An Incentive Mechanism for Decentralized Water Metering Decisions

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Abstract

The rateable value system for charging water services has been long demised by economists on the grounds that it is inefficient and that it is built on cross subsidies. However, very few of these economists (not to say none) have studied the inefficiencies brought about by universal metering or the conditions under which decentralized water metering decisions are optimal. The decision where to install water meters generally rests on either the consumer or the company providing the service. This paper shows that if left unregulated, both the consumer's and the company's decentralized water metering decisions are sub-optimal. This is because the firm when installing meters, does not take into account the fall in consumer surplus and the consumer, when voluntarily installing a meter in his dwelling, does not take into account the effect of his decision on the company's profits. To solve this externality problem and make the decentralized decision optimal, an incentive mechanism is proposed. This mechanism works through a series of reciprocal compensations whereby both the consumer and the company can reach the socially optimal solution in a decentralized way. The mechanism is materialized through a Coasian property rights approach where the parties involved reach the efficient solution by bargaining over welfare gains. To illustrate the incentives involved in metering water consumption two water concessions in Argentina are studied: Buenos Aires and Córdoba. Conclusions and policy recommendations are drawn from the theory and the two practical cases.

JEL Classification L95

1. Introduction

Pricing a natural resource such as water is no easy task. Firstly, it is hard to establish how much consumers are willing to pay for it, secondly it is hard to determine an opportunity cost for this resource in case of shortages, and finally because water consumption may involve hard-to-measure externalities. An excessively low consumption endangers population health, and can contribute to the spread of diseases. On the other hand, a high level of consumption can cause a drop in the level of water reservoirs hampering service continuity mainly in hot seasons.

When users consume water, they do not consider the effect of this consumption on future resource availability, nor do they internalize their decision on the consumption level of others. If water services are not charged based on actual consumption, the user lacks an incentive to curb consumption and consequently may incur in waste. In these cases, prices act by signaling the consumer the relative abundance of this resource. At times of scarcity (drought), the price of the resource should be higher to ration consumption and reflect the situation of relative shortage.

The price reflecting the resources that must be committed by society for the production of one additional unit of water is marginal cost. Only in the event that society is willing to pay the cost of producing and distributing the last cubic meter of water, must it be produced. What are the defining concepts of marginal cost? Obviously, the costs of extracting the water, treating it for drinking purposes, distributing it and collecting the effluents, but also the opportunity cost of the water used (drop in the level of water reserves). This concept of marginal cost is hard to quantify mainly when there are limits to the ability to provide service, indivisibility of capacity expansion, or when demand is seasonal. This is why it is not generally adopted as the rule for pricing drinking water services. The literature on water rates is vast and it is not the purpose of this article to review it but an excellent treatment of this subject can be found in World Bank (1977), Albouy (1983), OECD (1987) and Sabbaghi and Spulber (1994).

Currently in most Argentine provinces[1] (as in several other countries) water services are charged following a rateable value system based on the physical features of the dwelling like covered area, total area, land price, age of the building etc. This rate scheme has several problems: Since real consumption is not charged, customers consume until their willingness to pay is equal to the marginal price (zero) and incur in waste. It does not help when trying to detect leaks in pipes which leads to overproduction of water. It also generates a thick weave of cross subsidies between customers sometimes without any relationship with willingness to pay. Lastly, the fixed monthly fee may be greater than the utility the consumer gets from the service and since service disconnection is not allowed, the user may end up getting a negative net utility level from the service.

Since this rate structure is so inefficient several provincial and municipal governments are imposing mandatory universal metering[2]. However, universal metering is expensive and may not even be justified on economic grounds. If the decision to meter is not the consequence of a careful benefit - cost analysis, metering consumption may entail a reduction in consumer surplus, an increase in deadweight loss and an increase in metering costs that may more than offset any reductions in water production costs. If this is the case, then metering is not a profitable investment and should not take place. This paper addresses many important issues on the economics of water metering namely, when to meter, whom to meter, who should bear

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[1] See Artana et al. (1999) for an analysis of the concessions in Corrientes and Buenos Aires.

[2] This is the case of (among others) Córdoba, Mendoza, Corrientes and Buenos Aires

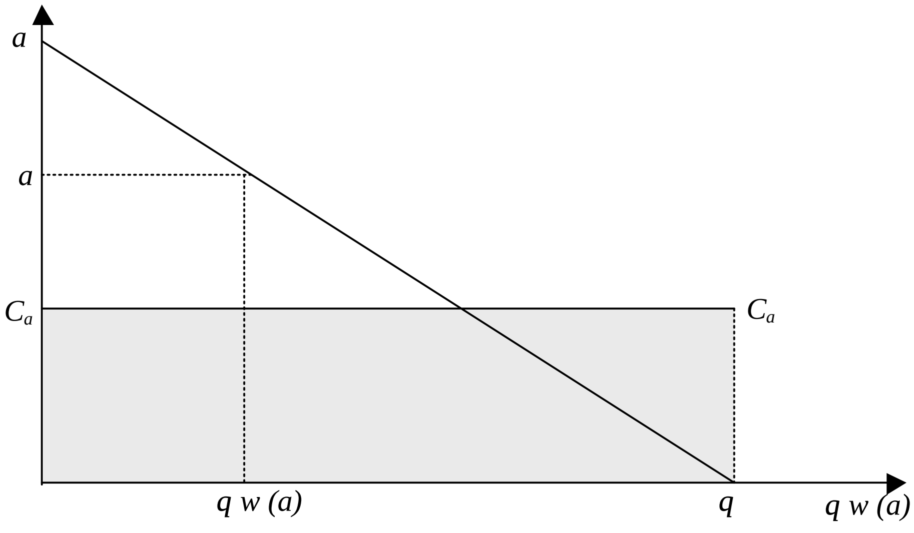
the cost of metering and who should decide when and where to meter. The paper proceeds as follows: Section 2 lays the main argument, that is when to meter. Section 3 deals with the question of who should be and who should not be metered and more importantly who should make the decision to meter. This section shows that, if left unregulated, both the consumer's and the firm's water metering decisions are sub-optimal. Section 4 introduces an incentive mechanism whereby decentralized decisions become optimal and Pareto efficiency is restored. Section 5 presents a Coasian property rights approach where both the firm and the user can reach the optimal solution through bargaining. Lastly, Section 6 illustrates two practical cases of water concessions in Argentina. The paper concludes making policy recommendations drawing from the theory and the two practical cases.

