Scale and scope economies and the efficient vertical and horizontal configuration of the water industry: a survey of the literature

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Abstract

This paper surveys the literature on scale and scope economies in the water and sewerage industry. The magnitude of scale and scope economies determines the cost efficient configuration of any industry. In the case of a regulated sector, reliable estimates of these economies are relevant to inform reform proposals that promote vertical (un)bundling and mergers. The empirical evidence allows some general conclusions. First, there is considerable evidence for the existence of vertical scope economies between upstream water production and distribution. Second, there is only mixed evidence on the existence of (dis)economies of scope between water and sewerage activities. Third, economies of scale exist up to certain output level, and diseconomies of scale arise if the company increases its size beyond this level. However, the optimal scale of utilities also appears to vary considerably between countries. Finally, we briefly consider the implications of our findings for water pricing and point to several directions for necessary future empirical research on the measurement of these economies, and explaining their cross country variation.

Key words: Water utilities, Scale, Scope and Integration Economies, Unbundling

JEL classification: L25, L51, L95

1. Introduction

The water industry has experienced substantial changes in many countries over the past several decades. But, unlike other network industries (e.g. telecommunications and electricity), where vertical unbundling aimed at facilitating competition has been the norm, in the water industry there has been no common restructuring paradigm. Hence, there exist different industry configurations across countries and also within countries.

In some countries, water supply is vertically integrated with sewerage services (e.g. the UK), while in others (e.g. Japan, Germany, United States) these services are often owned and/or operated by separate entities. In Portugal one observes both vertically separated and integrated water and sewerage operations. In Australia where water services are publicly owned, Sydney Water Corporation supplies water and wastewater services in the Sydney region but it does not manage its own bulk water supplies but instead buys bulk water from the Sydney Catchment Authority (SCA) which manages Sydney's drinking water storage and catchments. In Melbourne bulk water and wastewater disposal services are provided by Melbourne Water to three regional retail monopolies, which are responsible for local distribution and retailing services to their respective areas (IPART, 2007). In Japan and Germany, it is common for municipally owned integrated retail and distribution companies to obtain their water from an upstream bulk water supply company, which is often, but not always, jointly owned by the downstream distribution companies it serves. In some countries we observe a convergence in the operation of water, gas and electricity utilities (e.g. Germany, Switzerland, Italy, and some publicly owned systems in the United States such as in Los Angeles).

France like most continental European countries and Japan, has many small water utilities, with boundaries and often ownership linked to municipal or other government jurisdictions. However, the operation of French utilities in general differs from the European norm. Whereas assets remain in public ownership, in most cases their operation is contracted out to large private water companies. In contrast, in the Netherland and the United Kingdom, amalgamation of publicly owned water utilities has resulted in firms that are very large by international standards.

In addition to these contrasting industry structures, there are also contrasting reform proposals in different countries. For example, in Japan public authorities intend to consolidate the industry by promoting mergers between companies across municipalities, and there is a policy debate with regard to the potential benefits of vertically integrating upstream and downstream water companies (Urakami and Parker, 2011). By contrast, in the UK, the current policy debate in England and Wales focuses on the feasibility of further unbundling the industry, so as to facilitate the potential introduction of upstream competition in areas such as water abstraction, and sludge disposal and on allowing mergers between water companies (Cave, 2009). Thus far, the water regulator has enacted a mandatory accounting separation regime, requiring companies to provide cost information for different activities (Ofwat, 2009), and has advanced hypothetical future industry structures, some of which are designed to impose stronger separation aimed at facilitating competitive entry (Ofwat, 2010).

Policy makers should base their reform proposals on an assessment of the respective costs and benefits. In particular, the efficient configuration of the water and sewerage industry should be driven by the industry's underlying economies of scale and scope, as these indicate the relative cost advantages from horizontal and vertical integration. Thus, robust estimates for economies of scale and scope are important for the proper evaluation of any reform proposals.

The objective of this study is to provide a critical review of the empirical literature on economies of scale and scope in the light of so as to inform policy makers considering reform in the water industry. We also identify several methodological issues in the empirical methods that have been employed, thereby identifying the challenges that future empirical research will need to address to provide improved estimates of scale and scope economies.

The paper unfolds as follows. Section 2 gives a brief summary of the theory of economies of scale and scope. Section 3 then provides a critical review of numerous empirical studies that have examined economies of scale and scope in water and sewerage industries. Section 4 next considers the policy implications of scale and scope economies in the water industry. Finally, Section 5 points out potential improvements for future empirical research on the influence of vertical and horizontal integration on water industry costs.

2. Methodological aspects in the estimation of scale and scope economies

In this section we review the theoretical definitions of the measures of economies of scale and scope applied in the empirical literature, and discuss the characteristics of cost functions that underlie the empirical estimation of these measures. Our discussion largely follows the seminal work of Baumol et al (1982).

2.1 Measures of scale and scope economies

The degree of scale economies defined over the entire output set of N outputs, is given by

$$S_N(y) = \frac{C(y)}{y \cdot \nabla C(y)} = \frac{C(y)}{\sum_{i=1}^{n} y_i C_i(y)}, \qquad [1]$$

where $y = (y_1, y_2, \ldots, y_n)$ is a $n \times 1$ vector of products, $C(y)$ is the underlying cost function detailing the relationship between outputs and costs, and $C_i(y) = \frac{\partial C(y)}{\partial y_i}$ is the marginal cost of product i. There are said to be increasing, constant or decreasing returns at y if $S_N(y)$ is greater than, equal to, or less than unity, respectively. Therefore, if increasing returns to scale are present, ($S_N > 1$), a proportional increase of all products induces a less than proportional increase in costs. Since the firm would gain from increased production, it is said to be operating with economies of scale. Conversely, if ($S_N < 1$) then at y the potential proportional change in cost would exceed the proportional change in output and thus, the firm operates with diseconomies of scale.

The provision of water and/or sewerage services implies the production of more than one product or service. Hence, in addition to scale economies production is also characterized by economies of scope, that is there also exists the possibility of obtaining cost savings from the joint production of a bundle of products in a single company, in contrast to their separate production in specialized firms. Economies of scope relate to the increment of costs resulting from splitting up the output set into two product lines T and N-T, where the output vectors of specialized firms are restricted to be orthogonal to one another, such that, $y_i \cdot y_j = 0$, $i \neq j$. Economies of scope exist if the following condition holds:

$$C\left(y_T\right)+C\left(y_{N-T}\right)>C\left(y_N\right) \qquad [2]$$

and diseconomies of scope occur if the inequality is reversed.

The degree of scope economies at y relative to T is defined as

$$SC_T(y)=\frac{C(y_T)+C(y_{N-T})-C(y_N)}{C(y_N)} \qquad [3]$$

Fragmenting the production into these two subsets increases, decreases or leaves unaltered the total cost when $SC_T(y)$ is greater than, less than or equal to zero, respectively. In other words, if $SC_T(y) > 0$ it is cheaper to jointly produce all of the N products in vector y than to separately produce the output vectors y_T and $y_{N\text{-}T}$.

A firm’s scope of operation may vary vertically and/or horizontally. Vertical scope refers to upstream and downstream stages. For example, an upstream water abstraction and treatment company would increase its vertical scope if it entered the distribution business. In contrast, a change in the firm's horizontal scope would refer to a change in the degree of product diversification. For example, a water retailer could add gas or electricity retailing.

Given the distinction between vertical and horizontal scope, if *T* denotes the subset of upstream products, and *N*-*T* the subset of downstream products, then equation [3] measures the degree of vertical scope economies.

A related concept to scope economies is the presence of cost complementarities. Cost complementarities exist when the marginal cost of producing one output decreases as the output of another product increases, e.g.

$$C_{ij} = \frac{\partial^2 C}{\partial y_i \partial y_j} < 0, i \neq j \qquad [4]$$

Baumol et al (1982) show that the presence of cost complementarities is a sufficient condition for the existence of scope economies. This theoretical finding is highly relevant, as it allows a basic test for the presence of scope economies even in empirical applications where only integrated firms are observed.

Panzar and Willig (1981) state that economies of scope arise from the presence of sharable inputs among different outputs and production processes. They arise, for example, if a given input is indivisible, so that the production of a small set of products would leave excess capacity in the utilization of that input. This is often the case of certain physical assets. Alternatively, an input may have some properties of a public good so that when it is employed in one production process it becomes freely available for another. This property is characteristic of intangible resources and skills (e.g. managerial expertise, knowhow, etc.).

