]). Since $n+1$ symmetric firms serve this demand up to x each, the Cournot-Nash symmetric equilibrium is such that the FOC is verified: $P'((n+1)x^*)x^* + P((n+1)x^*) = 0$. Let $Q^* = (n+1)x^*$ and summing within the $n+1$ FOC leads to $P'(Q^*)Q^* + (n+1)P(Q^*) = 0$. Hence, at the Cournot equilibrium, we must have $\hat{\eta}(Q^*) = \frac{1}{n+1}$ where $\hat{\eta}(Q)) = -\frac{P(Q)}{P'(Q)Q}$. Now with $Q^* = q(p_n)$ and $P'(Q^*) = \frac{1}{q'(p_n)}$, we have $\eta(p_n) = \hat{\eta}(Q^*) = \frac{1}{n+1}$. Moreover since $\hat{\eta}'(Q) = -\frac{1}{Q}(1 + \eta(Q)(\Xi + 1)) \leq 0$, then $\dot{p}_n = \frac{-1}{\hat{\eta}'(q(p_n))q'(p_n)} \frac{1}{(n+1)^2} < 0$. Last, for each firm the equilibrium gross revenue is $p_n x^* = \frac{1}{n+1} p_n q(p_n) = \frac{r(p_n)}{n+1}$. ■

Section 3.1: feasible mechanisms. Since $U(\theta,\tau) = \Pi^I(\mu(\tau),\theta) + T(\tau) + nt(\tau)$, from relation (5), in the text, θ must be the incumbent's best reply to $\mathcal{C}(\tau)$ that is:

$$\theta = \arg\max_{\tau \in [\underline{\theta},\bar{\theta}]} U(\theta,\tau) \Leftrightarrow \begin{cases} U'_\tau(\theta,\theta) = 0 \\ U''_{\tau\tau}(\theta,\theta) = -U''_{\tau\theta}(\theta,\theta) \leq 0 \end{cases}$$

[23] This could be done by considering a cost function like $C(q,\mu,\theta) = \theta(cq + \mu)$.

From the second (local) concavity condition, we can derive the second order IC:

$$U''_{\tau\theta}(\theta,\theta) = -g(\mu(\theta))\mu(\theta)\mu'(\theta) \geq 0 \Leftrightarrow \mu'(\theta) \leq 0$$

Denoting $U(\theta) = U(\theta,\theta)$ and differentiating the first order condition $U'_\tau(\theta,\theta) = 0$ with respect to θ leads to:

$$U'(\theta) = -\int_0^{\mu(\theta)} zg(z)\,dz = -H(\mu(\theta)) < 0.$$

By integration $U(\theta) = \int_\theta^{\bar{\theta}} H(\mu(\tau))\,d\tau + U(\bar{\theta})$ and $U\left(\bar{\theta}\right) = 0$ is a sufficient condition to verify (4) in the text $(U(\theta) \geq 0, \forall\theta)$. Now the government's expected welfare writes:

$$\mathcal{E}W = \int_{\underline{\theta}}^{\bar{\theta}} \left[G(\mu(\theta))S(p_n) + U(\theta) + nu(\theta) - (1+\lambda)T(\theta)\right]dF$$

Substituting $T(\theta)$ and $t(\theta)$ leads to:

$$\begin{aligned}\mathcal{E}W &= \int_{\underline{\theta}}^{\bar{\theta}} \left[G(\mu(\theta))S(p_n) + U(\theta) + nu(\theta) - (1+\lambda)\left(U(\theta) - \Pi^I(\mu(\theta),\theta) - nt(\theta)\right)\right]dF \\ &= \int_{\underline{\theta}}^{\bar{\theta}} [G(\mu(\theta))S(p_n) - \lambda(U(\theta) + nu(\theta)) \\ &\quad + (1+\lambda)\left(\Pi^I(\mu(\theta),\theta) + n\Pi^E(\mu(\theta)\right)]dF \end{aligned} \tag{A.1}$$

Then integrating $\int_{\underline{\theta}}^{\bar{\theta}} U(\theta)f(\theta)d\theta$ by parts yields:

$$\int_{\underline{\theta}}^{\bar{\theta}} U(\theta)f(\theta)d\theta = \int_{\underline{\theta}}^{\bar{\theta}} \left(\int_\theta^{\bar{\theta}} H(\mu(\tau))\,d\tau\right) f(\theta)d\theta = \int_{\underline{\theta}}^{\bar{\theta}} H(\mu(\theta))F(\theta)d\theta.$$

Last substituting in (A.1), with $\alpha = \frac{\lambda}{1+\lambda}$, gives:

$$\mathcal{E}W = \int_{\underline{\theta}}^{\bar{\theta}} \{G(\mu(\theta))S(p_n) - n\lambda u(\theta) + (1+\lambda)[G(\mu(\theta))r(p_n) - (\theta + \alpha\varphi(\theta))H(\mu(\theta))]\}dF \qquad \blacksquare$$

