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The impact of productive efficiency and quality of a regulated local public utility on final goods prices and consumers welfare

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The impact of productive efficiency and quality of a regulated local public utility on final goods prices and consumers welfare

Alessandro Petretto*

Abstract
In this paper, we reconstruct the process by which the decisions of a regulated local public utility, in terms of productive efficiency and quality of the service provided, impact on prices of final consumption goods, supplied in a oligopolistic market operating in the same geographic area. We obtain some formula for these effects which can be quantified by estimating firms' conditional input demand function of the public service and firms' inverse demand function for this public good, non-rival, component. Finally, we draw the effects of productive efficiency and quality on consumer welfare and cost-of-living, via changes on tariffs, external effects and final goods prices.

Keywords: regulation, x-efficiency, oligopoly, consumer welfare

JEL Classifications: L51, D11, D21

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1. Introduction

Local public services, like water distribution, sewerage treatment and disposal, waste collection and disposal, gas and electricity distribution, local public transport by road as well by rail, not only supply *consumption goods* to resident households but also act as *inputs* in local firms production processes by influencing their costs, and consequently their final prices. First, this insertion in the productive processes occurs throughout the level and the dynamics of tariffs, so a crucial role is played by the productive (in)efficiency pushing down (up) the costs of the firm producing the service. Secondly, public services affects production processes of firms supplying final goods throughout their quality, that, combined with specific environmental characteristics of the area, spreads positive externalities all around.

Indeed, local public services, although in general excludable and rival ones, have also some public good component. For instance, waste collection and disposal, and sewerage service have positive external effects by cleaning the area and by reducing water and air pollution. Gas and electricity distribution can be organised in order to save exhaustible resources and to supply clean energy. Public transport, reducing the use of private cars, can limit urban congestion costs and air pollution. All those effects create positive externalities for households and create in some way a favourable environment for sales and exchanges of final consumption goods, thus rising local firms productivity. In this respect we may think at an enlarged notion of "accessibility" of the area, a well known concept introduced into modern regional economics (Behrens and Thisse 2007).

Aim of this note is to enlighten, by a simple model, the process by which the decisions of a regulated local public utility (RLPU), i.e. a natural monopoly producing and providing a service, can determine, via cost-efficiency and quality, a shift on final goods prices set in markets operating in the same geographic area. This shift, together with the increase in consumer externality, impacts also on consumers welfare itself. In particular cost-efficiency and quality of local public utilities impact directly, via tariffs, and indirectly, via prices of final goods and externalities, on households welfare, by influencing the "utility affordability", according to an enlarged notion of it*.* The affordability concept usually refers to the direct impact of public utilities tariffs changes on household's expenditure and welfare[1], while here we try to enlarge the notion by considering also the effects throughout final goods prices and external effects, i.e. by looking at the dynamics of households' cost-of-living index. In other words, we want to emphasize that affordability of, say, waste collection and disposal depends not only on the level of tariffs paid by households but also on the level of final private goods, in some way influenced by quality and costs of the local public service for the firms in the market.

The main results of the paper are the following ones.

(i) A reduction of RLPU production efficiency increases domestic and business tariffs, and then also final goods prices, and reduces consumer welfare. The sign of such changes are rather intuitive, but we obtain some formal and exact expressions that could be measured and tested by empirical analysis.

(ii) A reduction of public service quality determines some contrasting effects. On one hand, it drives down RLUP production costs and then tariffs and final goods prices. On the other hand, a reduction of quality reduces the positive external effect to consumers and firms. We draw some conditions in order to sign the total effect. Also these conditions could be tested by empirical analysis.

The plan of the paper is the following one. In section 2, we analyse the structure of the three-stage game we are going to model, and we describe consumer preferences and choices, as well the technology and the subsequent cost functions of the firms involved in the game. In section 3, we find a Cournot equilibrium price for a consumption good, and we analyse the RLPU choices upon tariffs, quality and managerial effort. In section 4, we make some comparative statics by determining the impact on final good price of decisions taken in the first stage by the RLPU and by determining the final impact on consumer welfare of the increase of tariffs, final good prices and the public good component provision. In the

[1] For a rigorous analysis of the impact of price change on poor and then on public utilities affordability, see Makdissi and Wodon (2007). Differently from us, in that paper the concept is studied in a more appropriate general equilibrium context. For an empirical research referring to the affordability of some recent utilities reform in Italy see Miniaci *et al.* (2008).

Appendix we propose an input-output application for obtaining some numerical calculations of these effects. Section 5 concludes.

2. The structure of the model

The model we are going to present, although carrying out typical partial equilibrium results, has some general equilibrium features as it tries to link decisions taken by different agents in the economy (the Public utility manager, the producers and the consumers). In this regard, we consider an economic district where n local firms, $l=1\ldots,n$, are competing in supplying a final good j and a RLPU is providing a public service to local population and firms. We model this economy with a three-stage sequential game; in the first one, the RLPU chooses tariffs and quality of the public service; in the second stage, the n firms, taking as given the RLUP strategies, reach an oligopolistic equilibrium *à la Cournot*. Finally, in the third stage, the representative consumer, facing tariffs, quality and final good price, chooses the consumption of the public service and of the final good. Therefore, by backward induction, the RLUP is able to carry out its strategies by knowing firms and households demand functions and firms are able to choose their output quantities by knowing households demand functions.

To summarize, the set-up we have in mind is represented with the following table.

STAGE	PLAYERS	STRATEGIES
1	Local public utility	Cost-efficiency, tariffs and quality of the public service
2	Oligopolistic firms	Final consumption good quantity and price
3	Representative consumer	Private good and public service consumption

2.1. *Consumer preferences and demand functions*

We start by showing the structure of representative consumer preferences by means of the dual surplus function:

$$v = v(t^h, p_j, G), \tag{1a}$$

where (1) denotes the indirect utility function with marginal utility of income equal to one (no income-effect), t^h denotes the domestic customers tariff which household is facing, p_j denotes the price of the final consumption good *j*, and *G* denotes the public good component, or the externality, spread by the local public service to all citizens and firms in the area.

By envelope theorem, and Roy identity applied to this context, we have that

$$D^h(t^h, p_j, G) = -\frac{\partial v(t^h, p_j, G)}{\partial t^h} \tag{2a}$$

is the consumer demand of the public service and

$$d_j^h(t^h, p_j, G) = -\frac{\partial v(t^h, p_j, G)}{\partial p_j} \tag{3a}$$

is the consumer demand of the final good *j*.

Also we have that

$$\phi(t^h, p_j, G) = \frac{\partial v(t^h, p_j, G)}{\partial G} \tag{4}$$

is the inverse demand or "virtual price" of *G,* i.e. the marginal-willingness-to-pay of the representative consumer for the externality of the public service[2].