2.Theoretical background

There is a firm that provides water services to a city with N dwellings, each of which has a water demand function of $q\,w(a)$ where q is a demand parameter (say, the number of dwellers per house) and $w(a) < 1$ is the unitary water demand function (i.e per dweller). The water company provides services both on a metered and unmetered basis. For unmetered water services it collects a fixed monthly charge h per dwelling based on its physical features i.e. area, covered area, property age etc. For the metered service, the company collects a different fixed monthly charge j h (presumably with $j < 1$) and a volumetric charge of a [\$ / m^3] for consumption in excess of a minimum threshold qw^*. If the dwellers consume less than qw^*, they will only be charged the fixed fee j h. If they consume more than the minimum threshold, they will have to pay consumption in excess of the threshold, $T(a) = j\ h + q\ a\ [w(a) - w^*]$[3]. Metering cost C_m is a monthly expense per dwelling that includes meter purchase and installation, meter reading and maintenance and is assumed to be borne by the company.

When water consumption in not metered, the marginal water rate is zero and demand per dwelling is maximal at q (as $w(a)$® 1). After the meter is installed and actual consumption is charged, demand falls to $q\ w(a) < q$. C_a is the per unit water production cost. Graph 1 illustrates the water demand levels of a dwelling with consumption parameter q and for different values of the volumetric charge a.

Graph 1: Change in demand with metering



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[3] Alternatively, the consumption level of the dwelling could fall below the threshold by having a high unitary water demand $w(a)$ but a very low q.

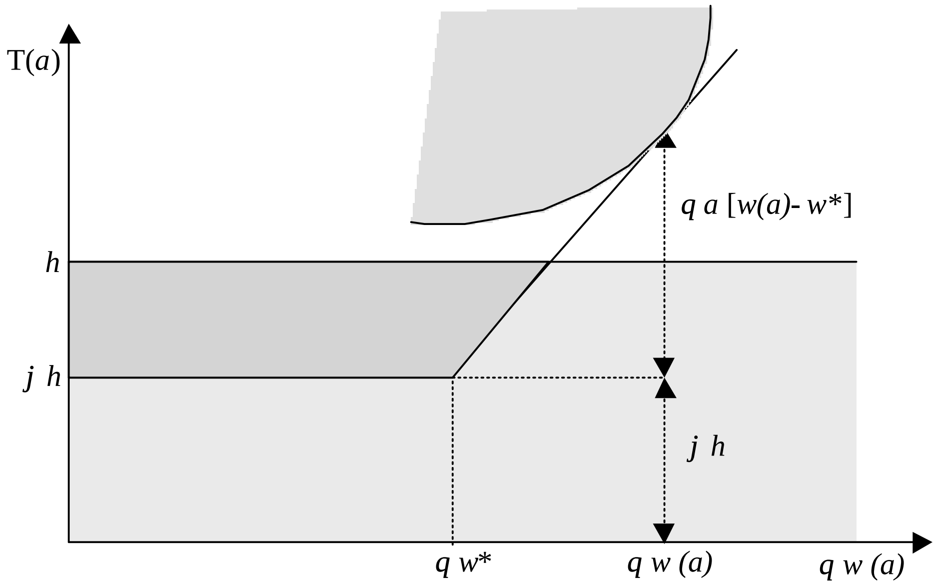
Before metering, the dwellers reach their satiation levels (q) as marginal consumption is not charged. When the meter is installed, dwelling consumption falls to *q w(a)*. The shaded rectangle shows pre metering water production costs q C_a per dwelling.

The fixed rateable monthly fee h ~ [h_, ̄h] is a random variable with density g(h) and cumulative density G(h). Demand parameter q is also a random variable with conditional density f(q / h) and cumulative density function F(q / h). q is assumed conditional on h because as h increases (presumably because the house is larger or because it has a garden) average q should also increase as water consumption (after the meter has been installed) should be higher. If the demand parameter q is related to the number of dwellers, it is reasonable to assume that a larger house (higher h) will lodge more people than a smaller one (lower h) and consequently expected consumption after metering should also be higher. The total number of water connections the company has (both metered and unmetered) is given by:

$$N_T = N \int_{\underline{h}}^{\bar{h}} \left\{ \int_0^{\bar{q}} dF(q/h) \right\} dG(h) = N$$

The monthly payment T(*a*) collected by the company is illustrated in Figure 2 for a dwelling with monthly consumption q*w(a)* **in excess** of the minimal threshold *qw**, rateable monthly charge h before metering and j h after the meter has been installed (with j presumably < 1).

Graph 2: Monthly payment T(*a*) before and after metering



2.a. The decision to meter consumption

The decision of whether or not to install a meter depends on who makes the decision. If that decision is left to an omnipotent social planner (the regulator R) he will install meters in those dwellings that bring about an increase in marginal welfare. For a generic dwelling with fixed monthly fee h and demand parameter q, welfare before metering will be

$$W_{before} = q \int_0^{\infty} w(x)\, dx - h + (0 - C_a)q + h = q \left[\int_0^{\infty} w(x)\, dx - C_a \right]$$

After the meter is installed with metering costs borne by the company and actual consumption is charged, the welfare function becomes

$$W_{after} = q \left\{ \int_0^{a} w^{*}\, da + \int_a^{\infty} \left[w(x) - w^{*} \right] dx \right\} - f\, h + q\, \left\{ (0 - C_a) w^{*} + (a - C_a)\left[w(a) - w^{*} \right] \right\} + f\, h - C_m$$

The variation in welfare will be given by

$$\Delta W = q \left\{ a w^{*} + \int_a^{0} w(x)\, dx - C_a w^{*} + C_a q + (a - C_a)\left[w(a) - w^{*} \right] \right\} - C_m$$

Rearranging,

$$\Delta W = q \left\{ \int_a^{0} w(x)\, dx + (a - C_a) w(a) - (0 - C_a) \right\} - C_m = q\ DWL(a) + q\ C_a - C_m$$

This is, charging the consumer based on actual consumption will bring about an increase in welfare *(ΔW* > 0), only if water production costs before metering (θ C_a) were high enough to compensate for the dead weight loss (*DWL(a)* < 0) created by the increase in the volumetric charge and metering costs (C_m). Obviously, this condition will not always hold. For a given volumetric charge a, metering will make sense in those dwellings where water was being wasted (q is high), whenever water production costs C_a are high, or when metering costs C_m are low. The cutoff demand parameter θ will be

(1) $$\Delta W = 0 = q_R^{*} \left\{ \int_a^{0} w(x)\, dx + (a - C_a) w(a) - (0 - C_a) \right\} - C_m = 0$$

The term within brackets in (1) has to be positive, which in turn means that for metering to be welfare enhancing (ΔW > 0), the increase in the company's marginal profits has to more than offset the fall in consumer surplus and metering costs C_m. The higher the q_R* in (1) the more positive the equation will be and the greater will be the welfare gains brought about by metering.