Additionally, Teece (1980) discusses how the economies of scope and the boundaries of the firm may be affected by the presence of transaction costs, market failures and other institutional considerations. Following the theoretical analysis by Williamson (1975), Teece points out that the joint production by an integrated or diversified firm is efficient only when the transaction costs of separate firms trading in the marketplace (e.g. due to costs of contracting, information asymmetries and opportunism) can be reduced through internal organization. On the other hand, since the internalization of transactions also entails costs, the relative efficiency of integrated production is not just driven by the technological determinants of scope economies, but also by whether the costs of internal organization are lower than the transactions costs of using the market by separate specialized firms. Hence, as Panzar and Willig (1981:272) note, “when the multiproduct cost function summarizes both the production and organizational costs of operating the firm, economies of scope is the precise condition required for the emergence of multiproduct firms in a competitive environment”.

2.2 Empirical estimation strategies.

Estimation of scale and scope economies, as well as cost complementarity requires the econometric estimation of either a cost *function* or a cost *frontier*. The difference between the two approaches is that the former assumes firms’ cost-minimizing behaviour. This assumption results in an average response econometric approach and therefore does not control for the presence of inefficiency. By contrast, under frontier techniques scale and scope economies are determined based on the efficient cost frontier, thereby reflecting these relationships based on an estimate of the best practice technology.

While there are a number of papers that employ non-parametric frontier techniques based on linear programming models, e.g. Data Envelopment Analysis (DEA) and Free Disposal Hull (FDH),[1] as we discuss in Section 3 most previous studies in the water industry estimate parametric econometric cost models.[2] To that end, it is necessary to decide (i) on the

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[1] Unlike parametric frontier econometric approaches (e.g. Stochastic Frontier Analysis, SFA), non-parametric frontier techniques do not require the assumption of specific functional form for the underlying technology.

[2] The literature on cost functions estimation for the water industry goes back to the pioneering works by Ford and Warford (1969), Hines (1969) and Andrews (1971).

functional form for the cost function; (ii) whether the function is a variable or a total cost function, and (iii) on the estimation technique.

The functional form must meet certain requirements to be consistent with economic theory and with reasonable behavioural assumptions. These include (a) regularity conditions; (b) flexibility; and (c) handling zero values. We therefore briefly consider each of these requirements in turn.

Firstly, the functional form needs to meet a number of generic conditions to ensure that it is a regular cost function, i.e. it must be consistent with the idea of producing each level of output at the minimum cost given input prices. Hence, it is required that the cost function must be linearly homogenous and concave in input prices, and non-decreasing in factor prices and outputs (provided that free disposability is assumed).

Secondly, the choice of functional form should not *a priori* constrain the measures of interest. For instance, the popular Cobb-Douglas form constrains economies of scale to be constant across firms and it precludes the existence of cost complementarities. . In other words, the functional form needs to be flexible and provide a good local approximation to any arbitrary twice differentiable function. That is it must not impose *a priori* restrictions on the value of the first and second partial derivatives, thereby imposing results with regard to scale and scope economies.

Thirdly, to estimate scope economies, the function must allow for zero outputs, as is the case with quadratic and composite cost functions, but is not case with the popular translog function which violates this condition[3]. This limitation implies that the translog function does not allow the direct estimation of the degree of economies of scope,[4] unless sufficient observations of integrated and non-integrated firms are available to allow separate translog

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[3] Griffin et al (1987) provides a good review of the properties of these and other functional forms employed in production and cost function analysis.

[4] This limitation is partially surmounted by applying a Box-Cox transformation, albeit sometimes inducing fairly unstable estimates.

estimation for upstream only, downstream only, and integrated producers of water, as for example demonstrated by Garcia, et al (2007) and Urakami (2007). While such diverse samples are not generally available in most countries, even when samples are limited to integrated firms only, the translog model does allow estimation of cost complementarities which, as discussed above, is a sufficient condition for the existence of economies of scope. Thus, while the translog functional form cannot estimate the actual cost benefits associated with scope economies, it still remains a potentially powerful tool for detecting the presence of scope economies when only integrated firms are observed. Table 1 shows that the quadratic and translog cost functions are the two most widely used functional forms in empirical studies in the water industry with the translog being by far the most prevalent modelling approach.

We next consider the implications of specifying a total cost or a variable cost function. The estimation of a total cost function assumes that all outputs are exogenous, all inputs are endogenous, and that firms employ cost-minimizing input levels for given levels of output and input prices.

$$C^T = f(Y, w, Z) \qquad [5]$$

where C^T is total cost, Y is the set of outputs, w is the vector of input prices, and Z is a vector of technical or environmental characteristics or cost shifters.

The assumption that the output of water utilities is exogenous is reasonable since utilities must satisfy consumers' demands. However, if some inputs are invariable, that is firms cannot quickly adjust them to meet changes in output, quality, or input prices, estimating a total cost function would be inappropriate because at least some inputs are fixed or quasi-fixed. In this case, a cost minimizing firm would minimize variable costs for given levels of output, input prices, *and* the level of its fixed inputs

$$C^V = C(Y, w_v, K, Z) \qquad [6]$$

where C^V is variable cost, Y is the set of outputs, w_v is the vector of variable input prices, K is the set of fixed inputs, and Z is the vector of technical or environmental characteristics or shifters. Then, the firm is considered to minimize the variable costs under the condition of having fixed input factors. However, in practice researchers who employ such quasi-fixed capital variable cost models, generally consider only the scope economies or cost complementarities between variable inputs. Thus, in empirical practice, the long run cost function approach allows a fuller estimation that includes the impact of capital as well as variable inputs on scope economies. The policy implications of these modelling differences are significant. For example, we would argue that conclusions with regard to the appropriate vertical configuration of an industry should in principle be based on a long run perspective of the relationship between costs and industry structure, rather than a short run perspective where capital costs are considered to be fixed. Thus the long run cost relationships captured in an economic model of total costs should capture not only the current operating costs for water distribution and treatment, but also the long run capital costs associated with developing new water supply sources and extending networks. Moreover, when considering efficient water pricing regimes, it is normally the long run marginal cost of water supply, and hence a long run total cost modelling perspective, and not short run marginal costs that should be considered (Olmstead, 2010).

Finally, regarding econometric estimation procedures, two general approaches are identified in the literature: the estimation of traditional cost function and stochastic frontier analysis (SFA) approaches. Regarding the traditional non-frontier approach, some studies use single-equation econometric estimation methods, such as ordinary least squares (OLS), while others use multi-equation methods, such as seemingly unrelated regressions (SUR), and estimate the cost function together with factor demands, factor expenditures or factor shares (e.g. by applying Shephard’s lemma), with the latter approach potentially allowing one to obtain more efficient estimates. The stochastic frontier approach allows for firm level inefficiency and thereby estimates the best practice frontier, rather than the average response function provided by traditional econometric approaches.

3. Empirical Evidence on Scope and Scale Economies in the Water and Sewerage Industry

3.1 Economies of Scope

The relatively limited empirical literature on scope economies in the water industry has focused on the analysis of the potential cost savings derived from the vertical integration of different water supply activities, as well as from the horizontal diversification of water utilities into other non-water activities. Figure 1 depicts the vertical supply chain of the water and sewerage industry and several potential alternatives of integration.

[Insert Figure 1 about here]

We classify previous studies into three categories: (i) those that analyze economies of scope between the water and sewerage businesses, e.g. between the *W* and *S* blocks in Figure 1; (ii) those that investigate scope economies between vertical stages of water businesses only, e.g. between upstream water production (collection & treatment) and water delivery (downstream distribution and customer service activities) in Figure 1; and (iii) those that analyze the integration economies existing from the joint provision of water with other services, e.g. gas and electricity in Figure 1.[5] Table 1 provides a review of empirical studies organized around this classification. The last column in Table 1 shows the main findings on integration economies and cost complementarities reported in each study, generally measured as in expressions [3] and [4].

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[5] Additionally, a few studies analyze the effect of integrating other activities, such as water delivery and waste-water activities, and different stages of sewerage activities (Stone & Webster Consultants, 2004); and water and sewerage services with environmental services (e.g. Hunt and Lynk, 1995; Lynk, 1993). These are also discussed further below.

[Insert Table 1 about here]

(i) Economies of Scope between water and sewerage activities

As Table 1 shows, the number of studies that investigate scope economies in the water industry is not particularly large. Moreover, these studies employ different econometric techniques to estimate variable and total cost functions using different functional forms, and a wide variety of output definitions.