A simplifying hypothesis, which will result useful later on, is to assume for (1a) a separable additive function like this one:

$$v = v_1(t^h, G) + v_2(p_j, G), \tag{1b}$$

according to which the direct demand functions for the private goods assume the familiar partial equilibrium form:

$$D^h(t^h, G) = -\frac{\partial v_1(t^h, G)}{\partial t^h}, \tag{2b}$$

[2] See Cornes (1992, p. 239) and recall that in our case the marginal utility of income is equal to 1.

$$d_j^h(p_j, G) = -\frac{\partial v_2(p_j, G)}{\partial p_j}, \qquad (3b)$$

where the sole novelty is due to the external (public good) effect, for which no separability is allowed because we imagine that it can favour the consumption of both goods.

Notice that (2b), (3b) and (4) define the equilibrium of the third stage of the game, giving the choices of the consumer who faces the strategies by both private firms and RLPU.

2.2. *Technology and cost functions of competing firms in final good market*

As far as the technology of the firms supplying the consumption good, we represent this by the following set of cost functions:

$$C_l(t^f, G, X_{lj}), \qquad l=1,..n, \qquad (5)$$

where t^f is business customer tariff for the direct use of the public service as input in producing output level X_{lj} of good j, whose total supply in the area is $X_j=\sum_l X_{lj}$. Also the externality G enters the production process as a (non-rival) public input[3].

By Shephard's Lemma[4], we get the conditional public service input demand of firm l:

$$\frac{\partial C_l}{\partial t^f} = q_l(t^f, G, X_{lj}), \qquad (6)$$

and the aggregate demand of business customers in the whole "industry" of good j:

$$\sum_l q_l(t^f, G, X_{lj}) \equiv D^f(.). \qquad (7)$$

Moreover, by extending the notion of inverse demand or "virtual price" of a consumption public good (or externality) to the public input G, we represent the marginal-willingness-to-pay of firm l for the externality of the public service favouring the production process of j with the following expression:

$$-\frac{\partial C_l}{\partial G} = \varphi_l(t^f, G, X_{lj}), \qquad (8)$$

[3] Actually, the cost function depends also on the price of private inputs, but as they remain constant in the subsequent analysis we have dropped them out from (5).
[4] See, for instance, Jehle and Reny (2001, p. 129).

The sum over the n firms of the marginal valuations gives the aggregate marginal- willingness-to-pay for the public input by all the firms in the industry of the area:

$$\sum_{l} \varphi_l (t^f, G, X_{lj}) \equiv \Omega(.) \,. \tag{9}$$

2.3. *RLPU technology and cost function*

For taking into account the quality dimension in the RLPU production process, we follow the conventional wisdom of imagining the technology represented by an output set where there are both "desirable" and "bad" outputs, the latter being those with a low quality[5]. Consequently, let us represent the RLPU output set with the following notation:

$$\Im(r, A) = \{(Y, B) \in \Re_+^2 : is\ technically\ \ feasible, given\ r\ \ and\ A\}, \tag{10}$$

where $Y=y^h+y^f$ is the total output supplied to satisfy households (domestic customers) demand, and firms (business customers) demand respectively, r is a vector of inputs and A is a vector of environmental variables – like population density, altitude, orographical characteristics of the soil, level of precipitations, etc. Both r and A define the boundaries of the output set. B is a conventional bad output, consequently if with $m \in [m^-, m^+] \subset \Re_+$ we represent an index of service provision quality, measuring quality attributes by a positive real number within a closed interval defined by the technology of the service, the bad output is such that: $B(m);\ B'(m) < 0,\ B(m^+) = 0, B(m^-) \to \infty$.

Notice that m could be an index of organoleptic properties of drinking water gushing out of the aqueduct or an index of supply continuity and safety for water, gas, electricity distribution. It could give a measure of time frequency of buses stops in the urban area or a measure of the extension and capillarity of a metro network or of the share of buses in the fleet using clean fuel. Further, it could be an index related to the technological level of waste disposal plants and so on[6]. The

[5] See for instance Prior (2006) and Picazo-Tadeo *et al.* (2008). Actually, m could also represent a multivariate statistics index obtained, for each public service, throughout an aggregation of a set of elementary indexes.

[6] These indexes are often inserted in the contract signed by the firm and the regulator by indicating some standard level the former has to achieve.

usual assumption is that the "desirable" outputs are strongly disposable, while the "bad" outputs are under the axiom of weak disposability, which means that if $(Y,B)\in\Im(r,A)$, also $(\beta Y,\beta B)\in\Im(r,A)$ with 0≤β≤1 (Färe *et al*. 1989). Thus increasing *m* is not a costless activity as it requires the RLUP to divert resources that could otherwise be devoted to producing the quantity *Y*. This implies a trade-off between quantity and quality.

By duality, the output set of the RLUP may be represented by a cost function that we assume to have the following functional form, separable on fixed and variable costs[7]:

$$C_{PU}(Y, m,a; A)= F(m, A)+[c(m)+a]Y. \tag{11}$$

Formally we have $\partial F/\partial m>0$: an increase of quality provokes an increase of fixed costs by asking for higher infrastructural investments[8]. *A* is assumed to influence production costs of the RLPU, so $\partial F/\partial A$, with the sign of the elements of the gradient vector depending on the specific variable considered. $c(m)+a$ is the marginal cost of the service, where $c(m)$ is the minimum cost, given the technology, supposed to be an increasing function of quality, $c'(m)>0$, as higher quality may require more labour and maintenance costs, while a is a variable of x-inefficiency rising a cost-padding phenomenon. It could be a measure of perk and wasteful expenditures carried on by the manager or alternatively a parameter decreasing with the managerial effort. Of course, if the regulated firm is fully x-efficient, $a=0$, otherwise, $a>0$.

Moreover, we reasonably assume that the externality effect spread by the local public service to all citizens and firms in the area will come, given the output level, through an interconnection between service quality and environmental variables according to the following synthetic function:

$$G= \xi(m,A), \tag{12}$$

with $\partial\xi/\partial m>0$, while the sign of the elements of vector $\partial\xi/\partial A$ is depending, once again, on the specific environmental variable considered.

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7 We have dropped out the vector of input prices as they remain fixed throughout the analysis.

8 For the recent and relevant strand of literature linking the quality of the service to investment costs and to ownership structure of a public utility, see Bennett and Iossa (2006).

Notice that, given (12) and the demand structure by consumer (from (1) to (4)) and by firms (from (6) to (9)), we are assuming that quality enter agents pay-offs only indirectly, i.e. throughout the external effect *G*[9].

By inverting (12), we may also represent RLUP cost function directly in terms of the externality[10]:

$$C_{PU}(Y,G,a;\,A)= F(\xi^{-1}(G,A),\,A)+[c(\xi^{-1}(G,A))+a]Y=F(G)+[c(G)+a]Y \tag{13}$$

Equipped with these tools we now go ahead to analyse the second and first stage of the game.