Solving for the cutoff q_R*,

(2) $$q_R^{*} = \frac{C_m}{\int_a^{0} w(x)\, dx + \left[(a - C_a)\, w(a) - (0 - C_a) \right]}$$

Meters should be installed in all dwellings with $q > q_R^*$. In these dwellings, the increase in the company's marginal profits will more than offset the fall in consumer surplus and metering costs bringing about an increase in welfare. The optimal number of meters from the regulator's perspective will be

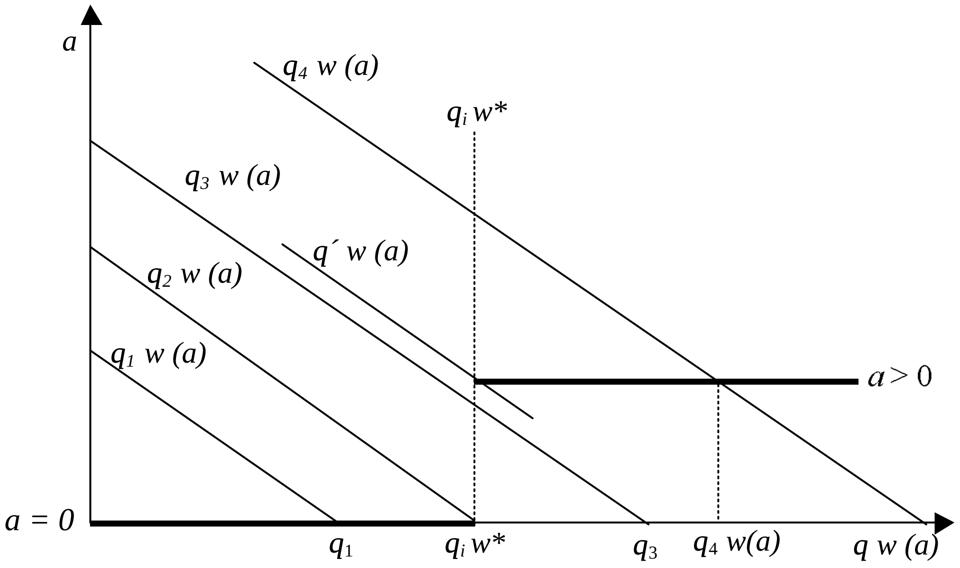
$$N_m^R = N \int_{\underline{h}}^{\bar{h}} \left\{ \int_{q_R^*}^{\bar{q}} dF(q\ /h) \right\} dG(h)$$

Furthermore, if (ex ante) satiation levels fell below or at the minimal threshold w^* it would not make sense to meter. This is a key element for a regulator when designing these minimum threshold levels. The following Lemma demonstrates this more formally.

Lemma 1: For dwellings with ex – ante satiation levels below or at the threshold , $q^*_R \to \infty$ *and* $N^R_m \to 0$*, then no meters should be installed.*

Proof: Given the existence of the threshold q_i w^* for each kind of dwelling, there are four cases to be studied and these are illustrated in Graph 3. The Graph shows demand functions for four kinds of dwellings compared to a generic threshold q_i w^*: q_1 that falls below its threshold, q_2 that falls right on the threshold, and q_3 and q_4 that fall above it. Since the marginal rate $a = 0$ below the threshold, type q_1 consumers will consume water until they are satiated at q_1 . q_2 consumers will also reach satiation but right at their threshold level q_2 w^*. Type q_3 consumers will also consume at the threshold but they will not reach satiation because to be able to do that they should pay a marginal water rate a greater than their willingness to pay. Only type q_4 consumers will consume above the threshold because only they can afford the marginal water rate.

Graph 3: Consumption below and above the threshold



To prove Lemma 1 we need to analyze case by case. It is clear that for type q_1 consumers, no meters should be installed as consumption would not fall. This type of consumers will consume at their satiation level because they still face a marginal water rate equal to zero and $w(a)$ þ 1. More formally and with the help of equation (2) we have that

$$(2) \qquad q_R^* = \frac{C_m}{\int_0^0 w(x)\,dx + \left[(0 - C_a) - (0 - C_a)\right]} \rightarrow \infty \quad \text{and therefore } N^R_m \rightarrow 0 \quad \text{Q.E.D}$$

The same result applies to type q_2 consumers. These will also reach satiation as they also face a marginal rate of zero. This result is indicating that *universal metering is incompatible with uncharged consumption thresholds. Dwellings with ex - ante satiation levels at or below the threshold should not be metered*. Put differently, if regulators want to meter they should never set thresholds above satiation levels.

Type q_3 consumers however do reduce their consumption levels when the meter is installed. Before metering, they satiated themselves at q_3 but after metering they cut consumption down to the threshold w^*q_3. This is because they cannot afford the marginal water rate a set by the regulator (a is above their willingness to pay). Since there is indeed a reduction in consumption, for some of these consumers metering will make sense. For type q_3 consumers equation (2) looks like the following:

$$(2) \qquad q_R^* = \frac{C_m}{\int_0^0 w(x)\,dx + \left[(0 - C_a)w^* - (0 - C_a)\right]} = \frac{C_m}{C_a(1 - w^*)}$$

The optimal number of meters will depend on the ratio of the costs involved and the threshold level. The higher metering costs, the lower water production costs and the higher the threshold, the fewer meters should be installed and vice versa. For type q_4 consumers equation (2) looks exactly the same as the original equation (2).

3.Decentralized metering decisions

Now assume that the regulator sets the threshold below satiation levels ($q\,w^* < q\,w(a)$) and decides to leave the decision on where to install the meter to the company or the consumer. It is easy to show that neither of these alternatives leads to a socially optimal solution.