Proof of Proposition 1. **a.** If $\theta \leq \hat{\theta}_n^\lambda$, $\mu^*(\theta) = \mu^C(\theta)$. If $\hat{\theta}_n^\lambda < \theta \leq \theta_n^\lambda$, $\mu^*(\theta) < 1 = \mu^C(\theta)$. If $\theta > \theta_n^\lambda$, $\frac{\mu^C(\theta)}{\mu^*(\theta)} = 1 + \alpha\frac{\varphi(\theta)}{\theta} > 1$.

b. From (9),

$$\frac{\partial\mu^*(\theta)}{\partial\theta} = \begin{cases} -\frac{[S(p_n)+(1+\lambda)r(p_n)][(1+\lambda)+\lambda\varphi'(\theta)]}{[(1+\lambda)\theta+\lambda\varphi(\theta)]^2} < 0 & \text{if } \theta > \hat{\theta}_n^\lambda \\ 0 & \text{if } \theta < \hat{\theta}_n^\lambda \end{cases}$$

At $\theta = \theta_n^\lambda$, μ^* is not differentiable with respect to θ, but it is clearly non-increasing as it is continuous and equal to 1 for $\theta \leq \theta_n^\lambda$ and less than 1 for $\theta > \theta_n^\lambda$.

c. Similarly,

$$\frac{\partial\mu^*(\theta)}{\partial\lambda} = \begin{cases} -\frac{S(p_n)(\theta+\varphi(\theta))+r(p_n)\varphi(\theta)}{[(1+\lambda)\theta+\lambda\varphi(\theta)]^2} < 0 & \text{if } \lambda > \lambda_n^\theta \\ 0 & \text{if } \lambda < \lambda_n^\theta \end{cases}$$

where $\lambda_n^\theta = \frac{S(p_n)+r(p_n)-\theta}{\theta+\varphi(\theta)-r(p_n)}$. At $\lambda = \lambda_n^\theta$, μ^* is not differentiable with respect to λ, but it is clearly non-increasing as it is continuous and equal to 1 for $\lambda \leq \lambda_n^\theta$ and less than 1 for $\lambda > \lambda_n^\theta$.

d. Convexity of φ implies that $\varphi(\theta) \leq \varphi'(\theta)\theta, \forall\theta \in [\underline{\theta}, \bar{\theta}]$. Then,

$$\hat{\lambda}_n'(\theta) = \frac{(n+1)S(p_n) + nr(p_n)}{r(p_n)\left(\varphi(\theta) - n\theta\right)^2}\left(\varphi(\theta) - \varphi'(\theta)\theta\right) \leq 0$$

whenever $\varphi(\theta) \neq n\theta$.

We then have the following cases.

- If $n > \frac{\varphi(\theta)}{\theta}$,

$$\lambda \lesseqgtr \hat{\lambda}_n(\theta) \Leftrightarrow \mu^*(\theta) \lesseqgtr \mu^I(\theta) \tag{A.2}$$

- If $n < \frac{\varphi(\theta)}{\theta}$,

$$\lambda \lesseqgtr \hat{\lambda}_n(\theta) \Leftrightarrow \mu^*(\theta) \gtreqless \mu^I(\theta) \tag{A.3}$$

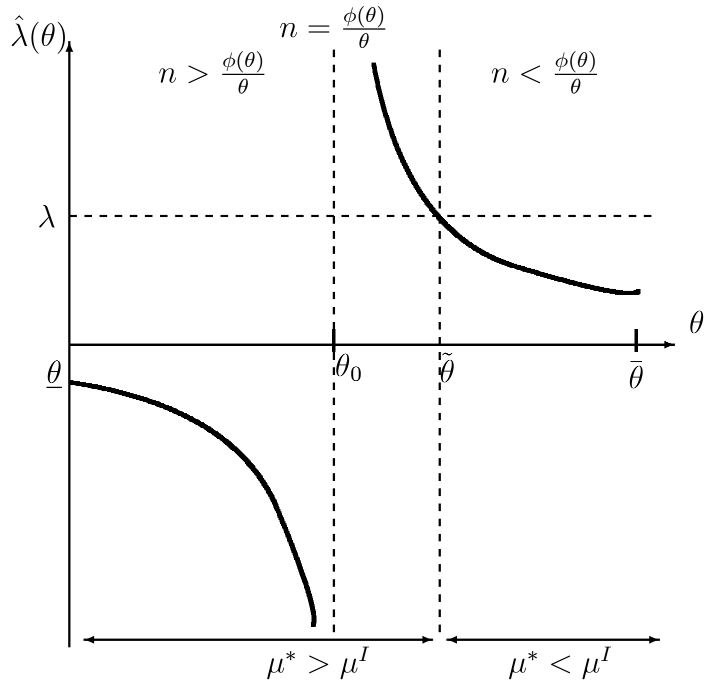
Assume now that $n > \varphi\left(\bar{\theta}\right)/\bar{\theta}$. Since $\varphi(\theta) \leq \varphi'(\theta)\theta, \forall\theta \in [\underline{\theta}, \bar{\theta}]$, this means that $n > \varphi(\theta)/\theta, \forall\theta$. We then have $\hat{\lambda}_n(\theta) < 0 < \lambda$, $\forall\theta$. From A.2, this implies that $\mu^*(\theta) > \mu^I(\theta)$.