Two pioneering studies on economies of scope between water and sewerage services are Lynk (1993) and Hunt and Lynk (1995). The former employed a long-run stochastic cost frontier model to assess the efficiency of Water only Companies (WoCs) and Water and Sewerage Companies (WaSCs) in England and Wales for the pre-privatization period, while the latter used a multi-product total cost function for WaSCs. Both studies used volumes of water supply, trade effluent, and environmental services as outputs. Environmental services were defined as turnover and included components such as water quality regulation, pollution alleviation, recreation and amenity, navigation, fisheries and charges for environmental services. The results find cost complementarities between water supply and sewerage services, as well as between water supply and environmental services.

Martins et al (2006) estimated a cubic variable cost function using data on 282 water and wastewater utilities in Portugal in 2002. Volumes of potable water delivered and wastewater collected were employed as outputs, whereas capital was treated as a quasi-fixed input. The authors controlled for customer density, number of wastewater connections related to wastewater service and ownership. However, no input prices were included due to limited data availability. They found evidence of economies of scope for the joint production of water supply and wastewater collection for the average utility and the smaller firms, and diseconomies of scope for larger utilities.

Two papers employed a translog variable cost specification to examine economies of scope for utilities that provide both water and wastewater services in Brazil, Moldova and Romania (Nauges and Van den Berg, 2008), and Sweden (Malmsten and Lekkas (2010). The outputs were volumes of water delivered and wastewater collected. While Nauges and Van den Berg (2008) assert that integration economies between water and sewerage services are present in these countries, the paper does not provide the underlying cost complementary estimates supporting this conclusion. Malmsten and Lekkas (2010) concluded that on average there were economies of scope between water and wastewater in the Swedish industry due to the cost complementarity between both activities.

Saal and Parker (2000) used residential customers for water supply and sewerage as outputs to estimate a translog total cost function model for the UK water and sewerage sector. Thus, while this study always finds statistically insignificant estimates for cost complementarities, it finds diseconomies of scope between water and sewerage services, when quality is ignored, but economies of scope when quality is controlled for. The authors suggested that there might be “quality-driven” economies of scope meaning that an improvement in the quality of one output might reduce the cost of producing another. For instance improved sewerage treatment quality might reduce the costs of treating drinking water, and vice versa.

The report by Stone & Webster Consultants (2004), which was commissioned and published by the UK water regulator, the Office of Water Services (Ofwat), is arguably the most comprehensive study on economies of scope between water and sewerage services in England and Wales. Two water and two sewerage outputs were employed in the cost modelling. Volumes of water (non-potable and potable) delivered and water connected properties capture water production and water distribution respectively, and sewerage connected properties and equivalent population served capture sewerage (wastewater) collection and sludge treatment & disposal (wastewater production) respectively. The authors estimate translog and quadratic (variable and total) cost models. The translog variable cost model and its quadratic total cost model found overall diseconomies of scope between water and sewerage services, while the total translog cost model found evidence of small but statistically insignificant economies of scope.

Finally, De Witte and Marques (2011) is the only study using non-parametric frontier techniques. They use a Free Disposal Hull (FDH) approach to estimate a total cost model for a sample of the 63 largest drinking water utilities in Portugal in 2005. The outputs were defined as volumes of water delivered, number of water and sewerage customers. No evidence of economies of scope between water and sewerage activities was found.[6]

From the above we conclude that the empirical evidence is mixed for economies of scope between water and sewerage activities. Whereas some studies found evidence of economies of scope between water and sewerage activities, and therefore a single utility should be more cost efficient in providing both services, other studies show inconclusive evidence or diseconomies of scope.

(ii) Vertical integration economies between water production and distribution

While the evidence with regard to scope economies between water and sewerage services is mixed, Table 1 indicates that there is, in contrast, more considerable empirical evidence for the existence of economies of scope between water production and water distribution activities (e.g. labeled as WP and WD in Figure 1).

For the US, Hayes (1987) estimated a generalized quadratic cost function on a sample of 475 US utilities for the years 1960, 1970 and 1976. He found that integration between

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[6] We note that Sauer (2004) suggested that there was no evidence of economies of integration between water and sewerage services between utilities in East and West Germany using data from a survey in 2002/03. The author estimated a generalised McFadden variable cost specification to test the cost structure in water utilities by including volumes of water delivered as the single output and four fixed factors, equity, number of supplied connections, network length and share of groundwater intake, whereas costs included labour, operational, chemicals and energy costs. However, the evidence with regard to scope economies provided by this paper is based solely on the inclusion of a dummy variable for those observations that also engage in sewerage activities.

retail and wholesale water supply is cost advantageous especially for small firms, and that the degree of economies of scope tends to fall over time for the largest firms and increase for smaller firms. A similar conclusion emerges from Torres and Morrison-Paul (2006), who estimated a variable generalized Leontief cost specification after controlling for customer density and size of service area, to account for the fact that US water utilities supply water to small populations across large service areas. Their results indicated that economies of vertical integration between the production of water for retail and wholesale customers are higher and significant for small utilities (75% reductions in costs), than for average utilities (45% reductions in costs) and large utilities (57% reductions in costs).

Kim and Clark (1988) and Kim (1995) estimated a translog total cost function on a sample of US 60 water utilities where outputs were volumes of water delivered to households and non-households. Both studies indicate the presence of cost advantages from the joint production of water supplied to residential and non-residential customers by reporting statistically significant evidence of cost complementarity between both outputs for the average firm.

Garcia et al (2007) employed panel data econometric techniques to estimate variable translog cost functions for a sample of 171 US water utilities in the state of Wisconsin. They have sufficient data to estimate three separate cost functions for non-vertically integrated water utilities that provide only production services (NVI-P), non-vertically integrated utilities that provide only distribution services (NVI-D), and vertically integrated water utilities that provide water production and distribution services (VI-P&D). This study finds economies of vertical integration for small water utilities (for utilities that supply water to final customers) and for utilities that charge high water prices. For a given water price, the lower is the water output supplied to final users, the greater are the economies of vertical integration. The authors point out that the production process is quite simple and therefore, the sharing of inputs across production and distribution stages was more cost advantageous for small utilities than for large ones, which means that a vertically integrated structure was more effective in this case. Moreover, for a given level of water output supplied to final users, the higher is the water price, the greater are economies of vertical integration. One explanation is that a high water price suggests a high mark-up on the upstream market (production) which creates significant distortions regarding input allocation at the downstream stage (distribution) and therefore, a vertically integrated structure is more cost effective in this case.

Urakami (2007) and Urakami and Tanaka (2009) examined similar issues in the context of the reorganisation of the Japanese water supply industry. Urakami (2007) estimated a translog total cost function for vertically integrated water utilities (water intake and purification and water delivery) and non-vertically integrated water utilities using 2003 data. The results suggest that economies of vertical integration exist between upstream water production activities and water delivery, meaning that water supply systems can achieve cost-efficiency from vertically integration, and this is particularly true for firms with a low purchased water ratio (e.g. the ratio of purchased water relative to water delivered). Water utilities that obtain 100% water from their own water resources could receive a 72.6% cost-saving benefit from vertical integration, whereas utilities that purchase 80%-90% of purified water from other large utilities could receive a 41.1% cost-saving benefit from vertical integration.

This result was later confirmed by Urakami and Tanaka (2009) where the authors estimated a composite cost function to examine economies of integration between vertically integrated water utilities and non-vertically integrated water utilities in Japan over the period 2001-2006. The results once again indicated that economies of scope existed between water delivery and water purification meaning that Japanese water utilities could achieve cost savings from vertical integration. Similarly, the study by Stone & Webster (2004) of the English and Welsh industry referred to above, reports strong cost complementarities between water production and distribution activities in the total cost model, while showing inconclusive evidence for the variable cost specification.

Garcia and Thomas (2001) specified a translog variable cost model for a sample of 55 water utilities in the French region of Bordeaux. Outputs were defined as the volume of water sold to final customers and water network losses, which was the difference between volumes distributed and volumes sold to final customers. The model allowed for the fact that water utilities cannot produce and sell water to final customers (a desirable output) without "producing" lost water in the form of water network losses an (undesirable output). Labour and energy were employed as inputs, and a set of environmental characteristics captured by the number of customers, network length, the number of local communities serviced by the water utility and proxies for production, stocking and pumping capacity were also included as determinants of costs. The results indicated that the joint production of a desirable and an undesirable output was more profitable than increasing efficiency in the production of the desirable output. More specifically, this result emphasizes that a possible source of vertical integration economies between upstream water production and downstream distribution activities, results from the ability of a vertically integrated firm to internalize decision making with regard to the relative costs of water treatment and network quality, thereby reducing the overall cost of providing water services.

