Measuring Economies of Vertical Integration in Network Industries: An Application to the Water Sector*

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9th June 2004

Abstract

This paper provides a framework that aims at distinguishing the technological economies of vertical integration from the vertical economies resulting from market imperfections. To illustrate our analyze, we use consistent panel data econometric methods to estimate cost functions on a sample of North-American water utilities. Contrary to what has been found for other network industries (electricity and gas for instance), we show that the economies of vertical integration are only significant for the smallest utilities.

Keywords: Vertical integration, water network, cost function, panel data.

JEL Codes: C33, L22, L95.

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* We are very grateful to Patrick Rey for helpful discussions on a preliminary draft. We also would like to thank participants at the CRDE seminar in Montréal and at the Applied Microeconomics Conference in Montpellier.

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Introduction

In most of network industries (electricity, gas, telecommunications, postal services, air, rail and urban transport) and in most countries, unprecedented transformations aiming at introducing more competition into what sectors which were considered as pure natural monopolies has been the main feature of the last decade. A key recommendation of policy-makers has been to broke up monopolies before introducing more competition.[1] Underlying this recommendation is the idea that natural monopoly and potentially competitive parts of a utility should be separated to prevent competition distortions. In most of network industries, the result has been to introduce competition at the production stage while maintaining transmission and in some cases distribution as local monopolies.

However, it has been recently argued that such a vertical disintegration of utilities can result in cost efficiency losses if production stages are characterized by strong economies of vertical integration. Sources of such economies of vertical integration are however often difficult to assess: A vertically integrated structure can be a cost effective system if there are substantial needs for coordination across stages, if markets for intermediary goods are not competitive enough or if there are high transaction costs associated with using these intermediary markets. Interestingly, most of the empirical studies trying to assess the presence of economies of vertical integration have reported substantial cost efficiency gains for vertically integrated structures.[2] However and to our knowledge, all the published empirical papers deal with the electric sector and none of them consider the market structure as a possible source of economies of vertical integration.[3] But as mentioned by Kaserman and Mayo (1991), the structure of utility costs is not independent of the market form. Economies of vertical integration may result from technological effects like a better coordination across stages or the non-duplication of fixed costs, but it can also be the consequence of market imperfections at upstream stages of the production process. If there

[1]The question of liberalization of these industries, its economic implications and political issues are also in the heart of discussions on structural reforms in the EU since a few years, see European Commission (1999).

[2]Working on a sample of 74 US electric utilities observed in 1981, Kaserman and Mayo (1991) have shown that for a vertically integrated firm producing the sample mean generation and distribution levels, costs of vertically disintegrated production are 11.96 percent higher than for vertically integrated production. Also working on a sample of US electric utilities, Kwoka (2002) concludes that disintegration would result in substantial cost increase, 42 percent at the sample mean. Very recently, Nemoto and Goto (2004) using a panel of 9 Japanese utilities observed from 1981 to 1998, report a cost efficiency gain for the vertically integrated structure going from 0.13 to 2.97 percent on average.

[3]Two approaches have been used for measuring economies of vertical integration. The first one is to test the separability among production stages as done by Lee (1995) or Hayashi et al. (1997) whereas the second introduced by Kaserman and Mayo (1991) is to rely on tests of subadditivity or economies of scope. None of these approaches explicitly consider that the cost function of a utility may differ according to the vertical organization of the sector.

are market imperfections, the allocation of inputs at the downstream stages will be distorted resulting in cost increase. A global measure of economies of vertical integration, as proposed by Kaserman and Mayo (1991) or Kwoka (2002), does not allow to distinguish between the technological economies of vertical integration and the impact of market imperfection on the cost structure. Yet, identifying the sources of economies of vertical integration is crucial as disintegration may only be cost effective in the case of upstream competitive markets. The conclusion given by a global measure of vertical integration could be subject of controversy in such a case. By separately estimating the cost functions of vertically integrated and non-vertically integrated structures and by imposing marginal cost pricing on the upstream market, we makes the distinction between the two sources of economies of vertical integration possible. Moreover we take into account the fact that the technological characteristics of the water utilities may differ according to their vertical structure (vertically integrated versus not vertically integrated).

Within network industries, the water sector still seems to be a special case as direct competition and production stage separation have not yet really been observed.[4] Water utilities are still viewed as natural monopolies that must be regulated by public authorities. This is quite surprising as there are important similarities between water and the other network utilities where competition has been successfully introduced.[5] As in gas and electricity, the production stage of the industry seems potentially competitive. As in gas and electricity, the distribution stage presents some characteristics of a natural monopoly. The network of pipes is naturally monopolistic in the same sense as are the networks of pipes (in gas) and wires (in electricity). So there is no obvious reason in principle for limiting competition in the production, distribution, storage stages and any other part of the production process which does not appear to be a natural monopoly except if economies of vertical integration are important. But as no measure of such economies have been yet published there is still no clear answer to the optimal organization of the water industry. One objective of this paper is to shed some light on this debate by providing an estimate of economies of vertical integration in the water network industry.

The paper is organized as follows. In the next section, we present the cost model and we

[4] England is a special case as the 1998 Competition Act has opened up the scope for more competition in water industry. Inset appointments which allow the existing regulated water utility to be replaced by another for a specific site are now authorized. Common carriage which occurs when one service provider shares the use of another's assets is also authorized by OFWAT.

[5] There are also important differences between networks. For instance, electricity can be carried on long distances at a reasonable cost and without substantial losses whereas the supply of water is rather local. But these differences can not explain by themselves the absence of competition. For example, it is claimed that the absence of competition could be related to absence of long-distance grid in water. But absence of network interconnection can be a symptom of no competition in the past: if an industry is established as a group of local monopolies with captive customers, the incentives to connect to other monopolists' systems are minimal.

derive the measure of global and technological economies of vertical integration. Then, in the following section, we present the database and our investigation area. In section 3, we present the result of the empirical application and we show that there are significant global economies of vertical integration only for large water utilities. Contrary to what has been found in the other network industries (electricity and gas for instance), we show that the technological economies of vertical integration are not significant in the water network industry. We conclude this paper by analyzing the main implications of these findings and by giving some directions for future researches.

1 Structure of production and vertical integration

1.1 The nature of economies of vertical integration

If an industry is characterized by several successive production stages[6], a single firm may be able to produce the complementary products (or services) resulting from these different stages more profitably than a number of firms would do. Such industries are viewed as presenting, at some stages, economies of vertical integration, i.e. the total cost of producing is lower in a vertically integrated structure than in a disintegrated one. The sources of economies of vertical integration, although difficult to identify, can be classified into three main categories: technological economies, transactional economies and economies resulting from market imperfections.

