

UNIVERSITA' DEGLI STUDI DI ROMA TRE

**SCUOLA DOTTORALE IN ECONOMIA POLITICA E METODI
QUANTITATIVI**

TESI DI DOTTORATO

**THREE ESSAYS ON
THE REGULATION OF PUBLIC UTILITIES**

CANDIDATA
Valeria Di Cosmo

RELATORE
Prof. Antonio Ranieri

Anno Accademico 2008/2009

A Sofia

Contents

Introduction	ii
1 Regulation and the Capital Structure Choice: a Critical Survey	1
1.1 Introduction	3
1.2 Rate of return regulation and the capital structure in regulated firms	4
1.3 Risk allocation,optimal debt level and RPI-X regulation	18
1.4 The model	32
1.5 The effects of changes in the price rule	35
1.6 Conclusion	38
Appendix	44
2 Debt and Efficiency in Italian Water Companies	47
2.1 Introduction	49
2.2 Related Literature	52
2.3 Efficiency Analysis and Data Description	58
2.4 The "Classical" Model	63
2.4.1 Theoretical Background	63
2.4.2 Estimator Specification	66
2.4.3 Empirical Results	67
2.5 The Bayesian Model	71
2.5.1 Theoretical Background	72
2.5.2 Model Selection	77

2.5.3	Empirical Results	78
2.5.4	Estimated Inefficiency and Comparison With "Classical" Results	79
2.6	Does Ownership Really Matter?	82
2.7	Economies of Scale in the Italian Water Sector	83
2.8	Conclusion	85
	Appendix	92
3	Are the Consumers Always Ready to Pay? A Quasi-Almost Ideal Demand System for Italian Water Demand	98
3.1	Introduction	100
3.2	Tariff Regulation of Italian Water Distribution Sector	102
3.3	Related Literature	103
3.4	Theoretical Background	105
3.4.1	Linear estimation of demand model	105
3.4.2	Generalizations of the Stone's model	107
3.4.3	Functional Flexible Forms and the Almost Ideal Demand System	111
3.5	Data Description	116
3.6	Econometric Analysis	117
3.6.1	Estimation Result (<i>i</i>): Benchmark Model	119
3.6.2	Estimation Results (<i>ii</i>): Demographic and Regional Effects	121
3.7	Conclusion	126
	Appendix	131

Introduction

L'analisi del settore delle *public utilities* non è solamente utile per comprendere l'evoluzione del meccanismo regolatorio in mercati che stanno acquisendo un'importanza sempre maggiore, ma permette anche di riconsiderare alcune conseguenze delle misure di politica economica.

Nel corso di questo decennio, la politica monetaria è stata caratterizzata dal mantenimento di bassi tassi di interesse, anche allo scopo di stimolare la domanda interna e sostenere la crescita economica.

Tali manovre, oltre a influenzare l'andamento dell'economia mondiale, hanno anche interessato il settore dei servizi di pubblica utilità: la riduzione dei tassi di interesse ha portato gli investitori a rivalutare l'indebitamento come fonte di finanziamento sia a causa dell'abbassamento del suo costo relativo, sia grazie all'alto livello di sicurezza e all'alta prevedibilità dei rendimenti garantiti. Di conseguenza, si è assistito ad un aumento notevole dei livelli di indebitamento per tutti i gestori di *public utilities*, accompagnato da una drastica riduzione delle equities emesse, negli USA, nel Regno Unito e in alcune *utilities* italiane. Le diverse politiche di prezzo attuate dai diversi enti regolatori non sembra abbiano contrastato tale fenomeno, che è andato aggravandosi in tutti i paesi nel corso dell'ultimo decennio.

Tuttavia, solo pochi contributi nella letteratura recente hanno approfondito le cause e le conseguenze di tale indebitamento; inoltre, pochi lavori hanno fornito delle risposte riguardo alle misure di policy che l'autorità regolatoria dovrebbe eventualmente implementare.¹

Un primo obiettivo del presente lavoro, pertanto, è rappresentato dall'analisi della

¹Una dettagliata rassegna di questi lavori è contenuta nel primo Capitolo.

letteratura esistente circa le possibili cause di un aumento dell'emissione di debito nelle compagnie di servizi di pubblica utilità; sulla base del modello teorico assunto come riferimento dell'analisi sono stati, quindi, evidenziati i possibili legami che possono determinare rapporti di causa-effetto fra alto indebitamento e riduzione dell'efficienza nelle compagnie che forniscono servizi di pubblica utilità. Un secondo obiettivo è stato quello di testare empiricamente il legame fra alto indebitamento ed efficienza nelle compagnie che gestiscono il servizio idrico italiano. I risultati di questa indagine hanno permesso di confermare una relazione causale positiva fra alti livelli di indebitamento e bassa efficienza così come ipotizzato nel modello teorico.

Infine, l'ultimo obiettivo è stato quello di analizzare l'impatto sull'utente finale delle possibili misure di policy attuabili dal regolatore, verificando in particolare quali siano le possibili conseguenze di un aumento della tariffa finale rispetto alla domanda dei consumatori.²

Quest'ultimo punto è particolarmente interessante poiché la presenza di una domanda anelastica è tra le principali ragioni che rendono necessaria la regolamentazione del servizio: verificare la reazione dei consumatori ad un aumento del prezzo finale significa, quindi, valutare il grado di regolamentazione necessario all'interno del settore considerato.

Grazie alla stima di un sistema completo di domanda presentata nell'ultimo capitolo della tesi, è stato possibile verificare che la domanda d'acqua presenta come prevedibile un basso livello di elasticità, rilevando tuttavia l'esistenza di forti differenziazioni territoriali del fenomeno e in particolare tra le regioni del Nord e Sud Italia.³

Vengono di seguito brevemente illustrati: (i) le conseguenze che i risultati ottenuti nell'ambito della tesi possono offrire all'analisi dei servizi di pubblica utilità e dei sistemi di regolazione, anche in relazione alla letteratura esistente; (ii) i principali elementi emersi dall'analisi e dai risultati delle stime condotte in merito alla domanda nel caso specifico

²Se per alcune utilities come l'acqua sono presenti sia nella distribuzione che nella gestione gli elementi caratterizzanti del monopolio naturale, in altri settori, come l'energia, la distribuzione può essere liberalizzata. Tuttavia, a nell'erogazione, il network rimane soggetto ai vincoli dettati dal monopolio naturale.

³Infatti, la sola esigenza di istituire un monopolio naturale che emerge in tutte le *public utilities* a causa della presenza di subadditività dei costi che caratterizzano la costituzione della rete, non giustificherebbe da solo la presenza di un regolatore. E' proprio la presenza di una domanda inelastica a rendere necessario l'intervento di un'autorità che, da un lato, garantisca al produttore un prezzo adeguato per la copertura dei costi e, dall'altro, la tutela del consumatore finale.

del settore idrico italiano.

Analisi dell'offerta dei servizi di pubblica utilità e risultati della tesi. Il basso livello dei tassi di interesse che ha caratterizzato l'economia nel corso di questo decennio unito a politiche di prezzo non sempre attente alle scelte di finanziamento operate dalle imprese, hanno favorito un innalzamento dei livelli di indebitamento delle compagnie che gestiscono i servizi di pubblica utilità, sia negli Stati Uniti e nel Regno Unito sia in alcuni settori italiani.

La particolarità di questo fenomeno risiede nella sua trasversalità: infatti, diversi regolatori hanno recentemente fronteggiato il rischio di bancarotta dei gestori dei servizi di pubblica utilità.⁴ Le risposte offerte dalla letteratura in merito alle cause del fenomeno hanno riguardato sia gli Stati Uniti, in cui i prezzi vengono fissati tramite una regola di tipo *rate of return*, sia il Regno Unito, dove il prezzo viene stabilito grazie ad un meccanismo di tipo *price cap*.

Nel primo caso, infatti, le imprese che forniscono *public utilities* hanno un incentivo ad aumentare il loro livello di debito, sapendo che possono scaricare parte dei costi di finanziamento nella tariffa finale determinata dal regolatore. Quando il meccanismo di fissazione di prezzo avviene seguendo la regola incentivante di *price-cap* proposta da Littlechild (1983), l'impresa regolata può opportunamente far aumentare il livello di indebitamento in modo da costringere il regolatore a trasferire una parte del rischio dagli azionisti ai consumatori, nella preoccupazione di garantire la continuità del servizio ed impedire all'impresa di incorrere in un processo di fallimento.⁵

Naturalmente l'indebitamento non rappresenta in quanto tale un elemento di criticità, in quanto l'aumento di debito entro una soglia del 50-60% sul totale dell'attivo dell'impresa può avere effetti positivi: infatti, la riduzione del costo del capitale che ne consegue, grazie al minor ricorso all'equity può riflettersi positivamente sul valore dei prezzi attesi dai consumatori finali.⁶

Quello che si vuole sottolineare è la mancata considerazione nella letteratura specializ-

⁴Vedi Ofwat (2004) e Ofgem (2007).

⁵Si veda Littlechild, S. (1983): 'Regulation of British Telecom's Profitability', Report to the Secretary of State, Department of Industry, London.

⁶Per ulteriori approfondimenti riguardo alla soglia del 50% si veda Ofwat (2004) e il Capitolo 1.

zata delle possibili conseguenze derivanti da livelli di indebitamento particolarmente elevati (ad esempio superiori al 50%), potenzialmente in grado di mettere l'impresa a rischio di insolvibilità. Accanto alla valutazione dei benefici iniziali, occorre in sostanza analizzare cosa succede in presenza di livelli eccessivi di indebitamento, e quale possa essere la relazione fra le scelte di *capital structure* - influenzate dal comportamento del regolatore - ed il livello di efficienza d'impresa.

Un altro aspetto poco analizzato dalla letteratura, ma fondamentale per comprendere gli effetti reali dell'indebitamento, si riferisce alla distinzione in termini di proprietà fra scelta di indebitamento ed emissione di azioni. Infatti, mentre l'indebitamento non priva l'imprenditore della proprietà dell'impresa, lo strumento azionario trasferisce il controllo della società agli azionisti. Ne segue che la scelta di un maggior indebitamento da un lato si accompagna ad un incremento nella proprietà e, quindi, all'incentivo di migliorare la propria *performance*; dall'altro implica una maggiore esposizione debitoria, a cui può seguire un aumento della probabilità di fallimento e, quindi, un disincentivo per l'imprenditore ad essere efficiente.

Queste caratteristiche fanno emergere una relazione non lineare fra efficienza e debito, che dovrebbe implicare un'attenta scelta del meccanismo di formazione dei prezzi da parte del regolatore al fine di assicurare che l'impresa fornisca la migliore prestazione possibile.

In questo quadro, nella tesi si è voluto valutare se in Italia, nel caso specifico del settore idrico, le compagnie con livelli di debito alti presentassero dei livelli di efficienza minori rispetto alle altre compagnie. La scelta del settore idrico non è stata casuale: da un lato tale settore è caratterizzato dalla presenza di monopolio naturale anche nella gestione del servizio e di un sistema di fissazione di prezzi ibrido fra il *price cap* ed il *rate of return*. Dall'altro lato, ha rappresentato una fonte di interesse la possibilità di valutare, a 14 anni dalla sua promulgazione, gli effetti della cosiddetta "legge Galli", promotrice di un processo di liberalizzazione, razionalizzazione e consolidamento delle imprese operanti nel settore. Oltre a valutare il legame fra alti livelli di debito ed efficienza, si è voluto verificare il legame fra proprietà privata ed efficienza, nonché la dimensione attuale delle economie di scala.

La prima parte della tesi, pertanto, si scosta dalla letteratura esistente per diversi aspetti: in primo luogo, presenta una spiegazione teorica che lega inefficienza e debito alle

scelte di prezzo effettuate dal regolatore; in secondo luogo presenta due distinti approcci econometrici per verificare come il debito e la struttura proprietaria siano delle variabili in grado di influenzare direttamente l'inefficienza delle imprese; infine, lo sviluppo dell'analisi empirica ha permesso la costruzione di un database originale che raccoglie dati relativi alla struttura finanziaria nonché alla capacità di produzione dei gestori del servizio idrico italiano.

In particolare, la presenza di due criteri di stima differenti (sia classico che bayesiano) ha permesso sia il confronto diretto con altri lavori finalizzati alla stima frequentista dell'efficienza nel settore idrico, sia di correggere (tramite l'approccio bayesiano) la distorsione per piccoli campioni insita nella metodologia classica. Il lavoro presentato nel secondo Capitolo della tesi costituisce, a mia conoscenza, la prima stima bayesiana effettuata per valutare l'efficienza nel settore idrico.

I risultati delle stime (sia bayesiane che frequentiste) confermano l'intuizione teorica secondo cui alti livelli di debito incidono negativamente sull'efficienza delle imprese. Inoltre, i risultati econometrici confermano che in Italia la struttura proprietaria non sembra invece incidere sui risultati finali in termini di *performance* dell'impresa. In altre parole, gli stessi livelli di efficienza (o inefficienza) si riscontrano nelle imprese indipendentemente dall'assetto proprietario. Questo elemento conferma l'intuizione teorica espressa nel primo Capitolo della tesi, secondo cui un aumento del livello di debito può essere accompagnato da un aumento di efficienza solo in caso di un aumento nel controllo della struttura proprietaria da parte dell'imprenditore. Nel caso in cui la proprietà non sia correlata positivamente con l'efficienza, un aumento del debito si riflette in una riduzione degli incentivi e, quindi, in un aumento dell'inefficienza. Dall'analisi, inoltre, emergono forti eterogeneità fra le compagnie italiane; circostanza che dovrebbe spingere il regolatore a ridurre la dispersione delle diverse realtà imprenditoriali, nonostante gli sforzi già fatti in questo senso a partire dalla legge Galli.

Analisi della domanda del settore idrico italiano. Nell'ultimo contributo presentato nel terzo Capitolo della tesi, viene stimato un sistema di domanda quadratico per valutare l'elasticità dei consumi italiani d'acqua rispetto al reddito e ai prezzi, completando in questo senso l'analisi svolta nei primi due capitoli.

Considerato come una possibilità per il regolatore di difendere le imprese dal rischio di bancarotta e rilanciare la qualità del servizio sia quella di praticare dei prezzi diversificati nel caso in cui l'investimento riesca o fallisca, risulta di primaria importanza stabilire come tale politica di prezzo possa riflettersi sui consumi.

Sebbene l'acqua sia un servizio indispensabile e quindi abbia una domanda piuttosto rigida, al fine di considerare le diverse politiche possibili mi è sembrato utile proporre un'analisi completa della domanda del consumatore, ovvero considerando le diverse voci di spesa che caratterizzano il suo paniere ed applicando in modo rigoroso i requisiti teorici che emergono dalla teoria della domanda.

Occorre sottolineare come un'evidenza empirica che confermi la rigidità della domanda del "bene" acqua suggerisca che la flessibilità dei prezzi al consumo possa in qualche modo penalizzare gli utenti finali, caricandoli delle inefficienze delle imprese stesse. La stima del sistema QUAIDS proposta, infatti, (i) dimostra che l'elasticità media italiana della domanda d'acqua risulta in linea con le stime riguardanti gli altri Paesi europei e (ii) consente di includere nell'analisi delle intercette traslanti che permettono la valutazione delle dinamiche della domanda per area territoriale e per gruppo familiare.

Questa seconda ipotesi, in particolare, assume particolare rilevanza: i contributi presenti in letteratura, stimando la sola equazione di consumo d'acqua e non considerando la sua relazione con gli altri beni presenti nel paniere di consumo, tendono infatti a sovrastimare l'elasticità della domanda d'acqua e non riescono a cogliere le diversità regionali che invece caratterizzano il settore. L'analisi condotta ha evidenziato come nelle regioni del Mezzogiorno un aumento del livello dei prezzi dell'acqua porti ad una contrazione dei consumi maggiore rispetto a quella che si riscontra nelle regioni del Nord. Questo risultato implica delle conseguenze di policy per il regolatore che voglia evitare una discriminazione fra consumatori appartenenti a realtà territoriali diverse.

Inoltre, includendo nell'analisi anche le specificità demografiche delle famiglie italiane, risulta che un aumento della tariffa idrica si rifletterebbe in una contrazione dei consumi rilevante solo per quanto riguarda gli anziani.

Anche in questo caso, pertanto, il regolatore dovrebbe assicurarsi di non svantaggiare determinate categorie di consumatori tramite le politiche di prezzo. Sebbene la spesa per l'acqua sia ancora marginale all'interno del paniere dei consumatori italiani, la stima del

sistema QUAIDS appare sicuramente come uno strumento efficace per la valutazione del problema generale del diritto ai servizi di pubblica utilità a carattere universale e che devono quindi essere garantiti a tutti i cittadini.

Chapter 1

Regulation and the Capital Structure Choice: a Critical Survey

Abstract¹

The first aim of this paper is to present a survey of the recent literature that investigates the source of the capital structure choices in regulated firms. Secondly, this paper proposes a theoretical model that investigates the relationship between regulated firm's efficiency and her optimal debt level. The first part of the paper analyses how the choice of the capital structure can influence the regulator's pricing policy; particularly, I focus my attention on how the bankruptcy risk induces the regulator to establish prices higher than optimal, in order to partially avoid the firm's financial distress. However, the existing literature does not explicitly consider the underlying relation between firm indebtedness and firm's efficiency and underestimate the impact of ownership decisions in determining the exerted effort. Then, my theoretical model consider the issued debt both as a potential source of bankruptcy risks and the financing choice that allows the entrepreneur to increase his control on the firm's ownership. The results of my analysis are as follows: debt and effort emerge to be non linearly linked, then there are some price values that encourages the dash for debt without promoting a rise in the final effort. Moreover, I demonstrate that also the price cap scheme becomes inefficient if the regulated firm can autonomously chose her capital structure

J.E.L. Classification Numbers: Regulation, Ownership, Financial Leverage, Equity finance, Debt finance

Keywords: G38, L51

¹I thank William Addessi, Gaetano Bloise, Simon Cowan and Massimo D'Antoni for helpful comments and suggestions. All errors are of course mine.

1.1 Introduction

The determinants of the firm's capital structure have been widely analyzed in literature; in particular, the seminal work of Modigliani and Miller (1958) highlights that, under strong assumptions (i.e. absence of information asymmetries between the principal and the agents, absence of taxes, no costs of financial distress), the gearing level chosen by the firm does not affect neither the firm's cost of capital nor the firm's value. Accordingly to the MM hypothesis, any attempt to substitute debt for more expansive equity is ineffective, as it increases the financial risk to remaining equity holders who demand higher returns to their capital.

However, lots of contributions demonstrate that, once some of the strong assumptions underlying the MM model are relaxed, arguments for (or against) a change in the leverage level emerge. Generally, firms can benefit from the tax advantage of the deductibility of interest payments against taxable profits; moreover, an adequate leverage structure can be used under asymmetric information in order to give the right incentives to the firm's manager.²

Undeniably, a lesson can be drawn from all of these contributions: simply introducing some market externalities (e.g taxes) or allowing the model to include some more realistic assumption than the presence of full information lead the linkage between the firm's debt choice and the firm's cost of capital to emerge.

Surprisingly, however, the literature on the firm's capital structure does not investigate how the firm's choices change in a regulated sector; more precisely, only few works are devoted to exploit the relation between the firm's chosen capital structure and the regulator's pricing system : Spiegel and Spulber (1994, 1997) analyze how the firm's debt choice are influenced in presence of a rate of return regulation, whereas De Fraja and Stones (1994) make some policy prescriptions in a price cap regulated framework.

These authors demonstrates that both the rate of return and the price cap schemes are partially affected by the firm's financing choice. Moreover, also the empirical evidence provided by Ai and Sappington (2002) for the US and by Saal et.al.(2007) for the UK,

²A detailed analysis on determinants of firm's capital structure is outside the scope of the present paper, but an excellent survey is provided in Harris and Raviv (1991).

highlight that both the pricing schemes are unable to prevent a strong dash for debt and to guarantee an improvement in the quality level of the final services.³

Then, the first aim of this work is to present a detailed survey in order to analyze the existing literature on the firm's capital structure choices in a regulated sector. Particularly, I focus on the market of public utilities.

Secondly, I will develop a theoretical model that links the capital structure choice of regulated firms to their performances in presence of information asymmetries. Moreover, I try to investigate the possible source of this phenomenon and to propose a pricing rule that consider both the firm's capital structure and the final exerted effort.

The paper is structured as follows: in Section I the relation between the rate of return regulation and the firm's capital structure is investigated and a brief examination of the existing literature on this topic is provided; in section II an analysis on the recent U.K. utilities performance is performed and some other theoretical contributions on the RPI-X approach are discussed. In section III I propose a theoretical model that relates the ownership choice of the entrepreneur to the debt level and, then, to the exerted effort. Finally, I propose some policy prescription to the regulator, in order to promote an efficient pricing scheme. Section IV concludes the work

1.2 Rate of return regulation and the capital structure in regulated firms

In the regulated sectors, the price set by the regulator reckon on the firm's expected costs, the firm's financial expenditure and the firm's return to the asset base. Simplifying, the price level sets by the regulator (q) can be seen as given by:

$$q = E(C) + r \times RAB \tag{1.1}$$

³Ofwat (2002) demonstrates that in the UK water sector the average level of debt is stabilized around 90%, and in the electricity industry gearing is risen about 25% during the last 10 years, there is still no theoretical convergence on the determinants of this fly-from-equity phenomenon.

On the quality of the UK water services see Saal et.al. (2007). For a more general approach on the UK technical efficiency, see Parker et.al. (1997).

in which C are the costs of the firm during the regulated period, RAB is the firm's rate base and r is the firm's allowed return and, under specific assumptions discussed below it is equal to the firm's cost of capital.⁴

This rule holds both for the rate of return and to the price cap regulation, even if these regimes are quite different for the risk allocation between the shareholders and the consumers, as discussed below.

Under the rate of return regulation, given (1.1), the prices are sensitive to changes in the firm's cost structure. Then, this pricing rule does not provide the right incentives to a cost reduction, but may assure a "fair return" to the invested capital.⁵ The debate to determine the exact meaning of "fair" resolves, for many U.S utilities, on setting the rate base as the actual cost of the firm's physical capital (adjusted for depreciation). Alternatively, regulators may allow firms to recover the cost of 'used-and-useful' assets, which are those assets judged by the regulator to be necessary to service customers' demands.⁶ Then, the particular U.S regulation framework implicitly mines the regulator's credibility: although the regulator's pricing system is substantially given by (1.1) the lack of well defined pricing rules and the continuous changes of the commissioners that evaluate the applied scheme makes the regulator's choice discretionary.

As highlighted by Guthrie and Evans (2006) and by Guthrie (2006), the traditional cost computation can be also unfavorable for the regulated firm, as it can not assure the right incentive mechanism to the firm's manager. A variety of other cost measurement methods has been suggested in order to better satisfy the requirements for an efficient rate of return regulation, which should be independent from the firm's investment decisions. In particular, these authors underline that another regulation scheme, focused on the

⁴The RAB which namely is the "cost" of the asset, as defined by Guthrie and Ewans (2005), differs among utilities and countries: for example, in the UK water sector, is equal to the share prices averaged over the first 200 trading days from the date of privatisation. Generally, the regulatory framework for major UK privatised utilities has converged on a market value approach to determine the regulatory asset base, as noticed by Grout et. al. (2001).

⁵The definition of the "fair" return is not unambiguously specified. The Supreme court has established that a regulated firm is entitled to "fair return upon the value of that which it employs for the public convenience." (Supreme Court Decision of *Smyth v. Ames*, 169 US 466, 1898). This "fair" return is not applied to all of the firm's assets, just those that are used to meet demand (that is, 'used-and-useful' assets). After a long debate on the meaning of "fair", the sentence "*Federal Power Commission vs Hope Natural Gas and Co.*", Supreme Court, 1944 (320 U.S. 591, 64 S.Ct. 281) determines that the return should be sufficient to assure "the financial integrity of the enterprise so to maintain its credit and to attract capital".

⁶See Newbery (1989) ch. 4

optimized replaced costs (or optimized deprived value) of the asset can be used by the regulator in order to influence the firm's suffered risk.

A discussion of the U.S. cost computation method is out of the scope of the paper, but it's important to highlight that the cost measurement, the cost of capital and the allowed rate based are strictly interconnected. Then, the regulator can fix the final prices in such a way that the firm's market value equals the regulator's allowed rate base. Moreover, when regulatory settings are normalized in order to guarantee that the firm's market value equals the firm's RAB, the allowed rate of return r equals the firm's cost of capital.

The cost of capital is frequently measured as a weighted average of the cost of debt (namely, the riskless rate of return) and the cost of equity.⁷ The latter is determined usually employing the CAPM model, even if the shareholder's risk premium reflects the regulator's behavior, and then it is discretionary defined.⁸

The cost of equity, then, is quite arbitrarily fixed, as it has to reflect the systematic business risk which is never perfectly predictable. The cost of capital, however, due to the equity component can be greater than the riskless rate and, in order to set an appropriate incentive scheme and to assure the outside investor participation it is important to understand the firm's financing choice in order to choose the optimal pricing rule, under (1.1).

Moreover, from the (1.1) simply equation the importance of the capital structure chosen by the firm for the consumer's welfare emerges: indeed, an increase in the firm's cost of capital makes the prices of the service to rise and then the consumer's surplus to fall.

⁷Formally, the cost of capital is given by:

$$r = r_a a + r_d d$$

in which a is the shareholder's equity, d is the issued debt and r_a and r_d are the allowed returns to equity and debt respectively.

Since the regulator guarantees some liability constraints, the debtholders are supposed to suffer no risk and then r_d is always equal to the riskless rate. Therefore, the return to equity has to be determined considering an adequate compensation for the risk substained by the shareholders.

⁸The CAPM model makes the expected return to equity equal to:

$$E(r_A) = \left[r_D - r_A + \frac{cov(r_E, r_M)}{var(r_M)} E(r_M) \right]$$

that is:

$$E(r_A) = r_D - r_A + \beta E(r_M)$$

in which r_M is the market return on the regulated firm.

At this, understanding both the relation between the capital structure and the regulator behavior as well as the determinants of the firm's capital structure choice, may be helpful in determining a model of regulated pricing system.

There are two main fields that investigate the determinants of the cost of capital and the regulator's behavior: the first is proposed by Guthrie and Ewans (2006) and Guthrie (2006) and sustain that the firm's cost measurement is the key of the regulator's behavior as it influences the risk suffered by the shareholders, and then can reduce (or rise) the cost of capital. According to this approach, then, the firm's capital structure choice is irrelevant in determining the cost of capital, that is influenced only by the regulation choices, that affect the shareholders risk premium and then, the return to equity.

On the contrary, a second group of works connects the firm's capital structure decision to the regulator's pricing strategy.⁹ Obviously the differences between these models are substantially ascribable to the considered pricing system: in the U.S. the regulator rises prices in order to ensure the shareholders from the investment risk while in the U.K the regulator try to protect the consumers against a rise in the expected prices.

The main idea underlined in Guthrie and Ewans (2006) and in Guthrie (2006) is that an optimal cost measurement can determine the optimal cost of capital. These authors sustain that the cost of capital is totally determined by the regulator, as he can lead to changes in β (i.e. the coefficient of the shareholder's risk premium) by choosing the cost measurement and by setting the firm's rate base. Then, the firm is like a passive agent in the game and her capital structure decisions do not affect the regulator's behavior or the cost of capital.

It is important to highlight that these authors find that the optimal price regulation must lie between the pure price cap and the rate of return system. Indeed, although the rate of return guarantees that the investments are always undertaken, as it shifts the risk from the shareholders to the consumers, there are some incentives for the shareholders to overinvest with respect to the socially optimal level and to choose riskier projects than in under-regulated framework.

Indeed, as the regulator always protects the investors with some forms of limited lia-

⁹See Spiegel (1994), Spiegel and Spulber (1994,1997) , Dasgupta and Nanda (1993) and Taggart (1981,1985) for the U.S. and of De Fraja and Stones (1994) and Stones (2007) for the U.K experience

bility, it is convenient to invest more in order to be defended against some negative shocks on the undertaken (sunk) investments.

This rises the risk of the investment and then, indirectly, the cost of capital. In other words, even with a rate of return regulation the behavior of the shareholders can lead to a rise (instead of reduction) in the cost of capital, and then it would be optimal to adopt some binding rules, as RPI-X regulation, even if this pricing system is not always an efficient rule. As long as the regulator's commitment is not credible, the firm can find convenient to delay her investment in order to obtain a rise in the regulated prices.

The main contribution given by these authors is represented by the intuition that the measurement of the firm's cost, the rate base and then the cost of capital have to be determined by the regulator simultaneously as they are strictly interrelated. Moreover, these authors recognize that in order to incentive the firm to not delay the investment and to behave optimally it is important to correct the pure rate of return regulation with some elements derived from the price cap system.

Despite the relevance of their theoretical contribution, it is quite difficult to undertake an empirical research to test their intuition, as it is almost impossible to measure econometrically the firm's behavior or the manager's incentives.