Following the same idea, Martins et al (2008) and Corton (2011) also employ volumes of water delivered and water losses as outputs in their analysis of the water industry in Portugal and Peru, respectively. They concluded that there were economies of integration from the joint production of water supply and water losses, thereby supporting the result of

Garcia and Thomas with regard to the internalization of cost trade-offs between water treatment and water distribution system maintenance costs in a vertically integrated system.

(iii) Economies of scope for multi-utilities

Finally, there is a small group of studies providing evidence on economies of scope for the joint provision of water, natural gas and electricity, i.e. the so-called multi-utilities. Fraquelli et al (2004) and Piacenza and Vannoni (2004) employed several cost function specifications such as the composite, translog, and separable quadratic total cost functions to test for economies of scope between utilities that provide gas, water and electricity in Italy for total costs but without including any exogenous factors. Both studies show that the composite cost function performs better than the other models and small multi-utilities benefit from cost savings in the range of 13% to 33% with respect to specialised utilities. The authors report that the degree of economies of scope for the pairing gas-water was higher (14%-30%) than the other pairwise output combinations (gas-electricity and water-electricity), which are in the range of 5% to 21%.

Farsi et al (2008) and Farsi and Filippini (2009) employed several cost function specification such as a quadratic total cost function with random effects and random coefficients, translog random effects with time variant and time varying efficiency and a “true” random effects model to examine the cost efficiency and economies of scope between utilities that provide gas, water and electricity in Switzerland. Both studies indicated that more than 60% of the utilities in their sample exhibit economies of scope. Cost savings from joint production are in the range of 20% to 30% of total costs for small multi-utilities, and in the range of 4% to 15% for median multi-utilities.

3.2 Economies of Scale

The presence of economies of scale in the water industry is a topic that has been relatively more investigated than scope economies. In this review we have primarily focused on those studies in which it is possible to identify estimates of the degree of economies of scale for particular utility sizes.[7] Thus, Table 2 shows the degree of scale economies corresponding to the sample mean of each study, generally measured as in expression [1] above. A cursory look at Table 2 reveals that, with few exceptions, most studies found that long-run economies of scale prevail for the average size ($S(y)>1$). Broadly, the degree of economies of scale also seems to be larger for the smaller average sizes, suggesting that smaller water utilities may be able to reduce their average costs by increasing output. This general relationship between average scale and estimated scale economies for the average firm in a sample is also illustrated in Figure 2, which graphically summarizes the scale estimates reported in Table 2. However, the range of company scale differs widely across countries and hence across the studies. Thus, the largest company in one country may be the smallest size in a different sample from another country. Moreover, conclusions with regard to optimal scale, when made, vary considerably. Thus, Mizutani & Urakami (2001) found that economies of scale in Japanese water utilities are exhausted when population served reaches 766,000, while Fraquelli and Moiso (2005) reported that economies of scale are present up to a scale of 90,000 megalitres (Ml), or equivalently a population served of 1 million, in Italy.

Table 3 summarizes variation within the results of studies reporting scale estimates for different size categories, according to the volume of water delivered. This gives an alternative insight on the behaviour of average costs within each sample. For most studies, the last column in Table 3 indicates that the degree of economies of scale tends to decrease as

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[7] See Abbot and Cohen (2009) for a review of papers on scale economies not discussed here.

the size of operation increases.[8] Thus, Table 3 suggests that within each country study, while there are economies of scale for small firms, these economies of scale are exhausted at relatively modest firm sizes, as also noted by Abbott and Cohen (2009) in their previous literature review. Further, in several cases, diseconomies of scale arise for the largest utilities. This holds both for water only and water and sewerage companies. Notable exceptions are the studies by Torres and Morrison (2006) and Mizutani and Urakami (2001). Therefore, in most countries (ray) average cost estimates for water supply seems to be U-shaped, indicating that economies of scale exist up to a certain level, and diseconomies of scale exist if companies become too large, as first noted by Kim (1987) and confirmed by Saal and Parker (2000), Ashton (2003), Stone & Webster Consultants (2004) and Bottaso and Conti (2009).

[Insert Tables 2 and 3, and Figure 2 about here]

There are few studies specifically focused on the analysis of cost functions and scale economies in the sewerage industry. The early paper by Knapp (1978) on a sample of sewerage works in England and Wales found significant economies of scale in the operation of sewerage purification and treatment works in the lower region of the observed output range (up to 16,600 thousands cubic meters annually of sewage flow) but few economies thereafter. Fraas and Munley (1984) found that marginal costs markedly decline with increases in the size of the waste flow suggesting the importance of scale economies in wastewater treatment on a sample of 178 US sewage treatment plants, albeit they do not provide any estimate of the degree of scale economies. Renzetti (1999) finds that scale economies are prevalent in a sample of water and sewerage treatment utilities in Canada, but that they also decline with the size of the utility. He estimates the degree of scale economies $S = 1.364$ for the sample mean, but he does not report the scale of the average firm.

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[8] This conclusion is also found in studies that analyze the impact of size on unit costs (e.g. Boisvert and Schmit, 1997; Shih et al, 2004).

These results suggest that the need for mergers or fragmentation in the water and sewerage sector depends on the degree of fragmentation present in the industry in each country as well as the dispersion of the population (Gomez and Garcia-Rubio, 2008). For instance, for Portugal, Martins et al (2006) suggested that water and sewerage utilities should be merged with neighbouring utilities but care should still be taken so that the merged companies should not become too large as diseconomies of scale may arise. By contrast, Saal et al (2007) suggests that given the very high scale of English and Welsh WaSCs, productivity growth rates over the 1985-2000 period were negatively affected by increases in scale, thereby suggesting that WaSC mergers were detrimental to industry performance.

From our cross-country comparison we cannot derive precise findings on what would be the optimal utility size. The optimal scale varies not only across countries but also across firm types within the same country. Thus, Fraquelli and Giadrone (2003) for example, reported that economies of scale in the Italian water and sewerage industry are present up to a scale of 15,000 megalitres or equivalently 100,000 connections; while for water only companies Fraquelli and Moiso (2005) reported that economies of scale are present up to a scale of 90,000 megalitres, or equivalently a population served of 1 million.

A further quantitative analysis to determine the factors that explain the variation in the scale economies estimates across studies would require running a meta-analysis. However, the estimates of scale economies results from studies that are hardly comparable in terms of output definition and the type of density variables included in the estimation. Further, the number of available studies is not sufficient to perform a statistically valid meta-analysis, especially given the large number of explanatory factors that should be included to address differences in estimates across studies. Thus, as Table 2 suggests, the basic hypothesis of such a meta-analysis would be that variation in the estimates arises because of differences in (i) variable specification (water production, water distribution, water and sewerage, choice of output proxy); (ii) cost function specification (variable cost, total cost, multiproduct function, single product function); (iii) functional forms (Cobb-Douglas, Quadratic, Translog, McFadden, Cubic, Composite, Fourier); (iv) estimation technique (OLS, SUR, SFA, FDH, GMM); (v) measures of utility size, (vi) time span; (vii) countries (e.g. sixteen countries/regions); and (viii) the inclusion of additional firms' operating characteristics (e.g. population density, water quality, water abstraction sources). Moreover, the quality of evidence generated by a meta-analysis largely depends on the quality of primary studies which make up the review. Even if it was the case that a meta-analysis including all the studies in Table 2 was statistically feasible, this would be seriously compromised by the quality divergences in the estimates of scale economies. Thus, apart from the fact that scale economies estimates in Table 2 come from both peer-reviewed and non-peer-reviewed studies, some studies provide statistical significance tests for their estimates, while others do not. Therefore, some quality assessment would be required, after which the list of primary studies to be included in the meta-analysis should be substantially shorter. Such limitations make it unfeasible to conduct a meta-analysis. We therefore focus our conclusions on policy implications that can be derived from the available evidence, and suggestions to improve future research.

4. Discussion and policy implications

Our literature review shows that past studies come to a range of conclusions regarding the degree of scope and scale economies in the water industry. These differences are likely to be the consequence of a variety of factors, including that: (i) data is sourced from a variety of countries in a variety of time periods; (ii) the studies use a variety of output measures; (iii) some studies include a range of extra variables related to different operation characteristics (density, etc.); (iv) Some studies use single-equation econometric estimation methods, such as ordinary least squares (OLS), while others use multi-equation methods, such as SUR, and (v) a number of different functional forms are considered.