First, vertical integration may be a cost effective solution due to the presence of technological economies. These technological economies come from physical interdependencies in the production process. There are technological economies if there are economies of scope across different production stages. The economies of scope across stages can be related to the existence of important complementarities or coordination economies between two stages. These coordination economies include a greater adaptability to non-anticipated events and a better information for taking a decision that is going to have an effect at different production steps. It is for example the case for determining the optimal production or distribution capacity from a joint decision system concerning plant size and transmission system. An important limit to the presence of technological economies is the size of the vertically integrated structure. Large integrated firms will result in important internal incentive problems. This is especially the case if the managerial objectives of each production stage are not aligned with the whole structure objective. In a

[6]We may think to the usual distinction between production, transmission and distribution in the electric industry or in the telecommunication networks.

vertical setting, a subordinate manager may have lower incentives to come up with good ideas to reduce production costs as this investment may by expropriated by the firm's owner, Grossman and Hart (1986). Hence, technological economies will exist if the coordinations gains overwhelm the internal incentive costs.

Transactional economies may be another important determinant of vertical integration. The transaction costs associated to the use of a market for the intermediary product may be in some cases large. These transaction costs are associated to the design, the negotiation and the enforcement of contracts between buyers and sellers of the intermediate product. Transactions also involve costs in cases of asset specificity and incomplete contracts. The economies may come from a reduction in opportunistic behavior in the bilateral exchange, and a relative efficient conflict resolution machinery, Williamson (1985).

Other drivers of vertical integration include market imperfections. First, if there are important scale economies at the production stage, the upstream firm may in such a case exercise monopoly power in pricing the intermediate product. This would result in inefficient combinations of inputs at the downstream stage. Another market imperfection that may favor vertically integrated structure is the foreclosure problem, Hart, Tirole, Carlton, and Williamson (1990) or Rey and Tirole (2003). Foreclosure refers to a dominant firm's denial of proper access to an essential good in order to extend a monopoly power from one market on another.[7]

In assessing the optimal degree of vertical integration in a network industry, it is important to make the difference between the technological economies (better coordination, no duplication of fixed costs) that may favor a vertically integrated industry from the characteristics of markets for intermediate goods (existence of monopoly power and transaction costs) that favor vertically separated firms. It is crucial to separate and identify these two issues as it is clear that the welfare consequences of vertical integration will depend upon the motivation for vertical integration. Integration to take advantage of technological vertical economies will, other things equal, improve welfare, whereas integration with the intention of market foreclosure may, in some circumstances, reduce welfare.

1.2 Measuring economies of vertical integration in a multi-stage industry

Several studies (mostly focusing on the electric sector) have tried to assess the level of the economies of vertical integration. Some authors (Lee, 1995, Hayashi et al., 1997) have tested

[7] The foreclosure issue does not seem to be the main market imperfection problem of the water sector as water suppliers usually operate on geographic separated markets. We will more carefully discuss this point in the empirical section of the paper.

the cost separability of the different production stages. The issue addressed by these authors is in fact to test whether input proportions used to produce the final output depend or not on the price of the intermediate good. This indirect test does not allow to properly measure the economies of vertical integration.

More recently, Kaserman and Mayo (1991) have proposed to measure the economies of vertical integration by evaluating the economies of scope in a multiproduct cost framework. The idea is that a fully verticaly-integrated utility produces all stage outputs. By nullify one output, the production cost of this output can be assessed. In a two-stage production process, Kwoka (2002) has slightly adapted this framework in order to properly compare the costs of an integrated utility with the cost of a pure-distribution utility. Three major drawbacks emerge from this measure of economies of vertical integration. First, because the definition of economies of scope involves zero output at some stage, using a translog cost function is not possible. The previous studies have estimated a quadratic cost function that imposes some constraints making the approximation of the cost function less flexible. Second, this approach explicitly considers that the data generating process of the cost of a utility is the same whatever is the vertical organization of the sector. The cost model requires to examine a single cost function. The implicit assumption made by these authors is that the production technology and the estimated parameters are identical whether the firm is integrated, a pure-production utility or a pure-distribution utility. But this implicit assumption is not likely to hold as the production technology may strongly differ according to the vertical organization and hence so do the cost-minimizing program of the different utilities. Last, the measure for economies of vertical integration proposed by Kaserman and Mayo (1991) and Kwoka (2002) is a global measure that does not allow to distinguish between technological determinants and market imperfections. For these reasons, we propose to estimate a different cost function for each type of utility. This requires to estimate a cost function for a vertically-integrated (VI) utility and cost functions for all types of non-vertically integrated (NVI) utilities.

1.2.1 Cost structure for a vertically-integrated utility

In order to simplify the presentation of the model we consider a firm characterized by two production stages vertically related, indexed by $s = 1, 2$ and called the production and the distribution stage, respectively. The cost model can easily be extended to a higher number of successive stages.

At stage s, the utility uses a vector X_s of k_s inputs and we denote by Z_s the capital and technical variables of the corresponding stage. We note Y_1 the intermediary output produced at the first stage and Y_2 the final output produced at the second stage. In the water network industry, Y_1 and Y_2 represent the water withdrawn and treated and the water sold to final users. The overall cost minimization program of the VI utility writes:

$$\min_{X_1,X_2} \quad \sum_{k1} w_{1k_1} \times X_{1k_1} + \sum_{k2} w_{2k_2} \times X_{2k_2} \tag{1}$$

$$s.t. \quad Y_2 = g^{vi}(X_1, X_2|Z_1, Z_2), \tag{2}$$

where w_1 and w_2 are respectively the factor prices of stages 1 and 2. The overall cost function of the VI utility writes $C^{vi}(Y_2, w_1, w_2|Z_1, Z_2)$. The cost minimization requires to equalize the relative marginal productivity of inputs at each stage, but also across the two successive stages. Equalization of relative marginal productivity of inputs across stages is specific to a vertically integrated structure.

1.2.2 Cost structure for non-vertically integrated utilities

Let us assume now that the two stages are not integrated. The gross output Y_1 is produced by a utility (production utility). Then Y_1 is sold to another separated utility (distribution utility) which uses it as an input of the distribution stage.

The production stage, $s = 1$ Let's us consider first the production utility. We can derive the related variable cost functions:

$$\min_{X_1} \quad \sum_{k1} w_{1k_1} \times X_{1k_1} \tag{3}$$

$$s.t. \quad Y_1 = f_1^{nvi}(X_1|Z_1). \tag{4}$$

The production cost function is:

$$C_1^{nvi}(Y_1, w_1|Z_1) = \sum_{k1} w_{1k_1} \times \widehat{X}_{1k_1}^{nvi}(Y_1, w_1|Z_1), \tag{5}$$

where $\widehat{X}_1^{nvi}(Y_1, w_1|Z_1)$ gives the optimal demands of inputs. The cost minimization of the production stage requires to equalize the relative marginal productivity of inputs used at this stage.