3. Final goods prices, tariffs and quality of the public service

3.1. *Second stage: Cournot equilibrium in the final good market*

Let us now suppose that the final good *j* is supplied in a Cournot oligopolistic market, where each firm considers as given, besides the output produced by others, also, as Stackelberg followers, the variables chosen by the RLPU, here working as a Stackelberg leader.

The usual Lerner index is represented by the following expression:

$$\frac{p_j - MC_{lj}}{p_j} = \eta_{lj} / \varepsilon_j, \qquad l=1,\ldots n, \tag{14}$$

where $MC_{lj} \equiv \dfrac{\partial C_l(t^f, G, X_{lj})}{\partial X_{lj}}$ is the marginal cost of firm *l* and $\eta_{lj} \equiv X_{lj} / X_j$ denotes its market share; $p_j = P(X_j, G) \equiv d_j^{h^{-1}}(.)$ is the inverse consumer demand function, observed by firms when setting their output-strategies, and $1/\varepsilon_j \equiv -\dfrac{P'(X_j, G)X_j}{p_j}$ is the correspondent elasticity.

Therefore, the price of the final good *j* is given by:

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[9] For optimal regulation, in particular in telecommunications, when service quality indicators enter directly consumer utility and demand functions see Sappington (2005) and Currier (2007). As the link between quality, externality effect and agents demand is one of the focus of our paper we have isolated it by giving up the direct enter of quality, which however could be considered paying only for a bit complication of the analysis.

[10] The environmental variables *A* have now exhausted their explicative role, thus, as they will be remaining fixed in the subsequent analysis, hereafter we are going to drop them out from the main functions and expressions.

$$p_j = \frac{MC_{lj}}{1-(\eta_{lj}/\varepsilon_j)} . \qquad (15)$$

If we suppose a symmetric oligopoly, we have $X_j = n\, X_{lj}$ with $X_{lj} = x_j$. Thus, the equilibrium price becomes:

$$p_j = \frac{MC_j}{1-(1/n)/\varepsilon_j} \equiv \gamma_j MC_j(t^f, G, x_j) . \qquad (16)$$

Moreover, in order to get from (16) a tractable function of equilibrium prices in terms of the variables settled by the RLPU in the first stage of the game, we make two further assumptions which simplify the analysis, with a limited loss of generality. Firstly, we assume that, in the relevant time, the mark-up $\gamma_j \equiv \frac{n\varepsilon_j}{n\varepsilon_j - 1} \geq 1$ is going to remain constant (i.e. it is approximately constant the consumer demand elasticity) w.r.t. both X_j and G. Notice that if the oligopoly were *à la Bertrand* in equilibrium would be γ_j=1, as well as in a perfect competitive market where $n \to \infty$. Secondly, in order to limit the interdependency complication coming from the fact that marginal cost in (16), and then the price, depends on output level of average firm, we assume that the cost function of average firm of industry *j* is given by the following functional separable form[11]*:*

$$C(t^f, G, x_j) = c_j(t^f, G)x_j . \qquad (17)$$

Indeed, given (17), $MC_j = c_j(t^f, G)$, i.e. the marginal cost of the average firm producing *j,* depends on the business tariff, t^f, with $\frac{\partial c_j(t^f, G)}{\partial t^f} > 0$ and on the external effect *G,* with $\frac{\partial c_j(t^f, G)}{\partial G} < 0$, but it is independent on the level of output, x_j.[12] Further, by applying Shepard's Lemma to (17), we have that the input demand and the virtual price of the average firm are respectively given by:

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[11] For a justification of this factorized functional form of the cost function see Cornes (1992, p. 107). Other general equilibrium complications might arise from firms profit distribution to households. We may avoid this problem by assuming that the shares of the firms are owned by people living outside the area.
[12] Therefore the supply function is infinitely elastic. This hypothesis, and the previous one on constant elasticity of demand, are rather familiar in the theory of tax incidence in non-

$$q(t^f, x_j, G) = \frac{\partial c_j(t^f, G)}{\partial t^f} x_j \,, \tag{18}$$

and

$$\varphi(t^f, x_j, G) = -\frac{\partial c_j(t^f, G)}{\partial G} x_j \,. \text{ [13]} \tag{19}$$

Therefore, equilibrium price becomes:

$$p_j = P(X_j, G) = \gamma_j c_j(t^f, G) \,. \tag{20}$$

The relationship between the equilibrium price and the variables of the public service is plotted in the following figure[14].

Insert Fig.1 here

3.2. First stage: RLPU choices

Let us suppose that our RLPU is constrained by a *Price-Cap* rule, putting a limit to average (unitary) revenue, P^0 [15] , and by the duty to reach at least a given

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competitive markets. Recall that this the case where a tax on the consumption good is fully shifted onto consumers. See for instance Salaniè (2003, p. 21).

[13] Notice that now, in Cournot equilibrium, we have that $x_j = d_j^h(p_j, G)/n$, hence, by substituting in (17), and then in (18) and (19), we get cost function and demand functions in equilibrium:

$$C(t^f, p_j, G, n) = c_j(t^f, G)\frac{d_j^h(p_j, G)}{n},$$

$$q(t^f, p_j, G, n) = -\frac{\partial c_j(t^f, G)}{\partial t^f}\frac{d_j^h(p_j, G)}{n},$$

and

$$\varphi(t^f, t^f, p_j, G, n) = -[\frac{\partial c_j(t^f, G)}{\partial G}\frac{d_j^h(p_j, G)}{n} + \frac{c_j(t^f, G)}{n}\frac{\partial d_j^h(p_j, G)}{\partial G}] \,.$$

Notice that for the latter equation, we have to assume, for regulatory concerns, that the virtual price of externality is in any case positive. In fact the first term in the square bracket is negative and the second one positive.

[14] Notice that demand function shifts with an increase of the externality effect, although we assume a constant elasticity.

[15] This criterion for applying *Price-Cap* regulation is behaving for one public service provided to different users (Armstrong *et al.* 1994), like that one we are here modeling. For instance, in the pricing method used in water service in Italy, $P^0 = (R/Y)_{-1}(1+K)$, thus the *Cap* on current average revenue is given by the previous period average revenue augmented by a "limit price" coefficient *K* (Utilitatis 2005). For a recent survey of the several *Price-Cap*

standard of quality interior to the interval defined by the technology, m^0 [16]. Hence, the RLUP manager[17] chooses tariffs, quality and managerial effort, by observing the household's demand function of the service, as a consumer good, and the firms demand function of the service, as an intermediate input. Notice that, while the first demand function is simply $D^h(t^h, G)$, the second demand function is a bit more complicated. Indeed, we have to recall that total industry output $X_j=nx_j$ is equal to consumer demand $d_j^h(p_j, G)$, then in (18) we have to substitute $x_j = d_j^h(p_j, G)/n$; therefore, given the equilibrium price specified in (20), we have

$$D^f(t^f, G) \equiv nq(t^f, x_j, G) = \frac{\partial c_j(t^f, G)}{\partial t^f} d_j^h(\gamma_j c_j(t^f, G), G), \tag{21}$$

with $\frac{\partial D^f}{\partial t^f} < 0$ and $\frac{\partial D^f}{\partial G} > 0$, if we assume[18] $\frac{\partial^2 c_j}{\partial t^{f2}} < 0$ and $\frac{\partial^2 c_j}{\partial t^f \partial G} > 0$.