Furthermore, even if the authors sustain that the optimal cost of capital has to be jointly determined with the rate base, their model can not explain the UK empirical evidence: in the water sector, the allowed rate base has always been determined as the share prices averaged over the first 200 trading days from the date of privatization; notwithstanding, the UK water utilities has experienced great variations in the cost of capital. Then it could be intuitive to think that the firm's choice of capital structure has to be linked to the regulator's behavior.

In other words, even if the works of Guthrie and Ewans surely highlight some aspects which are ignored by other approaches (as the linkage between the allowed rate base, the cost measurement and the cost of capital) their analysis can not completely explain the recent UK experience.

In order to better understand the optimal regulator's behavior about the cost of capital and to investigate how to correct the pure ROR system, it is useful to deeply analyze the contributions on the rate of return regulations and to determine which elements can be of

use to modify the price cap regulation.

ROR regulation and the firm's capital structure choice Very intuitively, it is possible to present the baseline of all of the U.S models that investigate the relation between the firm and the regulator. It is important to remind that the regulator has to set prices (q) in order to allow the firm to obtain a total coverage of operating costs $C(\bar{y}, I)$ which are function of output and investment, and a fair return on capital (represented by equity a and debt d).

Using a simple equation it can be summarized by:

$$q : \bar{y} - C(\bar{y}, I) = r_a a + r_d d \quad (1.2)$$

The return to capital is then considered as a weighted average of the return to equity and to debt, as discussed above. If the cost of debt and the cost of equity are determined separately, the regulator could be mistaken about the cost of equity, as he can not verify the true risk carried by shareholders. As the expected demand \bar{y} is supposed to be invariant with respect to price changes, and hypothesizing that

$$a + d = 1 \quad (1.3)$$

the derivative of (1.2) with respect to a is equal to

$$\frac{\partial q}{\partial a} = r_a - r_d$$

Then, as long as the cost of equity exceeds the cost of debt, the firm can induce price increases substituting equity for debt.

This consideration may appear very simple, but can be seen as a baseline to understand more complex relations between consumers, regulator, firms and outside investors, in the U.S

framework, as highlighted in the Taggart (1981,1985), Dasgupta and Nanda (1993), Spiegel and Spulber (1994), Spiegel (1994) and Spiegel and Spulber (1997) works.

As previously highlighted, the U.S price setting process has been defined from the beginning of this century, and then, the utilities privatization phenomenon can be considered completely stated. Therefore, all the contributions focused on the U.S situation are interested in analyzing the firm's decision rather than the regulator's; as the pricing system is well defined, it is interesting to understand the determinants of the firm's financial choice, rather than the regulator's behavior. Thus, the majority of these works establish how the firm can influence the regulator's prices managing her capital structure choices.

The only notable exception can be found in Dasgupta and Nanda (1993) that provide empirical evidence in order to demonstrate how the regulator harshness can influence the firm's capital structure choice, running up against a circularity process between the firm and the regulator itself.

The basic intuition under their model is that, given the debt choice, consumers and firm bargain over their share of the ex post divisible surplus, that excludes the debtholders, seen as the third part of the game. Then, as the firm issue debt, the ex post surplus falls and consequently, the available consumer surplus decreases. More the regulator cares to the consumer's welfare, more he will rise the final price, in order to avoid the bankruptcy risk, that is, any interruption of the firm service. Accordingly to the regulator's behavior, the firm finds optimal to increase her debt financing in determining her capital structure.

However, the authors recognize that also the prices are positively related to the firm's financial decision. Then, even if there are some differences between this model and the Spiegel (1994) and Spiegel and Spulber (1994) contributions, the conclusions on the optimal firm behavior are quite similar.

Hence, the main particularity of the Dasgupta and Nanda work is that the regulator does not guarantee any explicit limited liability to the debtholders (i.e the game is seen as being between the entire firm, composed by debt and equity holders, and consumers), but an implicit protection arises from the threat of the bankruptcy risk, that induces the regulator to rise the output prices.

Despite the Dasgupta and Nanda work, all the differences between the other contributions that analyze the U.S situation differ essentially only for the choice of the regulator

welfare function and, obviously, for the underlying assumptions on the information structure.

Explicit limited liability constraints are introduced by Taggart (1981), who imposes a strong regulator control on the firm, achieved by allowing the regulator to set price in order to avoid any bankruptcy cost. A simple pricing system is considered: in a two period framework, if the firm experiments high costs during the first period, in the second period the regulator can sign another contract and then fixes higher prices in order to completely cover the firm's debt.

In this way, the regulator saves the firm from the financial collapse, but also gives to the firm an incentive to ask a continuous rise in the regulated prices: as long as the first period price is less than the monopoly price for the second period, there is an incentive for the firm to issue more debt, in order to augment the probability of a rise in prices at the end of the period, when regulator could recontract. At this, the firm's optimally choose a potentially unbounded debt level in order to force the regulator to raise the final price.

In a similar framework, other examples of regulator who cares about bankruptcy costs can be found in Spiegel (1994) and in Spiegel and Spulber (1994), in which the relation between the regulator, the firm and the outside investors is analyzed.

If in Taggart (1981) the regulator avoids the bankruptcy risk simply imposing a non-negative profit condition, both in the Spiegel (1994) and in the Spiegel and Spulber (1997) works the regulator makes a credible commitment to the debtholders by imposing a limited liability constraint.

The difference between these models is simply the assumed welfare function: in Spiegel (1994) and in Spiegel and Spulber (1997), the regulator faces a Nash welfare function while in Spiegel and Spulber (1994) benthamian welfare function is hypotized. In both of the models the game structure is exactly the same, as they are three stage games, solved by applying the subgame Nash perfect equilibrium concept.

The same game structure is provided in Dasgupta and Nanda (1993) even if, as mentioned above, different assumptions on the debtholders limited liability constraint leads to a different analysis (but not to a different conclusion).

In order to reflect the lack of commitment in the regulator's pricing system the game is structured as follows: in the first period, the firm chooses the proportion of debt and

equity to finance her investment pursued in the first stage of the game. Then, perfectly competitive markets determine the equity and the debt prices and finally, the regulator set the equilibrium price.

Moreover, in both models, there is a random probability p , uniformly distributed on the relevant interval, that the firm can not repay her debt. This can be seen as an exogenous technological shock, out of the manager's control, which can lead the firm to bankruptcy.

It is interesting to note that any change in the welfare function chosen by the regulator is reflected only in a different bankruptcy risk faced by the regulated firm, but (under some conditions specified below) does not affect the decisional process accomplished by the firm to determine her debt level.

In other words, in both of the models, the firm chooses her optimal debt level which is the maximum exigible debt associated to the minimum risk of financial distress.

Remarkably, as long as the regulator chooses a welfare function that allows for a positive bankruptcy probability (benthamian welfare function), both the debt and the equity risks are partially suffered by the shareholders and partially by the consumers. On the contrary, when the regulator chooses to assign the same weight to the consumers and to the firm (Nash welfare function), the risk is totally suffered by the consumers, given the game structure adopted in these models.

Generally, then, if the regulator adopts a rate of return mechanism, the regulated firms rise their debt level high enough to make the regulator choose the maximum price level, that is, the level that makes the consumer's welfare constraint to bite.

Again, it is useful to remark the importance of a deep comprehension of the rate of return regulation in order to make useful correction to the rigid price cap system adopted until now by the UK regulator.

Consequently, it is important to understand the determinants of the firm's choices and the impact of the ROR system both on the investment level and on the risk allocation between agents.

If the regulator chooses to maximize a Nash welfare utility function, (Dasgupta and Nanda 1993, Spiegel 1994), he implicitly assigns the same weight to the firm and to the consumer and then maximizes the following equation:

$$\max_q W = CS^b \times [q - C(\bar{y}, p, I) - T(q, d, I)]^{1-b} \quad (1.4)$$

$$s.t. E [q - C(\bar{y}, p, I) - (1 + r_d)d - (1 + r_a)a] \geq 0$$

In which T are the bankruptcy costs and the non liquidated constraint assures to the outside investor an expected non negative profit.

At this point, the same welfare function can be used to explain two different situations; as highlighted by Dasgupta and Nanda (1993), the price setting can be seen as the result of a regulator preference for the consumers and then the firm's choice of capital structure is essentially the optimal response to the regulator's harshness. On the contrary, as underlined by Spiegel (1994), the regulator pricing rule can be seen as the optimal response of a firm's previous capital structure decision.

However, the differences between these two kind of model do not change the final result.

Both if the regulator forces the firm to respect some liability constraint or put a positive weight to the continuity of service (i.e. gives a greater importance to the consumers than to the firm in the welfare function) the firm will optimally choose an heavily indebted financial structure in order to force the regulator to push up the output prices.

In the Spiegel (1994) work, as the bargaining power between the consumers and the firm is solved independently from any regulatory decision, the optimal price $q^*(d, I)$, set by the regulator solving the problem (1.4), divides the ex post social surplus between the consumers and the firm according to their bargaining powers.

As mentioned above, the choice of q^* solves the existing trade off between the consumers surplus and the firm profits: a rise in the regulated prices reduces the probability of bankruptcy (and then the distress cost of the firm) and, at the same time, shifts the ex post surplus from the consumer to the firm. Then the optimal price has an implicit ceiling, given by the minimum consumer's surplus (here it can be even be equal to zero) and

cannot grow up to infinity. As a result, if the firm never incurs financial distress, the regulated prices reach their minimum level; if the firm issues debt in order to finance her investment, the price grows up while the consumer surplus sinks down. After a certain price level, determined by maximizing (1.4) under the hypothesis that the firm issued debt is greater than the amount emitted under the no-bankruptcy constraint, the firm has a positive probability to become financially distressed. Naturally, if the issued debt continues to grow, the prices reach their ceiling level, and the consumer's surplus becomes equal to zero.

As the firm manager maximizes the shareholder's income, it is optimal for the firm to issue a debt amount that leads the regulator to fix the price under which the probability to become financially distressed is equal to zero. In other words, the firm has incentives to issue debt only up to the point in which the regulator is ready to push the prices up.

This result can be seen as a consequence of the bargaining process underlined in the welfare function: since the negotiation between firm and consumers leads to an average cost pricing, the firm does not have any gain from a price increase on inframarginal units, so she never chooses debt levels that make herself susceptible to financial distress.

As the equilibrium is subgame perfect, the debt level which is optimal for the firm, is optimal also for the regulator and for the consumers: if the firm issues debt below the optimal level the consumers are strictly worse off, as the firm has not undertaken the investment, and consequently the product's quality deteriorates and the cost of production rises with the consumers expected prices.

Moreover, if the investment project requires more financial resources than given by the optimal debt level, the firm issues equity, in order to cover the financial gap and to undertake the investment. In this model, then, the equity risk is suffered by the shareholders, but the debt risk is totally charged to the consumers.

In conclusion, this model seems to be appealing as in equilibrium there is no underinvestment but it is important to highlight that the bankruptcy risk is entirely suffered by the consumers. Then the regulator follows a sort of myopic behaviour under which protect the final consumers against the bankruptcy risks simply rising their final tariffs. Then, the regulator effectively adopts an average cost pricing rather than a marginal pricing rule, leaving the regulated firms to benefit from the regulator's protection.

Furthermore, the model explicitly consider the presence of full information between manager and shareholders whereas the hypothesis of the presence of hidden actions or hidden informations may dramatically change these results.

Despite its importance, no works has been devoted to an examination of how the incentive to invest changes in regulated firm in presence of asymmetric information even if Leland and Pyle (1977) empirically demonstrate that information asymmetries in financial markets are particularly pronounced.

Recently, Spiegel and Spulber (1997) analyze the effects on the capital structure chosen by the firm in presence of asymmetric information between the regulator and the firm, but their results essentially depends on the investment level exogenously fixed by the regulator.

The game structure is the same as the Spiegel (1994) work, and a Nash welfare utility function is also assumed.

In their contribution, the firm has a private information on her cost structure, and then she can use her capital structure either to increase her leverage effect (and then force the regulator to push up the prices, as demonstrated by Spiegel and Spulber 1994), or to signal her private information on the cost component.

Therefore, in the considered game there are two different principals (the regulator and the shareholders) and then the firm has countervailing incentives in declaring her cost function: on one hand, she wants to signal to the regulator the presence of high costs in order to obtain a price rise; on the other hand, the firm needs to signal to the shareholder low expected costs (i.e. high profits), in order to boost the market value of her securities.

In their model eq. (1.3) holds, and then the restriction on the total amount of issued debt and equity implies that the firm's chosen capital structure is strictly linked to the investment's size. In the model different cases are analyzed, but here it is sufficient to consider that the regulated firm makes huge investments which are financed by debt until the optimal point, and then by equity in order to fill the financial gap, in the same way as highlighted by Spiegel (1994).

In this case, the firm's capital structure results uncorrelated with the firm's expected value: that is, there is a pooling equilibrium between the different firm's types (high or low costs). This result is strictly linked to the refinement criterion used by the two authors, but it can be intuitively explained simply considering the "countervailing incentives" that

emerge from the game structure. Indeed, for each type of firm the potential gains obtained from revealing her right type to one receiver are outweighed by the loss associated with the negative response of the second receiver. In this way, none firm has the incentive to reveal her type and then a pooling equilibrium results from the welfare function maximization. Furthermore, if the size of the investment changes, other equilibrium's types emerge.

It is than important to highlight that the choice of the Nash welfare function rules out any possible valuation on the firm's investment incentives. Moreover, the results founded in an asymmetric informational framework are not robust to changes in the refinement criterion.

Considering again the U.K experience, the choice of relaxing the RPI-X pricing rule in order to fix a ROR mechanism has to be undertaken also considering the regulator behavior. If the regulator is like an arbiter in the firm-consumer bargaining power, the risk-allocation result can be quite unfavorable for the consumers: as noticed by Helm (2003) in order to improve the incentives given to the managers, it can be useful to improve the punishment mechanism once the investment project fails.

It would be interesting then to analyze the changes in the firm's capital structure choice and in the investment levels investigating both the effects of a change in information and in the regulator's preferences.

Accordingly with the latter consideration, the work of Spiegel and Spulber (1994) analyzes the determinants of the regulated firm's capital structure choice assuming a Benthamian welfare utility function for the regulator.

In their model, a price-setting rule incentivate the regulated firm to pursue an optimal strategy and limit the bankruptcy risk. This implies the existence of a limited commitment ability of the regulator, due to the importance to guarantee the continuity of service; this condition is translated into a no-liquidation constraint imposed on the welfare maximization, while the bankruptcy is a punishment to the manager that experiment a negative efficiency shock, measured, as before, by p .

In this model, the price setting rule is given maximizing the utilitarian welfare function

under the no-liquidation constraint, that is:

$$\begin{aligned} \max_q W &= CS + b[q - C(\bar{y}, p, I) - T(q, d, I)], 0 < b < 1 \\ \text{s.t } R(q, 0, I) - H(d - R(q, 0, I)) &\geq 0 \end{aligned}$$

in which $R(q, 0, I) \equiv q - C(\bar{y}, 0, I)$.

Solving this model for the optimal price, leads to a marginal cost pricing under which the regulator sets the marginal expected weighted consumer surplus equal to the weighted effect of the regulated price on expected bankruptcy costs. Otherwise, if the firm runs to bankruptcy, the regulator fixes prices just high enough to ensure that the firm is never liquidated (and then the non liquidation constraint bites). Then, even if the regulated prices are increasing in the firm issued debt, the regulator is restrained by the firm's debt, since the prices he fixes cannot reduce consumer's benefit to an excessive extent. So, the increase in the optimal regulated prices can never be sufficiently large to avoid completely the firm's bankruptcy risk.

Accordingly, in equilibrium, the firm issues a positive debt amount, but her strategy is costly as she faces a positive probability of financial distress. This result can be understood considering that the marginal cost pricing system adopted by the regulator (if the firm has an efficiency sufficiently large) makes the firm to benefit for a price increase for all the inframarginal units. This concept can be better analyzed considering that, if the firm faces a positive bankruptcy probability she actually rises the shareholder's payoff enough to offset the possible losses associated to the bankruptcy risk. Then, up to a certain level of regulated prices, the firm takes advantage of issuing debt, even if she faces a positive probability of bankruptcy¹⁰.

¹⁰The authors evidence that the following condition must hold in order to assure that a rise in prices effectively reduces the bankruptcy costs:

$$\frac{q^* - \frac{\partial C}{\partial Q}(q^*, z^*, I)}{q^*} < \frac{1}{\eta}$$

in which η is the elasticity of demand. This implies that $\frac{\partial R}{\partial q}(q^*, z^*, I) > 0$ and then that $\frac{\partial z^*}{\partial q} < 0$

Then again, there is an implicit ceiling on the price rises but here, given the regulator behavior expressed by the utilitarian welfare function, the firm has to suffer part of the risk associated to the debt issuing.

It may be interesting to understand the role of the investment, which is ambiguously determined in this framework. As highlighted by the authors, if the marginal cost of bankruptcy is constant and the welfare weights are equal, then the regulated firm underinvest with respect to the social optimum and the applied prices are greater than the optimum level. So, by allowing the firm to issue debt, the regulator enforces his commitment by making more difficult to lower the regulated prices once the investment (and the consequent cost reduction) has occurred. In other words, the regulator commit himself to an inefficient regulatory process in order to protect the firm from his ex post opportunism and to give stronger incentives to the firm to reduce her costs ex ante.

Anyway, with respect to the U.K framework, these analysis are surely useful to understand the possible equilibria giving the regulator's behavior and may be helpful to understand the weakness of the ROR pricing system.

1.3 Risk allocation, optimal debt level and RPI-X regulation

The price cap model (or RPI-X model) differs from the traditional rate of return regulation system as in this framework the regulator fixes prices for a given period and then he does not consider the "fair" rate of return that should be assured to the shareholders.

It has to be noticed that, after the chosen time period, the regulator can review the prices, and then adjust them to incentive the investments. In this way, the price cap system is simply a rate of return rule with a lag of n periods (in UK equals to 5 years), chosen by the regulator (Helm 2004).

The basic price cap formula is given by:

$$q_t = (i_t - x_t \pm f_t - \chi_t)q_{t-1} \tag{1.5}$$

in which i_t is the inflation rate for the considered year, x_t is the allowed efficiency gain, χ_t

is the quality of the service adjustment factor, f_t is the exogenous adjustment factor and q_t is the fixed price.

Even if this pricing formula is very intuitive and it is supposed to hold in the following section, some correction to (1.5) are currently used in the UK in order to prevent firm's intertemporal manipulations. Vogelsang and Finsinger (1979) proposed to cap the prices considering the firm's average cost in the previous period instead of the inflation adjustment. Moreover, another alternative to the price cap is given by capping the firm's average or total revenue. The former method is applied to the UK, airports, regional electricity companies, and to British Gas while the latter is used to regulate electricity transmission grid owners in Wales.

However, a detailed study of the implication of the RPI-X regulation is out of the scope of this paper, but it is provided in Cowan (2002) as well as in Guthrie (2006); here it is important to highlight that the main difference between the ROR and RPI-X pricing system can be noticed in the different role covered by the firm and by the regulator. In the ROR system, the firm can set her capital structure in order to influence the prices set *ex post* by the regulator. As demonstrated by the previous analyzed works, the game between the firm and the regulator can be modeled considering a three stage game in which the regulator always moves after the regulated firm.

On the contrary, in the RPI-X framework, the prices are set by the regulator *ex ante* and then they are able to condition the firm's capital structure choice.

Moreover, the two pricing rules differs substantially for the risk distribution: if the regulator chooses a rate of return regulation, he implicitly leads the consumers to carry all the financial risk and then the investment project is always undertaken; meanwhile if he fixes prices following a price cap rule, he leaves the equity risk to the shareholders and then underinvestment can arise.

Besides, in the U.S framework, the cost of capital approximates the cost of government debt, considering that the service is provided by a monopoly: indeed the risk premium given to the equity is almost equal to zero, as the investors do not carry any risk, which is completely transferred to the consumers. Intuitively, this consideration is also supported by the previous analysis: in that models, the only way to create underinvestment (even with information asymmetries) was to leave some bankruptcy risk, and then the investment

undertaken by bondholders could be insufficient for the regulator requirements.

However, it has to be underlined that, in the U.S., the difference between the rate of return regulation and a theoretical price-cap rule is more theoretical than empirical: as highlighted by Ai and Sappington (2002), an empirical analysis of the U.S Telecommunication Industry emphasizes that under the price cap regulation there is a greater incentive to innovation than under rate of return, but generally there is only a little evidence that aggregate investment, profits and revenues are systematically different between these two different regulatory regimes.

On the contrary, in a pure RPI-X framework, the risk premium (that is, the β coefficient in the CAPM methodology) must be higher than zero, as the risk is totally suffered by the shareholders.

During the U.K privatization of network utilities this consideration has provided theoretically strong incentives in cost reduction and has prevailed in choosing the pricing formula adopted by the regulator, which was a pure pricing cap system. This choice can be also understood considering that , under the RPI-X rule, the regulator leaves to the firm the gains obtained from a reduction in cost below the level assumed by the regulator in setting prices: in this way the regulation can force the firm to rise her efficiency and then to obtain lower expected prices for the consumers.

Then, the UK approach seems to give an efficient answer to both the problems emerged in the U.S experience: the informational problem between the regulator and the firm at price setting and the incentives on utilities between price setting.

Therefore as the (1.1) and (1.5) hold, the firm may find convenient to reduce her cost of capital in order to experiment the same benefits of a cost reduction. During the 90s, in order to put the cost of capital down, the U.K. regulated utilities substituted expansive equity for cheaper debt.

The reason behind the debt increase is then alarming simple, and undermines the initial positivism on the price cap approach: there is an implicit trade-off in the price cap system between efficiency incentives and financial costs.

That is, if the regulator chooses to implement a rigid RPI-X system by assigning the risk to companies, the cost of capital increases. This effect can be exacerbate by a regulator ex post intervention, made to correct the initial pricing system and then to make the

allowed returns to rise in order to finance additional capital expenditures. The regulator intervention overwhelm his credibility and all the RPI-X incentives; then the investors can not correctly forecast the expected gains after a cost reduction. In this way, there is a negative effect on efficiency and the price cap becomes more harmful than useful.

Furthermore, as underlined by Cowan (2006), the utilities market is characterized by sunk investment and if the regulator denies his prior promise to the firm and set the new prices in order to repay also the return to capital, the firm's manager faces uncertainty about the future prices and can choose to delay the investment or simply to underinvest.

In spite of the initial enthusiasm, the recent UK regulation experience has highlighted that an application of a pure RPI-X system can be subjected to substantial failures and than has been partially revisited in the latest years, especially in the water sector, but also in the electricity and gas industries.

From the works of Helm (2003,2004), Ofwat (2004) and DTI (2004) emerge that, especially in the water sector, there is still a lack of convergence on a theoretical framework that can be adopted by the regulator. This can be due to the relatively recent privatization experience and then to the absence of a strong empirical evidence. On one side, it should be considered that, as the consumers are risk adverse, a pure rate of return regulation can not be adopted and ,on the other side, in order to encourage the huge investments that has to be undertaken it has to be determined a rule that leaves some guarantees to shareholder.

Recently, as the data and trends on the regulated firm are available for longer periods, the evidence suggests that considering prices independently from the risk allocation can lead to a shift in the firm's capital structure decisions and then to a different risk distribution.

From the empirical comparison emerges that after the 1999 price review the regulated firms choose to determine their capital structure with a large debt proportion. In 1999, the regulator cut the set prices by 10% (the so called p_0 cut) and fixes a RPI-0 rule, that is, a pricing rule that did not consider any inflation benefit.

After this decision, and considering the limited commitment undertaken by the regulator (empirically, annually there are some interferences between the regulator and the regulated firms) the flight from equity phenomenon dramatically increased, as highlighted by Helm (2004) and Ofwat (2004). This can be also explained considering that if the

set prices lies between the cost of equity and the cost of debt, equity financing becomes unprofitable for the outside investors and then accelerates the equity for debt substitution.

An instructive example is given by the Welsh Water experience: the company was totally financed by debt and then the risk was totally suffered by the consumers. It is important to notice that a debt default in this situation would be like a systemic risk, even if the consumers do not receive any risk premium to suffer it¹¹.

After that the original owner, Hydric plc. had encountered financial problems, the company was sell to Glas Cymru, a not-for-profit company limited by guarantee and 100% reliant on debt for its external finance. The result of a complete risk transfer, however, eliminate the manager's incentives and then the trade off between a lower cost of capital and the public interest emerges.

This evidence highlights that also the price cap mechanism is subject to some problems that characterize the rate of return approach: the informational issue between the regulator and the firm does not seem to be solved and also it may be interesting to investigate if the regulator can effectively condition the firm's decision process rather than be influenced by her capital structure choice.

The investigation of this topic reserves a particular attention as there is still no theoretical convergence on the causality direction between the firm and the regulator. Indeed, some authors sustain that the regulator can determine the firm's capital structure (De Fraja and Stones 2004), while others (Helm 2004,2006) think that also the firm can force the regulator to a rate of return mechanism in order to relax some incentive constraints.

In order to find an answer to all the emerging RPI-X problems, it may be useful to analyze some recent contributions that try to underline the strengthen and the weakness of the price cap approach and some possible solutions to the problems linked to the regulator behavior.

Changing the rules: the recent literature on the feasible RPI-X corrections

In the previous analysis emerges that a regulated firm take advantage of rising the RAB component as well as the capital expenditure, as the regulator has to consider all of these key variables in order to determine the final price.

¹¹See HM Treasury (2004)

So, the recently experienced fly-from-equity phenomenon in UK utilities can be alarming as the equity financing is both a buffer against possible negative shock and an incentive for a manager to respect the fixed investment plan. Moreover, it can be important to understand if the firm can force the regulator to modify his announced strategy or the regulator itself can fix an optimal-incentive pricing rule.

As the U.S and the U.K experience highlight, the application of a pure pricing system (ROR or RPI-X) can turn against the consumers welfare due to a decrease in the cost efficiency. Then, an optimal pricing system has to consider both the rate of return and the price cap regulation aspects.

In order to find a theoretical answer to the emerging U.K evidence, Helm (2004) suggests to adopt a mechanism that finance the RAB component with a RPI-X pricing system and the capital expenditure with a rate of return compensation.

Since the efficiency can be damaged by the regulator protection, the author proposes to strengthen the manager punishment if the investment project fails or if the operating costs do not experiment an efficient reduction.

This intuition relies on what Helm (2003,2004) defines the "split" cost of capital, that is the opportunity to finance the RAB component by debt (then with a lower cost of capital) and the capital expenditure by equity. In his recent contribution, Helm (2006) defines four different possible financial structure of a regulated firm and find that a "floated equity funds" would be optimal in order to have the control over the RPI-X possible problems and to unambiguously determine the efficient risk allocation.

The author suggests to bought the utilities with outside investors by the creation of an investor's fund, without selling the firm's asset. In this way, investors can enter whenever they choose from the floated fund without resealing the underlying companies. In this way, the equity risk is pooled within a portfolio, ownership of which carries the risks.

Although the author proposes a possible solution in order to manage the risk allocation, the impact of this strategy on incentives to invest must be still investigate. In other words, it is not clear how this approach can be reflected on the quality of the regulated firm's service.

The importance of a risk efficient allocation in the regulatory system emerges also in Cowan (2003), even if in this model the firm's capital structure is not explicitly considered.

This author analyzed a symmetric information framework, in which the firm's owners (shareholders) are risk neutral with respect to income, but risk adverse with respect to the prices. Finally, the consumers are hypotized to be risk adverse with respect to the income and to the prices. In his model, the author suggests that a two part tariff would be optimal in order to achieve both an efficient risk allocation between the firm and the consumers and an allocative efficiency.

Even if the author does not consider explicitly the capital structure problem, he also highlights how important would be to relax the rigid price cap formula in order to give to the regulated firm some insurance, which reflects the degree of consumers risk adersion. Again in this model, however, the incentives given to the firm's manager are not considered in the formal analysis.

Thus, it may be interesting to better understand whether the regulator can influence the firm capital structure and how an optimal incentive scheme can be adopted.

Surprisingly given the importance of the latter topic, the issue of asymmetric information between the regulator and the firm's manager has largely been ignored. Despite the Spiegel and Spulber (1997) work based on the rate of return regulation system, the existing literature has not paid enough attention to the possible deceptions implicit in relaxing the price cap regulation scheme.

Notwithstanding, the analysis on the optimal capital structure under price cap regulation in a symmetric information framework is provided in the works of De Fraja and Stones (2004) and Stones (2007).

The De Fraja and Stones (2004) model relies on the fundamental assumption of agent risk adersion: in their model, they assume that both the consumers and the shareholders are risk adverse, meanwhile the managers are risk neutral down to their reservation utility, and the debtholders are infinitely risk adverse.