The distribution stage, $s = 2$ Let us consider now a distribution utility that must buy the intermediate good Y_1 at a unit price w_{Y_1}. For such a water distribution utility, the cost minimization program writes:

$$\min_{Y_1,X_2} \quad w_{Y_1} Y_1 + \sum_{k2} w_{2k_2} \times X_{2k_2} \tag{6}$$

$$s.t. \quad Y_2 = f_2^{nvi}(Y_1, X_2|Z_2), \tag{7}$$

with w_{Y_1} the price of water input. The distribution cost function is the following:

$$C_2^{nvi}(Y_2, w_{Y_1}, w_2|Z_2) = w_{Y_1} \times \widehat{Y}_1^{nvi}(Y_2, w_{Y_1}, w_2|Z_2) + \sum_{k2} w_{2k_2} \times \widehat{X}_{2k_2}^{nvi}(Y_2, w_{Y_1}, w_2|Z_2). \quad (8)$$

where $\widehat{X}_2^{nvi}(Y_2, w_{Y_1}, w_2|Z_2)$ gives the optimal demands of second stage inputs and $\widehat{Y}_1^{nvi}(Y_2, w_{Y_1}, w_2|Z_2)$ the optimal derived demand in intermediate good. The cost minimization of the distribution stage requires to equalize the relative marginal productivity of inputs used at this stage. These inputs include the intermediate good, Y_1. The VI and the NVI structures are equivalent if and only if the two following conditions are satisfied:

$$w_{Y_1} = \frac{\partial}{\partial Y_1} C_1^{nvi}(Y_1, w_1|Z_1) \quad (9)$$

$$g^{vi}(X_1, X_2|Z_1, Z_2) = f_2^{nvi}(f_1^{nvi}(X_1|Z_1), X_2|Z_2) \quad (10)$$

that is if the intermediate good in a (non-vertically integrated) production utility is priced at its marginal production cost and if the production function of the VI structure can be decomposed into the two successive NVI stages. As we do not impose condition (10) to hold, we take into account the fact the being vertically integrated or not may result in different technologies of production (due for instance to the specification of assets or the need to solve internal incentives problem in the vertically integrated case).

Overall cost for a non-vertically integrated structure The overall cost for a NVI structure is equal to the variable cost of the production and the distribution stages less the cost of water purchase for the distribution utility. This water purchase cost corresponds, in fact, to a monetary transfer from the distribution utility toward the production utility. Moreover, we consider that the produced volume Y_1 and supplied to the distribution utility corresponds to the optimal derived demand in intermediate good of the distribution utility $\widehat{Y}_1^{nvi}(Y_2, w_{Y_1}, w_2|Z_2)$. Hence, the overall cost for a NVI structure is:

$$\begin{aligned} C^{nvi}(Y_2, w_{Y_1}, w_1, w_2|Z_1, Z_2) =& C_1^{nvi}(\widehat{Y}_1^{nvi}(Y_2, w_{Y_1}, w_2|Z_2), w_1|Z_1) + C_2^{nvi}(Y_2, w_{Y_1}, w_2|Z_2) \\ & - w_{Y_1} \times \widehat{Y}_1^{nvi}(Y_2, w_{Y_1}, w_2|Z_2) \\ =& \sum_{k1} w_{1k_1} \times \widehat{X}_{1k_1}^{nvi}(\widehat{Y}_1^{nvi}(Y_2, w_{Y_1}, w_2|Z_2), w_{Y_1}, w_1, w_2|Z_1, Z_2) \quad (11) \\ & + \sum_{k2} w_{2k_2} \times \widehat{X}_{2k_2}^{nvi}(Y_2, w_{Y_1}, w_2|Z_2). \end{aligned}$$

1.2.3 Economies of vertical integration

Global economies of vertical integration A direct comparison of C^{vi} and C^{nvi} allows to measure *the global economies of vertical integration*, that is the economies of integration resulting both from the technologies of production and from the possible market imperfection. Let us define GVI as a measure of such global economies of vertical integration in the following way:

$$GVI = \frac{C^{vi}(Y_2, w_1, w_2|Z_1, Z_2)}{C^{nvi}(Y_2, w_{Y_1}, w_1, w_2|Z_1, Z_2)} \tag{12}$$

If $GVI < 1$ then the vertical structure is characterized by global economies of vertical integration. In other words, given the level of final output to be produced Y_2, the price of inputs (w_1, w_2) and the price of the intermediate good w_{Y_1}, a vertically structure will produce at a lower cost. On contrary, if $GVI > 1$, there are diseconomies of vertical integration and two separated utilities are more efficient. Finally, if $GVI = 1$, there are no economies nor diseconomies of vertical integration.

Technological economies of vertical integration As mentioned previously, such a measure of economies of vertical integration, although interesting mixes the technological effects (interdependence between the two stages in the case of integrated structure and asset specialization in the case of non-integrated structure for instance) with the market effects (market for intermediate good non competitive resulting in non efficient allocation of inputs at the second stage). In order to distinguish between these market and technological effects, we propose the following approach. The idea is, first to compute the total cost of a non-vertically structure while imposing the intermediate good to be sold at its marginal production cost and, second to compare this cost to the one of a vertically integrated structure.

First, let us consider the NVI production utility. Following equation (5), the cost function writes:

$$C_1^{nvi}(Y_1, w_1|Z_1). \tag{13}$$

Let us assume that the intermediate good is be sold at its marginal production cost. In such a case we have:

$$w_{Y_1} = \frac{\partial}{\partial Y_1} C_1^{nvi}(Y_1, w_1|Z_1). \tag{14}$$

It is important to notice that this condition does not mean that the market for the intermediate good is assumed to be perfectly competitive. Two-part tariffs may be used by the production utility in case of increasing return to scale. But in that case, the fixed charge does not have any effect on input allocation at the distribution stage, and what really matters is the marginal price. The fixed charge is just a transfer from the distribution utility toward the production utility that will cancel out when evaluating the total cost of the NVI structure. The condition (14) defines the price of the intermediate good as a function of the first-stage output and first-stage input prices:

$$w_{Y_1} = w_{Y_1}(Y_1, w_1|Z_1). \tag{15}$$

Let us now consider the NVI distribution utility. Its derived demand for Y_1 is $\widehat{Y}_1^{nvi}(Y_2, w_2, w_{Y_1}|Z_2)$, see equation (8). Marginal cost pricing at the first stage gives:

$$\widetilde{Y}_1^{nvi}(Y_2, w_1, w_2|Z_1, Z_2) = \widehat{Y}_1^{nvi}(Y_2, w_2, w_{Y_1}(Y_1, w_1|Z_1)|Z_2). \tag{16}$$

The total cost, net of water purchase cost, for a NVI distribution utility with marginal cost pricing at the first stage writes:

$$\begin{aligned}\sum_{k2} w_{2k_2} \times \widehat{X}_{2k_2}^{nvi}(Y_2, w_2, w_{Y_1}|Z_2) =& \sum_{k2} w_{2k_2} \times \widehat{X}_{2k_2}^{nvi}(Y_2, w_2, w_{Y_1}(Y_1, w_1|Z_1)|Z_2)\\ =& \sum_{k2} w_{2k_2} \times \widehat{X}_{2k_2}^{nvi}(Y_1, Y_2, w_1, w_2|Z_1, Z_2)\\ =& \sum_{k2} w_{2k_2} \times \widehat{X}_{2k_2}^{nvi}(\widetilde{Y}_1^{nvi}(Y_2, w_1, w_2|Z_1, Z_2), Y_2, w_1, w_2|Z_1, Z_2)\\ =& \widetilde{C}_2^{nvi}(Y_2, w_1, w_2|Z_1, Z_2).\end{aligned} \tag{17}$$