The choice of tariffs, quality and managerial effort results from the maximization of the total profit $\Pi(t^h, t^f, m, a)$, comprehensive of the firm owners/manager pay-off, given by revenues $R(t^h, t^f) = t^h y^h + t^f y^f$, less production costs, $C_{PU}(Y, m, a)$, with $Y = D^h(t^h, G) + D^f(t^f, G)$, and plus the benefit function of perk and wasteful expenditures (or conversely less the cost function of the managerial effort), $\psi(a)$, $\psi'>0$, $\psi''<0$. For the RLUP manager the pursuit of the latter goal can be in some way limited by the regulator pressure, represented by a parameter μ. Indeed, with an explicit manager preference on extra costs, the traditional effect of Price-Cap on

typologies see Guthrie (2006). For a quality-corrected *Price-Cap* formulation (when quality indicators influence directly the consumer demand) see Currier (2007).

[16] We are clearly assuming that the regulator can observe and measure the service quality (verifiability of quality level). See Sappington (2005) for an analysis of the general implications of the Minimum Quality Standards (MQS) criterion of regulating quality of public services. This constraint could be considered as an application of "sustainable development duties" which are recently specifying new roles for regulation in some European countries (Owen 2006, Bartle and Vass 2007).

[17] This is named by enterprise owners who may be private as well as public ones.

[18] By direct computation we obtain the following two expressions:

$$\frac{\partial D^f}{\partial t^f} = \frac{\partial^2 c_j}{\partial t^{f2}} d_j^h + \left(\frac{\partial c_j}{\partial t^f}\right)^2 \frac{\partial d_j^h}{\partial p_j} \gamma_j,$$

$$\frac{\partial D^f}{\partial G} = \frac{\partial^2 c_j}{\partial t^f \partial G} d_j^h + \frac{\partial c_j}{\partial t^f} \frac{\partial d_j^h}{\partial p_j} \gamma_j \frac{\partial c_j}{\partial G} + \frac{\partial c_j}{\partial t^f} \frac{\partial d_j^h}{\partial G},$$

where the only signs we have to assume are, as in the text, the two second derivatives of unitary cost function.

limiting x-inefficiency is partially reduced and, thus, the regulator must intervene by monitoring the RLUP activity.

Therefore, we have:

$$\underset{(t^h,t^f,m,a)}{\text{Max}} \quad \Pi(t^h, t^f, m, a) \equiv R(t^h, t^f) - [F(m) + (c(m) + a)Y] + \mu\psi(a) \qquad (22)$$

s.t.

$$\frac{R(t^h, t^f)}{Y} \leq P°$$

$$m \in [m^0, m^+]; m^0 > m^-$$

The correspondent Lagrangean is given by the following expression:

$$L=R(t^h,t^f) - [F(m)+(c(m)+a)Y] + \mu\, \psi(a) - \sigma [R(t^h,t^f) - P°Y] + \rho\, (m-m°). \qquad (23)$$

We assume that the regulator has set up both P^0 and m^0 at a level compatible with a non-negative total profit: $\Pi^* \geq 0$. Further, by the envelope theorem, we have $\frac{\partial \Pi^*}{\partial P°} = \sigma Y \geq 0, -\frac{\partial \Pi^*}{\partial m°} = \rho \geq 0$, i.e. if each constraint is relaxed, by allowing a greater average revenue and/or a lower quality standard, the maximum value of the (indirect) objective function does not decrease.

Necessary conditions for optimum are:

- *Productive (in)efficiency* (*a*)

$$Y = \mu\, \psi'(a), \text{ where } \frac{\partial C_{PU}}{\partial a} = Y \qquad (24)$$

By (24), in general $a^*>0$. However $a^*=0$ when the regulation pressure is hard and successful, i.e. when $\mu \to 0$. We may say that policies aimed, on one hand, at improving the efficacy and strength of regulation by monitoring and audit procedures of cost-padding (Laffont and Tirole, 1993, ch.12), and, on the other hand, at carrying on pro-competitive liberalization measures, and for pursuing the competition by franchise bidding, should in some way reduce *a* (Armstrong and Sappington, 2006). But it still remains a variable under manager's control. In the following figure we represent the level of productive inefficiency chosen by the manager and, in some sense, "allowed" by the uninformed regulator.

Insert Fig.2 here

- *Tariffs* (t^h,t^f)

If the *Price-Cap* constraint is binding, we obtain, after usual manipulations, the following structure of optimal tariffs, for households and firms:

$$t^u = \frac{c(m) + a - \sigma P^\circ}{1-\sigma} \frac{1}{1 - 1/\varepsilon^u}, \quad u = h, f, \tag{25}$$

where $\varepsilon^u \equiv -\frac{\partial D^u}{\partial t^u} \frac{t^u}{D^u}$ is the elasticity of demand for the service by domestic or business users; both assumed to be constant in the relevant time. From condition (25), the optimal tariff is an increasing function of quality and productive inefficiency[19]

$$t^u(m,a) = b^u[c(m) + a] - T^u, \tag{26}$$

where $b^u \equiv \frac{1}{(1-\sigma)(1-\frac{1}{\varepsilon^u})}$ is the mark-up over marginal cost (with some cost-padding) allowed to the RLPU for tariff *u, u=h, f.* Notice that we have $b^u > 1$, as, for regularity, it must be $\varepsilon^u > 1, \sigma < 1$. $T^u \equiv \frac{\sigma P^0}{(1-\sigma)(1-\frac{1}{\varepsilon^u})}$ is an implicit unit tax on output *u*, levied by the regulator for limiting the RLUP rent[20]. The following two figures represent the relationships between tariff *u*, productive inefficiency and quality.

Insert Fig.3a and 3b here

[19] See, for instance, the role of changes in costs and quality in determining the changes in average water users bills taken into account by OFWAT in UK (Zabel 2007).

[20] Notice that, by this formulation, the differentiation between domestic and business tariffs lies only on demand elasticity differences. Indeed if $\varepsilon^h > \varepsilon^f$ (in the sense that the public service is more substitutable by the consumer than by the firms), $t^f > t^h$ as we expect to happen. Actually, in real world, this differentiation is justified by other elements, mainly linked to equity concerns.

Indeed, with tariffs structure given by (25) and (26), the RLUP manager is able to cover variable and fixed costs and possibly get some extra-profit and wasteful expenditures[21].