More precisely, the consumer's indirect utility function, as well as the shareholders utility function, are supposed to be concave both in income and in prices, that is

$$U''(Y), U''(q) < 0$$

then, consumers and shareholders prefer a price stabilized in the mean rather than to bear price risk.

The assumption on the shareholders risk preferences can be explained considering that as the debtholders are infinitely risk adverse, the regulator must guarantee that the debt will be repaid under all circumstances, and then the cost of debt is equal to the risk-free interest rate. On the contrary, no limited liability is ensured to the shareholders, which bear a greater risk than the debtholders and (due to their risk aversion) require an higher return given an high firm's debt level.

The model is structured as a one period game: a positive exogenous shock on the firm's cost structure ($-c$) occurs with an exogenous probability p and then the regulator maximizes the consumer's indirect utility function under the debtholders, shareholders and firm constraints.

The maximization process leads to determine only the optimal price level, while the wages remain undetermined.

It is important to notice that, although in their model the authors explicitly consider the manager's effort as a cost, the model relies on the symmetric information hypothesis and then, for every price combination the provided effort (e) is always set at the optimal level.

Formally, the regulator faces the following problem:

$$\max_{q_H, q_L, e, w_H, w_L} pU(q_H) + (1-p)U(q_L) \quad (1.6)$$

$$\text{s.t. } pw_H + (1-p)w_L - \psi(e) \geq u_0 \quad (1.7)$$

$$\text{s.t. } q_H - (w_H - c - e) - (1+r_d)d \geq 0 \quad (1.8)$$

$$\text{s.t. } q_L - (w_L - e) - (1+r_d)d \geq 0 \quad (1.9)$$

$$\text{s.t. } \begin{bmatrix} p(q_H - w_H + c) + (1-p)(q_L - w_L) + e \\ -(1+r_d)d - (1+r_a)a \end{bmatrix} \geq 0 \quad (1.10)$$

in which L and H indicates the bad and the good state of the world, (1.7) is the manager participation constraint, (1.8) and (1.9) are the debtholders participation conditions and (1.10) is the risk adverse shareholders participation constraint.

Under these conditions, and considering the multiplier associated to (1.9) the maximization problem leads to the following conditions:

$$\begin{aligned}\psi'(e) &= 1 \\ q_H &= q_L\end{aligned}\tag{1.11}$$

As the wages remains undetermined, the authors arbitrarily impose the condition

$$w_L = \psi(e)$$

and then find the equilibrium debt level that can be issued by the firm.

In this way, the authors demonstrate that, under certain conditions, the regulator can influence the capital structure chosen by the firm, simply determining the optimal price level. It is clear, however, that the price cap condition imposed by (1.11) only ensures the consumers, as all the equity risk is suffered by the shareholders.

As the authors hypothesize that the equityholders are also risk adverse, the pricing rule has to shift through a rate of return compensation system: indeed, as long as (1.9) holds, it is impossible to both repay the debt and to guarantee a positive expected return to shareholders. Then, in order to provide an optimal insurance also to the shareholders, the socially optimal capital structure must leave some price uncertainty.

This can be demonstrated simply allowing the firm to choose her capital structure: in this case the authors find that the socially optimal level of debt is greater than its equilibrium level; then, in order to respect the debtholders constraint, the prices in the bad state of nature must rise with respect to the price cap rule.

It becomes clear, then, that the optimal capital structure must lie between the debt equilibrium level (pure price cap system with all the risk carried by the shareholders) and

the socially optimal debt level (rate of return regulation with all the risk suffered by the consumers); more precisely, the optimal capital structure has to be set where the benefit of an expected price reductions balances exactly the cost of the increase in price variability.

Some considerations can be drawn from this model, which is generalized by the Stones (2007) contribution. Firstly, it can explain the recently observed UK dash for debt phenomenon: as the shareholders are risk adverse, it is convenient for the firm to substitute equity for debt, in order to rise the prices variability and give a greater insurance to the risk adverse shareholders. This explanation is convincing only if it is reasonable to hypothesize that it is impossible to reach a sufficient risk diversification in the shareholders portfolios.

If the shareholders were risk neutral, the equity premium disappear from the CAPM model, and then a riskless return can be assumed on the shareholders investment. If this hypothesis holds, the model fails to provide an explanation to the firm's incentive in substituting equity for debt.

Indeed, the derivative of the welfare function with respect to the equilibrium debt level becomes exactly equal to zero, and the debt level chosen by the firm under a price cap system can be considered also the socially optimal debt level.

Secondly, it is possible to compare this model to the literature referred to the U.S. situation. As highlighted by Spiegel and Spulber (1994) and Spulber (1994), and also by the De Fraja and Stones (2004) under the assumption on the shareholders risk aversion, the firm *de facto* can induce the regulator to change his optimal pricing strategy, in order to guarantee the limited liability constraint to the debtholders and to assure the investors participation.

Thus, the conclusions of the model are embedded in his hypothesis: if a "fair" return has to be given to the shareholders, a price system which tends to the rate of return regulation has to be implemented.

In this way, the prescription to shift the pure RPI-X rule to a combination between the rate of return regulation and the price cap can be seen as a simply demonstration of the Helm (2004) conclusion: a change in the currently adopted UK regulator pricing system is desirable.

Notwithstanding, as the explanation given by this model about the recent gearing increase relies on the hypothesized shareholders risk aversion it does not consider other

possible determinants of the behavior of the UK regulated firms. Allowing for asymmetrical information problem can furnish some other keys that can be useful to interpret the actual UK situation and to consider some other policy implications.

Even if the contributions of Stones (2007) relies on the same assumptions of De Fraja and Stones (2004), it is interesting to briefly examine this model as it generalizes the previous conclusions removing the hypothesis that:

$$r_a(d) > r_d(d) \tag{1.12}$$

and investigating how the price controls determine the allocation of the risk between consumers and shareholders. Again, in this model, there is symmetric information between the regulator and the firm; the regulator maximizes the same welfare function, since he is supposed to consider only the consumer's indirect utility function, under the rationality constraint of the firm. As mentioned before, even in this model, the regulator has to reckon the limited liability constraint and has to assure a "fair" repayment to the invested shareholders capital.

Finally, it is important to underline that, if in De Fraja and Stones (2004) the manager has an independent role, in Stones he is assumed to simply maximizes the shareholder's utility function, but this hypothesis do not alter the equilibrium results as both of the model are set in a symmetric information framework.

In the work of Stones (2007), following the CAPM model, the cost of equity is simply equal to the covariance between the shareholders and market rate of return, that is:

$$R_e = cov(r_a, r_M)$$

in which $R(e)$ is the cost of equity and r_M is the rate of return to the market portfolio.

Here, the strong hypothesis is that if the firm has high costs (a negative shock), the market rate of return will be lower and if the firm has low costs (positive shock) the market

rate of return will be higher, that is:

$$\Delta R_M = R_{ML} - R_{MH} > 0$$

Then, maximizing (1.6) under only (1.8),(1.9) and (1.10) leads to:

$$r_a = cov(R_a, R_M) = \frac{p(1-p)}{a}(c - (q_L - q_H))\Delta R_M \quad (1.13)$$

Then, given the firm's capital structure, if $q_L = q_H$ (price cap regulation), the cost of equity is independent from the level of the price cap, because it is determined by the covariance between the shareholders and the market's returns. Furthermore, if the regulator chooses to reduce the firm profits (e.g. applying a tax), the market value of the equity falls, following the decrease of the firm's market value.

In the Stones model, then, if the regulator follows an RPI-X pricing scheme, the shareholders receive *de facto* the risk free return and the consumers sustain all the firm's cost variations, given by c .

This result can be explained by considering that if the covariance between the market return and the shareholder return is greater (lower) than zero, the shareholders return will be greater (less) than the market return, and the consumers share a greater (smaller) part of the business risk. The limit is reached when the covariance is exactly equal to zero, and the consumers carry all the business risk. Then, even if prices are higher in bad economic conditions, the return to the shareholders needs not to be lower: the risk is allocated between shareholders and consumers also in order to respect the high (or low) consumer's risk aversion. Theoretically, if the consumers are not too much risk adverse, the regulator can fix prices such that the cost of equity (and then, the shareholders expected return) is independent from the firm's business risk and then can be high even if the business risk is high.

This model generalizes the De Fraja and Stones (2004) results, as in equilibrium there are no feasible solutions to (1.6) in which $q_L^* \leq q_H^*$, and then it must hold that

$$q_L^* > q_H^* \forall d \in (0, 1) \tag{1.14}$$

The (1.14) states that the fixed price in the bad state of nature must always exceed the price in the good state; that is, the rate of return mechanism applies independently from the firm's capital structure, while in De Fraja and Stones this result applies only when the debt level exceeds its equilibrium level.

The Stones (2007) model achieves this result as he implicitly assumes that the cost of equity is influenced not only by the firm's debt level but also by the pricing formula. As result by (1.13) the regulator's decisions on prices and on the debt levels have a separate and an independent effect on the cost of equity and then an optimal variation in consumer prices can be determined at any firm's leverage level.

On the contrary of the De Fraja and Stones (2004) approach, the main result of the paper is that as $q_L^* > q_H^*$, the returns to shareholders need not to be associated to the firm's performance. Furthermore, the shareholders receive an expected return equal to the cost of equity, but the firm's cost of equity need not to be higher than the cost of debt¹².

Again this result implies that the regulator can change the risk distribution between consumers and shareholders simply manipulating the consumers prices, but here the optimality of the equilibrium level depends on the consumer's indirect utility functions and risk aversion as well as on the cost of equity.

It is remarkable that in the Stones model the price cap can never be an equilibrium rule and this reconfirm Helm (2004) intuition and generalize the De Fraja and Stones (2004) outcome.

Even in this model, the results rely on the shareholders risk aversion and on the consideration that the regulator has the option of setting prices such that the risk carried by shareholders (and then, the cost of equity) do not have to be tied to the firm's business risk.

Furthermore, the Stones (2007) model explain the U.K. recent empirical evidence, as

¹²Stones (2007), pg. 10

allowing the firm to determine her own capital structure, the following holds:

$$\begin{aligned} q_L^* - q_H^* &\neq c \Rightarrow 0 \leq d^{optimal} < 1 \\ q_L^* - q_H^* &= c \Rightarrow d^{optimal} = 1 \end{aligned} \tag{1.15}$$

Then the model theoretically justifies the 100% debt financing; notwithstanding, this particular result can be achieved only if the model parameters autonomously satisfy a particular condition: the relation between the cost of equity and the covariance between the shareholders' return and the market return must be linear¹³.

Even if these arguments may seem appealing and it is intuitive to consider that the regulator has to vary the prices in order to insure the shareholders to the nondiversifiable risks some considerations have to be done.

First of all, again in this model, as in the De Fraja and Stones (2004) the presence of perfect information does not allow to consider the perverse effect of the rate of return regulation on the manager's incentives scheme. As the shareholders are not linked to the firm's performance, it seems quite obvious that the manager can have some incentive to not exert the optimal effort level and then some investigations on this topic could be quite useful to better understand the optimal regulator's behavior.

Secondly, as the firm finds optimal to reduce her equity financing component, there is a reduction even in the buffer against possible negative shock, which are totally shifted to the consumers.

Finally, again the Stones model relies on the assumption of the shareholders risk aversion, that justify a partial distribution of the equity risk. As noticed before, it sounds a quite odd conclusion that it is useful to privatize a public service in order to shift part (or the totality) of the risk from the shareholders to the consumers. In this way, even in a symmetric framework, the consumers have to pay more only in order to pay the shareholders risk premium.

In the following Section I propose a theoretical model that consider both the regulated

¹³See Stones (2007), lemma 2 and lemma 3

firm capital structure choice and the level of effort exerted by the entrepreneur. I will demonstrate that there are some pricing scheme that allows the firm to rise her financial level but makes the exerted effort to be reduced.

1.4 The model

I consider a regulated economic sector in which a representative entrepreneur chooses the own ownership share and the level of effort, while the regulator chooses the prices that the firm can charge according to the quality of the service provided by the firm. It is assumed that there is asymmetric information concerning the effort provided by the entrepreneur and that the higher the entrepreneur's effort the higher the probability that the quality of the service is high.

The timing of the model is as follows. In the first stage, the regulator and the entrepreneur sign a contract, in which the price rule is specified. In the second stage, the entrepreneur undertakes the following choices: (i) the own share of the firm's ownership and (ii) the level of effort provision. At the final stage the state of nature is realized, both the agents observe the quality of the service and the entrepreneur receives her payment.

In the proceeding I formally introduce such hypotheses and investigate how changes of the price rule affect the equilibrium of the model.

The Probability Distribution of the Quality of the Service. The quality of the service is a stochastic variable that can assume two realizations: high or low. The probability of the high quality outcome depends positively on the effort provided by the entrepreneur. Specifically, the probability distribution of the quality of the service follows a Bernullian process where $p(e)$ is the probability that the high quality outcome, $1 - p(e)$ is the probability of the low quality outcome and e represents the effort provided by the entrepreneur. It is assumed that the probability of the high quality service is an increasing and concave function of e , that is, $p'(e) > 0$ and $p''(e) < 0$.¹⁴ The probability distribution of the quality of the service and its realization are common information, while the level of

¹⁴The concavity of the function $p(\cdot)$ is not necessary, in fact the results of the model do not change if $p(e)$ is linearly increasing in e , i.e. if $p''(e) = 0$.

the provided effort is a private information of the entrepreneur.

The Firm’s Capital Structure and the Entrepreneur’s Ownership Share.

For simplicity, it is assumed that the size of the investment project is equal to 1. The entrepreneur can finance such investment by issuing debt or equity, where d indicates the share of the investment financed by debt and $(1 - d)$ the share financed by equity.¹⁵

In this framework the debt level plays two roles. It represents a fixed cost that should be repaid in each state of nature, at the interest rate, r_d . Moreover, the debt share measures the share of the firm that is directly owned by the entrepreneur.

The Price Rule. It is assumed that the contract between the regulator and the entrepreneur sets the price that the firm can charge for each state of nature before observing the quality of the service. When the quality of the service is high, the firm can charge a price equal to q_H ; otherwise, the firm is allowed to charge a price equal to q_L .¹⁶ In this framework, it is reasonable to assume that q_H is at least equal to q_L , or greater; in particular, when $q_H = q_L$, the price cap formula holds.

Finally, the contract fixes an amount H that represents a part of the entrepreneur’s remuneration that is not related to the quality of the service and to the ownership structure of the firm. In the model H is always adjusted in order to be sure that the entrepreneur’s participation constraint is respected.

The Cost of Effort. The entrepreneur’s aversion to effort is given by the function $\psi(e)$, which is increasing and convex in the effort level. Formally, the following holds:

$$\psi'(e), \psi''(e) > 0 \tag{1.16}$$

¹⁵Notice that we assume that the entrepreneur does not use own capital in the investment project; however, the introduction of a positive share of own capital would modify only the level of the debt and equity share, but does not influence how such shares vary after a change of the price rule, that is the aim of our investigation.

¹⁶Without loss of generality, it is assumed that the price levels (q_H and q_L) measure the returns of the entire investment. Such assumption is not relevant since the economic costs are assumed constant between the state of the nature and the participation constraint is always under control.

The Entrepreneur's Choices. Given the previous assumptions, the entrepreneur's maximization problem is defined as follows:

$$\max_{e,d} EU_{manager} = p(e) [d(q_H - (1 + r_d) d)] + (1 - p(e)) [d(q_L - (1 + r_d) d)] + H - \psi(e). \quad (1.17)$$

Independently of the realization of the state of nature, the entrepreneur has a remuneration equal to H and suffers a cost in exerting effort e equal to $\psi(e)$. When the quality of the service is high the entrepreneur's returns are equal to $d(q_H - (1 + r_d) d)$, that is given by the product between the entrepreneur's ownership share d and the difference between the net revenue of the investment project (represented by the price q_H) and the cost of the debt. Similarly, $d(q_L - (1 + r_d) d)$ is the entrepreneur's payoff associated to the bad state of nature.

The entrepreneur chooses the level of debt and the level of effort by solving the maximization problem (1.17). The following conditions emerge:

$$e : p'(e) [d(q_H - (1 + r_d) d)] - p'(e) d(q_L - (1 + r_d) d) - \psi'(e) = 0 \quad (1.18)$$

and:

$$d : p(e) q_H + (1 - p(e)) q_L - 2(1 + r_d) d = 0. \quad (1.19)$$

Eq.(1.18) and eq.(1.19) can be rewritten in the following ways:

$$p'(e^*) d(q_H - q_L) = \psi'(e^*), \quad (1.20)$$

and

$$d^* = \frac{p(e) q_H + (1 - p(e)) q_L}{2(1 + r_d)}. \quad (1.21)$$

Eq.(1.20) describes the effort choice, where the right side of the equation represents the marginal benefit of effort and the left side the marginal cost. The effort provision

positively depends on the difference between the returns of the states of nature, weighted with the entrepreneur's ownership share, and on the capability of the effort to affect the probability distribution of the states of nature. Obviously, the level of effort negatively depends on the aversion to effort of the entrepreneur. From this condition emerges a first linkage between indebtedness and effort. The higher the entrepreneur's share, the higher the marginal benefit that follows an increase in the probability of the high-quality outcome and then the higher the incentive to provide effort.

Eq.(1.21) shows that the optimal level of debt, and then the entrepreneur's ownership share, is an increasing function of the prices and is a decreasing function of the unitary cost of debt. The weight that the entrepreneur gives to each price depends on the probability under which they will be applied. Here another linkage between effort and debt emerges. The higher the effort, the higher the probability of high returns and then the incentive to increase the size of the ownership rises.

Finally, both (1.20) and (1.21) suggest that there should be a comovement between the issued debt and the exerted effort. In the proceeding I demonstrate that such conclusion does not always hold and that the sign of the correlation depends on which policy instrument is subject to a change. If the regulator rises the price that characterizes the good state of nature q_H , there will always be a positive relation between the exerted effort and the issued debt. On the contrary, the sign of this relationship can be reversed if the regulator decides to rise the level of the price in the bad state of nature.

Before analyzing the effects of a change in the price rule, notice that substituting eq.(1.21) in eq.(1.20) it is possible to identify a condition that implicitly expresses the optimal effort as a function of the exogenous variables, that reads:

$$p'(e) \left[\frac{p(e)q_H + (1-p(e))q_L}{2(1+r_d)} (q_H - q_L) \right] - \psi'(e) = 0 \quad (1.22)$$

1.5 The effects of changes in the price rule

In this model I am not interested in deepening a welfare analysis. So, I do not investigate which would be the regulator's optimal choice, since the result would be strongly affected

by the specification of the regulator's objective function. In the proceeding I investigate how a change in the price rule affects both the effort provision and the capital structure of the regulated firm. That has strong implications for the study of the quality of the services in a regulated market.

Firstly I investigate how the equilibrium changes after an increase in the price of the high-quality service. Then, I develop the same analysis for an increase in the price of low-quality service.

The effects of a rise in q_H . Suppose that the regulator decides to increase q_H . The following propositions establish how the effort and the debt will change.

Proposition 1 *A rise in the price of the high-quality service, q_H , has always a positive effect on the effort exerted by the entrepreneur.*

Proposition 2 *A rise in the price of the high-quality service, q_H , induces the entrepreneur to rise the issued debt.*

The proof of Proposition (1) and of Proposition (2) are provided in the Appendix.

The economic intuition that underlies both propositions is quite simple. Proposition (1) suggests that an increase in q_H increases the provision of effort because the high-quality service has become relatively more convenient, the difference between the returns in the two states of nature has risen. That prompts the entrepreneur to try to produce a high-quality service. Since the marginal benefit of effort increases also the level of effort rises.

The economic interpretation of Proposition (2) is straightforward. A rise in the price q_H leads the entrepreneur to expand his ownership because, *ceteris paribus*, her expected returns have raised.

The previous effects reinforce each other. The higher the effort the higher the entrepreneur's ownership share and the higher the entrepreneur's ownership share the higher the incentive to provide effort. It follows that a rise in q_H induces an increase in both effort and debt.

The effects of a rise in q_L . Suppose that the regulator increases the price that the firm can charge when the quality of the service is low. The results of this analysis are

reported in the following propositions:

Proposition 3 *A rise in q_L increases the effort provided by the entrepreneur as long as the following condition holds:*

$$q_L < \frac{(1 - 2p(e))}{2(1 - p(e))} q_H. \quad (1.23)$$

Proposition 4 *A rise in q_L generally increases the level of debt. It could reduce the level of debt if and only if it negatively affects the provision of effort.*

The proofs are provided in the Appendix.

Proposition (3) states that an increase in q_L can induce an increase in the provision of effort only if the probability of the high-quality service is lower than one half, and the price of the low-quality service is less than one half of the price of the high-quality service scenario.¹⁷ Specifically: $0 \leq p(e) < \frac{1}{2}$ and $0 < q_L \leq \frac{1}{2}q_H$. Let's focus on the economic intuition.

The price q_L influences the effort choice either directly and indirectly. Firstly, an increase in q_L reduces the comparative advantage of being in the good state of the nature. This directly makes the choice to provide effort less convenient. Secondly, when q_L increases, the payoff in the bad state of nature becomes less penalizing and then the entrepreneur has the incentive to increase its ownership share. That increases the convenience to provide effort. Proposition (3) indicates that the indirect effect may overcome the direct effect only if $p(e)$ is low. That is reasonable because low probability of the high-quality service implies low level of effort and, overall, it implies that $p'(e)$ is relatively high and $\psi'(e)$ is relatively low. The reverse occurs when $p(e) > \frac{1}{2}$, the indirect effect never overcomes the direct effect which reduces the incentive to make effort.

Proposition (4) states that if the the price of the low-quality service rises, then the entrepreneur is generally induced to increase the own ownership share. But proposition (4) also highlights that such effect does not always prevail because of the way the provision of effort changes. In fact, if the entrepreneur decides to reduce effort, then the probability of the realization of the high-quality service falls and the expected returns too. Such indirect

¹⁷These are necessary but not sufficient conditions.

effect may prompt the entrepreneur to cut his own ownership share.

Previous results imply the following corollaries.

Corollary 1 *Starting from a price cap scheme, that is $q_H = q_L$, a rise in q_L does always reduce the effort provided by the entrepreneur.*

Corollary 2 *Starting from a price cap scheme, that is $q_H = q_L$, a rise in q_L does always increase the firm's issued debt.*

It is particularly important to highlight that the pricing policy proposed by Spiegel and Spulber (1994, 1997) for the US and by De Fraja and Stones (2004) for the UK can have some perverse effects on the effort level. More precisely, every pricing policy that tries to translate the risk from the shareholders to the final consumers by a rise in q_L , after a certain effort level will only allow to a rise in the final debt without an increase in the provided effort. This effect is essentially due to the misleading consideration given by these authors to the indebtedness level. On one hand, a greater debt always implies greater risk of financial distress; on the other hand, all these authors fail to recognize that the debt allows the entrepreneur to increase his ownership control. This substantially determines a controversial linkage between the indebtedness level and the exerted effort, that the regulator should carefully consider.

1.6 Conclusion

This Chapter analyzes the existing literature on the linkage between firm's capital structure choices and regulator's pricing policy and proposes an original theoretical model that explains the non linear relation between issued debt and exerted effort in presence of information asymmetries in a regulated firm.

The existent literature has focused only to the relation between the regulator's behavior and the firm's capital structure choice without correctly considering the manager incentives. Moreover, the recently experienced fly from equity phenomenon occurred in the UK, highlighted the importance of the choice of a pricing scheme that correctly incentive the

entrepreneur to exert the optimal effort level.¹⁸

In order to control the capital structure choices, some authors suggest to partially shift the economic risk of the firm from the shareholders to the consumers by rising the firm's payoff in the bad state of nature. Particularly, Helm (2003, 2006) stressed the importance of determining a "split" cost of capital, that recognizes the higher risk suffered by the shareholders in the ownership of public utilities, and then correctly incentive the firm's manager in choosing the optimal capital structure. Otherwise, De Fraja and Stones (2004) and Stones (2007) find that the price cap mechanism is suboptimal as it fails to cover the risks in the bad state of nature, and then it does not lead the economic system to the social efficiency. However, this literature underlines that the firm's high indebtedness is optimal for the regulator as long as the consumers face a lower expected prices (as the cost of debt is generally lower than the cost of equity) and the firm will obviously benefit of a greater protection.

Then, in this paper, I investigate the linkage between indebtedness level and the exerted effort. I demonstrate that, if the entrepreneur can determine the firm's capital structure, the price cap scheme does not lead to the optimal effort level. This is essentially due to the non-linear relation between effort and debt, related to the "ownership effect" that characterize the choice of the indebtedness level by the entrepreneur. Despite the previous contributions, in this paper I demonstrate that an higher debt level implies an higher risk of financial distress but also the possibility for the entrepreneur to extend his ownership control. This theoretical intuition can explain the dash for debt recently experiment by the UK economy in the regulated sector of utilities, and the absence of a consistent rise in the quality of the service. Particularly, if the regulator promotes a price cap pricing scheme, the entrepreneur is not correctly incentivated in determining the optimal effort level, but will continuously rise his debt level. This result is consistent with the De Fraja and Stones (2004) work. However, I demonstrate that a rise in the payoff in the bad state of nature can lead to some path under which the effort level decreases and the indebtedness of the firm rises.

Then my contribution partially overcomes the De Fraja and Stones (2004) result that

¹⁸See Ofwat (2004, 2007) and HM Treasury (2004).

prescribes a rise in the price associated with the worst payoff in order to make the firm switch from equity to debt financing and then to low the expected prices. Indeed, I demonstrate that this policy prescription can be misleading if the entrepreneur decides to low the exerted effort. Then, in order to find the optimal pricing rule, the regulator should consider not only the debt level, but also the effort exerted by the entrepreneur, and to jointly pursue both these objectives.

Bibliography

- [1] Ai,C. and Sappington, P.(2002) "The impact of State Incentive Regulation on the U.S. Telecommunication Industry", Journal of Regulatory Economics, vol.22, No.2.
- [2] Bobo, G. and Spiegel, Y. (2006) "Optimal state-contingent regulation under limited liability", RAND Journal of Economics, vol. 47, pp. 430-447.
- [3] Bolton, P. and Freixas, X. (2000) "Equity, Bonds and Bank Debt: Capital Structure and Financial Market Equilibrium under Asymmetric Information", Journal of Political Economy, vol.108, No.2.
- [4] Boussofiene, A., Martin, S., Parker, D.:(1997), "The impact on technical efficiency of the UK privatization programme", Applied Economics, Vol. 29, pp.297-310.
- [5] Cowan, S. (2002) "Price Cap Regulation", Swedish Economic Policy Review, vol.9. pp. 167-188.
- [6] Cowan, S. (2003) "Optimal risk allocation for regulated monopolies and consumers", Journal of Public Economics vol. 88 pp. 285– 303.
- [7] Cowan, S. (2006) "Network Regulation", Oxford Review of Economic Policy, vol.22, No 2.
- [8] Dasgupta, S. and Nanda, V. (1993): "Bargaining and Brinkmanship:Capital Structure Choice of Regulated Firms", International Journal of Industrial Organization, vol. 11, No.4 pp. 475-497.
- [9] De Fraja,G. and Stones,C.(2004): "Risk and Capital Structure in the Regulated Firm", Journal of Regulatory Economics, vol.26, No.1.