Using equations (13) and (16), the cost function of the NVI producer utility writes as a function of Y_2, w_1, w_2, Z_1 and Z_2:

$$\widetilde{C}_1^{nvi}(Y_2, w_1, w_2|Z_1, Z_2) = C_1^{nvi}(\widetilde{Y}_1^{nvi}(Y_2, w_1, w_2|Z_1, Z_2), w_1|Z_1). \tag{18}$$

The overall cost of a NVI structure, imposing condition (14) to hold, writes:

$$\widetilde{C}^{nvi}(Y_2, w_1, w_2|Z_1, Z_2) = \widetilde{C}_1^{nvi}(Y_2, w_1, w_2|Z_1, Z_2) + \widetilde{C}_2^{nvi}(Y_2, w_1, w_2|Z_1, Z_2). \tag{19}$$

Condition (14) makes the overall cost of a NVI structure no more depends on the price on the intermediate good w_{Y_1}. Moreover imposing this condition suppresses any misallocation of inputs due to market imperfection. Thus, any remaining economies of vertical integration are now purely technological. Such *technological economies of vertical integration* are measured by the ratio:

$$TVI = \frac{C^{vi}(Y_2, w_1, w_2|Z_1, Z_2)}{\widetilde{C}^{nvi}(Y_2, w_1, w_2|Z_1, Z_2)} \tag{20}$$

If $TVI < 1$ then the vertical structure is characterized by technological economies of vertical integration. If $TVI > 1$, there are technological diseconomies of vertical integration. Finally, if $TVI = 1$, there are no technological economies nor diseconomies of vertical integration.

2 Vertical integration and costs for Wisconsin water utilities

2.1 Vertical integration in the water network industry

VI water utilities are still the norm in most of the countries. There are two main reasons justifying the persistence of such market structures. First, a specific characteristic of the water supply services is that they are local services: the production plant and the distribution network are often very close (mainly because of network losses and alteration of the water quality during transportation). Second, water quality is essential and introducing multiple water supplier in a same distribution network may creates some difficulties, Bisshop (2001). These difficulties include the compatibility of water treatments realized by the different producers, the origin of water in the network, or the liability in case of sanitary problem.

Coordination between the delivery service and producers is also important, especially for the volume of water that must be injected into the network. The distribution stage may require from the production stage additional water flow in order to compensate for a low rate of network return or to adapt deliveries to peak-load demand. Each stage of the water supply process (production and distribution) is also constraint by pressurization facilities. Once again, a good coordination between is necessary to maintain a sufficient pressure at the tap of users. Other problems can arise depending on whether the network is meshed or in arborescence. In the first case, the water can circulate in all directions. In the second case, water flows thanks to gravity and the production stage must thus be located upstream.

2.2 Vertical integration issues in the Wisconsin

2.2.1 Organization of the Wisconsin water sector

The Wisconsin is quite typical of the North-American water industry. The water utilities are on average small (in 2003, there were approximately five hundred water systems in Wisconsin delivering water to less than three thousand customers, on average) and most of them are municipally owned (in year 2003, only 6 over the 512 utilities were privately owned). The Wisconsin water utilities are regulated by the Public Service Commission of Wisconsin (PSC). The general principle of regulation for Wisconsin water utilities is a rate of return framework.

2.2.2 Defining vertically and non-vertically integrated utilities

Following the theoretical model, we consider a two-stage production model. The Production & Treatment stage, P&T, corresponds to resource extraction, transfer from the source of supply to the production facilities and treatment of raw water. The Transmission & Distribution stage, T&D, includes all the operations involved into the the transmission of water to final customers through distribution mains and the customer services.

The PSC regulates three classes of water utilities defined by the number of final users. Due to data limitations, we were not able to keep in our sample the smallest utilities. We have finally in our sample a panel of 204 services observed from 1997 to 2000. This sample is made of:

- 171 *vertically-integrated (VI) utilities*. These utilities neither buy water from a wholesale supplier nor resale water to another service. They are pure vertically integrated utilities.
- 17 *non-vertically integrated (NVI) production utilities*. A water utility belongs to this class if it operates as a water supplier for another service.
- 16 *non-vertically integrated (NVI) distribution utilities* for which more than half of the water sold to final users is bought from another utility. This 50% threshold has been chosen as it is high enough for making the production function specific.

2.2.3 Vertical integration issues in the Wisconsin

From 1997 to 2000, 15.9 million of gallons of water have been sold on average each year by a water utility to another. This significant amount of water represents around 7.6% of the total volume of water distributed in the Wisconsin. Both resale and final user water prices are regulated by the PSC. For instance, there exist some specific rules (the Purchased Water Adjustment Clause) that allows a supplier to revise its water price in case of an increase of the water wholesale price. The average water resale price was for this period 1.26 US$ per Mgals (compared to the average water price for residential and industrial user, 2.73 and 1.53 US$ per Mgals respectively).

As mentioned previously, one possible positive effect of vertical separation could be to induce more internal efficiency, Grossman and Hart (1986). In the specific case of the water industry, vertical separation may induce more network efficiency at the downstream stage and so, more water savings. Due to market imperfections on the upstream market, the marginal price of purchased water can be higher than the first stage marginal cost of production. Hence, the downstream firm may face more incentives to reducing network water losses. In Table 1, we

Table 1: Network efficiency and vertical integration

	Obs.	Network loss rate[(a)] Mean	Min	Max	Stdev.	Network loss index[(b)] Mean	Min	Max	Stdev.
Distribution Utilities	64	0.094	0	0.252	0.065	0.193	0	0.632	0.140
Integrated Utilities	684	0.175	0	0.515	0.094	0.304	0	1.990	0.251
Total	748	0.169	0	0.515	0.095	0.295	0	1.990	0.246

[(a)]: 1–Volume sold / volume produced, in (%).
[(b)]: (Volume sold - volume produced) / network length, in (Mgal/Feet).

compare the network efficiency of water utilities according to the proportion of water purchased to another service. It is interesting to notice that the network loss rate is smaller for NVI distribution utilities than for VI utilities (less than 10% on average versus more than 16% on average). This higher network efficiency of NVI distribution utilities may be attributed to a different network structure. In order to take into account this possible effect, a network loss index weighted by the network length has been computed. Results for this index are similar (and even stronger) to those obtained with the network loss rate. Distribution utilities tend to have less network losses than integrated services.