Notice that if *Price-Cap* constraint is not binding and then σ=0, it is $T^u = 0$ and $b^u = \dfrac{1}{1-\dfrac{1}{\varepsilon^u}}, u = h, f$, as in case of a pure un-regulated monopoly.

- *Quality* (*m*)

As far as the choice of quality index is concerned, we have the following condition equating the marginal cost with a "corrected" marginal revenue of quality:

$$CMR_m \equiv (1-\sigma)MR_m + \sigma P^\circ \sum_{u=h,f} \frac{\partial D^h}{\partial G} \xi'(m) + \rho = MC_m, \tag{27}$$

where

$$MR_m \equiv \frac{\partial R}{\partial m} = \sum_{u=h,f} t^u \frac{\partial D^u}{\partial G} \xi'(m) > 0,$$
$$MC_m \equiv \frac{\partial C_{PU}}{\partial m} = F'(m) + c'(m)Y + (c(m)+a) \sum_{u=h,f} \frac{\partial D^u}{\partial G} \xi'(m) > 0.$$

Hence, an increase of quality level firstly increases fixed costs and variable costs, then produces an externality which increases domestic and business users' demand and consequently, again variable costs, but also revenues. If both regulation constraints are not binding, and then σ=ρ=0, condition (27) collapses to the usual one, referring to a unregulated monopoly supplier (Sappington 2005): $MR_m = MC_m$. If the *Price-Cap* constraint is not binding, i.e. $R(.) < YP^\circ$ and σ=0, while standard quality constraint is binding, i.e. $m^*=m^\circ$ and ρ>0, condition (27) implies $MR_m<MC_m=MR_m+\rho$. However no comparison can be made between MC_m and MR_m when also σ>0.

In the following figure we represent (for simplicity with σ=0) the equilibrium level of quality m^* in two cases: the one where the quality constraint is not binding ($m^* > m_1^0$) and the one where it is binding ($m^* = m_2^0$), respectively.

[21] In this respect, we assume, as for oligopolistic firms, that RLUP profit will be distributed to shareholders living outside the area.

Insert Fig. 4 here

4. The impact on final good price and consumer welfare of productive efficiency and quality

4.1. *The impact on final good price*

We are firstly interested in exploring the effects on p_j of an increase of *a,* coming from a reduction of the regulator controlling power on RLUP productive efficiency, and of a reduction of *m*, coming from a relaxation of the standard quality constraint leaving room for the RLUP manager to expand the profit. What we are going to study is some static comparative exercises around the equilibrium of the previous sequential game.

We can settle the following two summarising Propositions.

Proposition 1

The impact of a productive efficiency reduction of the service provided by the RLPU on final good price is given by the following expression:

$$\Delta p_j = \gamma_j \frac{\partial c_j}{\partial t^f} b^f \Delta a \,. \tag{28}$$

Proof

The impact of a change of the tariff on marginal cost of good *j* is given, according to the so called Young's theorem[22], by the derivative of conditional input demand function w.r.t output (the "technical coefficient" in industry *j*): $\frac{\partial MC_j}{\partial t^f} = \frac{\partial^2 C}{\partial x_j \partial t^f} = \frac{\partial^2 C}{\partial t^f \partial x_j} = \frac{\partial q(t^f, x_j, G)}{\partial x_j}$. Hence, from (20), the impact on price is given by $\Delta p_j = \gamma_j \frac{\partial q}{\partial x_j} \Delta t^f$, which, with cost function (17), input demand function (18), becomes $\Delta p_j = \gamma_j \frac{\partial c_j}{\partial t^f} \Delta t^f$. Thus, the inflationary push on price of good *j* of the tariff

[22] See Cornes (1992, p. 106).

is proportional to the derivative of unitary cost factor w.r.t. business tariff. On the other hand, from (26) we have $\Delta t^f = b^f \Delta a$, i.e. the change on the tariff is proportional to the change in the efficiency parameter *a*. By substituting, we obtain expression (28). □

Expression (28), surely positive, is quite intuitive as it says that the inflationary push of productive inefficiency of the RLUP is simply given by multiplying the effect of tariff on the firm unitary cost with the mark-ups prevailing in the oligopolistic final good market and in the regulated monopoly.

Proposition 2

The impact of a quality reduction of the service provided by the RLPU on final good price is given by the following expression:

$$\Delta p_j = -\gamma_j \left[\frac{\partial c_j}{\partial t^f} b^f c'(m) + \frac{\partial c_j}{\partial G} \xi'(m) \right] \Delta m . \qquad (29)$$

Proof

A containment of quality index reduces, on one hand, the variable costs and then the marginal cost of the RLPU. Consequently, from (26) we have a reduction of the tariff given by $\Delta t^f = -b^f c'(m) \Delta m < 0$. Then, by taking into account $\Delta p_j = \gamma_j \frac{\partial c_j}{\partial t^f} \Delta t^f$, we get the first term in the square bracket of (29), giving a final good price reduction. On the other hand, we have an externality effect created by the quality index change on marginal cost of producing good *j*, given by $\frac{\partial MC_j}{\partial G} \xi'(m) = \frac{\partial^2 C}{\partial x_j \partial G} \xi'(m) = \frac{\partial (\frac{\partial C}{\partial G})}{\partial x_j} \xi'(m) = -\frac{\partial \varphi}{\partial x_j} \xi'(m)$. However, with cost function (17) and virtual price function (19), we have $-\frac{\partial \varphi}{\partial x_j} = \frac{\partial c_j}{\partial G} < 0$. Thus, we get the second term in expression (29), giving the inflationary push of a lower quality. □

The sign of (29) is uncertain depending on which of the two opposite effects tends to prevail. Also in (29), the two mark-ups play a relevant role; but now, while

b^f tends only to contain the inflationary push of quality reduction, γ_j determines two opposite effects, via a costs containment and a costs increase. Notice that, by inserting expression (28) in (29), we obtain a combination of the two inflationary effects: $\frac{\Delta p_j}{\Delta m} = c'(m)\frac{\Delta p_j}{\Delta a} + \gamma_j \frac{\partial c_j}{\partial G}\xi'(m)$, i.e. the inflationary effect of an increase of the quality is spread by the inflationary push due to productive inefficiency. In other words, the effect of better quality may be inflationary (deflationary) if the inflationary effect of productive inefficiency is high (low) because it is high (low) the capacity of the RLPU manager to translate extra-costs on tariffs. This result may be synthesized by the following:

Corollary 1

$$\frac{\Delta p_j}{\Delta m} \geq (<)\, 0 \quad iff \quad \frac{\Delta p_j}{\Delta a} \geq (<)\, \chi \equiv \gamma_j \vartheta_m \,. \tag{30}$$

According to (30), the threshold χ increases with the mark-up in final good market γ_j and with $\vartheta_m \equiv \frac{\left|\frac{\partial c_j}{\partial G}\right| \xi'(m)}{c'(m)}$, a parameter measuring the relative effect of *m* on the costs structure of the two goods, the final one and the public service.