- [10] Grout, P.A., Jenkins, A. and Zalewska,A. (2001) "Privatisation of Utilities and the Asset Value Problem", CMPO Working Paper Series No. 01/41.
- [11] Guthrie,G. (2006): "Regulating Infrastructure: The Impact on Risk and Investment," Journal of Economic Literature, American Economic Association, vol. 44, N. 4, pp.925-972.
- [12] Guthrie, G. and Evans, L. (2006): "Incentive Regulation of Prices When Costs are Sunk," Journal of Regulatory Economics, Springer, vol. 29(3), pp. 239-264.
- [13] Harris, M., Raviv, A. (1991) "The Theory of Capital Structure", The Journal of Finance, vol. 37, No. 1.
- [14] HM Treasury/DTI (2004) "The Drivers and Public Policy Consequences of Increased Gearing: A Report by the Department of Trade and Industry and HM Treasury".
- [15] Helm, D. (2003), 'Whither Water Regulation?', chapter 1 in D. Helm (ed), Water,Sustainability and Regulation, Oxford: OXERA, May, pp. 1–12. (also available on www.dieterhelm.co.uk)
- [16] Helm, D. (2004) "Water: The Periodic Review 2004 and the Environmental Programme" University of Oxford, mimeo, available on www.dieterhelm.co.uk
- [17] Helm, D. (2005) "Water: The Environment and the Regulation: Changing Functions, Changing Frameworks", University of Oxford, mimeo, available on www.dieterhelm.co.uk
- [18] " (2006) "Ownership, Utility Regulation and Financial Structures : an Emerging Model", University of Oxford, mimeo, available on www.dieterhelm.co.uk
- [19] HM Threasury (2004) "Pre-Budget Statement".
- [20] Leland, E. and Pyle,D.H. (1977) "Informational Asymmetries Financial Structure, and Financial Intermediation", The Journal of Finance, vol. 32, No.2.
- [21] Levy,B. and Spiller, P. (1994) "A Framework to Resolve the Regulatory Problem" in B. Levy and P.Spiller eds. "Regulation, Institutions and Commitment", Cambridge University Press

- [22] Myer, R.A. (1976) " Capital Structure and the Behaviour of the Regulated Firm under Uncertainty", Southern Economic Journal, vol.42, pp.600-609
- [23] Myers,S.C.(1984) "The Capital Structure Puzzle", The Journal of Finance, vol.39 No.3
- [24] Modigliani, F. and Miller, M.H. (1958) "The Cost of Capital, Corporation Finance and the Theory of Investment", American Economic Review, vol. 48, No. 3, pp.261-297.
- [25] Newbery, D. (2002) "Privatization, Restructuring and Regulation of Network Utilities (Walras-Pareto Lectures)", The MIT Press.
- [26] Ofwat and Ofgem (2006) "Financing Networks: a Discussion Paper", Office of Water Services and Office of Gas and Electricity Markets, available on www.ofwat.gov.uk
- [27] Ofwat (2002) "The Capital Structure of Water Companies", Office of Water Services final report.
- [28] Ofwat (2004), 'Future Water and Sewerage Charges 2005–10: Final Determinations'.
- [29] Ofwat (2007), "Water and Regulation: Facts and Figures", Office of Water Services.
- [30] Saal, D. ; Parker, D. and Weyman-Jones, T.:(2007), "Determining the contribution of technical change, efficiency change and scale change to productivity growth in the privatized English and Welsh water and sewerage industry: 1985–2000", Journal of Productivity Analysis, Vol. 28, No. 1, pp. 127-139.7
- [31] Spiegel,Y.and Spulber,D.F.(1994) "The Capital Structure of a Regulated Firm", RAND Journal of Economics, vol.25, No.3.
- [32] Spiegel,Y.and Spulber,D.F.(1997) "Capital Structure with Countervailing Incentives", RAND Journal of Economics, vol.28, No.1.
- [33] Spulber,D.F. (1988) "Bargaining and Regulation with Asymmetric Information about Demand and Supply", Journal of Economic Theory, vol.44.
- [34] Stones, C. (2007) "Risk Sharing, the Cost of Equity and the Optimal Capital Structure of the Regulated Firm", Working Paper, University of York, n. 05/31.

- [35] Taggart, R.A. (1981) "Rate of Return Regulation and Utility Capital Structure Decisions", Journal of Finance, vol. 36, No. 2, pp. 383-393.
- [36] Taggart, R.A. (1985) "Effects of Regulation on Utility Financing : Theory and Evidence", Journal of Industrial Economics, vol. 33, No. 3, pp. 257-276.
- [37] Titman,S. and Wessels, R. (1988) "The Determinants of Capital Structure Choice", The Journal of Finance, vol. 53 No.1.
- [38] Usman, M. (2004), "Optimal Debt Contracts with Renegotiation", Journal of Economics & Management Strategy, Vol. 13, pp 755-776.
- [39] Vogelsang, I. and Finsinger, J.: (1979)“A Regulatory Adjustment Process for Optimal Pricing by Multiproduct Monopoly Firm", Bell Journal of Economics, Vol.10. Titman,S. and Wessels, R. (1988) "The Determinants of Capital Structure Choice", The Journal of Finance, vol. 53 No.1.

Appendix

Proof. I jointly derive (1.22) with respect to e , q_H and q_L , obtaining the following rule:

$$\left[\frac{(q_H - q_L)^2}{2(1+r_d)} p'(e) - \frac{G''(e)p'(e) - p''(e)G'(e)}{p'(e)^2} \right] \Delta e + \left(\frac{2p(e)(q_H - q_L) + q_L}{2(1+r_d)} \right) \Delta \pi + \left(\frac{(1-2p(e))(q_H - q_L) - q_L}{2(1+r_d)} \right) \Delta c = 0$$

If the difference between q_H and q_L is almost equal to zero, the following holds:

$$\left[\frac{(q_H - q_L)^2}{2(1+r_d)} p'(e) - \frac{G''(e)p'(e) - p''(e)G'(e)}{p'(e)^2} \right] < 0$$

I firstly proof that:

$$\left(\frac{2p(e)(q_H - q_L) + q_L}{2(1+r_d)} \right) > 0 \tag{1.24}$$

Simply algebra manipulations allows me to rewrite (1.24) as:

$$q_L < \frac{(1 - 2p(e))}{2(1 - p(e))} q_H$$

that, for a sufficiently small difference between q_H and q_L , holds for every value of $p(e)$. Then, e is always an increasing function in q_H .

Secondly, I will proof that q_L has an ambiguous effect on e , that is:

$$\left(\frac{(1 - 2p(e))(q_H - q_L) - q_L}{2(1 + r_d)} \right) < 0$$

that, after some manipulations can be rewritten as:

$$\frac{(1 - 2p(e))}{2(1 - p(e))} q_H < q_L$$

that is always satisfied if $p(e) > \frac{1}{2}$. However, if $p(e) < \frac{1}{2}$, $\left| \frac{(1-2p(e))}{2(1-p(e))} \right| < 1$ and then q_L can also have some positive effect on the final effort level. ■

Proof. Firstly I proof that there is always a positive relation between q_H and the issued debt. Then I derive eq. (1.19) with respect to q_H and obtain:

$$\frac{\partial d}{\partial q_H} = \frac{p(e)}{2(1 + r_d)} + \frac{q_H - q_L}{2(1 + r_d)} p'(e) \frac{\partial e}{\partial q_H}$$

which is always greater than zero.

Secondly, I will proof that the relation between the debt level and q_L is not straightforward.

Deriving d with respect to q_L leads to:

$$\frac{\partial d}{\partial q_L} = \frac{1 - p(e)}{2(1 + r_d)} + \frac{(q_H - q_L)}{2(1 + r_d)} p'(e) \frac{\partial e}{\partial q_L}$$

and then the debt will increase as long as $\frac{\partial e}{\partial q_L} > 0$, and decrease when $\frac{\partial e}{\partial q_L} < 0$ and $\frac{1-p(e)}{2(1+r_d)} < \frac{(q_H - q_L)}{2(1+r_d)} p'(e) \frac{\partial e}{\partial q_L}$. Then, if $\frac{\partial e}{\partial q_L} < 0$ and effort decreases, there can be value of q_L such that $\frac{1-p(e)}{2(1+r_d)} > \frac{(q_H - q_L)}{2(1+r_d)} p'(e) \frac{\partial e}{\partial q_L}$ and then the debt level rises.

It is then straightforward to see that in the price cap scheme, when $q_H = q_L$, a rise in the

final price always lead to an higher level of debt. ■

Chapter 2

Debt and Efficiency in Italian Water Companies

Abstract¹

This paper empirically investigates the impact of a high level of financial leverage on the efficiency of a sample of 65 Italian water companies. In order to disentangle the sources of inefficiencies I adopt both a Classical and a Bayesian stochastic frontier approaches. Firstly, I test whether a positive relation between the regulated firm indebtedness and the firm specific inefficiency exists; secondly I investigate if the ownership of Italian water companies matters in determining the firm's performance and, finally, I examine if the recent consolidation process occurred between different water companies affects the economies of scale that characterized the Italian water sector before the 1994 reform. The estimation results are strongly encouraging: the firm's leverage level emerges as the main determinant of the inefficiencies whereas the ownership seems to have not affected the firm's performance. Moreover, estimation results reveal a positive degree of economies of scale for small water companies. This result indicates that local communities may benefit from merging into different water districts.

J.E.L. Classification Numbers: C51, Q25, L10, L32 .

Keywords: Efficiency Analysis, Capital Structure, Water Distribution Utilities, Price Regulation, Gibbs Sampling.

¹I thank William Addessi, Maddalena Barbieri, Pierpaolo Pierani, Antonio Ranieri, Andrea Tancredi, participants in conferences at the University of Turin , at the WIEM conference in Warsaw and at the EAEPE conference for helpful comments and suggestions. Remaining errors and expressed views are my own.

2.1 Introduction

Recent literature highlights that there is a positive relation between the regulated firms capital structure choice and the regulator's pricing policy.²

Particularly some authors notice that regulators can not credibly commit to leave regulated firms to financial distress since any service disruption should be avoided.³ Moreover, the consumer welfare is positively affected by a low cost of capital, that can be achieved by a greater proportion of debt with respect to the equity financing.

Then, in this framework, regulated firms can optimally issue debt in order to force the regulator to determine a more favorable pricing scheme, that fully insure the debtholders from any bankruptcy risk.

Particularly, in the water sector, the empirical evidence for these models is provided by the UK Authority for the water sector (OFWAT) who recently highlights that the UK water companies experienced a fly-from-equity phenomenon after the 2004 price revision, in order to conveniently rise their levels of debt, that in the future will potentially overcome the 0.5 of the firm's total asset value.⁴

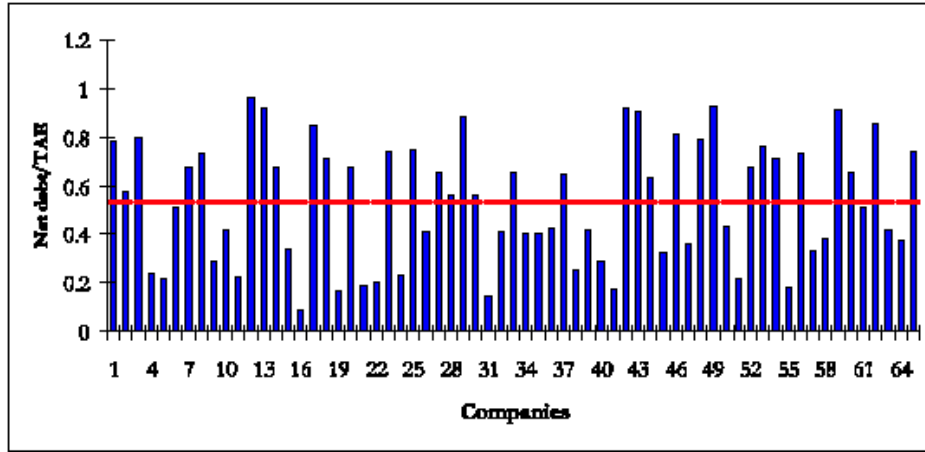
In Italy, the financial leverage level of the regulated water companies is even more alarming, as emerges in the following Figure:

²See Taggart (1981, 1985), Dasgupta and Nanda (1993), Spiegel (1994), Spiegel and Spulber (1994, 1997), De Fraja and Stones (2004).

³see Spiegel and Spulber (1997) and De Fraja and Stones (2004)

⁴See OFWAT (2004).

FIGURE 1: ITALIAN WATER COMAPANIES LEVERAGE LEVEL (2007)⁵



The red line indicates the average of the leverage level.

In order to understand if only an high gearing level implies a slowdown in the firm's productivity or there are other determinants of the inefficiency of the Italian regulated water firms, I firstly investigate the role of excessive financial leverage level on 65 Italian water firms, and then I analyze the relationship between ownership and efficiency.

This choice is essentially due to study the effects of the 1994 Italian water sector reform, known as the "Galli's Act". The Galli's Act allows to a (partial) liberalization of the water sector and to a division of the Italian climate homogeneous areas into 99 sub-regional administrative divisions (ATO), that can autonomously decide their water company concession. Despite the law formally encouraged the consolidation between different companies, there is still a great company heterogeneity in different ATO.⁶ Moreover, it is quite frequent that a company serves more than one optimal administrative division.

Then the other aims of the present paper are (i) to analyze how the privatization affected the firm's performance and (ii) investigate the possible presence of economies of scale.

In Italy there is no an unified and official database that collects data from all the water companies. Moreover, there is still a lack of transparency in some of the ATO management, since it is not possible to know how the final tariff is determined, that is, the data on firm's

⁵Measured as the ratio between net debt and the firm's total asset value.

⁶See the Appendix.

operative costs and cubic meters of water delivered are not published by the different local authorities.⁷ Then, an important part of my work was to collect all the necessary data from the balance sheets of the water companies.⁸ As all the multiutility companies have an unified balance sheet, the data of the water branch were explicitly required.⁹

Technically, the analysis is performed with two different approaches: a "classic" stochastic frontier estimation, a technique that has been widely used in economic literature in order to determine the efficiency of a company management, and a Bayesian analysis that, at the best of my knowledge, has never been performed to evaluate the efficiency in the water sector. My analysis is particularly innovative because (*i*) it is the first empirical investigation on the relation between the water regulated companies and their financing choices and (*ii*) it's the first Bayesian stochastic frontier analysis of the water sector.

Therefore, my analysis can be directly compared with similar studies characterized by the classical estimation technique (see Fabbri and Fraquelli, 2000 and Antonioli and Filippini, 2001) but also present Bayesian results that overcome the well known small sample bias problem, that often occurs in sectors that are characterized by a finite number of competitors.

The results for the Italian water companies are strongly encouraging: firstly, the firm's leverage level emerges as the main determinant of firm inefficiencies in both kind of estimates. This result suggests that regulator's policy should also reckon in the relationship between leverage and efficiency before determining an appropriate pricing mechanism. Then, even if a dash for debt implies lower final prices, the consumers (and the regulator) should also expect a negative effect due to the rise of company inefficiency.

Secondly, in the analyzed sample, the relation between the firm's inefficiencies and the firm's ownership is not significant. This means that the recent privatization process does not seem to affect neither the firm's leverage level, nor the firm's inefficiency. This result seems counter intuitive, but it is not surprising considering the specificity of the Italian

⁷Particularly, some of the ATO claim to ignore the financial indicators that I use in my analysis whereas other ATO simply refuse to cooperate and do not provide the required data.

⁸Provided in the AIDA databank.

⁹This part of my work would be impossible without the help of the Local Authority for Public Services, that is allowed to contact all the ATO and the multiutilities company.

The majority of companies cooperate, but the vast heterogeneity of firms that refuse to diffuse their official data allows me to consider my sample as randomly selected.

water sector. On one hand, the absence of a strong and independent regulator leads to regulation uncertainty that can compromise the performance of all the water firms, independently of their ownership. On the other hand, the presence of 93 different ATO can lead to the well known "regulator's capture" problem, and then to discourage a positive firm's performance. Moreover, it should be considered that the privatization process is a quite recent phenomenon and it has interested only partially the Italian water companies.

Thirdly, the estimation results reveal a positive degree of economies of scale for small water companies. Then, although the Galli's Act explicitly encourages the consolidation between different water companies, the small local communities may still benefit from merging into water districts.

The outline of the paper is as follows. In Section II a generalized cost function for water utilities is presented. The Classical estimation results are discussed in Section III, while the Bayesian analysis is presented in Section IV. Conclusion of the study are summarized in the final section. The data and variables construction are presented in the Appendix.

2.2 Related Literature

At the best of my knowledge, all the empirical contribution on the efficiency of the water sector consist on classical estimates of stochastic frontiers. Then in this Section, I briefly present the more relevant contributions that investigate the possible source of water company inefficiencies.

The existent literature can be grouped as follows: *(i)* a first group of papers investigate the relationship between firm's ownership and firm's inefficiency and *(ii)* some other works determine the linkage between inefficiency and the presence of economies of scale and scope in the water sector.

For the first group, a seminal paper for the water industry is provided by Teeple and Glycer (1987), who estimate the performance of 92 US water delivery companies and find a weak relation between private ownership and firm's efficiency.

Moreover, these authors highlight the importance of the financing choice to correctly determine the firm's inefficiency. Although these authors do not consider the leverage level as an exogenous variable that directly affects the firm's inefficiency term, they include the

firm's financing choice in the price of capital measurement.

This work is particularly important for my analysis as, at the best of my knowledge, it is the only paper that explicitly recognize the importance of the source of financing in analyzing the firm's performance.

Furthermore, beyond the output variable, Teepes and Glyer reckon on other explicative variables, such as the connection per mile of lines, the percentage of connection metered and a water treatment index, in order to control all the possible sources of difference among different firms. Then, this work highlights both the importance of a correct specification of financing choice and the well known omitted variable bias: in order to correctly understand the source of inefficiency, it is important to include the variables that clarify the existing relation between cost of production and firm's performance.

A different result is obtained by Bhataccaryya et al. (1994) that examine a sample of 225 public and 32 private water utilities using the data from a 1992 survey on the US water industry. These authors determine that the publicly owned firm are more efficient than the private utilities on average, but they are also more dispersed between best and worst practices.

Furthermore, the same authors analyze in 1995 a sample of 221 companies, and find that for small companies the private ownership negatively affects the firm's inefficiency, while the reverse occurs for high output levels. Then, again, the linkage between ownership and efficiency is not straightforward but depends on the size of the considered firm.

The second group of authors explicitly investigate the presence of economies of scale and scope in the water sector.

Clagget (1994), Ashton (2000), Garcia and Thomas (2001) and Sauer and Frohberg (2007) investigate the linkage between firm's size, spatial effects and the firm's performance for a sample of US, French and German water utilities.

All these authors find the presence of economies of scale and then highlight the role of vertical integration in order to improve the final firm's performance.

To better understand the Italian specificities, I finally present the contributions given by Fraquelli and Fabbri (2000) and Antonioli and Filippini (2001), that also investigate the presence of economies of scale and scope in Italian water utilities. However, although these works investigate the determinants of inefficiency of the Italian water sector they do

not consider the importance of the choice of the source of financing.

Fraquelli and Fabbri analyze 173 water Italian utilities for the year 1991. Before the publication of the Galli's Act, in 1994, the Italian water sector was highly fragmented, and then the sample given by 173 companies represented only the 3% of the total Italian suppliers, even if they count for more than the 50% of the total water production.

Now the situation have changed, and in Italy there are more than 100 water suppliers; however, the actual regulation policy promotes the consolidation between small companies, in order to constitute of a single water supplier for every defined optimal homogeneous area (ATO).

Fraquelli and Fabbri firstly estimate a transcendental logarithmic equation, in which they do not consider the price of capital in order to avoid any collinearity problem. Moreover, due to the relatively small number of observation, they include in the estimate the demand share equations, and then adopt the SUR methodology.

Finally, imposing all the theoretical restriction, they have to switch to a Cobb Douglas specification, that they find to better fit their data.

In order to control for the size effects, they separate the companies by the number of served consumers. They find that for small companies (i.e. with a number of served inhabitants lower than the national average) the possibility to benefit of economies of scale exists. Otherwise, for greater companies, there are no benefits from a size increase.

Also Filippini and Antonioli (2001) analyze a panel of 32 Italian companies for 5 years, from 1991 to 1995, and estimate a Cobb Douglas efficiency frontier with a random effects estimator.

Although their findings are quite similar to Fraquelli and Fabbri (2000), they do not find any evidence that larger service areas result in scale economies in water distribution. Moreover, these authors directly include in their analysis a dummy variable that indicates the presence of water chemical treatment.

However, a shortcoming of the existent literature on Italian's water companies is to include directly in the cost function the environmental variables that should affect the inefficiency terms. Then, it is possible that their results are affected by a bias due to a wrong specification of the cost function.

Moreover, both the studies on Italian water sector ignore the impact of financing choice

in determining firm's efficiency. In order to include the recent theoretical findings and to investigate the relationship between firm's indebtedness level and firm's final performance I propose in my analysis a financial indicator (precisely, an index of the leverage magnitude).

Finally, these works are potentially affected by the small sample bias, since they present only Classical estimates.

In order to better highlights the different econometric results presented by different authors, a brief summary of the relevant literature analyzed in the previous section is presented in Table 1.

TABLE 1 EXISTING LITERATURE

AUTHORS	TIME	ENVIRONMENTAL VARIABLES	ESTIMATOR	TOPIC	RESULTS
Teeples and Glycer (1987)	1980	size and area served type and ownership of the firm water storage capacity water treatment firm source of financing	Translog SUR	Own.	no significant difference between public and private
Bhataccaryya et. al. (1994)	1992	ownership of the firm	Translog MLE	Own.	public on average more efficient but also more dispersed
Bhataccaryya et. al. (1995)	1992	service quality size and area served type and ownership of the firm dummies for ground water	Translog MLE	Own.	controversial for the ownership
Ashton (2000)	1987-1997	ownership of the firm	Translog FE	EcS	significant scale effects
Fraquelli and Fabbri (2000)	1991	number of consumers water storage capacity treatment costs	Cobb Douglas SUR	EcS	significant scale effects
Garcia and Thomas (2001)	1995-1997	number of municipalities network lenght water stocking pumping capacity	Translog SUR, GMM	EcS	significant scale effects
Antonioli and Filippini (2002)	1991-1995	number of consumers size and morphology of distr.area system of water collection length of distr.pipes	Cobb Douglas RE	EcS	significant scale effects
Sauer and Frohberg (2007)	2000	allocative efficiency	SGM OLS (corrected)	EcS Own.	significant scale effects no clear effect for the ownership

2.3 Efficiency Analysis and Data Description

As highlighted in the first Section, the main scope of this paper is to investigate whether in Italian water companies a positive relation exists between inefficiency and debt levels.

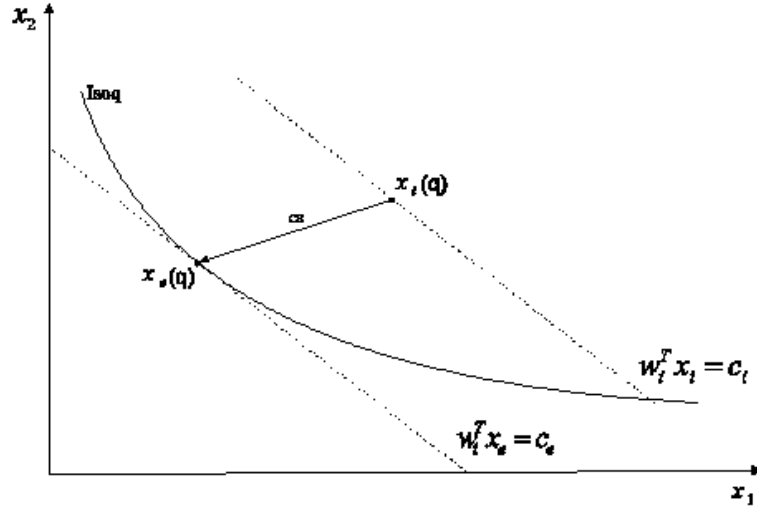
The intuition lies on the consideration that, in the water sector, the regulator may adopt measures in order to protect (up to a certain point) the regulated firm against any bankruptcy risk. Therefore, this intervention can implicitly incentive the water companies to substituting equity for debt (see De Fraja and Stones, 2004). However, these authors do not consider the effects of capital structure choices on the firm's ownership and, then, on the entrepreneur's exerted effort. More precisely, a rise in the issued equity implies the sale of the firm's ownership (from the entrepreneur to the shareholders) while an increase of the debt level does not affect the entrepreneur firm's control.

Then, up to a debt level sufficiently high (say \bar{d}), the entrepreneur (that is the main firm's owner) conveniently exert the maximum effort in order to benefit of the payoff associated to a good state of the world. After the \bar{d} level, however, the probability of a financial distress becomes too high to make the entrepreneur exerting the maximum effort. If the firm fails, the entrepreneur will pay directly only for the capital he owns, without incurring in the risk to be fired by the shareholders.¹⁰

This theoretical intuition suggests that for values above a given indebtedness treshold, the firm's efficiency is supposed to decrease. In order to test this assumption, I suppose that each firm, producing the output $y \in \mathbb{R}_+$ given the vector of input prices $\mathbf{w} \in \mathbb{R}_{++}^M$, chooses a vector of inputs $\mathbf{x} \in \mathbb{R}_+^M$ in order to minimize his total production cost ($c_i \in \mathbb{R}_+$). Figure 2 simply illustrates this problem, for $M = 1, 2$.

¹⁰See the Chapter 1 of the present work for the formal model related to this economic intuition.

FIGURE 2: TECHNICAL AND ALLOCATIVE INEFFICIENCY



Then the efficient use of inputs is \mathbf{x}_e , as this point lies both on the isoquant q and on the isocost line closest to the origin $\mathbf{w}_i^T \mathbf{x}_e$. Then, by using \mathbf{x}_e to produce y_i the producer effectively minimizes his costs, whereas producing the quantity y_i by the inefficient input quantity \mathbf{x}_i , the firm faces a total cost given by:

$$c_i = \mathbf{w}_i^T \mathbf{x}_i > \mathbf{w}_i^T \mathbf{x}_e = c_e$$

Moreover, the firm has access to a technology A for turning inputs into outputs. I suppose that this technology depends upon a vector of unknown parameters α .

Finally, simply imposing that the cost minimization problem should guarantee that the firm produces an output at least equal to y_i , leads me to rewrite the optimal cost function as:¹¹

$$c_e = f(y_i, \mathbf{w}_i; \alpha) \tag{2.1}$$

Equation (2.1) is the so-called cost frontier and measures the minimum cost that can

¹¹See Mas Colell et.al. (1995), pg. 139. Particularly, it is possible to write the firm's problem as:

$$\begin{aligned} &\min \mathbf{w} \cdot \mathbf{x} \\ &\text{s.t. } g(\mathbf{x}) \geq y_i \end{aligned}$$

be obtained from a given level of input prices. In practice, actual cost of a firm may rise above the minimum level. The deviation of the actual from the minimum achievable cost is a measure of inefficiency. Formally, (2.1) can be extended to:

$$c_i = f(y_i, \mathbf{w}_i; \alpha) v_i u_i \quad (2.2)$$

in which $0 < u_i \leq 1$ is the firm's inefficiency (i.e. for a firm that has a cost equal to c_e , $u_i = 1$), and v_i is a statistical noise. Therefore, the measure of the firm's inefficiency is conceptually different from the statistical noise that characterizes the error term in (2.2). Precisely, I suppose that the factors that determine a deviation of the i -th generic firm from the cost frontier (and then included in the firm's inefficiency term) are under the firm's management control.

I also suppose that the cost function is log-linear (Cobb Douglas or Translog specification). Then I can take logs and write (2.2) as:

$$\ln c_i = \alpha_Y \ln y + \sum_i^N \alpha_i \ln \mathbf{w}_i + u_i + v_i \quad (2.3)$$

In order to estimate (2.3), I consider as endogenous variable the operative (total) costs of the firm.¹² As indicator for the (total) output variable, y_i , the existing literature frequently adopts the total cubic meters of water delivered to the consumers.¹³ The main advantage of this indicator is that this variable is exogenous with respect to the firm's operative costs, since the minimum quantity of water delivered is established by the regulator.

Although in my analysis I collect data for 65 firms, they actually provide water for more than the 50% of the total water supplied every year in Italy, since after the publication of the Galli's Act in 1994, a progressive consolidation of the water companies takes place.¹⁴

¹²Here I present an unified framework, but it is useful to notice that the log linearity of the cost function is a property that I need only in order to estimate (2.3) using classical methods, since the Bayesian techniques allows me to easily avoid possible non linearity in the cost function.

¹³see also Fabbri and Fraquelli (2000); Antonioli and Filippini (2001), Filippini et.al. (2004).

¹⁴I use as benchmark the ISTAT analysis on the water services (2005-2007).

In my sample there are two possible sources of heterogeneity. The first one is due to the presence of vertically integrated companies, that is, companies that manage both the aqueduct and the sewerage services. The other one is the dimension of the water suppliers that widely varies across different companies.

In order to control both these effects, I include in my analysis two dummy variables. The first one d_s assumes value 1 when the considered firm provided both the aqueduct and the sewerage services. The other one, d_c assumes value 1 when the final firm serves more than 250.000 final consumers.

The vector of input prices \mathbf{w} is given by:

$$\mathbf{w} = \begin{bmatrix} W_1 = P_K \\ W_2 = P_L \\ W_3 = P_M \end{bmatrix}$$

in which the price of capital w_1 is measured as the sum between the tangible and intangible assets on the total assets; the price of labour w_2 is the ratio between the total expenditure on the payroll costs and the total number of workers and, finally, the price of rough materials w_3 is given as the ratio between their expenditure and the total kilometers of pipe lines.¹⁵

Standard economic theory highlights that the cost function should assume the functional form given by (2.1). Then, other explicative variables that are supposed to directly affect the inefficiency (i.e. the so called environmental variables) should be included in the inefficiency mean instead of in the cost function.¹⁶

In my analysis, I consider that the vector of explicative variables (\mathbf{z}) should reflect: (i) the financial structure of the firm, in order to consider the effect of the debt on the final firm's performance, and, (ii) the firm's ownership.

Although the existing literature on the measurement of the water sector's inefficiency investigated the linkage between the firm's ownership and the firm's inefficiency, the final results are quite controversial. As result, it is difficult to determine if privately owned

¹⁵These indicators have been widely used in economic literature, see Fraquelli and Fabbri (2001) among others.

¹⁶On the classical form of a cost function see Mas-Colell et.al. (1995).

companies are effectively more efficient than the publicly owned firms.