Nevertheless, the available empirical evidence points to some general conclusions. Firstly, there is considerable support for the existence of vertical scope economies between upstream water production and downstream distribution activities. Secondly, the available evidence also suggests the existence of substantial economies of scope derived from the joint supply of water, gas and electricity. Thirdly, there is much more mixed evidence with regard to the existence of economies of scope between water and sewerage activities. Finally, while there is evidence that in many countries the average water company could benefit from economies of scale, a few cases studies have found diseconomies of scale for the average company. These findings on scale and scope economies have important business and policy implications with regard to (i) the debate on the efficient configuration of the water and sewerage industry; and (ii) the efficiency of water pricing practices.

With respect to the efficient industry configuration, the appropriate vertical and horizontal reorganization of the water and sewerage industry will vary from country to country according to the current firm size and the degree of vertical integration within and between water and sewerage services that prevails in each country.

The evidence on scale economies in particular suggests size and country specific policy conclusions. Thus, the policy of encouraging mergers between water utilities would reduce (increase) costs in countries with excessive industry fragmentation (consolidation) such as Germany, Japan, and Portugal (the United Kingdom and the Netherlands). Similarly, the policy of promoting diversified multi-utilities that bundle water and energy services would save costs relative to keeping separate water and energy suppliers, supporting the existence of such multi utilities in Germany, for example.

While no clear policy conclusions can be drawn from the existing literature with regard to the potential benefits or costs of integrating water and sewerage service provision, the preponderance of available evidence clearly suggests that vertical unbundling of the water supply system is costly relative to providing water services with a fully integrated water company. Hence, reform proposals aimed at vertically separating the water industry (e.g. like those under debate in England and Wales) might have costly policy implications, while consolidation of the water industry that results in increased vertical integration (e.g. Japan) might lead to significant costs reductions.

Given the evidence suggesting the presence of substantial scope economies between upstream water production and downstream distribution activities, improving economic efficiency through competition in and for water supply, is likely to be difficult to achieve if legal or ownership separation between water production and distribution is imposed. Further, the competitive benefits from the implementation of weaker forms of vertical unbundling to vertically integrated incumbents (i.e. accounting separation) are also likely to be limited in the presence of such vertical scope economies. Basically, vertically integrated water utilities would have an incentive to allocate any cost savings from vertical integration entirely to the upstream activity to forestall competitive entry into water markets. The results of our literature review therefore also strongly suggest that policies aimed at emulating the vertical separation of the electricity industry in order to facilitate competition in the water industry, will not only have detrimental cost effects, but are also unlikely to produce significant gains through introducing effective competition.

In any case, we wish to strongly emphasize that our results clearly highlight that the expected benefits (costs) of either consolidation, unbundling, vertical integration, or horizontal diversification strategies on productive efficiency have to be compared with the potential offsetting costs (benefits) related to the emergence of regulatory complications and the negative (positive) impact on competition. Policy makers who neglect such due diligence, and thereby ignore consideration of the underlying structure of water costs, do so at the peril of implementing reforms that will have a substantial detrimental effect on industry costs.

We next turn to policy implications related to water utility prices. However, given the extensive literature on water pricing models, (as for example, summarized in Mohayidin, 2009) we do not provide details of water pricing models and related policy implications, as this would be beyond the scope of this paper. However, we instead offer a brief discussion of scale and scope economies in relation to some prevailing pricing practices in the water industry.

Textbook economic theory suggests that the efficient allocation of water resources requires an alignment of the long run marginal cost of water provision, and the marginal benefits of water use. Thus, if all costs are internalized, efficient pricing could be achieved by setting prices so that they align with the long run marginal cost of water provision. However, in practice, as argued in PRI (2004), accounting for all relevant externalities can be cumbersome and expensive, since they are numerous, variable in time and space, and often challenging to measure. Moreover, improvements in the allocation of water resources could potentially be achieved through competition in the supply and demand for water, which better reveal the underlying economic costs of water supply. However, both such pricing and competition is only generally economically sustainable in the sense that economic costs are recovered for firms with constant or decreasing returns to scale, e.g. when marginal costs equal or exceed average costs. In contrast, in the well-known issue of sustainability for natural monopoly firms operating with economies of scale, economic losses result from implementation of strict marginal cost pricing regimes in the absence of subsidies.

Our scale economy results therefore suggest that in many cases there is the expected tension between the need for average cost pricing to insure that water provision is selffinancing, and the marginal cost pricing required for efficient water usage. This tension, has therefore resulted in the development of second-best solutions, such as Ramsey pricing, increasing and decreasing block tariffs, and two part tariffs, all of which aim to improve welfare through pricing systems that result in a relatively more efficient allocation of water resources while also achieving cost recovery (GeoEconomics Associates, 2002).

Practical rate-setting methods, as for example illustrated by the standards established by the American Water Works Association (AWWA, 2012), are traditionally designed to recover current full (operating and capital) costs. For instance, this is the case of the two main rate-setting methods recommended in the AWWA guidelines, or ‘M1’ manual, e.g. the base-extra capacity method (BEC) and the commodity-demand method, which are based on the average cost of service. However, average cost is a good estimate of long rung marginal cost only when there are no economies of scale. In the presence of economies of scale, average cost deviates from marginal cost, and hence, as Renzetti (1999) previously noted, the AWWA pricing rules are not designed to guarantee the efficient allocation of water.

Given this, the existence of scale economies has been a traditional justification for adopting declining block rate structures in the industry, in the sense that any cost savings resulting from increasing water usage should be reflected within the water rates (see AWWA report p. 105). However, the exhaustion of scale economies and the presence of diseconomies of scale beyond certain sizes, together with the pressure for the conservation and the efficient use of water resources in water-stressed regions, instead provide a justification for the implementation of increasing block rate structures, for some utilities.

Thus, on balance, the water supply industry’s structure suggests the continued need for economic regulation to insure its financial viability. However, such regulation will increasingly need to adapt so as to improve the efficiency of water use, through regulated consumer tariffs which encourage more efficient water use. In this sense, the Canadian Water and Wastewater Association provides one of the scarce examples of water rates setting consistent with marginal cost pricing principles (GeoEconomics Associates , 2002). Thus, the CWWA adopts a two-part tariff structure so that a volumetric variable fee is set at the marginal cost of supply while a connection fee is set up to recover the utility’s fixed charges Nevertheless, this pricing scheme has regressive effects provided that the access fee is the same for all consumers, i.e. the smaller users pay a larger proportion of their income than larger users, which are typically better-off members of society (e.g. large gardens and swimming pool owners). In this case, as argued in GeoEconomics Associates (2002), the adoption of increasing block rates may help to mitigate the regressive impacts by transferring equity from high volume (and higher income) water users, to lower volume (and lower income) users.

When considering water pricing and efficiency considerations, vertical scope economies suggest that competition in water supply will be both costly and ineffective, as discussed above. However, this does not necessarily preclude appropriate price signals reflecting water scarcity. Thus, for example, regulators could reduce the environmental damage caused by water abstraction, through the establishment of variable abstraction charging based on the environmental impact of abstraction in different geographic locations. Vertically integrated firms could then internalize the environmental costs of different abstraction sources and balance these costs against the associated costs of water treatment and transportation. As a result, and assuming appropriate regulation incentivizing firms to reduce their overall costs of water provision, regulated consumer prices would more closely align with the overall total cost of water supply.

Moreover, in practical terms, the presence of vertical scope economies further challenges the pervasive AWWA average cost pricing rules, given that these rules rely on an ad hoc/ accounting based separation of joint costs across different vertical segments of a water utility in order to determine what proportion of fixed network costs and more variable volumetric costs should be allocated to different groups of customers when setting prices. However, as argued in CEPA's (2011) report for the UK water regulator Ofwat, in the presence of scale and scope economies, there is strong potential for biased cost assessment with accounting separation. This is because scope economies imply the nonseparability of costs, thereby implying that costs for different components of a vertically integrated firm cannot be accurately assessed in isolation. Thus, we believe policy makers should be aware that the presence of vertical scope economies may invalidate the very cost allocation mechanisms they employ in an effort to set appropriate water prices. Given this important consideration, we suggest that further research is required to consider whether practically implementable water pricing regimes can be implemented despite the potential biases in cost assessment in the presence of vertical scope economies.