2.3 The data

Most of the data used for the econometric application have been provided by the Public Service Commission (PSC) of Wisconsin and come from the annual report filled each year by each water utility. The annual reports provide expenses by production stage (source of supply, pumping, water treatment, transmission and distribution). However, as we do not observe capital expenses by production stage, we estimate a variable cost function associated to each stage.[8]

Outputs The P&T or stage 1 output, Y_1, corresponds to the total water supply, that is the volume pumped from groundwater and/or withdrawn from surface water. Y_1 is measured in thousands of gallons (Mgal). The T&D or stage 2 output, Y_2, is the volume in Mgal sold by the

[8]Working on the electric network industry, Kwoka (2002) concludes that there are three main sources for economies of vertical integration. The first and the largest cost saving from integration is the reduction in the operating and maintenance costs of power supply. The second source identified by the author is lower operation costs of both transmission and distribution for integrated systems. Last, reduction of overhead expenses can be expected in an integrated system. As all this costs are operating expenses, we believe that considering a variable cost function with capital as a quasi-fixed input should not biased too much our economies of vertical integration.

water utility to final customers.

Inputs We consider 6 inputs that may enter the production process at the P&T stage and/or the T&D stage. The water utility variable cost is the sum of expenses for labor L, Energy E, Water purchased Y_1, Chemicals CH, Operation supplies and expenses OSE and Maintenance M. The labor input at stage s, L_s with $s = 1, 2$ is defined as the number of hours worked in the year. This input is obtained by dividing the labor expenses at stage s by the corresponding unit labor price w_{Ls}. See Appendix A for more details about the computation of w_{Ls}. The energy input E is measured in thousands of kilowatts per hour (MkWh). The unit energy price w_E is obtained by dividing the energy expenses by E. The water input Y_1 corresponds to the quantity of water purchased by a water utility to another in Mgal. The price is obtained by dividing the expenses for water purchase by Y_1. The operation supplies and expenses OSE and the maintenance M inputs correspond to various heterogeneous inputs. As it is difficult to express M and OSE as a physical quantity, we have used the following approach. We have defined the price indexes w_{OSEs} and w_{Ms} for $s = 1, 2$ by dividing the expenses by the output of the corresponding stage, Y_s. The prices indexes are then defined in US$ per unit of output. See Appendix A for more details. For the chemicals input as we do not observe any physical measure of the quantity used, we proceed in the same way and compute a price index as a unit cost per thousand of gallons treated. Some descriptive statistics may be found in Table 2.

Capital and technical variables The capital of the P&T stage is represented by the actual capacity (in gallons per minute) of the pumping and power equipment and by the storage capacity (in thousands of gallons) of reservoirs. These two variables are respectively denoted by $CAP1_P$ and $CAP1_{WT}$. The physical measure of the capital used for the T&D stage is given by the length (in feet) of the distribution network, *Leng*. The number of users is finally used as a technical variable, $User$. We also consider the network return as a technical variable. For a vertically-integrated utility, the difference $Y_1 - Y_2$ corresponds mainly to the volume lost at the T&D stage but also to a few losses at the P&T stage and the volume internally consumed by the water utility. Thus, the water network rate of return *Rt* is equal to $\frac{Y_2}{Y_1}$. For a non-vertically integrated distribution utility, the network rate of return corresponds to the ratio between the volume injected into the network and the volume sold to final users. The difference between these two volumes is equal to the transmission and distribution losses.

Table 2: Technological descriptive statistics

VI utilities: n=171

Variable	Unit	Mean	Std. Dev.	Minimum	Maximum
Y_2	Mgals	419,299	632,330	15,173	4,290,751
w_{L1}	US$/Hour	15.77	1.83	10.98	21.07
w_{OSE1}	US$/1,000 Mgals	33.87	42.87	0.13	458.94
w_{M1}	US$/1,000 Mgals	72.56	98.48	0.06	1,345.53
w_{E1}	US$ / Mkwh	64.39	22.09	0.09	334.79
w_{C1}	US$/1,000 Mgals	57.08	55.30	1.50	443.16
w_{L2}	US$/Hour	12.93	2.25	7.75	19.09
w_{OSE2}	US$/1,000 Mgals	66.08	73.74	0.10	435.61
w_{M2}	US$/1,000 Mgals	202.31	141.89	0.99	868.75
$Length$	Feet	252,186	275,575	17,435	1,731,558
$CAP1_P$	Gals/minute	4,175	5,760.64	0.00	33,200.00
$CAP1_{WT}$	Gals	1.40	2.11	0.00	20.07
$User$	-	3,137	3,775.86	57.00	22,919.00
Rt	%	0.83	0.09	0.48	1.00

NVI production utilities: n=17

Variable	Unit	Mean	Std. Dev.	Minimum	Maximum
Y_1	Mgals	5,399,188	11,047,260	74,435	48,326,120
w_{L1}	US$/Hour	16.31	1.78	10.98	20.54
w_{OSE1}	US$/1,000 Mgals	18.83	24.34	0.06	109.05
w_{M1}	US$/1,000 Mgals	65.74	88.14	0.52	631.02
w_{E1}	US$ / Mkwh	53.05	16.04	32.80	147.19
w_{C1}	US$/1,000 Mgals	65.09	75.56	5.45	269.34
$CAP1_P$	Gals/minute	79,029	204,338	650	876,000
$CAP1_{WT}$	Gals	10.79	18.86	0.30	79.00

NVI distribution utilities: n=16

Variable	Unit	Mean	Std. Dev.	Minimum	Maximum
Y_2	Mgals	717,247	626,336	131,223	2,377,548
w_{E2}	US$ / Mkwh	94.80	103.08	6.29	518.55
w_{Y_1}	US$/1,000 Mgals	0.97	0.35	0.47	1.79
w_{L2}	US$/Hour	13.93	2.11	10.90	19.07
w_{OS2}	US$/1,000 Mgals	56.97	39.95	3.24	150.78
w_{M2}	US$/1,000 Mgals	195.24	89.42	18.06	388.21
$Length$	Feet	395,508	307,998	87,677	1,098,054
$User$	-	5,526	5,104	1,174	19,569
Rt	%	0.91	0.07	0.75	1.00

2.4 The cost model

Last, a functional form must be chosen in order to estimate the NVI and the VI cost functions. A translog approximation has been chosen as it is convenient flexible functional form for computing substitution and network (density and scale) returns measures, Christensen, Jorgenson, and Lau (1973). The translog approximation of the cost function writes:

$$\begin{aligned}\ln(VC) &= \alpha_0 + \sum_i \alpha_i \ln w_i + \alpha_y \ln Y \\ &+ \frac{1}{2}\sum_i \sum_{i'} \alpha_{ii'} \ln w_i \ln w_{i'} + \frac{1}{2}\alpha_{yy}(\ln Y)^2 + \sum_i \alpha_{iy} \ln w_i \ln Y \\ &+ \sum_k \alpha_k \ln Z_k,\end{aligned} \tag{21}$$

where VC represents the variable cost, w the input prices, Y the output and Z the other variables (capital and technical variables). We assume that the cost function satisfies the following symmetric restrictions : $\alpha_{ii'} = \alpha_{i'i}$. To ensure homogeneity of degree one in input prices, we divide the variable cost and the input prices by the price of a given input.[9] A system of input demand equations is derived according to Shephard's lemma as:

$$S_i = \alpha_i + \sum_{i'} \alpha_{ii'} \ln w_{i'} + \alpha_{iy} \ln Y, \tag{22}$$

where S_i is the cost share of factor i. The system made of the cost function (21) and the cost share equations (22) less one[10] is the cost model to be estimated.