Moreover, this latter effect is particularly interesting, as long as the Galli's Act introduced the possibility for every ATO to choose whether assign the water distribution to a public or to a private company.

Precisely, for the Italian water sector I distinguish between four different ownership regimes: *(i)* the 100% publicly owned companies (PUBLIC), *(ii)* the 100% private companies (PRIVATE), *(iii)* companies which are at the 51% (at least) public (MPU) and *(iv)* companies which are at the 51% (at least) private (MPR).

The analysis of Italian water utilities ownership is particularly innovative, as long as both the previous works by Fabbri and Fraquelli (2000) and Antonioli and Filippini (2001) analyze a sample of companies before the publication of the Galli's Law and then can not investigate the ownership effects, since before 1994 all the Italian water companies were totally publicly owned.

Then, the vector \mathbf{z} of explicative variables is defined as:

$$\mathbf{z} = \begin{bmatrix} z_1 = d_{LEV} \\ z_{21} = d_{public} \\ z_{22} = d_{private} \\ z_{23} = d_{MPU} \\ z_{24} = d_{MPR} \end{bmatrix} \quad (2.4)$$

in which, z_1 is a dummy variable that assumes value 1 if the leverage of the considered firm is above the OFWAT (2004) threshold, that is, if the ratio between firm's net debt and firm's total asset is greater than 0.5 and z_{2i} is a dummy which control the ownership of the water company.

Finally, I can consider the leverage as an exogenous determinant of the firm's inefficiency as the Italian regulator assures that if a firm is forced into bankruptcy or the company changes management, the new company totally inherit the old company's debts.¹⁷

¹⁷I also test this hypothesis with an Hausman test, that accepts the exogeneity assumption with a p-value of 0.2245

Summary of statistics of the considered variables are provided in the Appendix.

2.4 The "Classical" Model

2.4.1 Theoretical Background

The choice of the optimal functional form for the cost function is strictly related to both theoretical and empirical fulfillments. With respect to the theoretical background, Lau (1978, 1986) suggests that functional form must respect some selection criteria as theoretical consistency, flexibility and computational facility.

Empirically, the importance of flexibility in the estimated functional forms was firstly theorized by Diewert (1971) who sustains that the use of a second order Taylor approximation of a general cost function allows the researchers to both consider a general specification to fit the data and accomplish strong theoretical requirements.¹⁸

Albeit the use of flexible forms is convenient in order to reach more accurate specification, it should be considered that there is a strong trade-off between a good degree of approximation and a tractable number of parameters.

In order to find a sufficiently flexible functional form, a vast literature simply adds the square of logarithmic output and input prices to the Cobb Douglas specification. This procedure determines the well known translog specification given by:

$$\begin{aligned} \ln c_i = & \xi_0 + \alpha_Y \ln y_i + \sum_{i=1}^N \alpha_i \ln w_i + \frac{1}{2} \sum_{i=1}^N \sum_{j=1}^N \alpha_{ij} \ln w_i \ln w_j \\ & + \frac{1}{2} \alpha_{YY} (\ln y_i)^2 + \sum_{i=1}^N \alpha_{iY} \ln w_j \ln y_i + \alpha_{dc} d_c + \alpha_{ds} d_s + v_i + u_i \end{aligned} \quad (2.5)$$

in which c_i is the operative cost of the considered firm, y_i is the produced output, w_i is the i -th input price, d_c and d_s are the dummy variables that control for the number of consumers and the vertical integration, v_i is the noise, u_i is the firm cost inefficiency, ξ_0 is

¹⁸Following Sauer et.al.(2006), a flexible functional form is a form "whose shape is restricted only by theoretical requirements".

the constant term and $\alpha_{i(\cdot)}$ are the parameters that should be estimate.¹⁹

Given the chosen functional form, the question to be answered is: who is the efficient producer? The classical analysis gives two different solutions to this problem, that reflects the necessity to separately estimate the firm's constant term and the firm's specific inefficiency in the eq. (2.3).

In the first one the inefficiency term also include the firm specific intercept ξ_0 . Then, in order to estimate (2.3), it is possible to define:

$$\xi_i = \xi_0 + u_i$$

and then to estimate:

$$\hat{u}_i = \hat{\xi}_i - \hat{\xi}$$

where $\hat{\xi}_i$ are the OLS estimates of the intercepts and $\hat{\xi} = \min_j (\hat{\xi}_j)$. Then, \hat{u}_i is used as a measure of inefficiency (i.e. $-\hat{u}_i$ is a measure of firm's relative efficiency).

However, this approach has many drawbacks: the efficiency measure is relative, as the less inefficient company is treated as a full efficient company, and this has a serious impact on estimated inefficiencies if some data are mismeasured. Moreover, the use of the "min" operator makes it difficult to detect the right distribution of the \hat{u}_i , and then becomes difficult to calculate the standard errors of the firm's inefficiencies.

The second approach assumes that u_i has some one sided distribution and maximum likelihood estimation can be carried out as described in Kumbhakar and Lovell (2000). These authors also highlight that this second approach produces better estimates with

¹⁹Since the translog specification considers the variables in their logarithmic specification, the coefficients have a simply economic interpretation, as they reflect the elasticity of cost with respect to the estimated regressors.

A cost function corresponds to a well-behaved production function only if it is: *i*) monotonically increasing in output, *ii*) monotonically increasing in input prices and, *iii*) concave in input prices. In order to impose the theoretical requirement to the translog specification (i.e. concavity, symmetry and homogeneity of degree 1 with respect to input prices and non-negativity in output) the following assumption should be verified:

$$\sum_{i=1}^N \alpha_i = 1; \quad \sum_{i=1}^N a_{ij} = \sum_{j=1}^N a_{ij} = \sum_{i=1}^N \alpha_{iY} = 0 \quad (2.6)$$

respect to the "OLS approach" described before. Particularly, I estimate u_i assuming that this term follows a normal truncated distribution in zero.

It should be noticed that there are again two different specifications of the MLE procedure.

The first one was proposed by Battese and Coelli on 1993, and consider the following specification for u :

$$u_i = \delta_0 + \delta_h \sum_{h=1}^N z_h + \varepsilon_u \quad (2.7)$$

in which z_h are the environmental variables that influence the firm's specific cost inefficiency and ε_u is a white noise.

This approach is particularly appealing as inefficient performance measured by non-attainment of the cost frontier could be due to a conflict of objectives among firms, or in differences due to ownership as in Atkinson and Halvorsen (1986) or in differences in shadow prices as in Averch and Johnson (1982). Then it is useful to include some firm specific factor in the inefficiency mean μ , to explain and capture the existence of firm specific inefficiency, as highlighted by Reifshneider and Stevenson (1991).

Technically, in the first step the estimates of inefficiency effect are obtained, then the second step runs a regression model for the predicted inefficiency effects of the firms in terms of the \mathbf{z} vector of explanatory variables and the generic error term ε_u .

This procedure is particularly efficient as long as u_i is supposed to follow a truncated distribution with a non zero mean, and then the estimator should better fit the characteristics of each variable.

The second procedure of the firm inefficiency term allows to estimate the stochastic frontier and the u_i term simultaneously. This can be quite intuitive but implies that the distributions of the u_i have a zero mean. As noticed by Battese and Coelli (1993, 1995), it can generate severe bias in the efficiency estimates when the \mathbf{z} explanatory variables effectively does not fulfill this requirement. Then, in my analysis, I follow the Battese and Coelli specification and I estimate (2.7) with a two step procedure in order to find a measure of the firm inefficiency.

2.4.2 Estimator Specification

A shortcoming of the Battese and Coelli approach (and, generally, of all the MLE estimation approaches) is that some specific assumption on error and inefficiency distributions should be undertaken by the researcher. However, this approach overwhelm the modified OLS estimates since it does not imply an inefficiency measure that can be subject to misspecification in the final data. In the present framework I assume that:²⁰

1. $v_i \sim N(0, \sigma_v^2)$
2. $u_i \sim N^+(\mu, \sigma_u^2)$
3. v_i and u_i are independently distributed from each other

From these assumptions it is possible to calculate the maximum likelihood estimator for u_i , that reads:

$$E(u_i|\varepsilon_i) = \sqrt{\frac{\sigma_u^2 + \sigma_v^2}{\sigma_u^2 \sigma_v^2}} \frac{1}{\sqrt{2\pi} \left[1 - \Phi \left(-\frac{\frac{\sigma_u}{\sigma_v} \varepsilon_i - \frac{\sigma_u}{\sigma_u} \mu_i}{\sqrt{\sigma_u^2 + \sigma_v^2}} \right) \right]} \exp \left\{ -\frac{1}{2} \frac{\frac{\sigma_u^2}{\sigma_v^2}}{\sigma_u^2 + \sigma_v^2} \varepsilon_i^2 - \frac{\frac{\sigma_v^2}{\sigma_u^2}}{\sigma_u^2 + \sigma_v^2} \mu_i^2 \right\} + \frac{\sigma_u^2}{\sigma_u^2 + \sigma_v^2} \varepsilon_i + \frac{\sigma_v^2}{\sigma_u^2 + \sigma_v^2} \mu_i \quad (2.9)$$

Then, in order to estimate (2.3), I replace \hat{u}_i with (2.9).

Quite intuitively, an efficiency analysis is particularly important if a strong heterogeneity between firm performances occurs. The graph of the estimated MLE residuals is in the Appendix, but the performed test on the residual symmetry has been rejected for my sample with a p-value of 0.002.

²⁰As demonstrated in the Appendix, the likelihood function is proportional to:

$$p(c_i|y_i, w_i, p_i) \propto -\frac{1}{2(\sigma_u^2 + \sigma_v^2)} \sum_i (\varepsilon_i + \mu_i)^2 - I \ln \sqrt{\sigma_u^2 + \sigma_v^2} + \sum_i \ln \Phi \left(-\frac{\frac{\sigma_u}{\sigma_v} \varepsilon_i + \frac{\sigma_v}{\sigma_u} \mu_i}{\sqrt{\sigma_u^2 + \sigma_v^2}} \right) - I \ln \Phi \left(-\frac{\mu_i}{\sigma_u} \right) \quad (2.8)$$

in which $\varepsilon_i = v_i + u_i$. As usual, the log likelihood can be maximized with respect to the parameters to obtain maximum likelihood estimates.

2.4.3 Empirical Results

In order to respect the homogeneity requirement of the cost function expressed in (2.5), I divided the endogenous variable and the input prices for the price of capital, taken as the *numeraire*.

This transformation is strongly recommended in order to respect the (2.6) constraint, but also leads to a slightly change in the interpretation of the endogenous variable. As highlighted in the previous section, c_i was measured as the operative firm costs. Moreover, w_1 can be considered a proxy for the investment cost in the capital input, since it is calculated as the ratio between the material assets and the total assets. Then, dividing the operative cost by the index of the capital depreciation leads c_i to become an approximation of the firm's total costs, as long as it includes both the initial fixed costs and the operative expenditures.

From the empirical analysis, I expect a positive coefficient for the output variable, for all the input variables, for the number of inhabitants served and for the leverage. Moreover, since an increase in the labour and material prices should be reflected in the firm's operative cost, also the sign of the input prices should be positive.

The ownership and the sewerage dummies could be not significant: the privatization is a quite recent phenomenon in Italy, and then the results of the private management could not be strongly different from the public owned firm's performance. Moreover in Italy, as highlighted by Canitano et.al. (2005), the presence of 93 different water regulators leads to different concession contracts and, then, to different company's prescribed performances. Therefore, inefficiency can depend more on the contract between the regulator and the firm than on the firm's ownership.

This point is strongly related to the indebtedness level reached by the regulated firms: as differently owned firms not always have strongly different performances, I also expect that they have almost the same indebtedness level and, therefore, the same inefficiency.

The estimated cost function is dual to a well-behaved production function as it is non-negative, monotonically increasing, linearly homogenous and concave in \mathbf{w} . Non-negativity is checked by calculating the estimated value of the cost function for every data point. Monotonicity is satisfied as the estimated input demand functions are non-negative. The

cost function is constructed to be linear homogenous in \mathbf{w} , as I divided costs and input prices for the capital input price.

However, the Wald test suggests to accept the null hypothesis under which all the quadratic terms in (2.5) can be jointly imposed to be equal to zero.²¹

Then I estimate a Cobb-Douglas specification of (2.5), that reads:

$$\ln\left(\frac{c_i}{w_1}\right) = \xi_0 + \alpha_Y \ln y + \sum_{i=1}^3 \alpha_i \ln\left(\frac{w_i}{w_1}\right) + \alpha_{dc}d_c + \alpha_{ds}d_s + \nu_i + u_i \quad (2.10)$$

in which again u_i is given by (2.7).

Although the translog cost function has all the properties of a flexible form, it should be noticed that even the inflexible Cobb Douglas specification presents some important advantages, as it provides an immediate measure of the inefficiency term and to simply check both the homogeneity and the concavity properties of the cost function, as long as it is sufficient to verify that the conditions: $\alpha_i > 0$ and $\alpha_Y \geq 0$ hold for all of the estimated coefficients.

In order to verify the significance level of the environmental variables, I estimate (2.10) adding one by one the four different variables included in \mathbf{z} and performing a Wald test on the estimate results.

I find that only the leverage (z_1) is significant at the 90% level while the ownership dummies should not be included in my analysis. The results of the hypothesis test are reported in the following table:

²¹with a p-value equals to 0.1466

TABLE 2: TEST OF HYPOTHESIS FOR PARAMETERS OF THE MODEL

NULL HYPOTHESIS	χ^2 VALUE	P-VALUE
$H_0:z_1=0$	1.70	0.09**
$H_0:z_{21}=0$	-0.17	0.864
$H_0:z_{22}=0$	-0.38	0.704
$H_0:z_{23}=0$	0.06	0.952
$H_0:z_{24}=0$	0.63	0.526
$H_0:z_{21}=z_{22}=z_{23}=0$	0.18	0.9804

in which (**) indicates that it exceeds the 90-th percentile for the corresponding χ^2 distribution and so the null hypothesis is rejected.

I can estimate (2.10) with the two step procedure described above: in the first step I estimate (2.10) without u_i ; in the second step I estimate the inefficiency term given by:

$$u_i = \delta_1 z_1 + \varepsilon_{u_i}$$

by the MLE estimator and then I calculate \hat{u}_i .

The estimated coefficients and inefficiencies are reported in the following table, while a graph for the estimated inefficiencies is provided in the Appendix:

TABLE 3: “CLASSICAL” ESTIMATED COEFFICIENTS

	COEFF	ST. ERRORS	95% CONF. INTERVAL	
ξ_0	4.593	1.605***	1.4456	7.7408
α_y	0.344	0.085***	0.1860	0.5019
α_{wL}	0.325	0.084***	0.1599	0.4900
α_{wM}	0.218	0.060***	0.0995	0.3358
α_{dc}	0.708	0.290***	0.1393	1.2766
α_{ds}	0.636	0.277***	0.9191	1.1797
δ_{z1}	0.773	0.455**	1.4457	7.7408

in which (***) denotes a variable which is significant at the 1% level, (**), at 5% and (*) at 10% level respectively.

As highlighted at the beginning of this section, all the coefficients present the expected signs. Moreover, for the Italian data, debt seems to strongly influence the inefficiency component of the stochastic cost function.

In order to compare these results with the Fabbri and Fraquelli (2000) model, it should be noticed that in the present model I explicitly consider the price of capital, whereas in their work they estimate the stochastic cost frontier considering only the prices of energy, rough materials, and labour.

However, in my analysis, the cost elasticity with respect to output is equal to 0.344 whereas in Fabbri and Fraquelli (2000) was equal to 0.673 and in Antonioli and Filippini (2000) 0.603. These results can be due to the different structure between my models and the previous works. Although I consider the environmental variables as determinants of firm specific inefficiency, these authors insert the vector of \mathbf{z} variables directly as determinant of firm’s costs. This procedure may partially reduce the impact of output as determinant of the firm’s costs.

Moreover, the elasticity of cost with respect to material price is equal to 0.218, which is not statistically different by the results reported in the Fabbri and Fraquelli (0.11) and Antonioli and Filippini (0.2) frameworks. The exclusion of the price of capital in the Fabbri and Fraquelli analysis is partially reflected in the difference of the cost elasticity with respect to the labour price (0.325 in my model versus 0.39 in their work), but the comparison between my results and Antonioli and Filippini work, that finds an elasticity

equals to 0.327, highlights a good resemblance between our results. Finally, in my model, from the homogeneity condition imposed, it is possible to derive the elasticity of the capital input as 0.45.

My model, however, is positively affected by the proxy for the firm's size, that is strongly significant and by the presence of vertically integrated companies.

It is particularly important to deeply analyze the estimated coefficient of d_c : as highlighted before, after 1994 there was a strong incentive to consolidate different water companies, in order to reach an homogeneous level of consumer served and water delivered. The presence of the positive coefficient α_{dc} suggests that some scale economies may still emerge in Italian water sector. I will better analyze this topic in Section VII.

Even if a comparison with previous results is unquestionably useful, it is also important to consider that all the studies on Italian water sector consider only a small sample of firms.

As Van der Broeck et. al. (1994) emphasize, the Classical estimates can be severely biased for small samples, and then simply considering the obtained coefficients can lead to misleading results. In order to avoid this problem and to correct the estimated coefficients for the small sample bias, in the following section I also present a Bayesian analysis of the cost stochastic model analyzed before.

2.5 The Bayesian Model

The recent developments in Bayesian estimators offer effective tools for the evaluation of stochastic frontier models. The scope of Bayesian estimators is to get the posterior distribution for model parameters conditioning on prior beliefs on parameters (θ), models (M_j) and objective sample information. The methodology thus nests the formalized prior distribution $\pi(\theta, M_j)$ for the vector of parameters $\theta \in \Theta$, and the conditional distribution (likelihood) $\pi(y|\theta, M_j)$ to get the posterior density $\pi(\theta|y, M_j)$. This is basically obtained employing the Bayes rule:

$$\pi(\theta|y, M_j) = \frac{\pi(y|\theta, M_j) \times \pi(\theta, M_j)}{\pi(y, M_j)} \quad (2.11)$$

Since the posterior density is frequently a complex and unknown multivariate distribution, its analytical calculation can not be feasible or it is not ascribable to any known distributional forms. It is then possible either to obtain the posterior distribution via numerical integration or to find its adequate approximation by the calculation of the full conditional distribution of parameters, given the sample data.

From eq.(2.11) it is immediate to notice that the posterior distribution is basically the result of a weighted average of prior non sample information and the likelihood function; weights are inversely related to, respectively, the variance of the prior distributions and the variance of the sample information (“precision”). Formalizing a tight prior will thus result in highly constrained estimation, while a diffuse prior will result in weakly constrained estimation.

Priors definition may simply reflect the analyst’s beliefs on parameters, or its prior knowledge obtained from econometric studies. From a Bayesian point of view, the presence of subjective elements (formalized in an explicit and transparent manner) is an irreducible feature of any experimental trial and this perfectly suits the requirements of stochastic frontier models, as it is possible to easily impose the monotonicity requirement by prior elicitation.

In the following sections I briefly analyze the theoretical background of the Bayesian stochastic frontier approach and then I present my empirical results, with the correction for the frequentist estimation bias.

2.5.1 Theoretical Background

Priors

The basic stochastic frontier sampling model considered here is given by (2.10). In order to simplify the notation it is possible to follow Osiewalski and Steel (1998) and rewrite it as:

$$c_i = h(x_i, \alpha) + v_i + u_i \tag{2.12}$$

in which all the variables are expressed in logarithmic terms.

The peculiarity of the Bayesian framework is given by the fact that any difference

between models is totally determined by the prior choices. Then, all the consideration on the MLE and the OLS approaches proposed in the Classical estimates do not hold in this setting: Koop et. al. (1997) rightly remark that the model's choice does not depend on the nature of the effects, but on the marginal prior links between these effects.

In order to replicate the Classical analysis proposed before (i.e the so called "MLE approach") I assume that the inefficiency terms are truncated Normally distribution, and that the means of the inefficiencies depends on the same covariates as before, given by (2.4).

These considerations can be translated to a Bayesian structure considering a hierarchical prior for the inefficiency means μ_i . Following Osiewalski and Steel (1998) this can be done assuming u_i truncated Normal with mean (and standard deviation) μ_i which depends on z_1, z_{21}, z_{22} and z_{23} , i.e the dummy variables analyzed before.²²

In particular, I assume that:

$$u_i \sim N^+(\mu_i, \tau_u) \tag{2.13}$$

in which τ_u is the precision of u , and that:

$$\tau_u \sim \text{Gamma}(a, b)$$

in which a and b are numerical parameters. Moreover, as in the Classical framework, the mean of every inefficiency depends on the dummy variables given by (2.4):

$$\mu_i = \prod_{j=1}^4 \phi_j^{w_{ij}} \tag{2.14}$$

I also assume that the covariates that affects the inefficiency mean follows a normal distribution, that is:

$$\phi_i \sim N(0, 1)$$

²²As usual, in order to avoid perfect collinearity in estimation I drop one of the ownership dummies.

and then constitute independent draws from the same distribution.

Therefore, in the present setting, the coefficients of the dummy variables reflect the deviation of the considered company from a common mean, and I suppose that this deviation also is a normally distributed process.

A primer choice of truncated Normal distribution for the inefficiency term u_i is due to the possibility of a direct comparison with my previous analysis.

Moreover, in the Bayesian analysis it is possible to determine the prior on the parameter α in order to reflect the theoretical requirements discussed in the previous section. Particularly, the monotonicity constraint can be easily imposed considering that in the Classical model the parameter estimates should be strictly positive not only for the output but also for the input price's coefficients.

This can be translated in the Bayesian framework imposing a prior for the vector of α_i that have a density function defined on the positive axis, that is, I assume that α has a truncated normal multivariate density function which is defined from 0 to infinite, that reads:

$$\boldsymbol{\alpha} \sim N^+(m, \Sigma) \tag{2.15}$$

in which Σ is the variance and covariance matrix of the α vector.

Moreover, I also assume that the cost density function is Normal, with mean $h(x_i, \alpha) + u_i$ and precision given by τ , that is:

$$c_i \sim N(h(x_i, \alpha) + u_i, \tau)$$

in which the precision τ has the following prior distribution:

$$\tau \sim Gamma\left(\frac{c}{2}, \frac{d}{2}\right) \tag{2.16}$$

Then, the prior structure on the parameter of my model is simply given by:

$$p(\theta) = p(\tau)p(\alpha)p(\phi) \propto f_G\left(\tau\left|\frac{c}{2}, \frac{d}{2}\right.\right) f_{N^+}(\alpha) f_{N^+}(\phi, \tau_u)$$

Likelihood Function

The form of the likelihood function depends upon the assumption made about errors. Again I suppose that the error term v_i is normally distributed and that v_i and u_i are independent of one another for all i and j .

However, the distribution of u_i now includes also the presence of the hierarchical prior on μ_i and then the conditional distribution of c_i given all the parameters and the data is given by:

$$p(c_i|x_i, \theta, data) = f_N(c_i|x_i + u_i, \tau) f_N(u_i|\mu_i, \tau_u) I(u_i \geq 0) \quad (2.17)$$

Posterior Full Conditionals

According to the theoretical model described in the session (2.5), the posterior densities are given by:

$$p(\theta|c) = p(\theta)\mathcal{L}(c|\theta)$$

that is, the posterior is a weighted average between the prior informations and the evidence, represented by the likelihood function.

Despite in my framework the density of the posterior probability can not be ascribed to any well known functional form, it is quite easy to calculate the full conditional distributions. It is then possible to use the Gibbs sampling, a technique to obtain a sample from the joint distribution of a random vector by taking random draws from the full conditional distributions.

Formally, I characterize the posterior vector by ζ and then I partition it into different subvectors containing the full conditional distributions $(\zeta'_1, \dots, \zeta'_p)$. Then, it is possible to sample from these conditional distributions (i.e. ζ_i given all the other subvectors) quite easily.

The Gibbs sampling precedes as follows: given the $q - th$ draw, $\zeta^{(q)}$, each element of the next draw, $\zeta^{(q+1)}$, are obtained by the respective conditional probability as follows:

$$\begin{aligned} \zeta_{(1)}^{(q+1)} & \text{ is drawn from } p\left(\zeta_{(1)}|\zeta_{(2)} = \zeta_{(2)}^{(q)}, \dots, \zeta_{(p)} = \zeta_{(p)}^{(q)}\right) \\ \zeta_{(2)}^{(q+1)} & \text{ is drawn from } p\left(\zeta_{(2)}|\zeta_{(1)} = \zeta_{(1)}^{(q+1)}, \dots, \zeta_{(p)} = \zeta_{(p)}^{(q)}\right) \\ & \dots \\ \zeta_{(p)}^{(q+1)} & \text{ is drawn from } p\left(\zeta_{(p)}|\zeta_{(1)} = \zeta_{(1)}^{(q+1)}, \dots, \zeta_{(p-1)} = \zeta_{(p-1)}^{(q+1)}\right) \end{aligned}$$

Then, each pass consists of p steps, i.e. drawings of the p subvectors of ζ . The starting point $\zeta^{(0)}$ is arbitrary but it can be demonstrated (Tierney, 1994) that under specific conditions that are all satisfied in my analysis, asymptotically the final distribution is independent by the choice of the first draw.

As Osiewalski and Steel (1998) highlight, a drawback of the Gibbs sampling is that there is no independence between different draws, which are all linked by a Markovian structure and this can be negatively reflected on the efficiency of the numerical integration. This difficult can not be overcome, but other techniques as importance sampling that can also be adopted in my analysis, suffer from other inefficiencies (i.e. the choice of the weights also add subjective elements to the empirical analysis) that makes the Gibbs sampling the best technique to be adopted in my analysis (see Osiewalski and Steel, 1998). Moreover, the drawings of the Gibbs sample are asymptotically equivalent with the drawings from the posterior distribution and then the constant of normalization can be ignored, with a great calculus simplification.

Following Osiewalski and Steel (1998), the full conditional distributions of parameters and inefficiencies are calculated as follows:

$$p(\tau|data, u, \alpha) = f_G\left(\tau \left| \frac{c + N}{2}, \frac{1}{2} \left\{ d + \sum_i [c_i - h(x_i, \alpha) - u_i]^2 \right\} \right.\right)$$

in which N is the number of the firms in the sample, and

$$p(\alpha|data, u, \tau) \propto f_{N+}(\alpha) \exp \left\{ -\frac{1}{2}\tau^2 + \sum_i [c_i - h(x_i, \alpha) - u_i]^2 \right\}$$

Moreover, the full conditional distribution of the ϕ term with respect to all the data and the other parameters reads:

$$p(\phi|data, u, \tau) \propto f_N(\phi) \exp \left\{ -\frac{1}{2}\tau^2 + \sum_i [c_i - h(x_i, \alpha) - u_i]^2 \right\}$$

Finally, the full conditional distribution of inefficiency terms reads:

$$p(u_i|data, \theta) \propto f_{N+}(u) \exp \left\{ -\frac{1}{2}\tau^2 + \sum_i [c_i - h(x_i, \alpha) - u_i]^2 \right\}$$

2.5.2 Model Selection

I transpose the hypothesis underlying the different models analyzed in the previous sections in a Bayesian framework and I use the DIC criterion to establish which model better fits my data.²³

The four models that I considered are: (i) the model with no covariates (i.e. the original

²³The DIC (Spiegelhalter et al.,2002) model comparison criterion is based on trade-off between the fit of the data to the model and its corresponding complexity.

The goodness of fit is measured simply computing the mean deviance, calculated as:

$$D(\theta) = -2 \ln \mathcal{L}(c|\theta)$$

whereas the measure of the complexity of the model is given by:

$$p_D = \underbrace{E_{\theta|c}[D(\theta)]}_{D_{bar}} - \underbrace{D(E_{\theta|c}[\theta])}_{D_{hat}}$$

that is, p_D is the difference between the posterior mean deviance and the deviance of the posterior means.

Then, the DIC is defined as:

$$DIC = D_{bar} + p_D = D_{hat} + 2p_D$$

and then, the models with smaller DIC are better supported by the data, since they are estimated to be the models that would best predict a replicate dataset of the same structure as the one currently observed.

Cobb Douglas specification), (ii) the model in which the mean of the inefficiencies varies with all the dummies included in (2.4), (iii) the model in which inefficiencies depend only to the ownership dummies and, finally, (iv) the model in which the inefficiencies are linked only to the leverage dummy.

The results of my analysis are reported in the following Table:

TABLE 4: DIC WITH NORMAL ERRORS AND TRUNCATED DISTRIBUTION

	D_{bar}	D_{hat}	p_D	DIC
m_1 – no covariates	162.317	150.818	11.498	173.815
m_2 – all covariates	170.037	159.166	10.871	180.908
m_3 – ownership	165.053	154.015	11.039	176.092
m_4 – debt only	159.919	146.95	12.969	172.888

From Table 4 emerges that, coherently to the frequentist analysis, the model that better fits the data is the model in which only the leverage dummy is the determinant of the inefficiency mean.