Lemma 2: If left unregulated, both the consumers and the company will install a sub–optimal number of meters

Proof**:** If the company providing the water service is in charge of deciding where to install meters, it will do so by choosing to meter those dwellings that will increase its marginal profits. Therefore, for a dwelling with rateable fixed charge h and a demand parameter q, the company's benefits before metering consumption will be:

$$p_{before} = h + (0 - C_a)q$$

After incurring C_m and charging the consumer based on actual consumption, the company's marginal profits are:

$$\pi_{after} = q\left\{(0 - C_a)w^* + (a - C_a)\left[w(a) - w^*\right]\right\} + \varphi h - C_m$$

The change in company’s marginal profits,

$$\Delta\pi = q\left\{(a - C_a)\, w(a) - aw^* - (0 - C_a)\right\} - (1 - \varphi)h - C_m$$

And the cutoff demand parameter q,

$$\text{(3)} \qquad \Delta\pi = 0 = q_F^*\left\{(a - C_a)\, w(a) - aw^* - (0 - C_a)\right\} - (1 - \varphi)h - C_m = 0$$

If φ is ≤ 1, the term within brackets in (3) has to be positive. This means that the higher the q_F*, the higher the company’s increase in marginal profit and therefore the more the incentive to meter consumption. Solving for the cutoff q_F*,

$$\text{(4)} \qquad q_F^* = \frac{C_m + (1 - \varphi)h}{\left[(a - C_a)\, w(a) - (0 - C_a)\right] - a\, w^*} \neq q_R^*$$

For each value of h and for a given marginal rate a, the company will install meters in those dwellings with $q > q^*_F$. It can be easily seen that for $\varphi = 1$, $q_F^* < q_R^*$ and the firm’s optimal number of meters N_F^m will be larger than the optimal N_R^m. That is, the firm will install more meters than socially optimal[4]. The optimal number of meters from the company’s point of view is now

$$N_m^F = N \int_{\underline{h}}^{\bar{h}} \left\{ \int_{q_F^*}^{\bar{q}} dF(q/h) \right\} dG(h) \neq N_m^R \qquad \textit{Q.E.D}$$

The company will install a sub-optimal number of meters, because when switching to the metered regime, it does not take into account the fall in consumer surplus caused by the increase in the marginal water rate a (an externality). The company however, could offer the consumer a reduction in *h* (through φ) that could offset the fall in consumer surplus and make the consumer accept the change in regime. But the company has no incentive to do so voluntarily because lowering *h* would cause a first order fall in the firm’s revenues and profits.

The second part of Lemma 2 is demonstrated as above but in this case for the consumer. This one will have the company install a meter in his dwelling and start paying for actual consumption as long as he experiences an increase in consumer surplus. Before metering consumer surplus is

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[4] See Appendix I for a formal proof

$$CS_{before} = q \int_0^{\infty} w(x)\, dx - h$$

After having the meter installed and paying *m* to the company for metering costs the consumer gets

$$CS_{after} = q \left\{ \int_0^{\infty} w^* da + \int_a^{\infty} \left[w(x) - w^* \right] dx \right\} - \varphi h - m$$

The change in consumer surplus will be given by

$$\Delta CS = q \left\{ aw^* + \int_a^0 w(x)\, dx \right\} + (1-\varphi)h - m$$

And the equilibrium equation,

$$(5) \qquad \Delta CS = q_C^* \left\{ aw^* + \int_a^0 w(x)\, dx \right\} + (1-\varphi)h - m = 0$$

The term within brackets in (5) is negative and that the only way that there can be an increase in consumer surplus will be through a decrease in the fixed charge ($\varphi < 1$). The reduction in h (through φ) should be high enough to offset the term within brackets and meter charges *m*. It is also clear from (5) that for those dwellings with $q > q^*_C$ installing a meter would entail a fall in consumer surplus (equation (5) becomes more negative). Consumers will therefore voluntarily install meters in those dwellings with $q < q^*_C$ as long as there is a reduction in the fixed charge h ($\varphi > 0$). Otherwise no voluntary meter take – up will take place. The optimal cutoff θ from the consumer's point of view will be

$$(6) \qquad q_C^* = \frac{(1-\varphi)h - m}{\int_0^a w(x)\, dx - aw^*} \neq q_R^*$$

Again, if it is up to the Company to offer a reduction in the fixed charge h to have some users switch to the metered regime it will not happen. This is because a reduction in h causes a direct reduction in the Company's revenues and benefits. The optimal number of meters from the consumer's perspective and assuming a reduction in the fixed charge h is given by

$$N_m^C = N \int_{\underline{h}}^{\bar{h}} \left\{ \int_0^{q_C^*} dF(q/h) \right\} dG(h) \neq N_m^R \qquad \text{Q.E.D}$$

Here the difference stems from another externality: when choosing where to meter the consumer does not take into account the fall in water production costs or the increase in the company's marginal profits brought about by the decrease in consumption (and the increase in the marginal water rate). He only cares about the impact of the new regime on consumer surplus so he acts accordingly. Here there is a clear conflict between the Company and the user: for the latter to voluntarily switch to the metered regime he needs a cut in the monthly fee *h* but a reduction in *h* will entail a first order fall in revenues and profits for the company. If the decision to set φ is left to the firm, there will be no discounts and no consumers will voluntarily switch.

4. An Incentive Mechanism

So far it was demonstrated that without any kind of intervention by the regulator the decentralized decisions are sub – optimal. Only by sheer chance can the three thetas coincide and this is because there are externalities involved in metering water consumption. How can the decentralized decisions be optimal? The natural answer to this question would be to make both agents internalize the externalities. Only in this case would the three solutions coincide.

Lemma 3: Under the incentive mechanism the firm will install the socially optimal number of meters

Proof: Assume that the regulation establishes that the firm is responsible for choosing where to meter but at the same time it has to comply with the following demands. It has to compensate the user for the fall in consumer surplus and it has to pay for metering costs. Box 1 illustrates the payments involved.