3 Assessing the economies of vertical integration

3.1 Cost model estimation procedure

The translog cost function will be estimated around the mean of observations (in logs). Hence, all right-hand side variables are normalized by their sample means. We add to each equation an error term independently and identically distributed. The cost system can be written in a more compact way as:

$$Y = R\beta + \varepsilon, \tag{23}$$

where Y is the $(MHT \times 1)$ vector of dependent variables, M the number of equations in the cost system, H the number of utilities, T the number of periods and K the number of parameters.

[9] This is equivalent to imposing a set of restrictions on cost function parameters : $\sum_i \alpha_i = 1$, $\sum_i \alpha_{ii'} = \sum_{i'} \alpha_{ii'} = 0$, $\sum_i \alpha_{iy} = 0$.

[10] As the sum of cost shares is equal to unity, one of them is dropped to avoid singularity of the variance-covariance matrix of errors.

R is the $MHT \times K$ matrix of regressors and β the parameter vector. As standard in panel data econometrics, the error term is decomposed in an unobservable individual specific effect, μ, and a classical disturbance term, u. The term $\varepsilon = \mu + u$ is a $MHT \times 1$ vector.

Two different methods have been used to estimate the cost model. As it will be discussed, some variables in the right-hand side term of the system may be considered as endogenous. A way to treat this problem is to use instrumental variables (IV) estimators. We use the generalized method of moments (GMM, see Hansen, 1982) to estimate the parameter vector β. This method extends the IV method without imposing distributional assumption on the error term, gives consistent estimator but possesses good properties only for large samples. As, we have only a limited number of observations for NVI production and distribution utilities, we prefer using a fixed-effects method on the seemingly unrelated regression (Within-SUR, see Zellner, 1962) system. As the fixed term vanishes after the variable transformation, the problem of correlation between the regressors and the fixed term disappears. However, it is not possible to identify the parameters of the time-invariant regressors and the Within-SUR estimator is not efficient. As all the regressors in the cost model vary with time, we are not affected by the first problem. Moreover, we will use an iterative procedure *à la Zellner* that allows to increase the efficiency of the Within-SUR estimator.

Following Cornwell, Schmidt, and Wyhowski (1992), The GMM estimator with panel data is based on L orthogonality conditions: $E[A'(Y - R\beta)] = 0$, where A is a $MHT \times L$ matrix of valid instruments. For the equation m, we choose the instruments of Hausman and Taylor (1981)[11]: $A_m = [WX_m, X_{(1)m}, Z_{(1)m}]$, where $WX = \{X_{it} - \bar{X}_i\}$ for all i and t, and X the matrix of time-varying (exogenous and endogenous) variables, $X_{(1)}$ the matrix of time-varying exogenous variables and $Z_{(1)}$ the matrix of time-invariant exogenous regressors. Using these moment conditions approximated by their empirical counterpart leads to the GMM estimator of the system (23):

$$\hat{\beta}_{SGMM} = (R'A\hat{\Phi}^{-1}A'R)^{-1}R'A\hat{\Phi}^{-1}A'Y, \tag{24}$$

where $\widehat{\Phi} = \frac{1}{H}\sum_{h=1}^{H} A_h'\hat{\Sigma}A_h$, with $\hat{\Sigma} = \frac{1}{H}\sum_{h=1}^{H}\hat{\varepsilon}_{h,IV}\hat{\varepsilon}'_{h,IV}$ and $\hat{\varepsilon}_{h,IV}$ is the first-step Instrumental Variable residual.

The second method (Within-SUR) consists in transforming all the variables of the system by the within operator, W. $\tilde{Y}$ and $\tilde{R}$ denote the variables transformed by W. Then, the equations of system are simultaneous estimated by the SUR method. The Within-SUR estimator of the

[11]There exist even more efficient Instrument-Variable procedures, see Amemiya and MaCurdy (1986), and Breusch, Mizon, and Schmidt (1989). However the number of overidentifying restrictions is already important: adding more instruments can lead to bias estimates.

system (23) writes:

$$\hat{\beta}_{WSUR} = [\tilde{R}'(\hat{\Sigma}_{\varepsilon}^{-1} \otimes I_{HT})\tilde{R}]^{-1}\tilde{R}'(\hat{\Sigma}_{\varepsilon}^{-1} \otimes I_{HT})\tilde{Y}, \tag{25}$$

where $\hat{\Sigma}_{\varepsilon}$ is the variance-covariance matrix estimated from the Within residuals.

3.2 Cost estimate result

In order to use the GMM method presented in the previous paragraph, it is necessary to make some exogeneity assumptions for constructing the orthogonality conditions for the GMM criterion. There are several sources of potential endogeneity in our system of equations. First, the exogeneity of output levels is quite doubtful in practice. As shown in Table 1 the network loss rate significantly differ according to the vertical structure of the water service. Garcia and Thomas (2001), working on a sample of French water utilities, have shown that there exists a trade-off between water network efficiency and costs of network repair. Injecting higher water into the distribution network (and thus having higher losses) may be in some cases a cost effective alternative to network maintenance costs. Second, as some input unit prices are computed as a function of the water output, they may be endogenous if the latter is. For these reasons, we assume that the water volumes and the water network rate of return are endogenous in our model. Moreover, we will test the input price endogeneity using a Hansen test.

Vertically-integrated water utilities The 50 parameters of the variable cost function for VI utilities have been estimated by GMM, see Table C.1 in Appendix C. In fact and taking into account the cost share equations, the total number of parameters to be estimated is 113. However, since there are some cross-equation parameter restrictions, all structural parameters enter the cost equation. As said above, we have chosen the Hausman-Taylor's instruments, so that 183 instruments are used for our estimation. We have checked for the validity of moment conditions with the Hansen test statistic, which is equal to 60.25 with 70 degrees of freedom. The p-value of the test is 0.7906. Our model specification and the choice of instruments are not rejected at the 5 percent level. Table C.1 gives the estimate of the variable cost functions for the VI utilities. Recall that in this case the cost related to each studied stage depends not only on its own variables (input prices as well as capital and technical variables) but also on the variables of the other stage.