2.5.3 Empirical Results

In order to find a proper indicator for the posterior distributions, I use the simulated sample mean, consistently with the previous studies from Van der Broeck et. al (1994), Koop et.al. (1995), Osiewalski and Steel (1998) and Griffin and Steel (2007).

Table 5 presents a summary of the Bayesian estimated coefficients: all the exogenous variables present a coefficient which has a different value with respect to the corresponding Classical coefficients, described in Table 4.

It should be noticed, however, that even if the Classical and Bayesian estimates differ for the final coefficient values, their economic interpretation is exactly the same.

Obviously the comparison with previous analytical results is impossible, as Fabbri and Fraquelli (2000) and Antonioli and Filippini (2001) make frequentist estimates that can suffer from the small sample bias present in my previous analysis. Moreover, at the best of my knowledge, there are no studies on the water sector that apply Bayesian technique

to study the companies inefficiency, and then it is no possible to compare this results with some other related works.

TABLE 5: BAYESIAN ESTIMATED COEFFICIENTS

	COEFF	ST. ERRORS	95% CONF. INTERVAL	
ξ_0	3.694	1.3830***	0.9833	6.4046
α_y	0.374	0.0749***	0.2268	0.5205
α_{wL}	0.415	0.0927***	0.2332	0.5965
α_{wM}	0.232	0.0568***	0.1204	0.3431
α_{dc}	0.631	0.2205***	0.1993	1.0636
α_{ds}	0.491	0.2217**	0.0569	0.9260
δ_{z1}	0.860	0.5875**	-0.2910	2.0120

in which (***) denotes a variable which is significant at the 1% level, (**), at 5% and (*) at 10% level respectively.

Finally, Appendix E shows that all the exogenous variable have the imposed requirement, that is, both the coefficients of the explicative variables and the coefficient of the leverage's dummy are defined on the positive real axis.

2.5.4 Estimated Inefficiency and Comparison With "Classical" Results

As highlighted in the previous sections, the Classical stochastic frontier estimation can lead to a downward bias in the estimated coefficients, due to the presence of relatively small datasets.

However, it is possible to compare the inefficiency estimates in my two models as the Bayesian coefficients are included in the Classical confidence intervals, and the intervals of the two estimates partially overlap.

Therefore, considering a Classical approach, this can be particularly misleading if the calculated inefficiencies are the residual component of the cost stochastic frontier, given the noise term. Again, the Bayesian approach overwhelms the traditional analysis: specifying the prior on the inefficiency term as (2.13) the computation of inefficiencies is then simulated using the Gibbs sampling technique with 25000 iteration (with a burn in of 1000).

However, it is also possible to make a direct estimates comparison simply ranking the first 10 efficient company (i.e. the companies that perform better than the others) and the last 10 companies, as reported in Table 6.

This Table remarks the importance of the Bayesian estimates. As long as the Classical approach has been adopted, the company ranking is different from the corrected Bayesian sample. Even if the company's order does not completely varies, (e.g. the last companies are the same in both the estimates), there are strong differences particularly with respect to the first 10 companies in the rank.

Obviously, this can heavily affects the regulator's policy prescriptions, as it is important to correctly determined the right order of the inefficient companies and this can be done in an easy and intuitive way adopting Bayesian estimation techniques.

²⁴The results of the simulated betas are reported in the Appendix.

TABLE 6: INEFFICIENCY COMPARISON

Rank	Company (Classical Est.)	$\hat{u}_{Classical}$	Company (Bayesian Est.)	$\hat{u}_{Bayesian}$
1	16	0.031	19	0.228
2	41	0.052	16	0.244
3	19	0.068	41	0.254
4	59	0.131	10	0.272
5	8	0.139	22	0.273
6	22	0.149	11	0.292
7	1	0.151	64	0.294
8	39	0.159	34	0.294
9	10	0.162	39	0.296
10	34	0.163	63	0.304
..
56	30	0.657	25	0.609
57	56	0.668	29	0.621
58	52	0.674	54	0.631
59	5	0.680	30	0.647
60	6	0.692	56	0.658
61	40	0.696	52	0.672
62	47	0.750	6	0.687
63	23	0.787	23	0.792
64	46	0.795	46	0.822
65	14	0.829	14	0.980

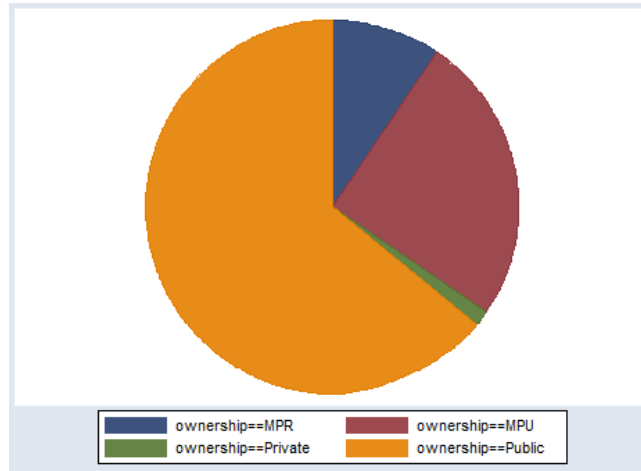
2.6 Does Ownership Really Matters?

Even if the main purpose of the present paper is to propose and verify the existence of a link between the firm's ownership and the firm's financial leverage, the lack of significance of the ownership variable in determining the company efficiency deserves more explanations.

As discussed in Section III, in Italy there are four different ownership type, i.e. companies that are totally public, companies that are totally private and companies that have more of the 50% of their management controlled by publicly or privately owners.

Graphically, the Italian situation can be represented as in the following Figure:

FIGURE 3: ITALIAN WATER COMPANIES OWNERSHIP



Although the Galli's Act required a consolidation process between companies, the same law established a strong dispersion of the Authorities (ATO). Actually, in Italy there are 93 different local Authority and the original project is not still accomplished, as originally the Galli's Act prescribed that 99 different ATOS should take place.

Obviously, the great number of authorities is problematic, as all of them can easily incur in the well known "regulator's capture" phenomenon, especially when the water companies are multiutilities with a great local power.

Consequently, the big issue for Italian water sector is to face the lack of a strong and independent regulator. The advisory body that formally controls the ATOS and acts as central Authority for the water sector (the Italian COVIRI) is still a part of the Environmental Ministry, and then it has no the necessary independence to determine prices and rules that are not subjected to the political control.

It is important to highlight that the regulatory uncertainty strongly affects the firm's efficiency as the small regulators can not have the power to effectively impose optimal prices and incentivating performance rules to the regulated companies. Then, only the presence of a powerful and independent regulator can guarantee a discrimination between efficient and inefficient companies. As Italian water sector still suffers the regulator uncertainty, the ownership of the firms should not be an important determinants of their final performance.

An examination of the firm's inefficiencies highlights that both the private and the public firms experiment almost the same inefficiency levels. The results are presented in the following Tables.

TABLE 7. CLASSICAL INEFFICIENCIES AND OWNERSHIP

MEAN OF \hat{u}	0.393
MEAN OF \hat{u} IF "PUBLIC" OWNERSHIP	0.387
MEAN OF \hat{u} IF "PARTIALLY PUBLIC" OWNERSHIP (MPU+PUBLIC)	0.395
MEAN OF \hat{u} IF "PRIVATE" OWNERSHIP (MPR+PRIVATE)	0.402

TABLE 8. BAYESIAN INEFFICIENCIES AND OWNERSHIP

MEAN OF \hat{u}	0.467
MEAN OF \hat{u} IF "PUBLIC" OWNERSHIP	0.462
MEAN OF \hat{u} IF "PARTIALLY PUBLIC" OWNERSHIP (MPU+PUBLIC)	0.473
MEAN OF \hat{u} IF "PRIVATE" OWNERSHIP (MPR+PRIVATE)	0.477

It should be underlined, however, that the results reported in the previous tables can dramatically change after the enhancement of the regulatory power; otherwise, any other consideration on the water company privatization should probably be postponed.

2.7 Economies of Scale in the Italian Water Sector

The recent literature analyzed in Section II highlights the role of the presence of scale economies in the water sector. Moreover, as highlighted before, one of the central goals of the Galli's Act was the elimination of the fragmentation both in terms of the number

of water firms and in terms of the management of the water cycle. Then, a consolidation process began on 1994 and the same companies were incentivated to manage both the aqueduct and the sewerage system. Then, it would be useful to investigate how effective the implications of the Galli's Act are, and then to investigate if the presence of economies of scale still emerges in the water sector.

I will follow the procedure proposed by Fabbri and Fraquelli (2000) and Antonioli and Filippini (2002) to compute the magnitude of the scale economies; the authors emphasized that for a logarithmic cost function with a single output a measure of economies of scale is given by the elasticity of the cost with respect to output:

$$\beta_Y = \varepsilon_{c,y} = \frac{dc}{dy} \frac{y}{c} \quad (2.18)$$

the economic interpretation of this condition is straightforward: the elasticity of cost with respect to output indicate how the cost changes if the output varies of one unity. Moreover, condition (2.18) can be rewritten as:

$$\varepsilon_{c,y} = \frac{MC}{AC}$$

in which MC are the firm's marginal costs and AC are the firm's average costs. Then the firm experiences increasing, constant or decreasing return to scale if the ratio between the marginal and the average cost is less, equal or greater than 1.

In the Cobb Douglas specification, the elasticity of cost with respect to a given variable is the derivative of the cost function with respect to the same variable. Then, my econometric results highlight that $\varepsilon_{c,y} = 0.34$ in the Classical estimates and $\varepsilon_{c,y} = 0.37$ in the Bayesian results. This means that the costs increase when volumes supplied are expanded, and then it is possible to conclude that, after 14 years from the publication of the Galli's Act, there are still some scale economies in the Italian water sector.

Moreover, it is interesting to determine if the elasticity of costs with respect to output varies considering the subsample of the firms that serve less than 250.000 final consumers

and the subsample of the firms that serve more than 250.000 consumers.

If significant output elasticities are found in these two subsamples it is possible to conclude that firm's size matters in determining economies of scale.

The estimation results of the Classical estimates of the elasticity of output in the two subsamples are reported in the following Tables.

TABLE 9. ELASTICITY OF OUTPUT FOR DIFFERENT SAMPLES (CLASSICAL)

	SMALL FIRMS	LARGE FIRMS
LGY	0.3114	0.3013
ST. ERRORS	0.099***	0.1244***

in which (***) denotes a variable which is significant at the 1% level, (**), at 5% and (*) at 10% level respectively.

TABLE 10. ELASTICITY OF OUTPUT FOR DIFFERENT SAMPLES (BAYESIAN)

	SMALL FIRMS	LARGE FIRMS
LGY	0.3259	0.3154
ST. DEV	0.1001***	0.1289***

in which (***) denotes a variable which is significant at the 1% level, (**), at 5% and (*) at 10% level respectively.

It is immediate to notice that the coefficients of the elasticity of costs with respect to output is greater for the small firm than for the large firms. Then, after 14 years from the promulgation of the Galli's Act, small firms still present economies of scale and then the regulator should better promote mergers between different water companies.

2.8 Conclusion

This paper analyzes the effects of the debt on the efficiency of 65 Italian water companies. I estimate a cost frontier in which the efficiency term depends on the firm's ownership and on the firm's financial leverage.

I find evidence of a strongly and positive relation between the firm's inefficiency and the presence of high debt levels, whereas the ownership does not significantly affect the efficiency of my firm's sample.

A recent theoretical literature²⁵ highlights the effect of the opportunistic behavior exerted by management of the regulated water companies on the final consumers in presence of high level of debt. Particularly, these authors assert that an high leverage should implies greater regulation protection that shifts the regulator's preference from a price cap system to a more rate of return oriented mechanism. More importantly, these authors point out that the dash for debt reduces the expected cost of capital and, then, the consumers expected final prices.

However, in the present work, I verify that for the Italian water sector an excessive use of the financial leverage can have a perverse effect on firm's efficiency. This result holds both for the Classical and for the Bayesian estimates.

Moreover, my analysis highlights that the frequentist estimates suffer from a small sample bias and this qualitatively affects the ranking of the company's inefficiencies.

Then, in a stochastic frontier with a relatively small sample, a Bayesian approach should be recommended.

Moreover, I also investigate if the private ownership is positively related to the firm's efficiency. Quite surprisingly, I find that for the Italian water sector there is no relation between firm's inefficiency and firm's ownership.

However, this result can be easily understood as in Italy there is no an independent Authority for the water sector, and the Italian regulation relies on 93 different (small) local Authorities, that can easily incur in the "regulator's capture" phenomenon. It could be said that, in Italy, the water companies are inefficient at the same level, despite their ownership.

The regulatory uncertainty is finally reflected in the failure of the Galli's Act prescriptions. Although the Gallis's Act prescribed a consolidation process between the Italian water firms, after 14 years from its publication the small water companies still benefit of positive economies of scale. Then, the big challenge in the present situation is to promote

²⁵See Spiegel and Spulber (1994, 1997), De Fraja and Stones (2004) and Stones (2007).

the effective independency of the Authority from the Environmental Ministry in order to guarantee a strong regulation that effectively pursues the consumer's welfare.

Bibliography

- [1] Antonioli, B., Filippini, M. (2001): "The Use of Variable Cost Function in the Regulation of Italian Water Industry", *Utilities Policy*, Vol. 10, pp.181-187.
- [2] Ashton, J. (2000): "Cost inefficiency in the UK water and sewerage industries", *Applied Economics Letters*, Vol. 7, pp. 455-458.
- [3] Atkinson and R. Halvorsen, (1986) , "The Relative Efficiency of Public and Private Firms in a Regulated Environment: the Case of US Electric Utilities", *Journal of Public Economics*, Vol. 29, pp. 281–294.
- [4] Averch J. and Johnson,L. (1962), "Behavior of the Firm Under Regulatory Constraint", *American Economic Review*, Vol. 52.
- [5] Battese, G.E., and Coelli, T.J., (1993): "A stochastic frontier production incorporating a model for technical inefficiency effects" Working Papers in Applied Statistics, No. 65, Department of Economics, University of New England, Amrmdale, NSW, Australia.
- [6] Battese, G.E., and Coelli, T.J., (1995): "A model for technical inefficiency effects in a stochastic frontier production function for panel data". *Empirical Economics* 20, 325–332.
- [7] Bhataccayya, A. et. al. (1994) : "An Examination of the Effect of the Ownership on the Relative Efficiency of Public and Private Water Utilities", *Land Economics*, Vol.70, No. 2

- [8] Bhataccayya, A. et. al. (1995) : "Specification and Estimation of the Effect of Ownership on the Economic Efficiency of the Water Utilities", *Regional Science and Urban Economics*, Vol.25, pp.759-784.
- [9] Canitano, G. and Di Laurea, D. and Doni, N. (2005): "La Convenzione di Affidamento e la Regolazione nel Servizio Idrico in Italia" Franco Angeli Press.
- [10] Clagget, T. (1994): "A Cost Function Study of the Providers of TVA Power", *Managerial and Decision Economics*, Vol. 15, pp. 63-72.
- [11] De Fraja, G. and Stones, C. (2004) "Risk and Capital Structure in the Regulated Firm", *Journal of Regulatory Economics*, vol.26, No.1.
- [12] Diewert, W.E. (1971): 'An application of the Shephard duality theorem: a Generalized Leontief Production Function', *Journal of Political Economy*, Vol. 79, No.3, pp. 481-507
- [13] Fabbri, P. and Fraquelli, G. (2000): "Costs and Structure of Technology in the Italian Water Industry", *Empirica*, Vol.27, pp. 65-82.
- [14] Ferrier, G.D.; Lovell, C.A. (1990): "Measuring Cost Efficiency in Banking: Econometric and Linear Programming Evidence", *Journal of Econometrics*, Vol. 46, Issue 1/2, pp. 229-245.
- [15] Garcia, S.; Thomas, A. (2001): "The Structure of Municipal Water Supply Cost: an Application to a Panel of French Local Communities", *Journal of Productivity Analysis*, Vol.16, pp.5-29.
- [16] Greene, W. (1980): "Maximum Likelihood Estimation of Econometric Frontier Functions", *Journal of Econometrics* 13:1, pp. 27-56.
- [17] Helm, D. (2003), 'Whither Water Regulation?', chapter 1 in D. Helm (ed), *Water, Sustainability and Regulation*, Oxford: OXERA, May, pp. 1-12. (also available on www.dieterhelm.co.uk)
- [18] Koop, G.; Osiewalski, J.; Steel, M. (1997): "Bayesian Efficiency Analysis Through Individual Effects: Hospital Cost Frontiers", *Journal of Econometrics*, Vol.76, pp.77-105.

- [19] Kumbhakar, C.S; Lovell, C.A. (2000): "Stochastic Frontier Analysis", Cambridge University Press.
- [20] Lau, L.J., (1978): "Testing and imposing monotonicity, convexity, and quasi-convexity constraints", in: Fuss, Melvin, McFadden and Daniel, Editors, (1978): "Production Economics: a Dual Approach to Theory and Applications", Amsterdam, North-Holland, pp. 409–453.
- [21] Lau, L.J. (1986), "Functional forms in econometric model building", in Z. Griliches and M. D. Intriligator, eds., Handbook of Econometrics vol. 3, New York, North-Holland Elsevier.
- [22] Murrillo-Zamorano, L. (2004): "Economic Efficiency and Frontiers Technique", Journal of Economic Surveys, Vol. 18, No. 1.
- [23] Ofwat (2004): 'Future Water and Sewerage Charges 2005–10: Final Determinations'.
- [24] Osiewalski, J. ; Steel, M. (1998): "Numerical Tools for the Bayesian Analysis of Stochastic Frontier Models", Journal of Productivity Analysis, Vol.10, pg. 103-117.
- [25] Sauer, J., Frohberg, K. (2007): "Allocative Efficiency of Rural Water Supply-a Globally Flexible SGM Cost Frontier", Journal of Productivity Analysis, Vol.27, pp.31-40.
- [26] Spiegel, Y. and Spulber, D.F. (1994) "The Capital Structure of a Regulated Firm", RAND Journal of Economics, vol.25, No.3.
- [27] Spiegel, Y. and Spulber, D.F. (1997) "Capital Structure with Countervailing Incentives", RAND Journal of Economics, vol.28, No.1.
- [28] Spiegelhalter, D. et. al. (2002): "Bayesian measures of model complexity and fit (with discussion)". Journal of the Royal Statistical Society, Series B (Statistical Methodology) Vol. 64, No.4, pp. 583–639.
- [29] Stones, C. (2007) "Risk Sharing, the Cost of Equity and the Optimal Capital Structure of the Regulated Firm" forthcoming in Journal of Industrial Organization.
- [30] Teeple, R., Glycer, D. (1987): "Cost of Water Delivery System: Specification and Ownership Effects", Review of Economics and Statistics, Winter.

- [31] Tierney, L. (1994): "Markov Chains for Exploring Posterior Distributions", *The Annals of Statistics*, Vol. 22, No. 4. (1994), pp. 1701-1728.
- [32] Van der Broek et. al. (1994): "Stochastic Frontier Models: A Bayesian Perspective", *Journal of Econometrics*, Vol.61, pp. 273-303.

Appendix

A. Companies and ATO

REGION	N.ATO	N.COMPANIES
PIEMONTE	6	29
LOMBARDIA	6	11
VENETO	7	12
FRIULI	1	1
LIGURIA	2	5
EMILIA ROMAGNA	9	10
TOSCANA	6	6
UMBRIA	3	3
MARCHE	4	6
LAZIO	4	4
ABRUZZO	6	6
CAMPANIA	2	2
PUGLIA	1	1
BASILICATA	1	1
CALABRIA	3	3
SICILIA	5	5
SARDEGNA	1	1

Data Source: COVIRI (2008). Data on Trentino Alto Adige, Molise and Valle D'Aosta are not available since the ATO are not yet established.

B. Summary Statistics

Variable	Obs	Mean	Std.Dev.	Min	Max
COST	65	4.24E+07	6.22E+07	1247524	3.39E+08
Y	65	4.58E+07	8.50E+07	393052	5.14E+08
PL	65	301993.4	2062760	13625.74	1.67E+07
PK	65	4963077	.2481719	.02	.91
PM	65	7869.799	25931.23	21.61	192972.4
LEVERAGE	65	0.5363	0.2489	0.0890	0.9622

C. Inefficiency Estimator

Proof. From the assumption made on residuals and inefficiency term follows:

$$f_U = \frac{1}{\sqrt{2\pi}\sigma_u\Phi\left(-\frac{\mu}{\sigma_u}\right)} \exp\left\{-\frac{(u - \mu_i)^2}{2\sigma_u^2}\right\}$$

in which μ is the mode of the error term, which is always different from zero. Moreover, the density function of v_i is given by:

$$f_V = \frac{1}{\sqrt{2\pi}\sigma_v} \exp\left\{-\frac{v_i^2}{2\sigma_v^2}\right\}$$

then,

$$f(u, \varepsilon) = \frac{1}{\sqrt{2\pi}\sigma_u\sigma_v\Phi\left(-\frac{\mu}{\sigma_u}\right)} \exp\left\{-\frac{(u - \mu_i)^2}{2\sigma_u^2} - \frac{(\varepsilon - u)^2}{2\sigma_v^2}\right\}$$

in which $\varepsilon = u + v_i$, from which:

$$f(\varepsilon) = \frac{1}{\sqrt{2\pi}\sigma_u\sigma_v\Phi\left(-\frac{\mu}{\sigma_u}\right)} \int_0^{\infty} \exp\left\{-\frac{(u - \mu_i)^2}{2\sigma_u^2} - \frac{(\varepsilon - u)^2}{2\sigma_v^2}\right\} du$$

that becomes:

$$f(\varepsilon) = \frac{1}{\sqrt{2\pi}\sigma_u\sigma_v\Phi\left(-\frac{\mu}{\sigma_u}\right)} \exp\left\{-\frac{1}{2}\left\{\frac{1}{(\sigma_u^2 + \sigma_v^2)}\varepsilon^2 + \frac{1}{(\sigma_u^2 + \sigma_v^2)}\mu^2 - 2\frac{\mu\varepsilon}{(\sigma_u^2 + \sigma_v^2)}\right\}\right\} \quad (2.19)$$

$$\times \int_0^\infty \frac{1}{2} \exp\left\{-\frac{1}{2}\frac{\sigma_u^2 + \sigma_v^2}{\sigma_u^2\sigma_v^2}\left[u - \frac{\sigma_u^2\varepsilon + \sigma_v^2\mu}{\sigma_u^2 + \sigma_v^2}\right]^2\right\} du$$

if I introduce the following variable:

$$x = \sqrt{\frac{\sigma_u^2 + \sigma_v^2}{\sigma_u^2\sigma_v^2}} \left[u - \frac{\sigma_u^2\varepsilon + \sigma_v^2\mu}{\sigma_u^2 + \sigma_v^2} \right] \quad (2.20)$$

which is normally distributed, with zero mean and unitary variance. Then, (2.19) becomes:

$$f(\varepsilon) = \frac{1}{\sqrt{2\pi}\sigma_u\sigma_v\Phi\left(-\frac{\mu}{\sigma_u}\right)} \exp\left\{-\frac{1}{2}\frac{(\varepsilon + \mu)^2}{\sigma_u^2 + \sigma_v^2}\right\} \int_{-\frac{\sigma_u^2}{\sigma_u^2 + \sigma_v^2}\varepsilon}^\infty e^{-\frac{x^2}{2}} dx$$

that is:

$$f(\varepsilon) = \frac{1}{\sqrt{2\pi}\sqrt{\sigma_u^2 + \sigma_v^2}\Phi\left(-\frac{\mu}{\sigma_u}\right)} \exp\left\{-\frac{1}{2}\frac{(\varepsilon + \mu)^2}{\sigma_u^2 + \sigma_v^2}\right\} \left[1 - \Phi\left(-\frac{\frac{\sigma_u}{\sigma_v}\varepsilon + \frac{\sigma_v}{\sigma_u}\mu}{\sqrt{\sigma_u^2 + \sigma_v^2}}\right) \right] \quad (2.21)$$

I find the conditional distribution $f(u|\varepsilon)$ simply applying the well known Bayes rule, i.e.

$$f(u|\varepsilon) = \frac{f(u, \varepsilon)}{f(\varepsilon)}$$

that is:

$$f(u|\varepsilon) = \frac{\frac{1}{\sqrt{2\pi}\sigma_u\sigma_v\Phi\left(-\frac{\mu}{\sigma_u}\right)} \exp\left\{-\frac{(u-\mu_i)^2}{2\sigma_u^2} - \frac{(\varepsilon-u)^2}{2\sigma_v^2}\right\}}{\frac{1}{\sqrt{2\pi}\sqrt{\sigma_u^2+\sigma_v^2}\Phi\left(-\frac{\mu}{\sigma_u}\right)} \exp\left\{-\frac{1}{2}\frac{(\varepsilon+\mu)^2}{\sigma_u^2+\sigma_v^2}\right\} \left[1 - \Phi\left(-\frac{\frac{\sigma_u}{\sigma_v}\varepsilon + \frac{\sigma_v}{\sigma_u}\mu}{\sqrt{\sigma_u^2+\sigma_v^2}}\right)\right]}$$

that becomes:

$$f(u|\varepsilon) = \left(\frac{\sqrt{\sigma_u^2 + \sigma_v^2}}{\sigma_u\sigma_v}\right)^{-1} \frac{\exp\left\{-\frac{1}{2}\frac{\sigma_u^2 + \sigma_v^2}{\sigma_u^2\sigma_v^2} \left[u - \frac{\sigma_u^2\varepsilon + \sigma_v^2\mu}{\sigma_u^2 + \sigma_v^2}\right]^2\right\}}{\left[1 - \Phi\left(-\frac{\frac{\sigma_u}{\sigma_v}\varepsilon + \frac{\sigma_v}{\sigma_u}\mu}{\sqrt{\sigma_u^2 + \sigma_v^2}}\right)\right]} \quad (2.22)$$

Then it is easy to calculate $E(u|\varepsilon)$, as from (2.20) I know that:

$$u = \sqrt{\frac{\sigma_u^2 + \sigma_v^2}{\sigma_u^2\sigma_v^2}}x + \frac{\sigma_u^2}{\sigma_u^2 + \sigma_v^2}\varepsilon + \frac{\sigma_v^2}{\sigma_u^2 + \sigma_v^2}\mu$$

and then:

$$E(u|\varepsilon) = \sqrt{\frac{\sigma_u^2 + \sigma_v^2}{\sigma_u^2\sigma_v^2}}E(x) + \frac{\sigma_u^2}{\sigma_u^2 + \sigma_v^2}\varepsilon + \frac{\sigma_v^2}{\sigma_u^2 + \sigma_v^2}\mu \quad (2.23)$$

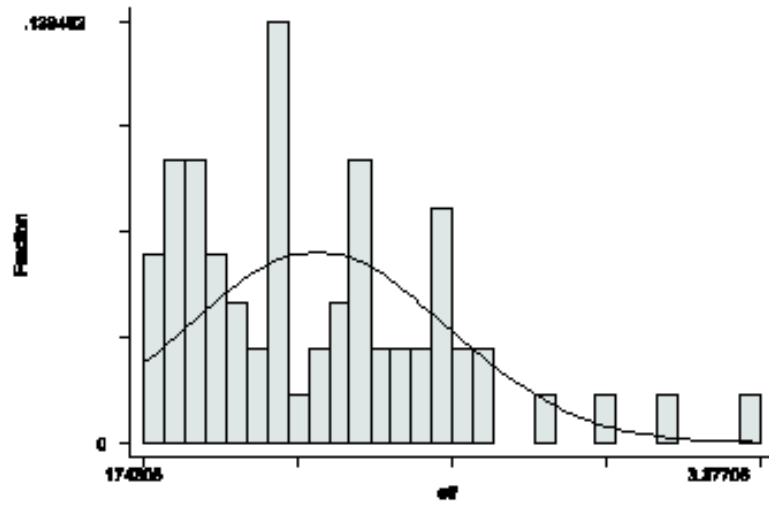
as long as, by definition, $x \sim N(0, 1)$, truncated to the left in $-\frac{\frac{\sigma_u}{\sigma_v}}{\sqrt{\sigma_u^2 + \sigma_v^2}}\varepsilon - \frac{\frac{\sigma_v}{\sigma_u}}{\sqrt{\sigma_u^2 + \sigma_v^2}}\mu$, eq.