5. Concluding remarks and suggestions for further empirical research

The more precise estimates on the magnitude of scale and scope economies in the water industry, the better informed regulators and policy makers are with regard to the potential costs and benefits of unbundling, consolidation, and merger proposals, as well as to the implications of alternative pricing schemes. In this sense, we believe that our review points out that there is a clearly need for further research and improved model specifications in this area. We therefore conclude by identifying several important areas of development that future empirical research aimed at increasing the precision of economies of scope and scale estimates should address. These include:

1. *Technology flexibility*. Most studies assume that different firm types share the same technology. For instance, many UK studies model a common technology for WaSCs and WoC water operations to allow a greater number of observations.

However, Saal and Parker (2006) provided evidence against the hypothesis that WaSCs and WoCs operate with the same technology. We note that this includes the need for more sophisticated modelling of different water source and treatment technologies, as differences in upstream technologies (e.g. reservoirs, boreholes, rivers) are likely to influence the extent of vertical integration economies with water distribution activities.

2. *Production environment*. Comprehensive and feasible modelling of operating characteristics (e.g. service area, density) which are likely to influence integration economies, is important. Differences in population density are likely to influence downstream costs and vertical integration economies. Likewise, it is desirable to incorporate quality measures or quality-adjusted outputs. Furthermore, largely due to data limitations, there is also limited use of chemicals and energy as inputs, and only one study directly includes the price of water as a driver for economies of integration (Garcia et al, 2007). As the optimal scale and scope of a water and/or sewerage utility will be influenced by settlement patterns, water resource availability and other operating characteristics, future research should aim to improve our understanding of how the production environment influences the costs, and hence the appropriate scale of a water or and/or sewerage firm.
3. *Functional form*. The majority of past studies employ a translog functional form, which generally allows the measurement of cost complementarities only. However, if one wishes to quantify the overall cost implications of integration economies, it is generally necessary to employ a quadratic or composite cost function approach, which can capture the full implications of vertical integration due to the benefits of shared fixed input usage as well as cost complementarity between outputs.

4. *Modelling of the Sewerage Supply Chain*. While several studies have tested for the existence of integration economies between overall water and sewerage activities, there is only one previous published study that has examined the presence of integration economies along the sewerage supply chain.
5. *Omission of Retail Activities*. There is limited available evidence that adequately evaluates the cost implications of retail separation from the rest of the supply chain: We emphasize that no information with regard to this particular form of unbundling is provided by the previous US studies which merely consider residential and non-residential outputs, but do not otherwise allow for separation of retail activities from upstream activities.
6. *Multicollinearity*. The multiple output specifications required to estimate scale and scope economies must often rely on the use of output variables that are highly correlated. Econometric approaches control for this effect and generally have larger standard errors and hence higher thresholds for statistical significance when multicollinearity is present. However, exploring other estimation approaches like non parametric methods (e.g. DEA), where results may be less sensitive to multicollinearity may allow improved estimation of scale and scope economies.
7. *Frontier Modelling and Efficiency*. While there are a number of papers that employ frontier approaches (e.g. data envelopment analysis, free disposal hull, stochastic frontier analysis), most previous studies estimate non-frontier econometric cost models and therefore do not control for the presence of inefficiency. That is, a cost-minimizing behaviour is assumed. However, scale and scope economies should ideally be determined based on the efficient cost frontier, thereby reflecting these relationships based on an estimate of the best practice technology. Otherwise, non-frontier estimation may confound inefficiency and (dis)economies of scope and

scale. It might therefore be worthwhile to explore whether estimated scale and scope economies differ when estimated with frontier approaches rather than average response approaches. Moreover, such frontier approaches allow exploration of whether systematic differences in efficiency exist between vertically integrated and separated firms.

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Table 1. Empirical research on economies of integration in the water industry

Studies	Sample	Model	Cost	Outputs	Input prices (quantities)	Control variables	Main findings
WATER & SEWERAGE							
Lynk (1993)	10 WaSCs and 28 WoCs (1979/80-1987/88) UK	SFA	TC	W_1, W_7, S_1	PL	Z1, Z2,Z5,Z6,t	$C_{W1,S1} < 0$ $C_{W1,W7} < 0$
Hunt & Lynk (1995)	10 WaSCs pre privatization (1979/80-1987/88) UK	Dynamic specification with interaction terms (OLS)	TC	W_1, W_7, S_1	PL	Z1,Z2, Z5,Z6,t	$C_{W1,S1} < 0$ $C_{W1,W7} < 0$
Saal & Parker (2000)	WaSCs (1985-1999) UK	Translog (SURE)	TC	W_2,S_2	PK, PL, PO	Z4, Z5	$C_{W2,S2} < 0$
Stone & Webster (2004)	WaSCs and WoCs (1992/93-2002/03) UK	Translog and Quadratic (SURE)	TC & VC	$W=W_3,W_4$ $S = S_3, S_4$	PK, PL, PE, PO (K1)	Z3, Z4, Z6, Z7	$C^V_{W3,S3} > 0$ $C^T_{W3,S3} > 0$ $C^V_{W4,S4} > 0$ $C^T_{W4,S4} > 0$ $C^V_{W3,S4} > 0$ $C^T_{W3,S4} > 0$ $C^V_{W4,S3} > 0$ $C^T_{W4,S3} > 0$ $C^V_{S3,S4} > 0$ $C^T_{S3,S4} > 0$
Martins et al (2006)	282 utilities Portugal (2002)	Cubic (OLS)	VC	W_3, S_5	None	Z8, Z9, Z10	$SC\ (W_3,S_5) = 0.455$ (sample mean) $SC\ (W_3,S_5) = -\ 0.113$ large
Nauges & Van den Berg (2008)	26 Brazilian (1996-2004) 38 Moldovan (2003-2004) 23 Romanian (2000-2004)	Translog (SURE)	VC	W_3, S_5	PL, PE, PS, PO (K2)	Z11, Z12, Z13, Z14, Z15, Z16, Z17	The authors assert (p.161) that they find integration economies, but do not provide estimates confirming this conclusion.
Malmsten & Lekkas (2010)	25 utilities cross section (2005) Sweden	Translog (OLS)	VC	W_5, S_5	PE, PLM (K2)	Z18	$C_{W5,S5} < 0$
De Witte & Marques (2011)	63 utilities (2005) Portugal	FDH	TC	W_3,W_6, S_6	(K3, L, O)	Z19, Z20, Z21	Absence of scope economies
WATER ONLY							
Hayes (1987)	475 US utilities (1960, 1970, 1976)	Quadratic (OLS)	TC & VC	W_8 , W_9	None	None	$SC\ (W_7, W_8) > 0$ The degree of *SC* tend to fall over time for larger firms and increase for smaller firms
Kim & Clark (1988) and Kim (1995)	60 utilities, (1973) US	Translog (MLE)	TC & VC	W_{10} , W_{11}	PK, PL, PE	Z22, Z23	$C_{W10,\ W11} < 0$
Garcia & Thomas (2001)	55 water utilities, France (1995-1997)	Translog (GMM)	VC	W_3 , W_{12}	PL, PE, PO (K2,K4,K5,K6)	Z11, Z24, Z25, Z26, Z27	$C_{W3,W12} < 0$ $SC_{W3,W12} = 23.67$ % at sample mean. Costs of network repairs and maintenance > costs of increasing production.
Stone & Webster (2004)	WaSCs and WoCs (1992/93-2002/03) UK	Translog and Quadratic (SURE)	TC & VC	$W=W_3,W_4$ $S = S_3, S_4$	PK, PL, PE, PO (K1)	Z3, Z4, Z6, Z7	$C^V_{W3,W4}<0$ $C^T_{W3,W4}<0$