Non-vertically integrated water utilities As the number of observations is limited to 68 for NVI production utilities and 64 for NVI distribution utilities, the cost function cannot be estimated using GMM. We use a Within-SUR model. Results of estimations is presented in Table C.2 and Table C.3.[12]

3.3 Analysis of cost estimate

Marginal and average costs From the cost function estimates, we have computed the marginal costs for the VI service and for the NVI utilities, see Table 3. We report in the following table estimated marginal and the average costs for the average utility. First, our estimates show quite low average and marginal costs. This is especially true for the NVI production utility. Second, these results give a good idea of the cost differential between the two stages. In particular, for the average service the sum of marginal costs for each stage is greater than the overall marginal cost. The main explanation is that the NVI distribution utilities bear water purchased expenses whereas these expenses are not borne by the VI utilities. Third, when we compare MVC and AVC, the greater value of AVC for the average VI utility seems to indicate the existence of economies of scale. On the other hand, the small difference between MVC and AVC for the NVI Utilities prompts us to be reserved on the nature of returns to scale. One possible explanation is that the sizes of the average VI and NVI utilities are significantly different. The size on the average VI utility (both measured in term of number of customers, water sold to

Table 3: Estimates of marginal and average costs

		Average utility	Minimum	Maximum
NVI Production utility	MVC	0.2064 (0.0349)	0.0887	0.9924
	AVC	0.1959 (0.0250)	0.1111	1.3540
NVI Distribution utility	MVC	1.0248 (0.0394)	0.6862	2.4040
	AVC	1.1188 (0.0102)	0.7608	2.4358
VI utility	MVC	0.7589 (0.0594)	0.0317	2.4985
	AVC	1.2021 (0.0448)	0.0645	3.8196

Notes: MVC for marginal variable cost, AVC for average variable cost. For the average utilty, values in parentheses give standard errors computed using the *delta* method, see Kmenta (1986).

[12]In order to check that firm's technological characteristics are not the same whether they are integrated or not, we have separately estimated the cost function for the production and the distribution stages using the VI utilities (648 observations). Then we have compared the estimated cost parameters with those obtained using the NVI production (68 observations) and distribution (64 observations) services. All these estimations are available from the authors upon request. The estimated coefficients appear to be significantly different both for the production and the distribution stages. This result tends to confirm that the technological characteristics of the water utilities differ according to the vertical structure (VI versus NVI). In such a case, estimating a single cost function on the whole dataset would clearly result in a mispecification of the econometric model.

final users, length of the network) is significant smaller than the size of the average NVI utility. The VI utilities may not have exhausted all economies of scale. It is possible that imposing the average VI utility to produce higher level of water will not result in the presence of scale economies.

Cost elasticities We now consider the way the number of customers, the volume of production and the size of the network may affect the variable cost. Considering both the number of customers and the length of network allows us to distinguish between returns to density (with respect to production and customers) and returns to scale in the water distribution process. The elasticity of production density EPD is computed as:

$$EPD = 1/\varepsilon_Y, \tag{26}$$

where ε_Y denotes the cost elasticity with respect to output. Returns to production density are increasing (implying economies of density), constant or decreasing when EPD is greater than 1, equal to 1 or less than 1, respectively. The returns to production density measure the cost savings that result from an increase in production, holding constant both the number of customers constant (i.e, the demand per user increases) and the size of network. The elasticity of customer density ECD is computed as:

$$ECD = 1/(\varepsilon_Y + \varepsilon_{User}), \tag{27}$$

where ε_{User} is the cost elasticity with respect to the number of users. Returns to customer density are increasing, constant or decreasing when ECD is greater than 1, equal to 1 or less than 1, respectively. The returns to customer density measure the cost savings that result from an increase in production to satisfy the demand from new customers (here the demand per customer is constant) for a given level of capital. Denoting by ε_K the cost elasticity with respect to capital K, elasticity of scale SCE is defined as:

$$SCE = (1 - \varepsilon_K)/(\varepsilon_Y + \varepsilon_{User}). \tag{28}$$

Returns to scale are increasing (economies of scale), constant or decreasing when SCE is greater than 1, equal to 1 or less than 1, respectively. Returns to scale measure the proportional increase of water volume and number of users made possible by a proportional increase of all inputs (including capital). For NVI production utilities, returns to density and returns to scale can not be differentiated because there is no distribution network and the only customer is the distribution service that purchases drinking water for delivering to its users.

All scale measures are computed for the average utility (at the sample mean of the variables) and are presented in Table 4. On one hand, we find returns to production density significantly

Table 4: Estimates of network returns for the average utility

		Average utility	Minimum	Maximum
NVI Production utility	EPD	–	–	–
	ECD	–	–	–
	SCE	1.4143 (0.3176)	0.7823	3.8924
NVI Distribution utility	EPD	1.0917 (0.0449)	0.9993	1.1952
	ECD	1.0049 (0.0618)	0.9261	1.0919
	SCE	1.0740 (0.0475)	0.9898	1.1671
VI utility	EPD	1.5839 (0.1155)	1.3937	2.1924
	ECD	1.4029 (0.1224)	1.2516	1.8601
	SCE	1.1668 (0.0879)	1.0409	1.5470

Notes: EPD for elasticity of production density, ECD for elasticity of customer density and SCE for scale elasticity. For the average utility, values in parentheses give the standard errors computed using the *delta* method, see Kmenta (1986).

different from 1 at 5% level (both for the average VI utilities and NVI distribution utilities). Existence of such economies of density means that an increase of the demand per user will result in a decrease of the average cost. These unexploited economies of density are greater when the water utility is vertically integrated. On the other hand, the returns to customers density are constant for the average NVI distribution utilities whereas they are strongly and significantly increasing (1.40, at 1% level) for the VI water utilities, at the sample mean. In the case of an integrated service, the network is not overloaded in terms of number of customers and so the network may accommodate more customers at a lower cost.

Concerning the NVI production utilities, the range for the scale elasticities is quite large indicating an important diversity in cost savings. However, for the average utility the returns to scale are not significantly different from 1 (constant returns). It is not surprising to find constant returns to scale for the average production utility since the production/generation stage in network utilities is often considered as potentially competitive. Nevertheless, the parameter related to the square of volume (in logarithm) is significantly positive, see Table C.2. This means that the returns to scale tend to increase with the water production. A possible interpretation of this result is that large production utilities benefit from high level of specialization and are able to exploit some scale economies. As a consequence, a vertical integration of the smallest production services would allow to save on the production cost. At the sample mean, the returns to scale are significantly different from 1 at a 5% level for the average VI utility. Existence of economies of scale in this case means that an increase of the service (i.e. production, customers and network) would result in a decrease of the average cost. This result is not surprising as it is a common view to say that the provision of network facilities for drinking water supply exhibits scale economies of such significance that it can be regarded as a natural monopoly. Last, the returns to scale for the NVI distribution utilities are not significantly greater than 1. This means that on average the water utility has exploited the economies of scale: the size of the network is efficient. Besides the size of the network is larger on average for the NVI distribution services than for the VI water services.

3.4 Results on vertical integration

Overall economies of vertical integration In order to estimate the overall economies of vertical integration, we have simulated the cost for different levels of final output and different prices for the intermediate good, both for a vertically integrated utility and for a non-vertically integrated structure. More precisely, we proceed in the following way.