Assume that $n < \varphi\left(\bar{\theta}\right)/\bar{\theta}$ and that $\lambda \leq \hat{\lambda}(\bar{\theta})$. Since $\hat{\lambda}(\bar{\theta})$ is non-increasing in θ, this implies that $\lambda \leq \hat{\lambda}(\theta)$, $\forall\theta \in (\theta_0, \theta]$, where θ_0 is such that $\varphi(\theta_0) = n\theta_0$. From (A.3), this implies that $\mu^*(\theta) > \mu^I(\theta)$.

e. Assume that $n < \varphi\left(\bar{\theta}\right)/\bar{\theta}$ and that $\lambda > \hat{\lambda}(\bar{\theta})$. Since $\lim_{\theta\downarrow\theta_0}\lambda(\theta_0) = \infty$, there exists a $\tilde{\theta} \in (\theta_0, \bar{\theta}]$ such that $\lambda > \hat{\lambda}(\theta)$, $\forall\theta \in (\tilde{\theta}, \bar{\theta}]$. From (A.3), this implies that $\mu^*(\theta) < \mu^I(\theta)$, $\forall\theta \in (\tilde{\theta}, \bar{\theta}]$. Figure 1 illustrates this case.

Figure 1

Proposition 1 e



■

Proof of Proposition 2. From (10),

$$\frac{d\mathcal{E}W}{dn} = \dot{p}_n[-q + (1+\lambda)(p_n q' + q)]F(\theta_n^\lambda) + \int_{\hat{\theta}_n^\lambda}^{\bar{\theta}} (1+\lambda)(\theta + \alpha\varphi(\theta))G(\mu^*(\theta))\dot{\mu}^*(\theta)dF \quad \text{(A.4)}$$

We first show that $\frac{d\mathcal{E}W}{dn} = 0$ for $n = \frac{1}{\lambda}$. We then show that $\mathcal{E}W$ is strictly quasi-concave in n.

1. Let $n = \frac{1}{\lambda}$. Then $[-q+(1+\lambda)(p_n q'+q)] = \frac{q}{n}(1-(n+1)\eta(p_n)) = 0$ since $\eta(p_n) = \frac{1}{n+1}$ from Lemma 1. The first term of (A.4) is thus nil. Moreover, the sign of the integrand is equal to the sign of $\dot{\mu}^*(\theta)$. But

$$\dot{\mu}^*(\theta) = \dot{p}_n \frac{-q(p_n) + (1+\lambda) r'(p_n)}{(1+\lambda)(\theta + \alpha\varphi(\theta))} = \dot{p}_n q(p_n) \frac{\alpha - \eta(p_n)}{(\theta + \alpha\varphi(\theta))} = \dot{p}_n \frac{q(p_n)}{(\theta + \alpha\varphi(\theta))}\left(\alpha - \frac{1}{n+1}\right) \quad \text{(A.5)}$$

so that $n = \frac{1}{\lambda} \Rightarrow \dot{\mu}^*(\theta) = 0$. The second term of (A.4) is thus also nil. As a result $n = \frac{1}{\lambda} \Rightarrow \frac{d\mathcal{E}W}{dn} = 0$.

2. Since $\dot{p}_n < 0$, $\forall n$ from Lemma 1 and $p_n q' + q > 0$, $\forall n$ from the fact that marginal revenue is necessarily positive at the market equilibrium, we obtain:

$$\dot{p}_n[-q + (1+\lambda)(p_n q' + q)]F(\theta_n^\lambda) \gtreqless \dot{p}_n \left[\frac{q}{n}(1-(n+1)\eta(p_n))\right] F(\theta_n^\lambda) = 0 \Leftrightarrow n \lesseqgtr \frac{1}{\lambda}$$

From (A.5), we obtain that $(1+\lambda)(\theta + \alpha\varphi(\theta))G(\mu^*(\theta))\dot{\mu}^*(\theta) \gtreqless 0 \Leftrightarrow n \lesseqgtr \frac{1}{\lambda}$. We thus have $\frac{d\mathcal{E}W}{dn} \gtreqless 0 \Leftrightarrow n \lesseqgtr \frac{1}{\lambda}$, i.e. that $\mathcal{E}W$ is strictly quasi-concave in n. As a result, $n = \frac{1}{\lambda}$ maximizes $\mathcal{E}W$. ■

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