Studies	**Sample**	**Model**	**Cost**	**Outputs**	**Input prices (quantities)**	**Control variables**	**Main findings**
WATER ONLY - Continued							
Torres & Morrison-Paul (2006)	255 observation, US 1996	Generalised Leontief Quadratic (MLE)	VC	W_8 , W_9	PL, PE, PPw (K5,K6)	Z24, Z27, Z28, Z29,Z30	*SC* (W_8,W_9) = 0.45 at sample mean
Garcia et al (2007)	171 VI firms, 17 NVI production firms and 15 NVI distribution firms (1997-2000) US	Translog (GMM)	VC	W_1 , W_9	PL, PE, PPw, PCh, PO (K2,K4,K5)	Z11, Z24, Z25,Z26,Z31	*SC* (W_1,W_9) = - 0.515 for the average firm (419,200 ML) *SC* (W_1,W_9)> 0 for utilities <100,000ML and for high intermediate water price
Urakami (2007)	561 observations from VI and NVI water utilities, Japan (2003)	Translog (SURE)	TC	W_3 , W_{13}	PK, PL, PPw, PCh, PO	Z32	*SC* (W_3,W_{13}) > 0 (41.1% - 76.2% cost savings from vertical integration)
Martins et al (2008)	218 utilities cross section (2002) Portugal	Quadratic (MLE)	VC	W_1 , W_{12}	None	Z8, Z11, Z33, Z34, Z35	Sample mean *SC* (W_1, W_{12}) = 0.327 Small utilities *SC* (W_1, W_{12}) = 0.706 Large utilities *SC* (W_1, W_{12}) = 0.057
Urakami & Tanaka (2009)	4,059 observations for consolidated and 4,268 for non-consolidated water utilities (2001-2006) Japan	Composite (SURE)	TC	W_3 , W_{13}	PK, PL,PO	Z36,Z37,Z38, Z39,Z23,Z13, Z32	*SC*(W_3, W_{13}) =0.534 for consolidated water utilities SC(W_3, W_{13}) =0.530 for non-consolidated water utilities
Corton (2011)	43 water utilities, Peru (1996-2005)	Translog (SFA)	TC	W_3 , W_{12}	PL1, PL2, PK	Z1, Z40, t	$C_{W13,W12} > 0$
MULTI-UTILITIES							
Fraquelli et al (2004) and Piacenza & Vannoni (2004)	90 utilities providing water, gas and electricity (1994-1996) Italy	Composite, Translog, Generalised Translog, Separable Quadratic (GLS)	TC	W, G, E	PK, PO	None	*SC*(W,G) higher than *SC*(G,E) and *SC*(W,E) for small and median utilities *SC*(W,G): 14%-30%, *SC*(G,E): 6.8%-19.7%, *SC*(W,E): 4.5%-21%
Farsi et al (2008)	87 utilities providing water, gas & electricity (1997-2005) Switzerland	Quadratic random effects and quadratic random coefficient (GLS)	TC	W, G, E	PK, PL,PE, PG	Z8	*SC* (W, G, E) > 0 for more than 60% of the utilities in their sample Small multi-utilities: 20% to 30% Median multi-utilities: 4% to 15%
Farsi & Filippini (2009)	34 utilities providing water, gas and electricity (1997-2005) Switzerland	Translog. SFA- Random effects and "true" random effects (GLS & MLE)	TC	W, G, E	PK, PL,PE, PG	Z8, t	$C_{W,E} < 0$ $C_{W,G} < 0$

Water outputs (W)
W1 – Water supply quality adjusted (Ml)
W2 – Residential water supply population (000s)
W3 – Water delivered (Ml, m^3)
W4 – Water connected properties (000s)
W5 – Volume of water produced (m^3)
W6 – No. of water customers
W7 – Water environmental services (turnover)
W8 – Wholesale water supply (Mgal)
W9 – Retail water supply (Mgal)
W10 – Residential water supply (Mgal)
W11 – Non-Residential water supply (Mgal)
W12 – Water losses (m^3)
W13 – Water purified (m^3)

Sewerage outputs (S)
S1 – Trade effluent (Ml,m^3)
S2 – Equivalent sewage quality treatment population
S3 – Sewerage connected properties (000s)
S4 – Equivalent population served (000s)
S5 – Waste water collected (m^3)
S6 – No. of sewerage customers

Other outputs
E – Electricity (KWh)
G – Gas (m^3)
W – Water (m^3)

Input prices and quantities
PL – Price of labor
PL1 – Price of direct labor
PL2 – Price of indirect labor
PLM – Price of labor and materials
PK – Price of capital
PE – Price of energy
PO – Price of other inputs
PPw – Price of purchased water
PCh – Price of chemicals
PS – Price of contracted out services
PG – Price of gas
K1 – Replacement cost value of assets
K2 – Network length
K3 – Capital costs (€)
K4 – Pumping capacity (gal/min)
K5 – Storage capacity (Mgals)
K6 – Treatment capacity (Gals)
L – Labor costs (€)
O – Other costs (€)

Control variables (Z)
Z1 – Regional characteristics (dummies)
Z2 – Technical change (dummies)
Z3 – Service quality (properties with supply interruptions>12 hours, at risk of sewer flooding, below the reference level for water pressure)
Z4 – Water quality (%)
Z5 – River quality (%)
Z6 – Sewerage quality (%)
Z7 – Operating environment (% of metered billed properties, of water from rivers, of sewage from trade effluent customers, average pumping head)
Z8 – Customer density (water connections/km^2)
Z9 – No. of connections related to wastewater service
Z10 – Ownership (dummy)
Z11 – Length of water distribution network (km)
Z12 – Average duration supply (hours/day)
Z13 – Population coverage (population supplied/ total population of the area)
Z14 – Number of connections per km of network
Z15 – Pipe breaks
Z16 – Water connections
Z17 – Average share of total volume sold to residential users per utility
Z18 – No. of total connections to the water distribution network and the sewerage
Z19 – Monthly peak factor (monthly consumption/ yearly average)
Z20 – Revenue from water and sewerage services
Z21 – Share of the revenues of non-drinking water delivery services in total revenues
Z22 – Service distance (miles)
Z23 – Load factor of the water system (%)
Z24 – Number of customers
Z25 – Production capacity (m^3/hour, gal/min)
Z26 – Stock and pumping capacity (m^3/h, Mgal)
Z27 – No. of towns served
Z28 – % of water from boreholes
Z29 – Size of the service area (Sq. miles)
Z30 – Expenditure on chemicals ($)
Z31 – Water network rate of return (water injected into network/water sold to final users)
Z32 – Water delivered/Water purchased (%)
Z33 – % of raw water acquired to other utilities
Z34 – Type of corporate management & regulation
Z35 – Hydrographical region (dummies)
Z36 – Population density (%, population per km)
Z37 – Purified water ratio (%)
Z38 – Daily supplied water per person (%)
Z39 – Water taken from underground sources (%)
Z40 – Firm size (dummy)
t – Time

Table 2. The empirical evidence on the degree of scale economies.

Studies	**Country**	**Model**	**Activities**	**Average utility: 000s cubic meters of water delivered**	***S*(y)**
Fox & Hofler (1985)	US	SFA(CD)	WP & WD	135.51	0.888
Kim (1987,1995), Kim & Clark (1988)	US	Quadratic(MLE)	WP & WD	43228	0.99
Bhattacharyya et al (1995)	US	Translog (SFA)	W	60672	0.966
Renzetti (1999)	Canada	Translog (SUR)	W&S	8100	1.249(1.465)*
Fabbri & Fraquelli (2000)	Italy	Translog(SUR)	WP & WD	18860	0.99
Garcia & Thomas (2001)	France	SFA(TL)	WP & WD	411	1
Mizutani & Urakami (2001)	Japan	Translog(SUR)	WP & WD	66620	0.92
Antonioli & Filippini (2001)	Italy	SFA(CD)	WP & WD	6772	0.95
Fraquelli & Giandrone (2003)	Italy	Cobb-Douglas(OLS)	W&S	14800	1.22
Ashton (2003)	UK	Translog(SUR)	WP & WD	63002	0.963
Stone & Webster Consultants (2004)	UK	Translog(SUR)	WP & WD	64041	1.09
	UK	Translog (SUR)	W&S	373329	0.71
Sauer (2005)	Germany	GMcFadden(SUR)	WP & WD	1200	2.08
Fraquelli & Moiso (2005)	Italy	SFA(TL)	WP & WD	59202	1.12
Aubert & Reynaud (2005)	US	SFA(TL)	WP & WD	3122	1.073
Vitaliano (2005)	US	SFA(CD)	WP & WD	37.817	1.23
Urakami (2006)	Japan	Translog (SUR)	WP	67867	1.083
	Japan	Translog (SUR)	WD	4370	1.104
	Japan	Translog (SUR)	WP & WD	7267	1.108
Torres & Morrison Paul (2006)	US	GLQ(SUR)	WP & WD	33228	1.23
Saal & Parker (2006)	UK	Translog(SFA)	WP & WD	62889	0.969
	UK	Translog(SFA)	W&S	373322	1.051
Martins et al (2006)	Portugal	Cubic(OLS)	W&S	1663	1.74
Kirkpatrick et al (2006)	Africa	Translog(SUR)	WP & WD	48259	1.16
Garcia et al (2007)	US	Translog(GMM)	WD	2620	1.19
	US	Translog(GMM)	WP & WD	1587	1.17