(2.23) becomes:

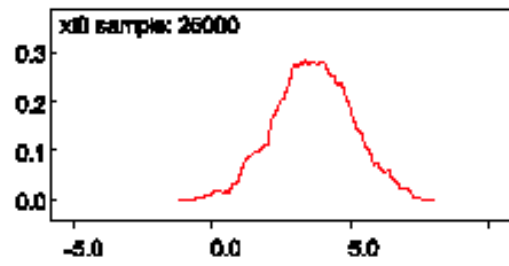
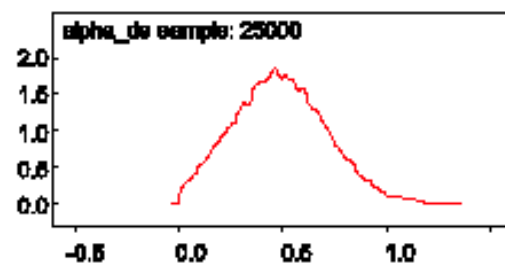
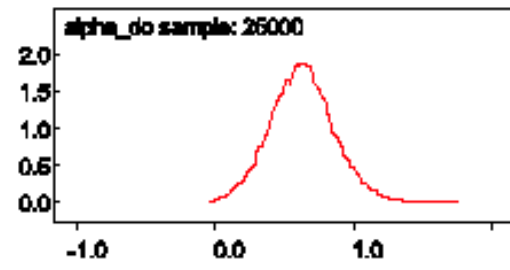
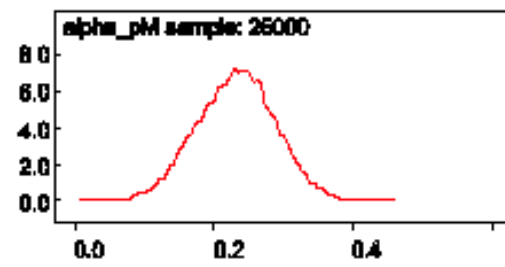
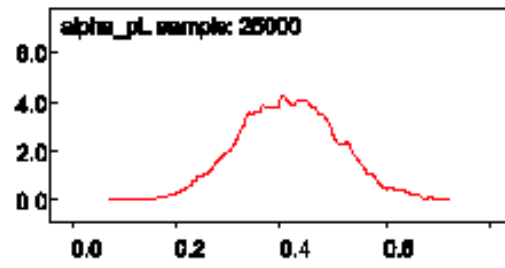
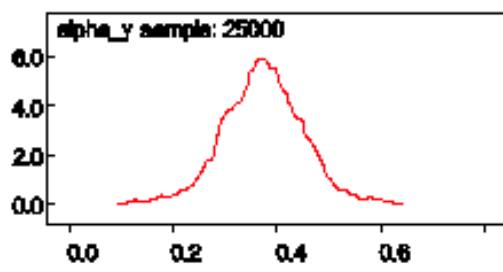
$$E(u|\varepsilon) = \sqrt{\frac{\sigma_u^2 + \sigma_v^2}{\sigma_u^2\sigma_v^2}} \frac{1}{\sqrt{2\pi} \left[1 - \Phi\left(-\frac{\frac{\sigma_u}{\sigma_v}}{\sqrt{\sigma_u^2 + \sigma_v^2}}\varepsilon - \frac{\frac{\sigma_v}{\sigma_u}}{\sqrt{\sigma_u^2 + \sigma_v^2}}\mu\right)\right]} \exp\left\{-\frac{1}{2}\frac{\sigma_u^2}{\sigma_u^2 + \sigma_v^2}\varepsilon^2 - \frac{\sigma_v^2}{\sigma_u^2 + \sigma_v^2}\mu^2\right\} + \frac{\sigma_u^2}{\sigma_u^2 + \sigma_v^2}\varepsilon + \frac{\sigma_v^2}{\sigma_u^2 + \sigma_v^2}\mu \quad (2.25)$$

■

D. MLE residuals



E. Bayesian distribution of exogenous coefficients



Chapter 3

Are the Consumers Always Ready to Pay? A Quasi-Almost Ideal Demand System for Italian Water Demand

Abstract¹

Despite the drinking water represents only the 1,3 per cent of the total water daily available for Italian consumers, this service is not easily replaceable with other goods. Moreover, although water is a basic need and then its consumption should be insured to all the citizen, the scarcity of this resource implies that all its losses should be strongly discouraged. The presence of these countervailing incentives related to the water consumption should be considered by the regulator in order to determine the optimal final tariff. This paper analyzes the water elasticity with respect to price and to income for the Italian consumers. The parameters have been obtained through estimation of a complete Quasi-Almost Ideal demand system, using households data from 1999 to 2005. The results are encouraging: the mean of the water price elasticity is aligned with the mean of the European countries, but the consumer's reaction of a rise in the final prices varies across familiar and regional patterns. Particularly, a rise in the final prices strongly affects the elder and the population that lives in the South of Italy. Then, the regulator should reckon on the affordability of the water consumption before choosing the final pricing policy.

J.E.L. Classification Numbers: D12, H41, L95

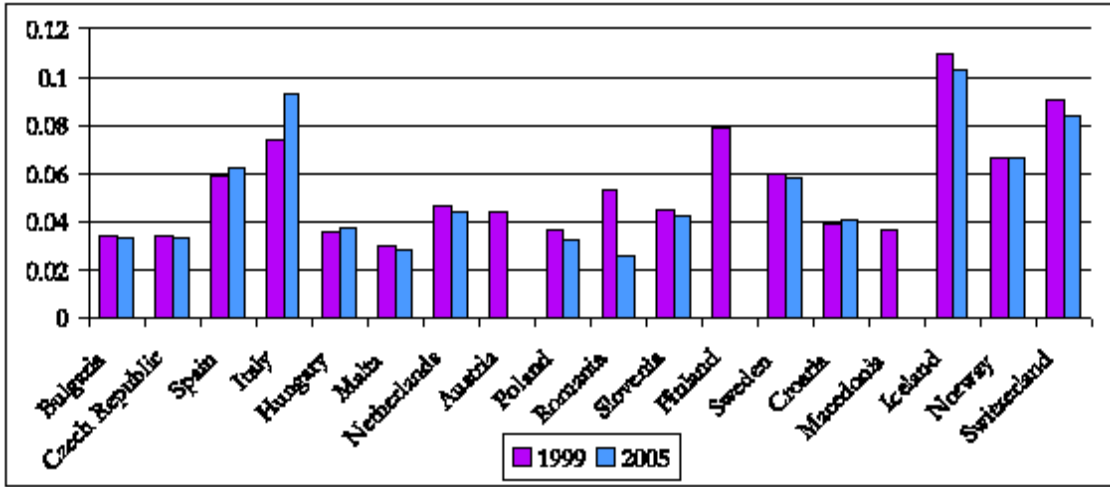
Keywords: Water, Demand Elasticity, Demand Analysis

¹I thank Silvia Tiezzi for her valuable comments and suggestions and the University of Siena to kindly provide me the data on Italian consumption. I also thank William Addessi for helpful comments and ISTAT that gives me the data on Italian water prices. All errors are of course mine.

3.1 Introduction

The latest ISTAT (2005) and EUROSTAT (2008a, 2008b) surveys on private Italian households consumption of water highlights that Italy is among the first five countries in Europe in terms of per capita consumption, as highlight in the following Figure:

FIGURE 1: USE OF WATER BY PRIVATE HOUSEHOLDS
(THOUSANDS OF M³)



Data source: my elaboration on Eurostat (2008) and Istat (2005)

Even if ISTAT (1999, 2005) made only two surveys on Italian water consumption, they both highlight that the Italian performance can be explained considering the inefficiency in the aqueduct system (that is reflected in an high amount of water losses) and investigating the final consumer’s behavior. In particular, this paper analyzes which are the effects of a possible pricing policy chosen by the water Authority to limit the final consumer’s waste.

Moreover, the need of huge investments in the water sector and the recent privatization process can lead to a rise in the final tariff and then it is important to investigate (i) the possible consumption patterns in response to a rise in the final prices, (ii) if there are some local specificities in order to adopt the more adequate pricing policy and (iii) to rightly consider the regional or climate specificities that may affect the determinants of the final tariffs.²

²See COVIRI (2008).

In Italy, the water sector was mainly regulated by the "Galli's Act", published on 1994, which established the institution of 99 local optimal administrative areas (ATO) each one of them regulated by a (different) local Authority. After 14 years by the Galli's Act publication, only 93 local Authorities effectively works. All these authorities can define a different final price for the several water companies that manage the water service in the different ATOS, and are coordinated by a central regulator (COVIRI), actually managed by the Italian Environment Ministry.

Although the final tariff can differ with respect to the final regulated company, the pricing rule is determined by an inter-ministerial board (CIPE) that proposes a price mechanism which is a synthesis of the price cap rule and the cost pass-through system.

It results in 93 local Authorities which are formally independent, but neither their coordinator (COVIRI), nor the authority that should establish the final pricing scheme (CIPE) are out from the government's control.

Then, it is possible to suppose that the high consumption standards highlighted in Figure 1 can be linked to the uncertainty of the water sector regulation, and then it may be interesting to determine how a variation in the final prices can change the final's consumers behavior.

Moreover, in order to determine whether a price reform affects the consumer's welfare it is important to consider how the final customers react after a change in the final prices. In other words, it would be interesting to determine the elasticity of the water demand with respect to his price and income.

Therefore, the aim of this paper is to calculate how the water expenditure varies after an increase in the final prices. Particularly, I firstly measure the Italian consumer elasticities with respect to income and prices; secondly, I include my analysis in a more exhaustive framework, analyzing also the reaction of the final consumers with respect to a change not only in the final water prices, but also in the prices of other goods and services. This leads to determine the presence of substitution effects between water and other goods. The parameters have been obtained through estimation of a complete Quasi-Almost Ideal demand system (QAIDS), using households data from 1999 to 2005, as proposed by Deaton and Muellbauer (1980a).

The results are encouraging: the mean of the elasticities of water prices is aligned with the mean of the European countries and reflects the recent literature findings.³ Moreover, this paper demonstrates that the consumer's reaction after a rise in the final prices is positively related both to the family patterns and to the climate area considered. Particularly, a rise in the final prices strongly affects the elder and the consumers that live in the South of Italy. Then, the regulator should also reckon on the accessibility of the water consumption before choosing the final pricing policy.

The outline of the paper is as follows. Section II analyzes the pricing scheme followed by the Italian regulators and in Section III I present a brief summary of the literature on water demand estimation. Section IV investigates the theoretical background under the choice of the QUAIDS estimation, Section V describes data while the estimation results are presented in Section VI. Conclusions of the study are summarized in the final section. The data and variables construction are presented in the Appendix.

3.2 Tariff Regulation of Italian Water Distribution Sector

The Italian water industry is composed of approximately 106 companies and is highly fragmented. For instance, there are water companies serving less than 1000 customers and companies serving more than 1.000.000 final customers. Moreover, there is also a great regional dispersion, since some companies operate at a provincial level, other at the regional level, and other serve more regions across Italy.⁴

I consider in my analysis only the water companies charged by the distribution of the water to the private households, ignoring the companies that produce and distribute water for agricultural and industrial purposes.

In Italy, the water companies are in the majority publicly owned, and the concession for the service is assigned directly from the local policy maker without a tendering process.

Therefore, the water companies operate as legal local monopolists. As highlighted before, the tariffs on the water distribution companies are determined at the local level by the 93 different authorities, following a common criterion proposed by CIPE.

³See Rizzi (2001).

⁴On the disaggregation between Italian water companies see also the second Chapter.

The Galli's Act tried to both introduce the full cost pricing principle and to promote cost efficiency. For this reason, this reform introduced a tariff regulation which at the national level is based on yardstick competition.

The final tariff is determined in two different steps. In the first one, each company defines its own tariff composed of a fixed charge and a variable component. Then, in the second step, the firm submits this tariff to the regulation authority for approval. The tariff is approved only if the level of the variable component does not exceed a range of approximately 30% with respect to the regulator's benchmarking valuation.

In order to determine the best tariffs, the regulator adopts the CIPE criterion, calculating the "ideal" variable costs of the regulated company as:

$$CV = 1.1Y^{0.67}KM^{0.32}PUMP^{0.1} \exp\{0.2UT\} + E + A$$

in which Y are the cubic meters of delivered water, KM are the length of the network in kilometers, $PUMP$ are the average pumping head, UT are the pro capita measure of water delivered, E is the expenditure for electricity and A is the expenditure for water bought.

3.3 Related Literature

At the best of my knowledge there are no studies that estimate water demand elasticity adopting a QAIDS procedure. This can be due to the fact that many authors are simply interested in determining the elasticity of water with respect to price and income without considering the possible relation between water and other goods.

Although the existing literature highlights that the water is essentially a necessary good, it should be useful to investigate his relation with respect to other goods in order to better understand the final consumer's behaviour.

Here it is important to notice that although several studies on the water sector adopt an empirical specification different from the demand system estimation, the results are directly comparable with this paper. More importantly, all the cited works highlight that the water

demand is not completely inelastic, and then some policy prescription can be drawn from a study of water consumption. The complete review of the estimation procedures adopted for the water sector is out the scope of the present paper, but it is important to notice that the standard formulation reads:

$$X = f(p, z)$$

in which X is the water consumption, p is the final tariff and z is a vector of exogenous variables that explain the water consumption, such as income, but also the household's type, consumption habits etc.⁵

A drawback of this approach, however, is that the estimated elasticity can change with the environmental variables adopted in the econometric analysis, whereas the QAIDS specification is more robust with respect to change in variables since exhaustively estimates a complete demand system.

Lot of works consider as exogenous variable the price of water and the household income.⁶ However, these regressors are quite often affected by endogeneity and then lead to final results that are severely biased. In order to control potential source of endogeneity, several authors adopt the assessed value of the property as instrument of the income level.⁷ Furthermore, Jones and Morris (1984), in order to better approximate income without incurring in endogeneity problems, adopt the educational level, age of residence and other similar variables as a proxy of the household's wealth.

Furthermore, lots of authors include in their analysis the presence of climate effects, in order to better control the final consumption paths. Some authors adopt a measure of rainfalls⁸ while some others introduce in their analysis a control variable for the temperatures and the climate that characterize their sample.⁹ Since in Italy there is a vast heterogeneity between different climate areas, also this paper controls for the presence of different climate areas, in order to investigate if the demand elasticity is positively related

⁵See Espey et.al. (1997) and Arbués et. al. (2003) for detailed surveys on water demand estimation procedures.

⁶See particularly Dandy et al. (1997), Corral et al. (1998), Renwick and Archibald (1998), Renwick and Green (2000) and Matinez-Espiñeira (2002).

⁷See Hewitt and Hanemann, 1995, Dandy et al., 1997 and Arbués et al., 2003.

⁸See Billings and Agthe (1980), Agthe et al. (1986), Nieswiadomy and Molina (1988), and Hewitt and Hanemann (1995).

⁹See Griffin and Chang (1990), Stevens et al. (1992) and Agthe and Billings (1997).

to this environmental characteristics.

3.4 Theoretical Background

Water is a very particular good: despite the drinking water represents only the 1,3% of the total water daily available for Italian consumers, it is not possible to rationalize its use beyond a minimum threshold. Then, as a basic need, the water consumption should be insured to all the citizen whereas the water losses should be strongly discouraged.

The presence of these countervailing incentives related to the consumption of water should be considered in order to choose the final optimal tariff; however, also the water demand for basic uses can be affected by the regulator's pricing scheme.

Although in Italy the drinkable water is relatively cheap, the necessary investments to improve the distributional services require huge financements; then it should be interesting to investigate the income and the price effects on the consumers demand elasticities in order to verify what kind of policy can be adopt in order to *(i)* induce an higher water saving and *(ii)* obtain the necessary funds to enhance public investments in the water sector.

The following section present a brief review of demand estimation method and derive the QAIDS system that will be applied in my empirical analysis.

3.4.1 Linear estimation of demand model

The primer studies on consumer demand essentially focused on the estimation of a single demand function, that reflects the consumer's preferences.

In this way, it was easy to estimate the elasticities of demand with respect both to the final prices and to the expenditure level. However, one of the aim of the demand analysis is also to investigate the substitution and income effects that can emerge only from the estimation of different consumption goods. Then, also theoretical requirements should be considered and properly included in the final analysis.¹⁰

¹⁰The standard theoretical requirements that should be assumed in estimating a demand specification are the homogeneity of degree zero in prices and in the budget share, the Walras Law, the adding up constraint and the negativity of the symmetric Hessian matrix.

The first attempt to build consistent estimates is provided by Stone (1954a), who explicitly includes the theoretical constraint into the demand specification.

Following Deaton and Muellbauer (1980a) it is possible to resume Stone's analysis considering the linear demand equation:

$$\ln q_i = \alpha_i + \varepsilon_i \ln x + \sum_{k=1}^N \varepsilon_{ik} \ln p_k \quad (3.1)$$

in which ε_i are the elasticities to the expenditure (x), and ε_{ik} are the cross-prices elasticities; q_i is the Marshallian's demands, generally given by:

$$q_i = f_i(x, p) \quad (3.2)$$

and α_i is the consumer specific constant.

Therefore, in order to maintain the number of explanatory variables sufficiently low, it is possible to rewrite the eq. (3.1) using a prices index, as:

$$\ln q_i = \alpha_i + \varepsilon_i \ln \left(\frac{x}{P} \right) + \sum_{k=1}^N \varepsilon_{ik}^* \ln p_k \quad (3.3)$$

in which

$$\varepsilon_{ik}^* = \varepsilon_i \underbrace{\frac{p_k q_k}{x}}_{w_k} + \varepsilon_{ik} \quad (3.4)$$

Then, (3.3) can be read as the Hicksian demand function since it depends on the real expenditure, on the "compensated" prices and on the consumer's budget share w_k .

The homogeneity restriction on the Marshallian demand function prescribes that

$$\sum_k \frac{\partial f_i}{\partial p_k} + \frac{\partial f_i}{\partial x} p_i = 0$$

and then, using the logarithmic transformation provided in (3.1), it becomes:

$$\varepsilon_i + \sum_k \varepsilon_{ik} = 0$$

and then:

$$\sum_k \varepsilon_{ik}^* = 0$$

In order to reduce the number of explanatory variables considered, Stone imposed a zero condition on the "weighted" cross prices elasticities. This transformation allows the empirical specification to correctly consider the substitution and income effects implicitly included in the prices elasticities. Then, it is possible to rewrite (3.3) as:

$$\ln q_i = \alpha_i + \varepsilon_i \ln \left(\frac{x}{P} \right) + \sum_{k \in K} \varepsilon_{ik}^* \ln \left(\frac{P_k}{P} \right) \quad (3.5)$$

in which the subset K includes all the cross prices elasticities that are significantly different from zero, i.e. rules out only the uncorrelated goods.

Generally speaking, if all the conditions of Marshallian demands are imposed simultaneously, the reduction of parameters were be attained, as the $n^2 + n$ original parameters becomes $(n - 1) \left(\frac{1}{2}n + 1 \right)$.

Moreover, the model proposed by Stone neither consider the utility maximization problem nor the duality condition, that allows to recover the Marshallian demands from the consumer's expenditure function.

3.4.2 Generalizations of the Stone's model

A model that generalize the first Stone's specification is the linear model, that is obtained from the utility maximization problem and from the theoretical requirement implicit in the Marshallian's demand functions.

Then, in this model, the microfundation of the consumer's behavior is explicitly con-

sidered and the utility maximization problem is solved in order to obtain an empirical specification.

I suppose that the consumer maximizes the following utility function:

$$\begin{aligned} \max u(q_i) &= \prod_{i=1}^N (q_i - \gamma_i)^{\beta_i} \\ \text{s.t. } \sum_{i=1}^N p_i q_i &= x \end{aligned}$$

from which:

$$\begin{aligned} \frac{\partial \mathcal{L}}{\partial q_i} = 0 &\Rightarrow \frac{\beta_i}{q_i - \gamma_i} = -\lambda p_i \\ \frac{\partial \mathcal{L}}{\partial \lambda} = 0 &\Rightarrow \sum_{i=1}^N p_i q_i = x \end{aligned}$$

Solving for every i and substituting the budget constraint leads to the following system of demand:

$$p_i q_i = p_i \gamma_i + \beta_i \left(x - \sum_{k=1}^N p_k \gamma_k \right) \quad (3.6)$$

which is known as the linear expenditure system, in which $\sum_{k=1}^N \beta_k = 1$.

It is then possible to determine the indirect utility function associated to (3.6) simply substituting the Marshallian demands in the utility function:

$$v_i = \frac{x - \sum_{k=1}^N \gamma_k p_k}{\beta_0 \prod p_i^{\beta_i}}$$

in which

$$\beta_0 = \frac{1}{(\sum_{k=1}^N \gamma_k p_k)^{\beta_i - 1} \beta_i^{\beta_i}}$$

It is then easy to solve for the expenditure level and then obtain the cost function, given by:

$$x = c(u, p) = \sum_{k=1}^N \gamma_k p_k + \beta_0 \prod p_i^{\beta_i} u \quad (3.7)$$

The economic interpretation of (3.7) is straightforward: the commodities γ_i are bought by the consumer at first at their respective prices p_i , leaving the other commodities $\sum_{k=1}^N p_k \gamma_k$ to be bought with the excess of the expenditure x .

Then, the total outlay is divided in constant parts, equal to β_i , between different commodities. Then, $\prod p_i^{\beta_i}$ reflects the unitary price that can buy the utility level u . Then it is possible to see this term as a price index, that represents the marginal cost of living.

Then, the utility maximization problem, subject to Walras' law, homogeneity and Hessian symmetry conditions allows to reduce the initial Stone's form to an equation with only $(2n - 1)$ parameters.

The principal drawbacks of the Stone's approach are mainly that: (i) the assumed linearity of the Marshallian demand functions can cause severe problems if economic data do not reflect this assumption and that (ii) imposing concavity of the expenditure function with respect to prices (i.e. $\beta_i > 0$) rules out the presence of inferior goods from the consumer's basket.

The last intuition comes directly from the demand theory, that prescribes that for inferior goods the following condition must hold:

$$\frac{\partial f_i(q, p)}{\partial x} < 0$$

but it is satisfied in (3.7) only if $\beta_i < 0$.

Then, the linear model present a trade-off between the possibility to allow the researcher to consider the presence of inferior goods and to impose the conditions for the duality form in the consumer utility maximization problem.

This can be easily understood considering that the linear model belongs to the class of additive separability models. This implies that, in terms of utility function, it is impossible to give a specific ordering to the demand functions associated to different goods. Intuitively, it means that all the consumer's assets are substitutes.

This hypothesis is hardly verified in economics data, then assuming additive preferences by estimating a linear demand system can lead to severe bias in the estimated coefficients.

Then, even if the linear system proposed by Stone (1954b) is directly derived from the demand theory and it represents a powerful instrument to perform the consumer's analysis, it is better to consider how other different models can satisfy the theoretical requirements allowing for a better fit of real data.

The Rotterdam Model

In order to avoid the problems given by preferences additivity, the Rotterdam model proposed by Theil (1965) and Barten (1966) again start from the empirical specification originally proposed by Stone (1954a) and given by eq.(3.1).

Also this approach explicitly consider the consumer's problem, totally differentiating the Marshallian demands, given in the (3.1) approximation:

$$d \ln q_i = \varepsilon_i d \ln x + \sum_{k=1}^N \varepsilon_{ik} d \ln p_k \quad (3.8)$$

Moreover, in this specification, elasticities are no assumed constant. Again, if (3.4) holds, multiplying all terms for the budget share w_i , leads to:

$$w_i d \ln q_i = \underbrace{w_i \varepsilon_i}_{p_i \frac{\partial q_i}{\partial x}} \underbrace{\left(d \ln x - \sum w_i d \ln p_i \right)}_{\sum w_i d \ln q_i} + \sum_j^N \underbrace{w_i \varepsilon_{ij}^*}_{\frac{p_i p_j}{x} s_{ij}} d \ln p_j \quad (3.9)$$

in which $j = k - i$, s_{ij} is the general off diagonal element of the Slutsky matrix. Then, $p_i \frac{\partial q_i}{\partial x} = b_i$ is the marginal propensity to spend in the i -th good.

As usual, in order to obtain consistent estimates for the coefficients, the adding up and the homogeneity constraints should be imposed statistically, i.e.

$$\sum_k b_i = 1 \text{ and } \sum_k c_{ki} = 0$$

in which $c_{ik} = \frac{p_i p_k}{x} s_{ik}$, from the Walras law, and

$$\sum_k c_{ik} = 0$$

from homogeneity. Then, in the Rotterdam model, it is possible to simultaneously check the presence of symmetry and homogeneity in prices of the Marshallian's demand functions.

Although a detailed review on the performance of the Rotterdam model is outside the scope of the present paper, it is useful to highlight that, even if the homogeneity requirement is strongly rejected by data, this model allows to simply estimate the substitution matrix, and then to determine whether the different goods are substitute or complements.

However, the main drawback of this model can be found in the lack of flexibility imposed by this theoretical specification. Even if the Rotterdam model can be easily used in order to determine the relation between different goods, the absence of global flexibility can not allow to make inference about homogeneity restriction through the sample.

3.4.3 Functional Flexible Forms and the Almost Ideal Demand System

After the pioneering contribution by Diewert (1971), functional flexible forms has been widely used in economics in order to approximate direct utility functions or cost functions.

Albeit a flexible form is defined as a second order Taylor approximation of an arbitrary function (i.e. an utility function) it should be remarked that it is possible to make inference from the empirical results only in the local point in which the second order approximation neatly fits the theoretical general form.

Consequently, even if the data seem to reject the demand theory for a specific theoretical

form, it should be carefully investigated whether the empirical analysis fails to confirm the theoretical hypothesis or the approximation fails to be sufficiently accurate.

The principal flexible form is the translog utility function, that, possess enough parameters to approximate any elasticities at a given point. However, Deaton and Muellbauer (1980a) suggest that a demand function derived from the indirect translog specification will be not easy to estimate, while the empirical specifications of the direct translog demand function are usually estimated under the quite implausible assumption that prices are determined by quantities.

Therefore, Deaton and Muellbauer (1980b) propose a different approach, which reckon in aggregation and satisfies the properties of theoretical demand functions.

In order to aggregate individual data and estimate the market demand, it is useful to investigate whether the Marshallian demands given by (3.2), can be represented only as a function of the aggregate income level, without imposing the strong condition for which the aggregate income mean is considered the only approximation of the income distribution.

Deaton and Muellbauer (1980a) suggest that, when Engel's curves are non linear, it is possible to determine a generalized linearity condition under which the aggregate demands are function of a representative income level, which depends on the degree of non linearity of the Engel curves.

In order to define a representative consumer (in order to achieve a perfect aggregation), an indirect utility function $v(x, p)$ and her corresponding cost function $c(u, p)$ should exist such that for some utility $u_0 = v(x_0, p)$ the budget share can be calculated applying the Shephard's lemma:

$$\bar{w}_i = w_i(u_0, p) = \sum_h \frac{x^h}{\sum_h x^h} w^h = \sum_h \frac{x^h}{\sum_h x^h} \frac{\partial \ln c^h(u^h, p)}{\partial \ln p_i} \quad (3.10)$$

in which h is the h -th household, with a cost function given by $\ln c^h(u^h, p)$. Then, Deaton and Muellbauer (1980a) demonstrates that the cost function of the representative agent must take the form:

$$c(u_0, p) = \theta [u_0, a(p), b(p)]$$

in which $a(p)$ and $b(p)$ can be seen as prices of intermediate goods that define the cost function together with the utility of the representative agent. Then it is possible to rewrite (3.10) as:

$$w_i(u_0, p) = \frac{\partial \ln \theta}{\partial \ln a} \frac{\partial \ln a}{\partial \ln p_i} + \frac{\partial \ln \theta}{\partial \ln b} \frac{\partial \ln b}{\partial \ln p_i}$$

but, since θ is homogeneous of degree 1 in a and b , it becomes:

$$w_i(u_0, p) = u_0 \frac{\partial \ln a}{\partial \ln p_i} + (1 - u_0) \frac{\partial \ln b}{\partial \ln p_i}$$

From this, it is easy to see that at constant prices each $w_i(u_0, p)$ is a linear function of the other $w_j(u_j, p)$ budget shares. If I consider the special case in which the expenditure levels are independent from the prices, the representative cost function is given by:

$$c(p, u_i) = [a(p)^\alpha (1 - u_0) + b(p)^\alpha u_0]^\frac{1}{\alpha} \quad (3.11)$$

in which α characterizes the form of the Engel's curve and u_i is the utility of the representative agent.

When α tends to zero, (3.11) becomes:

$$\ln c(p, u_i) = [(1 - u) \ln a(p) + u \ln b(p)] \quad (3.12)$$

and it is known as the cost function underlying PIGLOG preferences.

It is then easy to calculate the Engel curve for (3.12) as:

$$w_i = \gamma_i + \eta_i \ln x$$

in which γ_i and η_i are functions of prices.