Box 1: If the firm chooses where to install a meter then:

i. The regulator sets $\varphi = 1$

ii. The firm pays $q\left[\int_0^a w(x)dx - aw^*\right]$ to the user to be metered

iii. The company incurs C_m

If the firm proceeds as the regulation establishes then, for a generic dwelling:

$$\pi_{before} = h + (0 - C_a)q$$

And after incurring metering costs and compensating the user for the fall in consumer surplus, the firm gets:

$$\pi_{after} = \theta \left\{ (a - C_a)w(a) - aw^* - \int_0^a w(x)\,dx + aw^* \right\} + h - C_m$$

The change in the company's marginal profits will be

$$\Delta\pi = \theta \left\{ (a - C_a)\,w(a) - (0 - C_a) - \int_0^a w(x)\,dx \right\} - C_m$$

$$\Delta\pi = \theta_F^* \left\{ (a - C_a)\,w(a) - (0 - C_a) - \int_0^a w(x)\,dx \right\} - C_m = 0$$

Again, solving for the cutoff θ,

$$\theta_F^* = \frac{C_m}{\left[(a - C_a)\,w(a) - (0 - C_a)\right] + \int_a^0 w(x)\,dx} = \theta_R^*$$

And the decentralized decision becomes socially optimal. The trick here was to make the firm internalize the externalities created by the increase in the marginal water rate a. That is, the regulator set a Pigouvian tax to the firm equal to the externality it created. Now, what about the consumer? Is he better off with this incentive mechanism? It turns out that he is the same off as he was before metering generating a Pareto optimal allocation of resources. The changes in consumer surplus under the new mechanism (before and after receiving the compensating payment from the firm):

$$CS_{before} = \theta \int_0^\infty w(x)\,dx - h$$

$$CS_{after} = \theta \left\{ aw^* + \int_a^\infty w(x)\,dx + \int_0^a w(x)\,dx - aw^* \right\} - h$$

$$CS_{after} = \theta \left\{ \int_a^0 w(x)\,dx + \int_0^\infty w(x)\,dx + \int_0^a w(x)\,dx \right\} - h$$

$$CS_{after} = q\int_0^{\infty} w(x)\,dx - h$$

$$\Delta CS = q\int_0^{\infty} w(x)\,dx - h - q\int_0^{\infty} w(x)\,dx + h = 0 \qquad \text{Q.E.D}$$

Under the incentive mechanism the consumer is the same off as before metering reaching the efficient solution.

Lemma 4: Under the incentive mechanism the user will choose to install a meter in his dwelling only if it is socially optimal to do so

Proof : Now if it is the consumer who is entitled to choose whether or not to install a meter, then the regulation should establish the following rules: the firm must reimburse the consumer with any increases in marginal profits brought about by metering. Also the consumer should pay for metering costs himself and there should be no discounts in the monthly fixed charge h. Box 2 illustrates the side payments involved.

Box 2: If the consumer chooses where to meter then:

i. The regulator sets $j = 1$

ii. The user gets a refund of $q\left\{\left[(a - C_a)w(a) - (0 - C_a)\right] - w^*a\right\}$ from the firm

iii. The user pays for metering costs through m

Consumer surplus before metering will be again

$$CS_{before} = q\int_0^{\infty} w(x)\,dx - h$$

After receiving the payment from the company the consumer gets

$$CS_{after} = q\left\{aw^* + \int_a^{\infty} w(x)\,dx + \left[(a - C_a)w(a) - (0 - C_a)\right] - aw^*\right\} - h - m$$

And assuming that $m = C_m$ the equilibrium condition is given by

$$\Delta CS = \theta_C^* \left\{ \int_a^0 w(x)\,dx + \left[(a - C_a)w(a) - (0 - C_a)\right] \right\} - C_m = 0$$

Solving for the cutoff θ,

$$\theta_C^* = \frac{C_m}{\left[(a - C_a)\, w(a) - (0 - C_a)\right] + \int_a^0 w(x)\,dx} = \theta_R^*$$

Again, then the decentralized decision becomes socially optimal. Besides, the firm ends up the same off as before metering generating a Pareto increase in welfare. The firm now gets

$$\pi_{before} = h + (0 - C_a)\theta$$

And after reimbursing the user with the increase in marginal profits the firm gets

$$\pi_{after} = \theta\ \{(a - C_a)w(a) - aw^* - (a - C_a)w(a) + (0 - C_a) + aw^*\} + h - C_m + m$$

$$\pi_{after} = h + \theta(0 - C_a)$$

$$\Delta\pi = \theta\,(0 - C_a) - \theta\,(0 - C_a) + h - h = 0$$ *Q.E.D*

Again, optimality is restored. The mechanism induces both parties to reach the socially optimal solution in a decentralized way by means of mutual compensations.

5.A Coasian property rights approach for internalizing externalities

The key in achieving the optimal solution through a decentralized mechanism was to make both the firm and the user internalize the externalities that they created. In theory this is a very simple thing to do as it was demonstrated. The problem arises when trying to implement this mechanism in practice since the firm has no way of calculating consumer surplus to then write a check for that amount to the user whose consumption is about to be metered. Nevertheless, this is a typical externality problem that can be solved using a Coasian property rights approach. This is because property rights over charging regimes can be easily assigned to both parties and the transaction costs involved in bargaining are very low. Besides, in this scenario there are only two agents involved: the Company and the user and bargaining between them is easy and unexpensive.

Suppose that the firm is responsible for deciding where to install meters but following the rules set by the regulator in Box 1. That is, set $\varphi = 1$, pay the user a value equal to his net consumer surplus and incur metering costs. Suppose furthermore that the consumer has the right to stay with the rateable value system if he / she so wishes. That is, no one can make the consumer switch to the metered regime if he / she does not wish to do so. At the same time however, the user can give up that right and switch to the metered regime in exchange for a payment from the company. This is, the company can "bribe" the consumer to make him give up that right and have him voluntarily abandon the rateable value system to switch to the metered one[5]. Of course for this to happen both the company and the consumer have to be better off or at least there has to be a Pareto improvement coming out of the bargaining process. As was demonstrated before, the incentive mechanism does just that. Let us see how this could work.

If the water company wants to install a meter in any given dwelling then, and by definition, equation (3) has to hold:

$$\Delta \pi = q_F^* \left\{ (a - C_a)\, w(a) - aw^* - (0 - C_a) \right\} - (1 - \varphi) h - C_m \geq 0$$

Then for all dwellings with $q \geq q_F^*$ the company will make more money metering consumption. However, the regulation also imposes the restriction that $\varphi = 1$ and that the firm has to "buy the right to meter" from the consumer by fairly compensating him. This compensation will be *T* dollars per dwelling. Therefore, for the firm to be willing to meter consumption the following has to hold:

$$\Delta \pi = q_F^* \left\{ (a - C_a)\, w(a) - aw^* - (0 - C_a) \right\} - T - C_m \geq 0$$

How much money would the firm be willing to pay the consumer to make him switch? Or more importantly, how much money will the customer demand as a compensation? Obviously, the user has no incentive to truthfully reveal his consumer surplus change to the firm, and the firm wants to spend as little money in the process as possible because every dollar in compensation is a dollar less in profits.