4.2. *The impact on consumer welfare*

We now investigate the effect of productive efficiency and quality changes on consumer welfare, which, given (1b), (12), (20) and (26) may be now represented by the function

$$v(m,a) = v_1(t^h(m,a), \xi(m)) + v_2(p_j(m,a), \xi(m)) . \qquad (31)$$

Changes in productive efficiency produce two effects on consumer welfare[23]: via tariff for domestic customers, t^h, and via price of final good, p_j. Changes in quality, instead, produce three effects on consumer welfare: once again via tariff for domestic customers and via price of final good *j,* but also directly via the externality, *G*. We summarize the total effects with the following two propositions:

Proposition 3

The impact of a productive efficiency reduction of the service provided by the RLPU on consumer welfare is given by the following expression:

$$\Delta v = -[D^h b^h + d_j^h \gamma_j (\partial c_j / \partial t^f) b^f]\Delta a . \qquad (32)$$

Proof

By direct computation of the total differential of (31) and by substituting (28). □

The two effects in square bracket of (32) are both positive. Thus $\Delta v / \Delta a < 0$: the consumer is always worse-off with a higher productive inefficiency of RLUP and then only $a^*=0$ is going to maximize $v(m,a)$. Hence, a clear conflict arises between the consumer and the RLPU manager which is mediated by the role of regulator.

Proposition 4

The impact of a quality reduction of the service provided by the RLPU on consumer welfare is given by the following expression:

[23] For a general equilibrium analysis of more "exact" welfare measures of tax and price changes, see Creedy (2000).

$$\Delta v = -\left\{ [\phi - d_j^h \gamma_j (\partial c_j / \partial G)]\xi'(m) - [d_j^h \gamma_j (\partial c_j / \partial t^f) b^f + D^h b^h] c'(m) \right\} \Delta m \,. \qquad (33)$$

Proof

By direct computation of the total differential of (31) and by substituting (29). □

The sign of (33) is uncertain. Indeed, although a reduction of quality has a negative direct impact on consumer welfare, the latter may be, somewhat paradoxically, better-off if a decrease of quality implies a relevant reduction on domestic tariff and final good price given by a reduction on RLPU marginal cost. So there is a finite level of $m^* \geq m^0$ maximizing $v(m,a)$. Particularly interesting is the polar case of a perfect competitive setting in both markets and a First best context for the public service supply, which we may put in terms of the following statement:

Corollary 2

With $a=\sigma=\rho=0$, $b^f=\gamma_j=1$ and an Hotelling tariff structure[24] *such that $t^u=c(m)$, $u=h,f$, we get the familiar Samuelson condition for efficient supply of public goods, according to which the social marginal benefit of public good G, SMB_G, is equal to its social marginal cost, SMC_G.*

Proof

If we maximize $v(m,a)$ w.r.t. m, from (33) we get the F.O.C.

$$[\phi - d_j^h (\partial c_j / \partial G)]\xi'(m) = [d_j^h (\partial c_j / \partial t^f) + D^h] c'(m) \,.$$

This, given that $dG = \xi'(m)dm$ and that, by (13), $c'(m)\dfrac{\partial \xi^{-1}}{\partial G} = c'(G)$, can be rewritten as:

$$SMB_G \equiv [\phi - d_j^h (\partial c_j / \partial G)] = [d_j^h (\partial c_j / \partial t^f) + D^h] c'(G) \equiv SMC_G \,. \ \square$$

By summing up (32) and (33) effects we obtain the total effect -ΔV of x-inefficiency and low quality of the public service on consumer welfare. Such a total effect may be usefully linked to the effect on consumer cost-of-living index which

[24] Notice that, in this case, we assume that fixed costs of firm producing the public service are financed by some national Authority without taxing the local community or applying a fixed poll to local users.

gives an exact measure of the public service general affordability. In compact terms we have the following statement:

Corollary 3

The impact of reduction of RLUP productive efficiency and quality on household cost-of-living is given by $1-\Delta V$ *.*

Proof

The total effect (32) plus (33) can be easily rewritten as

$$-\Delta V = D^h \Delta t^h + d_j^h \Delta p_j - \phi \Delta G =$$
$$= \frac{\partial E(t^h, p_j, G)}{\partial t^h}\Delta t^h + \frac{\partial E(t^h, p_j, G)}{\partial p_j}\Delta p_j - \frac{\partial E(t^h, p_j, G)}{\partial G}\Delta G \equiv \Delta E(t^h, p_j, G)$$

where $E(t^h, p_j, G)$ is the expenditure function[25]. Now with

$$CLIndex \equiv \frac{E(t^{h1}, p_j^1, G^1)}{E(t^{h0}, p_j^0, G^0)} = \frac{E(t^{h0}, p_j^0, G^0) + \Delta E(t^h, p_j, G)}{E(t^{h0}, p_j^0, G^0)}$$

we represent the consumer cost-of-living index[26] from time 0 to time 1. If we normalise by putting w.l.g. the "reference household expenditure" equal to one, $E(t^{h0}, p_j^0, G^0) = 1$, the cost-of living index becomes:

$$CLIndex \equiv 1 + \Delta E(t^h, p_j, G) = 1 - \Delta V \ . \quad \square$$

Consequently, by summing up (32) and (33) we have a clear measure of the impact of a decrease of cost-efficiency and quality of the public service on a wide affordability notion which includes the change of both consumer prices as well as of the externality.

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[25] Notice that the concept must be converted to our context where the compensated (hicksian) demand function coincides with the uncompensated (marshallian) one (Cornes 1992, Creedy 2000). Further, $-\Delta V$ is the amount of *numeraire* (the surplus) the consumer is available to give up to buy D^h and d_j^h after the increase in the two prices and in the externality; hence it is equal to the expenditure function change.

[26] See Cornes (1992, pp. 222-223 and p. 239).

5. Some conclusion and a bridge towards empirical analysis

Local public services run as consumption goods to resident households as well as inputs in local firms production processes by influencing their costs and consequently their final prices. This insertion in consumption and productive decisions processes occurs, first of all, throughout the level and the dynamics of tariffs, so a crucial role is played by the productive efficiency pushing up or down the costs of the firm producing the service. Secondly, the public service enters consumer utility as well as production processes of firms supplying final goods throughout the quality of provision, that, combined with specific environmental characteristics of the area, determines the degree by which this spreads positive externalities all around.