The specification proposed by Deaton and Muellbauer (1980b) assumes that:

$$\begin{aligned}\ln a(p) &= a_0 + \sum_k^K a_k \ln p_k + \frac{1}{2} \sum_k^K \sum_i^K \gamma_{ki} \ln p_k \ln p_i \\ \ln b(p) &= \ln a(p) + \beta_0 \prod_i p_i^{\beta_i}\end{aligned}$$

in which all parameters have been defined in the previous sections. Then, the consumer's expenditure function is given by:

$$\begin{aligned}\ln c(p, u_i) &= \ln x = a_0 + \sum_k a_k \ln p_k \\ &\quad + \frac{1}{2} \sum_k \sum_i \gamma_{ki} \ln p_k \ln p_i + u \beta_0 \prod_i p_i^{\beta_i}\end{aligned}\tag{3.13}$$

in which α_i, β_i , and γ_{ik} are parameters. In order to satisfy the homogeneity requirement, the following restrictions must hold:

$$\sum_i \alpha_i = 1; \quad \sum_k \gamma_{ki} = \sum_i \gamma_{ki}; \quad \sum_i \beta_i = 0$$

For this specification, the budget shares can be computed following (3.10), and then:

$$w_i = \frac{\partial \ln c(u, p)}{\partial \ln p_i} = \alpha_i + \sum_j \frac{1}{2} (\gamma_{ik} + \gamma_{ki}) \ln p_k + \beta_i u \beta_0 \prod_i p_i^{\beta_i}\tag{3.14}$$

as in Section (3.4.2), I find the indirect utility function simply solving (3.13) for u , considering that the agent is also an utility maximizing consumer, which gives:

$$u = \frac{\ln x}{\beta_0 \prod_i p_i^{\beta_i}} - \frac{a_0 + \sum_k a_k \ln p_k}{\beta_0 \prod_i p_i^{\beta_i}} - \frac{1}{2} \frac{\sum_k \sum_i \gamma_{ki} \ln p_k \ln p_i}{\beta_0 \prod_i p_i^{\beta_i}}$$

then, substituting into (3.14) reads:

$$w_i = \alpha_i + \sum_i \frac{1}{2}(\gamma_{ik} + \gamma_{ki}) \ln p_k + \beta_i \left(\ln x - \underbrace{\left(a_0 + \sum_i a_i \ln p_i \right) - \frac{1}{2} \sum_k \sum_i \gamma_{ki} \ln p_k \ln p_i}_{\ln P} \right) \quad (3.15)$$

Then, imposing the previous constraint and verifying that the following holds:

$$\begin{aligned} \sum_k \gamma_{ki} &= \sum_i \gamma_{ki} = 0 \\ \gamma_{ki} &= \gamma_{ik} \end{aligned}$$

The model given by (3.15) satisfies the homogeneity, adding up and symmetry properties. As the AIDS model derives from PIGLOG preferences, exact aggregation is possible, and then, aggregate equation of (3.15) is given by:

$$\bar{w}_i = \alpha_i + \sum_i \frac{1}{2}(\gamma_{ik} + \gamma_{ki}) \ln p_k + \beta_i \ln \left(\frac{\bar{x}}{P} \right) \quad (3.16)$$

in which \bar{x} is the expenditure of the representative consumer, and \bar{w}_i is the expenditure share of the i -th good. Then (3.16) represent the Marshallian demand functions.

A Better Approximation to Reality: QUAIDS Demand Systems

The accuracy of the AIDS estimates however, can be improved allowing (3.16) to include a non linearity in the relation between w_i and \bar{x} . Banks et.al.(1997), show that both rich and poor households could have the same expenditure for some particular commodities (alcohol or clothes) and then the Engel curves referred to these goods are not monotonic in the total expenditure. Then, in order to consider also this specification in the demand

system analysis, they include in (3.16) a quadratic term for $\ln \bar{x}$.

The theory behind that choice is strictly related to the perfect aggregability problem: to preserve the general AIDS flexibility and to guarantee the aggregability across different consumers, Gorman (1981) demonstrates that the maximum possible rank for a demand system that is linear in functions of income is equal to 3.

Then, Banks et. al. demonstrates that the only possible choice to preserve these requirements and also allow for a non linearity in total expenditure is to add a quadratic term in (3.16), which should be also dependent on prices. Finally, these authors proof that the QAIDS system has the desirable property that for goods that are income inelastic (i.e. like water), an increase in income is followed by (i) a decrease in the income share allocated to that good and (ii) to a reduction of the income elasticity of that good.

Formally, (3.16) becomes:

$$\bar{w}_i = \alpha_i + \sum_k \frac{1}{2}(\gamma_{ik} + \gamma_{ki}) \ln p_k + \beta_i \left[\ln \left(\frac{\bar{x}}{P} \right) + \varpi (\ln x)^2 \right] \quad (3.17)$$

in which ϖ is a parameter.

3.5 Data Description

In my analysis I use a sample of households data from 1999 and 2005.¹¹ Particularly, I consider data referred to private households that lives in Italian cities. This choice is due to the consideration that in Italy, available data on prices do not reflect the block-pricing structure, but are simply a mean of the prices collected for the chief towns of all different regions. OECD (1999) and Arbués et.al. (2003) highlight that the pricing structure is less relevant in urban than in agricultural contests, and then I consider the average price in order to estimate my QAIDS specification.

Then, following Tiezzi (2005) I select six different goods in order to estimate (3.17): (i) drinkable water; (ii) food; (iii) housing; (iv) medical care and education; (v) leisure and

¹¹I use the data provided by ISTAT in its Italian consumer's expenditure survey and in its price index. All the data are at constant prices with basis 1998.

spare time; *(vi)* other goods.

As much as possible, durable goods have been removed from the expenditure categories, to avoid possible complications due to the investment nature of durables. This directly derives from the (weak) separability assumption that I made on the utility function (3.17).

Furthermore, in Italy, the Galli's Act published in 1994 established 99 different local Authorities for the water sector, dividing the Italian territory in the same number of local administrative regions (ATO). Since every Authority can autonomously decide the final water tariff, there is a strong heterogeneity in the final consumer's prices.

However, the Italian data on consumer's expenditure level and on the final prices, provided by ISTAT, present a regional aggregation level. Then, in my analysis I firstly present a benchmark case in which I consider the Italian data as a whole, then I try to capture Italian specificities including in my analysis different regional and demographic dummies.

As discussed in the following Section, the inclusion of territorial dummies strongly improves my analysis and leads to correctly consider the final price elasticities with respect to prices and income.

Summary statistics for the considered sample are provided in the Appendix.

3.6 Econometric Analysis

In order to impose the theoretical restriction to the econometric model, I normalize all the exogenous variables around their mean. This approach allows me to impose the required concavity condition to the Slutsky matrix. Although the coefficients of the Slutsky matrix in the QUAIDS system depend on prices and income, they become constant in the normalization point because at this point they are only functions of known parameters. Then, it is possible to impose the (local) concavity condition for the Slutsky matrix at the normalization point simply reparametrizing this matrix with the Cholesky decomposition. In this procedure, I follow Lau (1978) and Moschini (1998,1999). Then, it is possible to rewrite the Slutsky matrix (S) as:

$$S = -TT$$

where T is a triangular matrix such that $t_{ij} = 0$ for $i \neq j$. Then, the elements of the Slutsky matrix at the normalization point become:

$$s_{ij} = -\alpha_i \delta_{ii} + \alpha_i \alpha_j - c_{ij} \quad (3.18)$$

in which δ is the Kroeneker delta, which is equal to 0 for $i \neq j$. Then, substituting the results of the Cholesky decomposition in the eq.(3.18) leads to:

$$c_{ij} = \alpha_i \delta_{ii} - \alpha_i \alpha_j - (tt')_{ij}$$

which can be estimated. Moreover, Moschini (1998, 1999) points out that imposing these restrictions to a system that violates the local concavity leads to achieve the convergence of the estimated parameters. This technique, however, restricts the rank of the substitution matrix and thus yields to the Semiflexible Almost Ideal Demand System, because the price coefficients are estimated with less information.¹²

Here the rank of the T matrix has been reduced from 5 to 3, so that the number of c_{ij} parameters is reduced from 30 to 18.

Finally, I impose the adding up and the homogeneity constraints, and then I can correctly evaluate the behavioral responses to a change in the regulatory settings by looking at the price elasticities of demand for drinkable water. The Marshallian elasticities measure the percentage reduction in the demand of the goods affected by a 1% rise in the final price. Then, the elasticities can be thought as measures to understand the effectiveness of the Authority decision to rise the final prices. They indicate how effective this measure is in order to reduce the water consumption, which sometimes is linked to high level of water waste. In my benchmark analysis, I simply consider the mean elasticities for all the Italian data. Since at this stage of my analysis I do not partition my sample in different classes, it is impossible to verify whether a rise in the final tariff negatively affects population that lives in different regions. Then, at the end of this Section, I will also include some terri-

¹²See Moschini (1998).

torial and familiar dummies in order to correctly include in my analysis different familiar (and regional) patterns.

From demand system in (3.17) I can easily calculate the matrix of Marshallian (non compensated) elasticities of demand as:

$$\varepsilon_{ij} = \frac{c_{ij}}{w_i} - b_i \frac{w_j}{w_i} + b_j \frac{b_i}{w_i} \ln \left(\frac{x}{P^*} \right) - \delta_{ij}$$

in which, again, δ is the Kroeneker delta.

Finally, I calculate the vector of income elasticities as:

$$\varepsilon_i = \frac{b_i}{w_i} + 1$$

3.6.1 Estimation Result (i): Benchmark Model

I firstly estimate eq. (3.17) for the system described above and I evaluate the Italian demand elasticity with respect to price and income.

In order to have consistent estimates of the parameters of the demand system the explanatory variables must be independent from the residuals. This may not happen when total expenditure is endogenous. To test this possibility I use a Hausman–Wu (HW) test. This is a Likelihood Ratio (LR) test distributed as a χ^2 with 5 degrees of freedom.¹³ I thus reject the null hypothesis of exogeneity of total expenditure and I estimate the unrestricted demand system with the method of Three-Stages Least Squares (3SLS), using as instruments all the exogenous variables included in the original demand system plus the estimated value of the log of total expenditure from the auxiliary regression.¹⁴

Elasticities have been calculated at the sample mean (over 7154 observations) and standard errors are computed using the Delta Method¹⁵.

¹³The value test statistic is very high: 390242.77 with a p-value of 0.00

¹⁴I also test the AIDS specification versus the QAIDS model. The null hypothesis is rejected by the data with a $\chi^2 = 4926.882$ and then I adopt the quadratic specification.

¹⁵This method linearizes non-linear functions around the estimated parameter values and calculates their standard errors.

The estimation results are reported in the following Table:

TABLE 1: MARSHALLIAN ELASTICITIES, ITALY
(AVERAGE 1999-2005)

	p_1	p_2	p_3	p_4	p_5	p_6
q_1	-0.23	0.07	0.06	0.04	0.01	-0.39
q_2	0.01	-0.81	0.07	0.09	0.01	0.37
q_3	0.01	0.18	-1.04	0.27	-0.07	1.03
q_4	-0.01	-0.12	0.26	-0.87	0.16	-1.46
q_5	0.01	0.24	-0.08	0.36	-1.12	1.41
q_6	-0.04	-0.32	-0.06	-0.42	0.05	-2.12

The considered variables are q_1 =water consumption, q_2 =consumption of food and nonalcoholic beverage, q_3 =housing, q_4 =medical care and education, q_5 =leisure and spare time, q_6 =others and their corresponding prices.

It is possible to notice that drinkable water has an elasticity perfectly aligned with the European mean (-0.23, versus -0.2), and, quite intuitively, the elasticity of substitution between water and other goods is almost zero.¹⁶ Indeed, the rigidity of demand can be easily explained considering that water is a necessary service, and then can not be considered as a marketable good.

Demand elasticities with respect to income are reported in the following Table.

TABLE 2: MEAN INCOME ELASTICITIES 1999-2005 ITALY

	q_1	q_2	q_3	q_4	q_5	q_6
$\ln(y)$	0.43	0.26	-0.39	2.04	-0.82	2.90

The considered variables are q_1 =water consumption, q_2 =consumption of food and nonalcoholic beverage, q_3 =housing, q_4 =medical care and education, q_5 =leisure and spare time, q_6 =others and y is the consumer's income.

These results confirm that water (and the consumption of health and education) is not a perfectly inelastic service. Indeed the household expenditures are quite sensitive to a change in the income levels, together with the consumption of food and non alcoholic beverages.

¹⁶See OECD (2007).

However, in order to disentangle the territorial effects, due to the great heterogeneity of climate area and to better investigate the linkage between a rise in the final price and the different consumer's reaction, I include in (3.17) also regional and demographic intercepts. The results of this analysis are presented in the following paragraph.

3.6.2 Estimation Results (ii): Demographic and Regional Effects

As highlighted before, I include in the benchmark model also a specific intercept that varies with (i) the familiar patterns considered and (ii) the geographical region at which the considered family belongs.

The choice of the familiar patterns lies on the intuition that family groups with lot of children can have consumption habits that differs from other family groups, such as a couple of elder people.

Moreover, the choice of different regional dummies can be understood considering that the vast climate heterogeneity between Italian regions can surely explain a difference in consumption attitudes. Finally, in the North of Italy the water is relatively cheap, since the water is relatively abundant. On the contrary, in the South, the climate is more arid, and it is difficult to bring the water to the final consumers, and this makes the water relatively more expensive, as highlighted in the following Table.

TABLE 3: WATER PRICE ACROSS MACRO-REGION, (AVERAGE 1999-2005)

MACRO-REGION	PRICE INDEX
NORTH-WEST	114.6465
NORTH-EAST	114.8818
CENTRE	115.8817
SOUTH AND ISLAND	117.0135

In order to include both the demographic and the regional effects it is possible to follow Alessie and Kapteyn (1991) and Rizzi (2001) in rewriting (3.17) as:

$$w_i = (\alpha_i + d_{iV}) + \sum_j \frac{1}{2}(\gamma_{ik} + \gamma_{ki}) \ln p_k + \beta_i \left[\ln \left(\frac{\bar{x}}{P} \right) + \varpi (\ln x)^2 \right] \quad (3.19)$$

in which d_{iV} are the regional and the familiar dummies that I include in my analysis.

Again in this estimation I impose the concavity to the Hessian matrix and I estimate the final system with a 3SLS procedure, since the null hypothesis of the income exogeneity was again rejected with a p-value of 0.000.¹⁷

Then, I initially consider four different family patterns: (i) couples of elder (i.e. both members have more than 65 years old), (ii) couples of young (i.e. both members have less than 65 years old), (iii) couples of young with one child and, finally, (iv) couples of young with two children. The following Table presents my results on the mean water elasticity with respect to price and income among different familiar patterns, in the considered sample (1999-2005):

¹⁷Also the null hypothesis of the AIDS model vs the QAIDS specification was rejected with a $\chi^2 = 3058.646$.

TABLE 4: PRICE AND INCOME WATER ELASTICITY FOR FAMILIAR PATTERNS

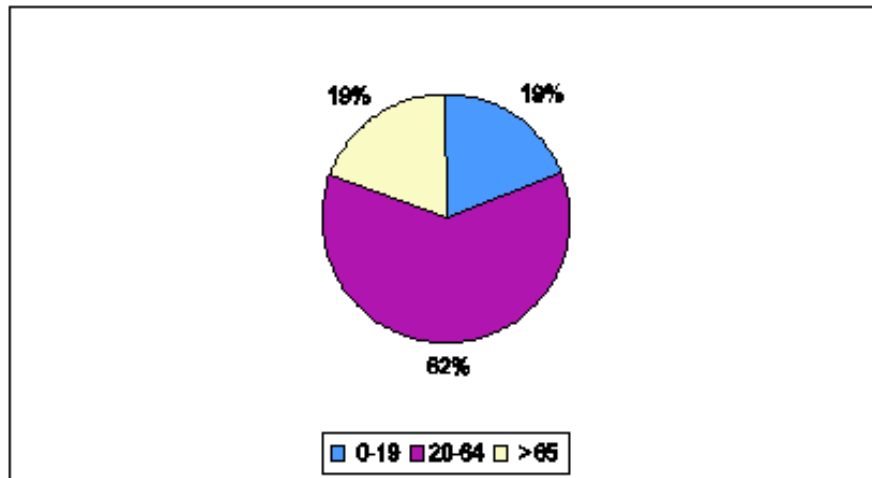
(AVERAGE 1999-2005)

	n_1	n_2	n_3	n_4
p_{water}	-0.36	-0.18	-0.14	-0.16
y	0.46	0.40	0.41	0.43

n_1 =couple of elder, n_2 =couple of young, n_3 =couple of young with 1 child, n_4 =couple of young with 2 children.

From Table 4 it is possible to notice that, although the difference in the behavior of the couples with and without children, there is no a significant variation of their consumption after the increase of the final prices. However, from this disaggregation it is possible to notice that the couples of elder are more sensitive to a price variation of the 1%. Moreover, they also present a different elasticity with respect to income with respect to the other family groups. The water presents again an elasticity of substitution almost equal to zero with respect to the other goods, and then the cross elasticities are not reported in this Table.¹⁸ However, it should be interesting to notice that the different behavior registered by the n_1 familiar group is different from the other groups only for the water and for the leisure time. The following Figure gives a representation of the age groups in Italy:

FIGURE 2: ITALIAN AGE GROUPS (2005)



Data source: Istat (2005)

¹⁸Data and statistics are available upon request to the author.

From the previous Figure and estimates, it is possible to infer that, a rise of the final price leads the 19% of the population to reduce the water consumption of the 36%, whereas the 65% of the population will contract the final consumption of the 17%. Then, it is possible to assume that a rise in the final price will not change the water consumption level for the majority of the population, and then it would be an ineffective measure to control the water waste. Since the Authority can not boost the water rationing simply rising by the 1% the final prices more accurate strategies should be implemented (such environmental education) in order to incentive citizen to adopt water saving habits.

Finally, I estimate the price and income elasticities for the Italian macro-regions. According to ISTAT, I divide Italy in four different subsamples: (i) all the north-eastern regions (i.e. Trentino Alto Adige, Friuli Venezia Giulia, Emilia Romagna and Veneto), (ii) all the north-western regions (Piemonte, Liguria and Lombardia), (iii) the regions in the centre of Italy (Lazio, Toscana, Marche and Umbria) and, (iv) the South and the Islands, that is Puglia, Basilicata, Calabria, Campania, Sicilia and Sardegna.

Estimating (3.19) considering the dummies for the Italian macro regions confirms my initial intuition: the elasticity of water demand is greater in the South than in the North of Italy, while all the other demand elasticities remain almost equal. These other results are reported in the following Table.

TABLE 5: MEAN WATER ELASTICITY FOR REGIONAL PATTERNS (1999-2005)

	NW	NE	CE	SO
ε_{11}	-0.07	-0.01	-0.12	-0.40
ε_{22}	-0.8	-0.8	-0.81	-0.81
ε_{33}	-1.01	-0.99	-1.01	-1.1
ε_{44}	-0.88	-0.89	-0.86	-0.87
ε_{55}	-1.08	-1.07	-1.11	-1.20
ε_{66}	-2.12	-2.12	-2.14	-2.12
y_{water}	0.23	0.28	0.36	0.55

ε_{11} =elast.of water, ε_{22} =elast. of food, ε_{33} =elast. of housing services, ε_{44} =elast.of health and education, ε_{55} =elast. of leisure, ε_{66} =elast.for other goods and no=north west, ne=north-east, ce=centre, so=south and islands

From the Table above it is possible to notice that the elasticity of water with respect to prices strongly varies across different Italian regions.

As highlighted in Table 3, in the South of Italy consumers are more sensitive to changes in the final prices, since the actual tariff is higher for the consumer that live in arid regions. As highlighted before, since the local Authorities can quantitatively determine the final amount of the tariff, it is straightforward to verify that where the service has an higher cost, via the cost pass-through system, also the final tariff is higher.

However, this pricing mechanism is highly distorsive and penalize all the consumers that live in a climate unfavorable area.

The presence of a central and independent Authority should assure a better management of the final tariffs, since it would be possible to insure a cost repartition between different local realities. Moreover, since there is still a misleading use of the water resource (see ISTAT, 1999), the regulator should reckon on the importance of a optimal pricing strategy, that both enhances the consumer's equality and the firm's efficiency.

Finally, comparing my final estimates with the works that consider the same exogenous variables will lead to some interesting results. My estimates find that the value of demand elasticity with respect to the average price is bounded between -0.01 and -0.4 and the elasticity with respect to income is almost equal to 0.45 .

I find that the 33% of these works estimate an elasticity with respect to price greater than -0.40 and that only two authors (the 10% of the total) find also a positive correlation between water demand and water price.¹⁹ Finally, the remaining 57% of the works that consider the average price as a determinant of the the water demand confirm my econometric results.

¹⁹An exhaustive analysis of the water elasticity with respect to price is provided by in Albués et.al. (2003), and it is out of the scope of the present paper.

3.7 Conclusion

In this paper I estimate a complete Quasi-Almost Ideal demand system using households data from 1999 to 2005, in order to determine the water elasticity with respect to income and to prices for the Italian consumers. The parameters have been obtained through estimation of

The first relevant result is that the Italian average elasticity of water with respect to price is aligned with the European mean (-0.23 versus -0.2), and with the analyzed literature (with boundaries given by -0.01 ; -0.4) confirming that water demand is not perfectly inelastic.

Secondly, I find evidence that in Italy exists a strong difference among macro-regions and familiar groups.

The demographic effects are important in determining the final consumer behavior since their estimation highlight that the couples of young or the families with children are less sensitive to a change in the final prices than the couple of elder. Moreover, the regional effects strongly matter in determining the households elasticity with respect to price.

Indeed, my econometric results highlight that the families that live in the South of Italy experiment a contraction in the final consumption greater than in the North of Italy after a rise of the 1% in the final prices.

This behavior can be explained considering that in the South of Italy the climate is more arid and the water networks are less efficient than in the Northern regions; this may lead to a different sensibility with respect to a change in the final prices.

The regulator should reckon on these regional and demographic characteristics both to develop an affordable pricing policy and to determine an optimal price that makes the final consumers control any water waste. Moreover, since both families and young couples seem to poorly react after a rise in the final prices, also environmental education should be encouraged.

Bibliography

- [1] Alessie, R. and Kapteyn, A. (1991); "Habit Formation, Interdependent Preferences and Demographic Effects in the Almost Ideal Demand System", *The Economic Journal*, Vol. 101, No. 406. (May, 1991), pp. 404-419.
- [2] Arbués, F. et.al. (2003); "Estimation of Residential Water Demand: A State-of-the-Art Review", *Journal of Socio-Economics*, Vol.32, pp. 81-102.
- [3] Banks J., Blundell R. and Lewebel, A. (1997); "Quadratic Engel Curves and Consumer Demand", *The Review of Economics and Statistics*, No.4.
- [4] Billings, R.B., Agthe, D.E., (1980); "Price Elasticities for Water: a Case of Increasing Block Rates, *Land Economics*, Vol. 56, pp. 73-84.
- [5] Blundell, R. (1988); "Consumer Behavior: Theory and Empirical Evidence: a Survey", *The Economic Journal*, No.98.
- [6] Comitato per la Vigilanza delle Risorse Idriche (COVIRI) (2008); "Relazione annuale al Parlamento sullo stato dei servizi idrici", Roma.
- [7] Corral, L., Fisher, A.C., Hatch, N., (1998); "Price and Non-price Influences on Water Conservation: an Econometric Model of Aggregate Demand Under Nonlinear Budget Constraint", Working Paper No. 881, Department of Agricultural and Resource Economics and Policy, University of California at Berkeley
- [8] Dandy, G., Nguyen, T., Davies, C., (1997); "Estimating Residential Water Demand in the Presence of Free Allowances", *Land Economics*, Vol.73, pp. 125-139

- [9] Deaton, A. and Muellbauer, J. (1980); "Economics and Consumer Behaviour", Cambridge Press
- [10] Diewert, W.E. (1971); "An Application of the Shephard Duality Theorem: a Generalized Leontief Production Function", *Journal of Political Economy*, Vol.79, pp.481-507.
- [11] Espey, M., Espey, J., and Shaw, W.D., (1997); "Price elasticity of residential demand for water: a meta-analysis", *Water, Resources Research* Vol. 33, No.6, pp.1369–1374.
- [12] Eurostat, (2008a); " Use of Water from Public Water Supply by Services and Private Households".
- [13] Eurostat, (2008b); "Data on Population in the EU Area".
- [14] Griffin, R.C., Chang, C., (1990) ; "Pretest Analysis of Water Demand in Thirty Communities", *Water Resources Research*, Vol.26, pp. 2251–2255.
- [15] Hewitt, J.A., Hanemann, W.M., (1995);. "A Discrete/Continuous Choice Approach to Residential Water Demand Under Block Rate Pricing", *Land Economics*, Vol. 71, pp. 173–192.
- [16] ISTAT; "I consumi delle famiglie", 1999-2005.
- [17] ISTAT; "Indici dei Prezzi al Consumo", 1999-2005.
- [18] ISTAT; "Sistema delle Indagini sulle Acque", 1999, 2005.
- [19] Kulshreshtha, S.N., (1996) "Residential Water Demand in Saskatchewan Communities: Role Played by Block Pricing System in Water Conservation", *Canadian Water Resources Journal* 21 (2), 139–155.
- [20] Lau, L.J., (1978); "Testing and Imposing Monotonicity, Convexity, and Quasi Convexity Constraints", in: Fuss, M., McFadden, D. (Eds.) *Production Economics: A Dual Approach to Theory and Applications*, Vol. 1. North-Holland, Amsterdam.
- [21] Jones, C.V.and Morris, J.R., (1984). "Instrumental Price Estimates and Residential Water Demand" ,. *Water Resources Research*, Vol. 20, pp. 197–202.

- [22] Martin, R.C., Wilder, R.P., (1992); "Residential demand for water and the pricing of municipal water services", *Public Finance Quarterly* Vol. 20. pp. 93–102.
- [23] Martínez-Espíñeira, R., (2002); "Residential Water Demand in the Northwest of Spain" *Environmental and Resource Economics*, Vol. 21, pp. 161–187.
- [24] Moschini, G., (1998); "The Semiflexible Almost Ideal Demand System", *European Economic Review*, No. 42, pp. 349–364.
- [25] Moschini, G. (1999); "Imposing Local Curvature Conditions in Flexible Demand Systems", *Journal of Business and Economic Statistics*, No.4.
- [26] Nieswiadomy, M.L., (1992); "Estimating Urban Residential Demand: Effects of Price Structure, Conservation and Education", *Water Resources Research*, Vol. 28, 609–615.
- [27] Nieswiadomy, M.L., Molina, D.J., (1988); "Urban Water Demand Estimates Under Increasing Block Rates", *Growth and Change*, Vol. 19, pp. 1–12.
- [28] OECD (1999); "Household Water Pricing in OECD Countries", OECD, Paris.
- [29] Point, P., (1993) ; " Partage de la Ressource en Eau et Demande d’Alimentacion en Eau Potable", *Revue Economique*, Vol. 44, pp. 849–862.
- [30] Renwick, M.E., Archibald, S.O. (1998); "Demand Side Management Policies for Residential Water Use: Who Bears the Conservation Burden?", *Land Economics*, Vol. 74, pp. 343–359.
- [31] Renwick, M.E., Green, R., (2000); "Do Residential Water Demand Side Management Policies Measure Up? An Analysis of Eight California Water Agencies", *Journal of Environmental Economics and Management*, Vol. 40, pp. 37–55.
- [32] Rizzi, P. (2001); "Invecchiamento della Popolazione e Consumi Privati in Italia, 1961-2020", *La questione Agraria*, No.4, pp.71-109.
- [33] Stevens, T.H., Miller, J., Willis, C., (1992). Effect of price structure on residential water demand. *Water Resources Bulletin* 28 (4), 681–685.

- [34] Stone, J.R.N (1954a); "The Measurement of Consumer's Expenditure and Behaviour in the United Kingdom, 1920-1938" Cambridge University Press.
- [35] Stone, J.R.N (1954b); "Linear Expenditure Systems and Demand Analysis: an Application to the Pattern of British Demand", *Economic Journal*, Vol.64, pp.511-527.
- [36] Tiezzi, S. (2005); "The welfare effects and the distributive impact of carbon taxation on Italian households", *Energy Policy*, No.33, pp. 1597–1612.

Appendix

A. Summary Statistics

VARIABLE	MEAN	ST. DEV.	MIN	MAX
v_1	19.20	10.03	2.324	166.67
v_2	434.88	134.45	65.16	1538.05
v_3	561.636	211.956	65	3844.57
v_4	183.13	149.14	0.98	3349.72
v_5	222.462	216.612	0.733	3000
v_6	719.818	328.330	48.722	4434.49
p_1	115.4075	19.647	95.70	200.899
p_2	101.297	1.323	97.767	106.389
p_3	101.784	2.15	96.021	110.7872
p_4	101.022	1.348	98.121	106.893
p_5	101.596	1.087	98.140	105.123
p_6	100.99	0.67	99.7014	103.670
x	2141.146	716.28	402.118	9771.78

v are the expenditure in the six different goods described in Section (3.5), p are the respective prices and x is the total expenditure.