Since we cannot expect truthful revelation of preferences, these will have to come out spontaneously of the bargaining process. The firm will start making bids to the consumer until the consumer feels that he has been properly compensated. When is that? Exactly when *T* equals the fall in consumer surplus, not a penny more since giving more money to the user would imply that the firm was not maximizing profits. The maximum compensation the firm would be willing to pay is:

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[5] Gans, King and Woodbridge (2000) have suggested a similar property rights approach for telephone number portability. The user has the right to keep his phone number when switching local companies but at the same time, he can sell this right (and the number) to the current local company in exchange for a certain amount of money. The transaction will occur as long as the number portability costs per user are higher than the user's willingness to pay to keep his number otherwise porting the number would be cheaper for the company than paying the compensation to the user. Applying a property rights approach to water metering is more appropriate than in number portability though since metering costs are fully per user costs whereas number portability are mainly fixed costs that have to be sunk before any customers switch companies.

$$T = q\left[\int_0^a w(x)dx - aw^*\right]$$

Which represents the net fall in consumer surplus. Only by this payment will the consumer be fully compensated for the fall in consumer surplus caused by metering actual consumption. Replacing the value of *T* in the formula above,

$$\Delta\pi = q_F^*\left\{(a - C_a)\, w(a) - (0 - C_a) - \int_0^a w(x)\, dx\right\} - C_m = 0$$

Which is nothing but the optimal metering formula where $q_F^* = q_R^*$ and the firm will choose to install meters in only those dwellings where it is socially optimal to do so.

Unfortunately, the same property rights approach cannot be used when it is the consumer who chooses where to meter and the water company is given the right not to meter. This is, the consumer may want the firm to meter his consumption but since the firm has now the right to choose the charging mechanism it wishes, it may refuse to install the meter. The problem lies in the fact that now the consumer cannot “bribe” the firm to meter his consumption because to reach the optimal solution it is the firm that has to pay the consumer the increase in marginal profits according to the policy steps in Box 2. In other words, the firm would have to give the consumer the increase in profits brought about by its decision to meter the consumer’s dwelling. If the firm has the right not to meter then it does not have the incentive to negotiate anything with anybody and the mechanism breaks down.

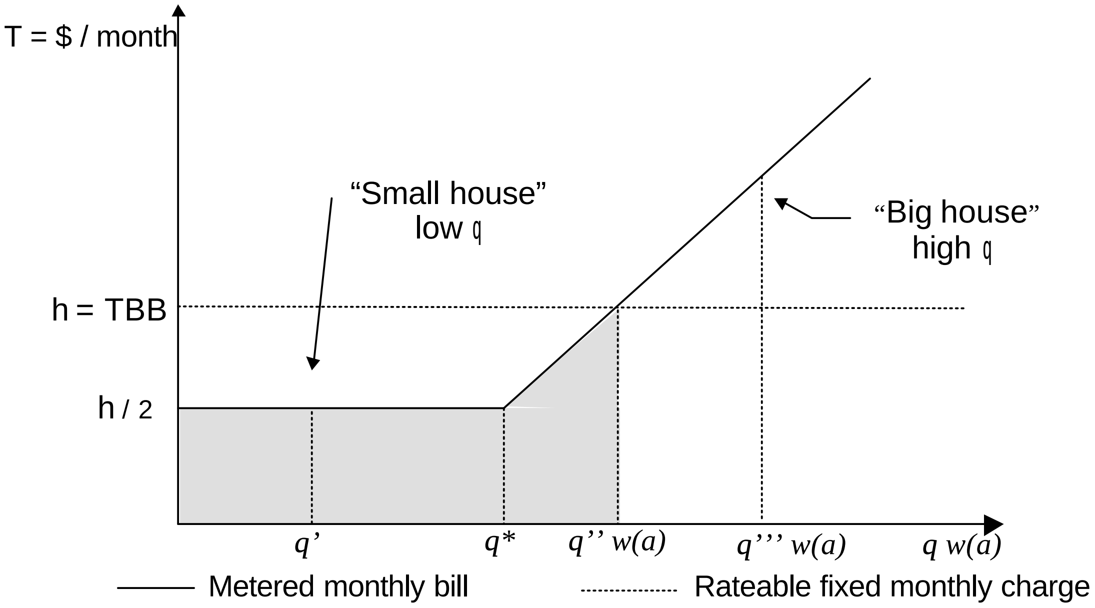
As a preliminary conclusion the following policy recommendations can be drawn from the theory so far

1. Universal metering is seldom socially optimal, and it is sub - optimal whenever there are uncharged consumption thresholds.
2. The optimal policy recommends keeping the current system of rateable monthly fixed charges which in turn implies that metering costs should be recovered through the volumetric charge a. This in turn means that a should be calculated simultaneously with the optimal number of meters. This is because were metering costs recovered through any other charge (i.e, a fixed fee like *m*), the Company should reimburse this charge to the user as it applies the optimal policy of compensating him for the fall in consumer surplus. Therefore under the optimal mechanism the Company has no other way of recovering metering costs than through the volumetric charge a.
3. The decentralized decisions are not optimal. Therefore, the Regulator has to establish some rules. These are illustrated in Boxes 1 and 2 and are based on payments from the firm to the user to reach the optimal solution.
4. Metering costs should be borne by the party making the decision to meter.
5. The Coasian property rights approach suggests that the company should be the one deciding where to install the meters and the negotiations should involve giving the user the right to choose the charging regime he pleases. At the same time however, the user can give up that right in exchange for a payment from the firm. This payment should compensate the user for the net fall in consumer surplus.

6.1. The Buenos Aires water concession: Rate structure and metering policy

The Buenos Aires Concession Company (Aguas Argentinas) has three kinds of customers: residential, non residential and empty lots. For each type of customer there is a different rate structure but all three share the same rateable fixed monthly charge called TBB (tarifa básica bimestral). There are also two kinds of rate regimes, metered and unmetered. For non residential customers metering is compulsory and metering costs are borne by the customer. For residential customers however, metering is optional and metering costs are borne by the party choosing to meter be it the Company or the consumer.