The Propositions of previous section point out that in order to ascertain the impact of efficiency and quality on final good prices and on consumer welfare is crucial to derive and analyse the consumer demand function, the firms conditional demand function of the private component of the public service, as well as the inverse demand functions for the public good (non-rival) component of this by business users and consumer users, i.e. the so called virtual prices. We derive all these functions but it is a task of empirical estimation of these functions to derive numerically the dimension of this impact. Actually it is not, for lack of data and information, an easy task, even referring to linear cost functions as we did. The latter hypothesis however is simplifying the theoretical model as, in the main formulas, it appears straightforward the role of the derivative of unitary cost function with respect to business tariffs and the externality.

In any case, Proposition 1 clarifies that the inflationary push of productive inefficiency directly depends, as it is intuitive, both on the mark-up realised in the market of final goods and the mark-up allowed to the RLPU, but it depends also on the "technical coefficient" of public service input acquired by the oligopolistic industry of final good j. According to Proposition 2, instead, the effect on final price j of a quality reduction in general cannot be signed, as it depends on two opposite forces: a reduction of RLPU variables cost and a decrease of the externality, the latter depending on function which describes the way by which quality gives rise to a public input. When this effect is relevant the impact of quality reduction (increase) may be indeed inflationary (deflationary).

For both impact effects on the final price, a relevant role is played by the degree of competition on market of final goods – here represented by the term (1/*n*) - and of regulation pressure on the public utility management – here enlightened by the parameters μ, P^0 and m^0.

Finally, according to Proposition 3, we have that changes in productive efficiency produce two effects on consumer welfare: via tariff for domestic users, t^h, and via price of final good, p_j. This effect is surely negative and has also a negative impact on Cost-of-living (and affordability) index. According to Proposition 4, instead, we have that changes in quality produce three effects on consumer welfare: once again via tariff for domestic users and via price of final good *j,* but also directly via the externality, *G.* The effect of a decrease of quality will be negative, taking into account of its positive external effect, but it could be, somewhat paradoxically, positive if there is a corresponding significant reduction of tariff for domestic users and final goods prices.

The sign and the numerical dimension of these effects could be ascertained only with a specific empirical analysis, giving us some appropriate estimation of cost and demand functions. Indeed, this paper has tried to put clearly on the ground the main theoretical arguments for building this desirable econometric model. In the meantime, we resort in the Appendix to an input-output analysis, at a local level, for deriving some numerical estimates of the expression obtained in Proposition 1.

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Appendix

Measuring the impact of production costs changes of public utilities on final prices: some calculations thorough input-output analysis

In order to obtain empirical estimations of the impact of efficiency and quality of a given local public utility on final good prices and on consumer welfare, along the Propositions of our model, we should derive econometric estimates of the consumer demand functions (2a), (2b) and (4), and firms' conditional demand function of the private and public components of the public service, (18) and (19). Further, we should estimate the unitary public utility cost function and the elasticities of demand for the public service included in (25). We also should have a mathematical expression of the technological relationship between quality and externality effect synthetized in (12). Clearly it is not an easy task, as most of these data and informations are not available at local level. However, some numerical calculations can be obtained by using an input-output matrix with reference to a specific local economy, where one or more local public utilities are providing services to an industry.

In this respect, Istituto Regionale per la Programmazione Economica Toscana (IRPET), an Italian research institute in regional economics, has got a detailed regional input-output matrix, which is also decentralised at the level of each one of the nine Provinces of Tuscany (Italy). So, for carrying on a numerical exercise, we have chosen to consider Prato, the most industrialised Province of the region, where there is a relevant textile industry with more than four thousand local firms competing each other and within the international market, a so called "industrial district".

From the IRPET I-O matrix we may pick up, with reference to the last year available, 2006, two coefficients: $a_{ET} = 0.036475$ and $a_{WT} = 0.003323$. The first one represents the input flow of *Energy and Gas* (E) employed in the production branch labelled as *Textile industry* (T) of the district of Prato, and the second one the input flow from *Water* (W) to *Textile industry*. According to our model notations (see (18)), we may transform the two coefficients in such a way:

$$a_{ET} = \frac{t_E^f q_E(.)}{p_T x_T} = \frac{t_E^f}{p_T}\frac{\partial c_T}{\partial t_E^f};\; a_{WT} = \frac{t_W^f q_W(.)}{p_T x_T} = \frac{t_W^f}{p_T}\frac{\partial c_T}{\partial t_W^f}$$

where, now, p_T must be interpreted as the price, in base year, of the *composite textile good* from the branch. Consequently, we get the following two equations:

$$\frac{\partial c_T}{\partial t_E^f} = \frac{p_T}{t_E^f} 0.036475; \quad \frac{\partial c_T}{\partial t_W^f} = \frac{p_T}{t_W^f} 0.003323.$$

Now, by applying $\Delta p_T = \gamma_T \frac{\partial c_T}{\partial t_k^f}\Delta t_k^f,\, k = E, W$, and by using for the mark-up a value approximately equal to one (given the high elasticity of demand of the good and n=4337)[27], we get respectively:

$$\frac{d\log p_T}{d\log t_E^f} = 0.036475; \quad \frac{d\log p_T}{d\log t_W^f} = 0.003323.$$

According to these estimates, an increase of 10% of *Energy* (*Water*) business tariff implies an increase of 0,36% (0,033%) in the price of the *composite textile good*.

Given (26), we can link this effect to changes in effective production costs of the public utilities supplying *Energy* and *Water* to textile firms of Prato, as in (28) of Proposition 1 (changes in productive inefficiency) and in the first part in (29) of Proposition 2 (changes in quality), by writing down:

$$\frac{d\log t_k^f}{d\log c_{PU}^k} = \frac{b^f c_{PU}^k}{t_k^f} = 1 + \frac{T_k^f}{t_k^f} \equiv \Gamma_k > 1, \quad k = E, W,$$

where, from (13), $c_{PU}^k \equiv [c_k(G_k) + a_k]$ and $\frac{\partial c_{PU}^k}{\partial a_k} > 0, \frac{\partial c_{PU}^k}{\partial G_k} > 0$. Hence, we get:

$$\frac{d\log p_T}{d\log c_{PU}^E} = 0.036475\,\Gamma_E; \quad \frac{d\log p_T}{d\log c_{PU}^W} = 0.003323\,\Gamma_W,$$

---

[27] With a elasticity of demand say of 2.5 we have $\gamma_T = \frac{4337.2{,}5}{4337.2{,}5 - 1} \cong 1.$

where, given a higher degree of competition in *Energy and Gas* sector than in *Water* sector, it will probably be $\Gamma_W > \Gamma_E > 1$.