Table 2. continued

Studies	**Country**	**Model**	**Activities**	**Average utility: 000s cubic meters of water delivered**	***S*(y)**
Bouscasse et al (2008)	US	Translog(GMM)	WP & WD	31000	1.03
Urakami (2007)	Japan	Translog (SUR)	WP & WD	22058	1.045
Nauges & Van den Berg (2008)	Vietnam	Translog (SUR)	WP & WD	14000	1.156
	Brazil	Translog (SUR)	W&S	425000	1.027
	Moldova	Translog (SUR)	W&S	3000	1.213
	Romania	Translog (SUR)	W&S	29000	1.048
Filippini et al (2008)	Slovenia	SFA(TL)	WP & WD	2299	1.088
Martins et al (2008)	Portugal	Translog (GMM)	WP & WD	1850	1.48
Iimi (2008)	Latin American countries	Translog (SUR)	W&S	26937	1.15
De Witte & Marques (2011)	Portugal	FDH	W&S	6457	1
Battasso & Conti (2009)	UK	SFA(TL)	WP & WD	67525	1.12
	UK	Translog (SUR)	W&S	381425	0.91
Tsegai et al (2009)	Africa	SFA(CD)	WP & WD	3090	1.1769
Urakami & Parker (2011)	Japan	Translog (SUR)	WP & WD	9409	1.078
Urakami & Tanaka (2009)	Japan	Composite (SUR)	WP & WD	10126	1.02
Baranzini & Faust (2010)	Switzerland	Translog (SUR)	WD	1234	1.10
Zschille & Walter (2010)	Germany	Translog (TFE)	WP & WD	3905	1.145
De Witte & Dijkgraaf (2010)	The Netherlands	Translog Fourier	WP & WD	111,000	0.935 0.943

*It refers to specific scale economies of residential (non-residential) water supply.

Table 3. The range of the estimates on scale economies in previous studies.

Studies	Country	Activities	Size	Water delivered (000s cubic meters)	*S*(y)
Fox & Hofler (1985)	US	WP & WD	Small	34	0.884
			Average	136	0.888
			Large	416	0.886
Kim (1987,1995), Kim & Clark (1988)	US	WP & WD	Small	2,272	1.330
			Average	43,228	0.990
			Large	214,387	0.870
Fabbri & Fraquelli (2000)	Italy	WP & WD	Small	350	2.380
			Average	18,660	0.990
			Large	393,960	0.680
Mizutani & Urakami (2001)	Japan	WP & WD	Small	6,408	0.856
			Medium Small	15,246	0.921
			Medium Large	42,131	0.881
			Average	66,620	0.905
			Large	355,550	0.966
Fraquelli & Moiso (2005)	Italy	WP & WD	Small	18,900	2.180
			Average	59,202	1.120
			Large	250,000	0.650
Aubert & Reynaud (2005)	US	WP & WD	Small	62.4	1.096
			Average	3,122	1.073
			Large	158,612	1.052
Martins et al (2006)	Portugal	W&S	Average	1,635	1.747
			Large	41,500	0.611
Torres & Morisson Paul (2006)	US	WP & WD	Small	2,555	0.980
			Medium	6,791	1.230
			Medium Large	22,568	1.160
			Average	33,228	1.230
			Large	112,010	1.450

Table 3 continued

Studies	**Country**	**Activities**	**Size**	**Water delivered (000s cubic meters)**	***S*(y)**
Filippini et al (2008)	Slovenia	WP & WD	Small	107	1.311
			Average	2,298	1.090
			Large	25,507	0.850
Martins et al (2008)	Portugal	WP & WD	Small	500	3.990
			Average	2,464	1.487
			Large	20,000	1.060
Nauges et al (2008)	Vietnam	WP & WD	Low	[36 ; 2,528]	1.292
			Medium	[2,657 ; 5,746]	1.141
			High	[5,925 ; 278,552]	1.011
	Brazil	W&S	Low	[31,000;123,000]	1.058
			Medium	[131,000;255,000]	1.027
			High	[268,000;2,600,000]	0.996
	Moldova	W&S	Low	[11;131]	1.364
			Medium	[136;421]	1.206
			High	[452;81,825]	1.094
	Romania	W&S	Low	[3,820;9,967]	1.056
			Medium	[11,182;21,142]	1.052
			High	[25,056;175,640]	1.036
Tsegai et al (2009)	Africa	WP & WD	Small	<1,200	1.149
			Average	[1,200 ; 3.400]	1.177
			Large	>3,400	1.156
Bottaso & Conti (2009)	UK	WP & WD	Small	9,001	1.010
			Average	67,525	1.120
			Large	292,288	1.240
Baranzini & Faust (2010)	Switzerland	WD	Small	10% smallest (min 94)	1.15
			Medium		1.10
			Large	10% largest (max 70,645)	0.95
Zschille & Walter (2010)	Germany	WP & WD	Small	430	1.380
			Average	3,905	1.146
			Large	46,179	0.799
De Witte & Dijkgraaf (2010)	The Netherlands	W	Small	59,000	0.917
			Medium	111,000	0.935
			Large	236,000	0.943

Figure 1. The vertical stages of the water and sewerage supply chain and the levels of industry integration

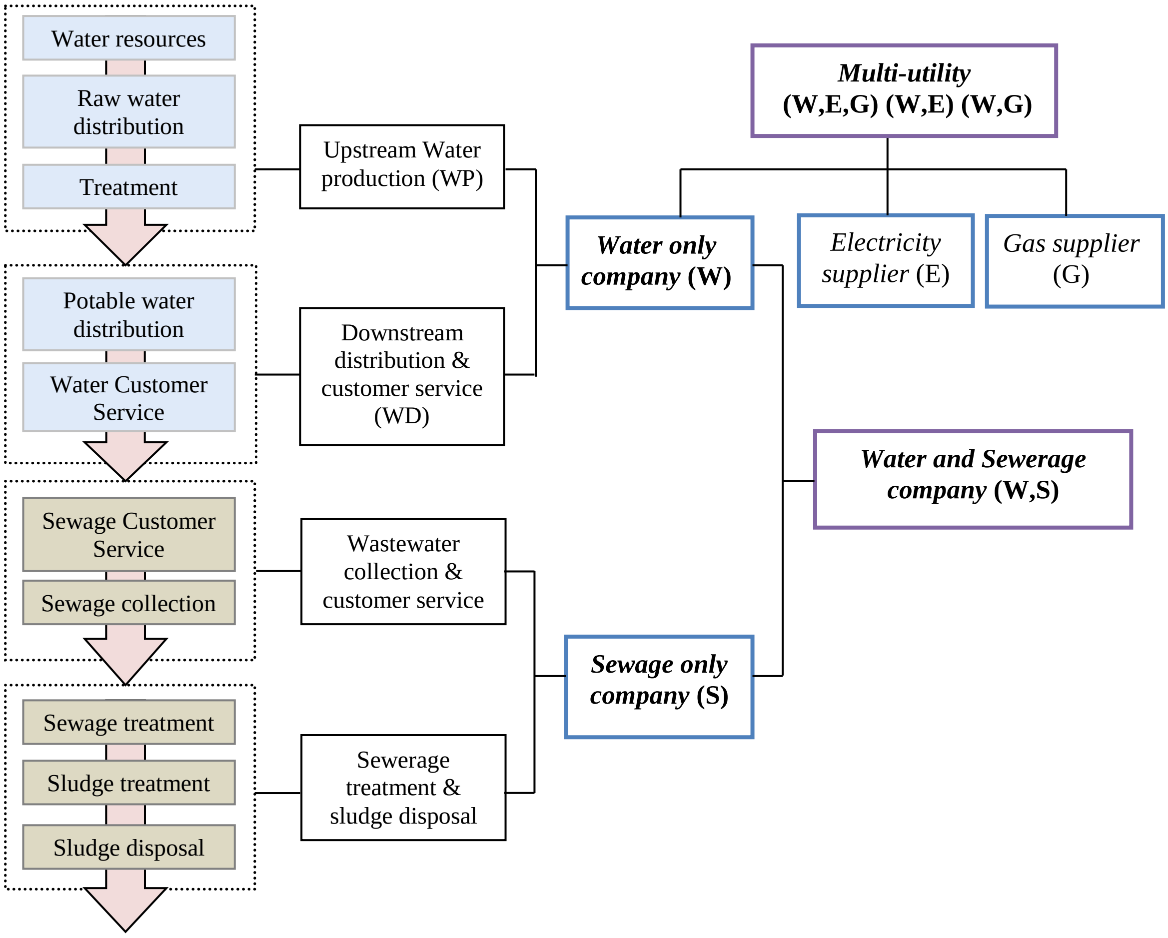

Figure 2. The degree of long run average economies of scale in the empirical literature