Graph 4 : Buenos Aires Concession rate structure for a residential user



The rateable fixed monthly charge TBB is calculated based on the following physical features of the dwelling: area, covered area, kind of dwelling, location and land price. Of course, and as all economists repeat tirelessly, this rate structure is plagued by cross subsidies, from rich to poor, from large houses to small ones, from expensive houses to unexpensive ones (however much water they consume) and so forth and so on.

Graph 4 shows the rate structure for a residential consumer before and after metering. According to the regulations, if the consumer switches to the metered regime he gets a 50% discount on the fixed charge (TBB) and has a consumption allowance of 30 m^3 beyond which he starts paying 0.30 $ / m^3 for water services and another 0.3 $ / m^3 for sewerage. Since either the consumer or the company can decide whether to install a meter one can easily see from Graph 3 which consumers will select the metered regime (and which will not) and which dwellings the company will select to meter and which not.

For each value of h (or TBB) all dwellings with demand parameters (and satiation levels) up to q'' will voluntarily choose to install a meter because their monthly bills will fall by half for dwellings up to q^* and between half and zero in dwellings between q^* and q''. However, and as it was demonstrated in Lemma 1, these dwellings should not be metered as their consumption levels will not fall because they pay less per cubic meter than they paid before. Besides the company's revenues fall for those dwellings that turned voluntarily to the metered regime.

For each value of h there will be a cut off q which will make both the consumer and the company indifferent to switching, this is q'' in Graph 3. For the dwelling with this parameter value the consumer's monthly bill will be $h = q'' a\,[w(a) - w^*]$ solving for q'' we get :

$$q'' = \frac{h}{a\,[w(a) - w^*]}$$

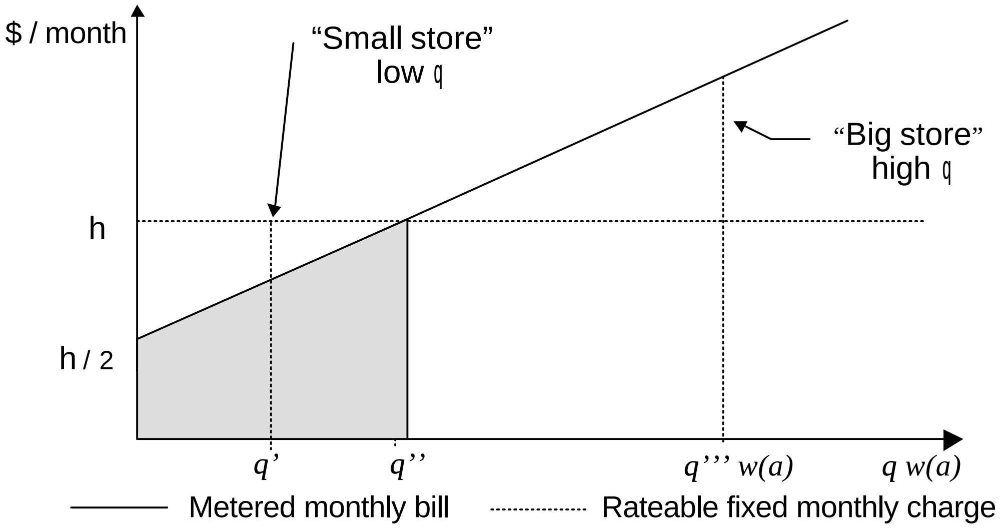
And consequently the number of pointless meters will be those installed (or to be installed) with satiation levels between zero and q'', namely

$$N_m^P = N \int_{\underline{h}}^{\bar{h}} \left\{ \int_0^{q''(a,w^*)} dF(q\,/h) \right\} dG(h)$$

However this does mean that all accounts with $q > q''$ should be metered, we know from equation (2) that only those dwellings with a q high enough to generate an increase in welfare should be metered.

The Company on the other hand will choose to meter those dwellings with $q > q''$ because by metering these dwellings it will increase revenues (See Graph 4). Since it also has to incur metering costs the Company will see an increase in marginal profits whenever the increase in revenues is high enough to cover water production and metering costs. This could happen for example for dwellings with q''' in Graph 4. However this is not the socially optimal cut off q because it does not include the fall in consumer surplus generated by the increase in the marginal water rate a. q''' will be lower and consequently the number of meters will be higher than the socially optimal.

Graph 5 : Buenos Aires Concession rate structure for a commercial user



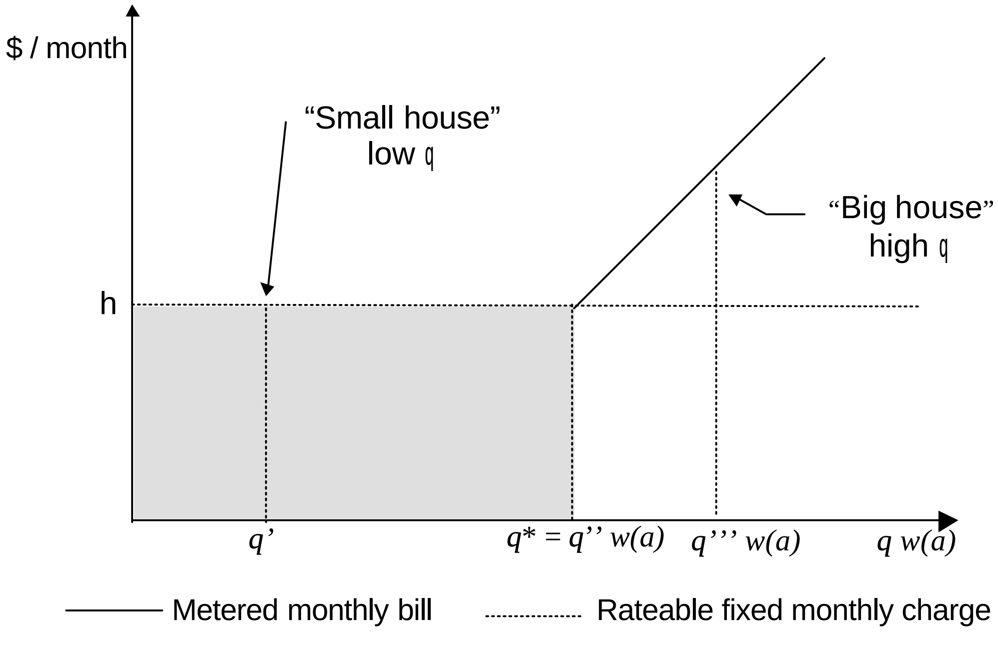
For a commercial user though the rate structure does not have a threshold, they start paying based on actual consumption since the very first cubic meter they consume but they also see their fixed charge h cut in half. Besides, metering is compulsory and metering costs are borne by the Company. In this case the company will never choose to meter those accounts with $q < q''$ (See Graph 5) because it will lose revenues. Metering will occur to the right of q'' for those accounts that offset water production and metering costs. Again, we know that this threshold will be inefficient because it does not take into account the fall in consumer surplus.