If we leave out of consideration the structure of our model, we may refer to the nominal I-O model by which the vector of prices $\boldsymbol{p}$ is, in a general equilibrium context, linked to the vector of value added coefficients $\boldsymbol{c}$ by the well known matricial structure: $\boldsymbol{p}=\boldsymbol{c}(\mathbf{I}-\mathbf{A})^{-1}$. By this system of equations we can evaluate the impact – the direct one and indirect one, throughout the effects on intermediate goods purchased by the *Textile branch* - on final price of a change of factors cost, and then tariffs, in the sectors of *Energy* and *Water*. The result of the matrix inversion tells us that the 2,91% of the final price of the composite textile good is given by *Energy* factors cost and the 0,15% by *Water* factors cost. Actually, these effects are very limited, if we compare them with the direct effects and those coming from imported intermediate goods. However, these effects result to be high if we compare them with those referring to other branches, outside the textile district, in Province of Prato. For instance, the effect of *Water* factors cost on *Textile industry* final price, although limited, is more that three times that one on the price of *Mechanics* branch and about the double of that one on the price of *Paper* branch.

Fig. 1: Equilibrium price of the final good *j* as a function of tariff and externality effect of the public service

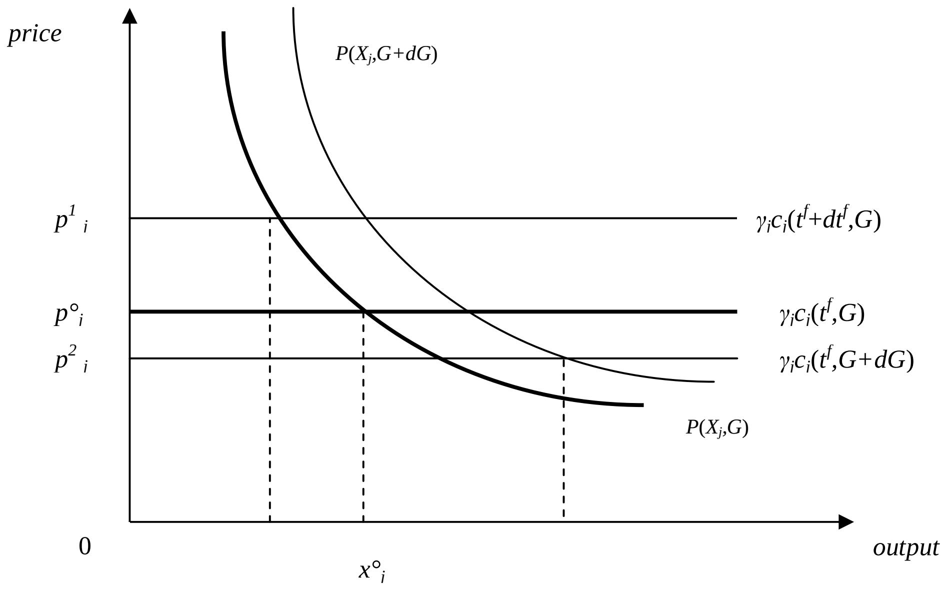

Fig. 2: the level of productive inefficiency chosen by the RLUP manager according to μ

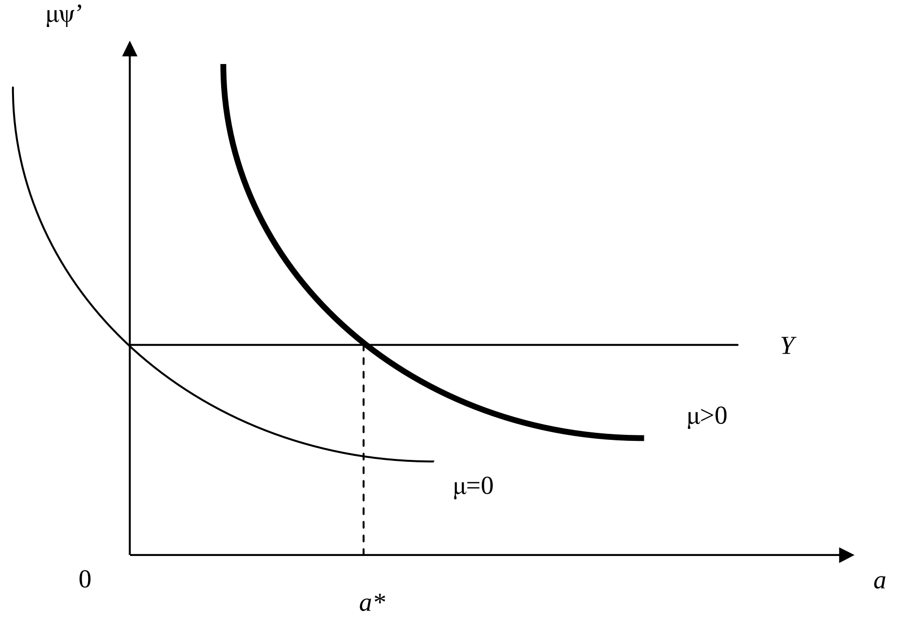

Fig. 3a: the relationship between t^u and a

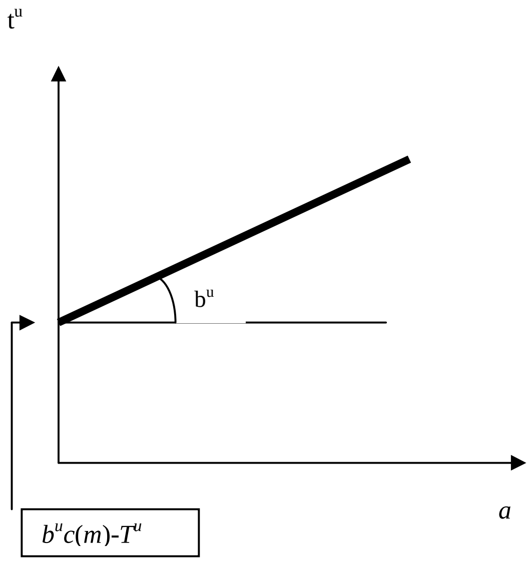

Fig. 3b: the relationship between t^u and m

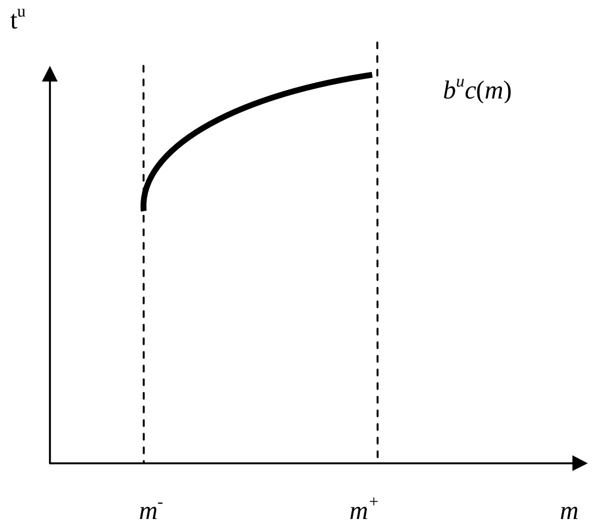

Fig.4: the RLUP choice of quality level within the mini-max interval and given two targets of m^0