Conclusion on Buenos Aires Concession: The rate structure is inefficient and probably causes more inefficiency than the old rateable value charging system. Creates perverse incentives in metering that benefit apparently only meter manufacturers especially knowing that the government does not charge the company for the water that it extracts from the Río de la Plata. If the government values in zero (zero opportunity cost) the water extracted from the river what is the point in curbing water consumption? Reducing the Company's water production costs?.

6.2. The Cordoba Water Concession: Rate structure and metering policy

The rate structure of Cordoba´s Concession Company is slightly different from that of Buenos Aires in three aspects. On one hand, and according to the concession contract, universal metering is mandatory. All dwellings should have meters following a pre - established schedule. On the other hand, metering costs should be borne by the company and there are no reductions in the monthly fixed charge h (j = 0) for either type of consumer. For residential consumers there are important consumption thresholds based on the covered area of the property whereas commercial customers start paying for actual consumption since the first cubic meter they consume.

Graph 6 : Cordoba Concession rate structure for a residential user



First of all and as it was demonstrated by Lemma 1, universal metering whenever there are consumption thresholds is senseless. The company will install meters it should never have installed (from $q = 0$ to q^* in Graph 6). These meters will lie idle and unread and the company will cut losses by not doing any maintenance or repair on them. On the other hand the company will start making money metering those dwellings where the increase in revenues cover water production and metering costs but we already know that these meters will be too many from the social point of view.

Notice besides, that under this mechanism no consumer will ever be better off since at best they will pay the same as before.

For the commercial user the story is similar but with one slight difference: the pointless meters will be fewer as there are no consumption thresholds.

Conclusion on Cordoba's Concession: The rate structure of this concession appears to be more in line with the optimal described by the theory, however and as demonstrated, universal metering is never optimal with uncharged consumption thresholds. In contrast with the Buenos Aires Concession, water extraction from rivers and dams is indeed charged by the Government so water appears to have an opportunity cost in Córdoba and consumption reduction is more justified.

7. Conclusions and Policy Recommendations

The importance of metering in water rate structures has been overstated in most water concessions in Argentina. This paper shows that metering is useful whenever necessary to bring about an increase in welfare. And it is justified on economic grounds whenever water production costs are high enough, metering costs are low enough, satiation levels are high enough (waste is considerable) and society values water by assigning it a positive opportunity cost. If society considers that water is free (zero opportunity cost) what is the point in metering consumption? Some may argue that the higher water consumption the larger residential (and commercial) effluent disposals with the consequent creation of a health hazard if effluents are not chemically treated before being dumped into rivers. If this were the case health costs incurred by excessive water consumption should be reflected in the price that water companies pay for every gallon of water they extract form reservoirs. This is not always the case. Besides, companies are generally obliged to treat water chemically before disposing it eliminating the health hazard argument in favor of metering.

If the purpose of metering is to reduce the Company's water production costs, this should not be the government's goal as the Company can take care of its cost structure without any help from the regulator. The Company has already the incentive to cut costs under the rateable value system of water charges. This is because water costs depend partially on the volume of water produced whereas revenues do not. Any reduction in the volume produced (however small) represents an equal increase in profits since revenues are fixed. All efforts aiming at reducing delinquent accounts and pipe leaks translate immediately into higher benefits. Besides, most pipe leaks occur in distribution trunks that are sometimes more than a hundred years old and not in house gardens. This facilitates the task of detecting leaks using macro meters.

Another aspect that is often missed when discussing the pros and cons of the rateable value system is capacity pricing. As in any other public utility service (i.e electricity, gas etc.) capacity planning should be done well in advance and capacity dimensioning should be in line with forecast peak demand. How should the cost of this capacity expansion be allocated among consumers? Again, as in most public utility services according to some "variable" that reflects peak capacity demand. In electricity this is referred to as "power demand" and is calculated as the installed power of the firm or household adding up the power demand of all machines and equipment (or appliances in a house). For a water system it should be done exactly the same way. One should add up capacity demands of all dwellings in a city, include a growth factor and dimension the plant accordingly. What are the variables that should be included in the calculation of household capacity demand? Those variables related to water demand, these are: property area, covered area, age of the building (since old buildings tend to have more leaks), presence of a garden, land value (as a proxy for income since water demand increase with income) as so on and so forth. Bu this is the rateable value system! In other words, this charging regime is coherent with capacity pricing based on capacity demand. Of course, this system does not do well at pricing use because it does not punish waste but it does price capacity correctly because it dimensions water plants based on variables that proxy peak water demand.

In sum, metering should be complementary to the rateable value system of capacity pricing. With the right incentives provided in this paper, both systems together should send the right signals to both consumers and investors alike, curtailing waste, inducing optimal capacity expansion and therefore maximizing welfare.

Appendix I

For $j = 1$, the following has to hold:

$$q_R^* = \frac{C_m}{\int_a^0 w(x)\,dx + \left[(a - C_a)\,w(a) - (0 - C_a)\right]} > q_F^* = \frac{C_m + (1 - j)h}{\left[(a - C_a)\,w(a) - (0 - C_a)\right] - a\,w^*}$$

Which in turn means that $N_F^m > N_R^m$ and the firms installs more meters than socially optimal.

Proof: To prove this result it will suffice to show that $\int_0^a w(x)dx > aw^*$

On one hand $aw^* = \int_0^\infty w^*\,da + \int_\infty^a w^*\,da = \int_0^a w^*\,da$

and on the other hand $\int_0^a w(x)dx = \int_0^\infty w(x)dx + \int_\infty^a w(x)dx$

But at the same time we also know that by definition $w(x) > w^*$, then:

$\int_0^a w(x)\,dx > \int_0^a w^*\,da$ and therefore $\int_0^a w(x)\,dx > aw^*$ Q.E.D

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