(1) We compute the estimated total cost for a VI utility assigned to sold to final users different quantities $\{Y_{2_1}, \ldots, Y_{2_K}\}$ uniformly distributed over a relevant range of values.

(2) We compute the estimated cost for a NVI distribution utility, assigned to sold to final users the same quantities $\{Y_{2_1}, \ldots, Y_{2_K}\}$. For each quantity of final output Y_{2_k}, we consider L possible prices of the intermediate good $\{w_{Y_{11}}, \ldots, w_{Y_{1L}}\}$. This results in $K \times L$ estimates of the cost of the NVI distribution utility and $K \times L$ derived demands in water, $Y_1^{nvi}(Y_{2k}, w_{Y_{1l}})$.

(3) We then compute the estimated cost for a NVI production utility assigned to produce the quantities $Y_1^{nvi}(Y_{2k}, w_{Y_{1l}})$.

(4) We compute total cost of production of the NVI structure, net of the cost for the intermediate good for each $(Y_{2_k}, w_{Y_{1l}}), \ldots, k = 1, \ldots K$ and $l = 1, \ldots L$.

(5) We compute the global economies of vertical integration GVI, defined by equation (12), for each $(Y_{2_k}, w_{Y_{1l}}), \ldots, k = 1, \ldots K$ and $l = 1, \ldots L$.

Notice that the capital variables are adjusted to each level of production. A statistical relationship between the level of production and the capital infrastructure (pumping and power equipment, storage capacity, network length) is first estimated for each class of utility. When

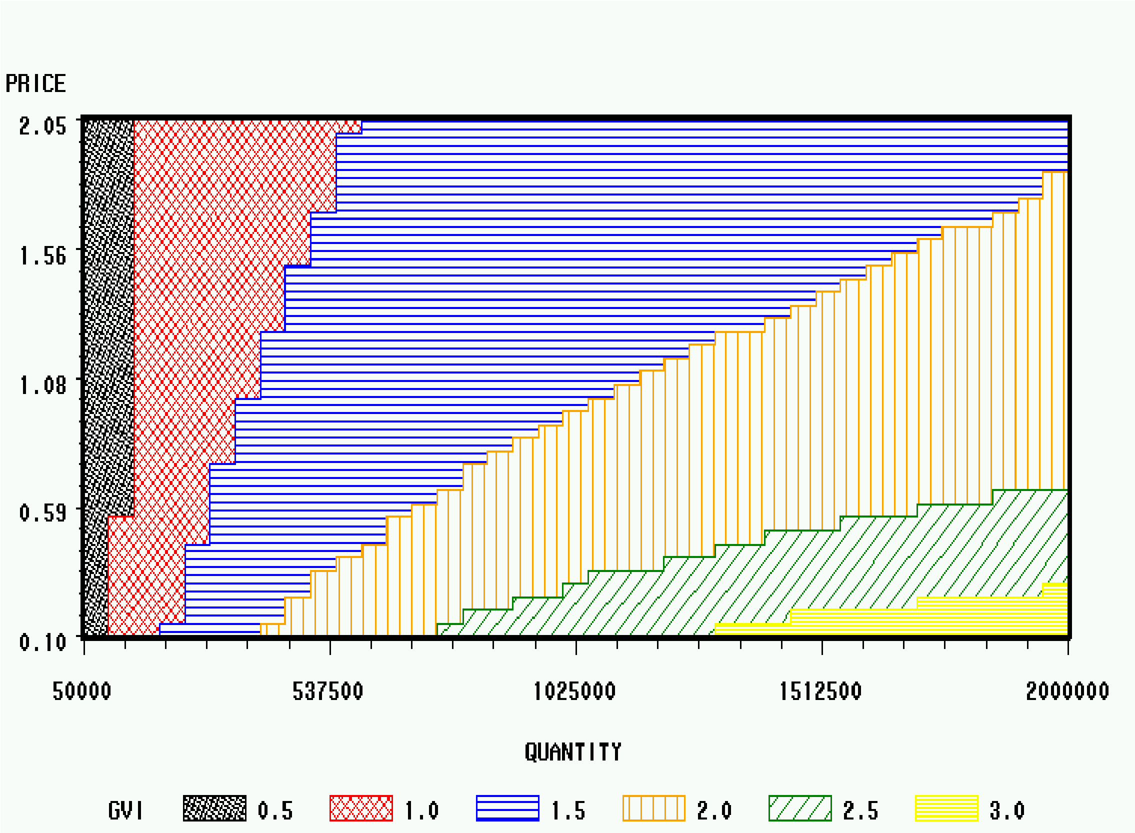

Figure 1: Global Economies of Vertical Integration

computing the cost associated to the different production level, the capital variable are adjusted according to the estimated statistical relationship. As the cost of a non-vertically integrated structure depends on the price for intermediary water, the overall economies of vertical are given for different level of the final output but also for different price of the intermediary good.

First, in the $(w_{Y_1} \times Y_2)$ space we both observe zones with global economies of vertical integration and with diseconomies. This means that there are both zones where a VI structure can produce water at a lower cost than a NVI structure, and other where a NVI structure is more cost effective. We find there are global economies of vertical integration for small services (i.e. for utilities characterized by a small volume of water sold to final users) and when the intermediary price for water is high (high intermediary prices create important distortions in term of input allocation). For small utilities, integration involves significant technological and transactional economies. This suggests that undue fragmentation can lead to a misallocation of resources (fragmentation of responsibilities for planning, investment, operations and maintenance may lead to a loss of efficiency because decision-makers do not have an appropriate level of control over decisions and actions that affect their efficiency). It is also likely that the market power on the intermediary good does not favor small utilities.

Second, for a given price of intermediate water, the lower is the final output, the higher are global economies of vertical integration. One possible explanation is that, for small water utilities,the specialization of inputs across stages is quite limited because the production process is more simple. Hence, there are higher interdependences across stages for small utilities than for large ones, which means that a VI structure is more cost effective in that case. For a given level of the final output, the higher is the intermediate water price, the higher are global economies of vertical integration. A high price of the intermediate water good means a high mark-up on the upstream market. This creates important distortions in term of input allocation at the downstream stage. In such a case being integrated would result in important cost savings.

Third, it is interesting to see where the average VI and NVI distribution utilities are located in the $(w_{Y_1} \times Y_2)$ space. For the average NVI distribution utility, the water price is 0.97 US$ per 1,000 Mgals and the final volume sold is 717,247 Mgals. Moreover, the GVI index is equal to 1.56: a vertical integration of the average NVI distribution utility would result in a significant increase of the production cost. The vertical structure of the average NVI distribution utility is optimal. The water volume sold by the average VI utility is equal to 419,299 Mgals. Whatever the water price on the intermediate market (on a relevant range, that is from 0.1 to 2 US$ per 1,000 Mgals), we find diseconomies of vertical integration. Vertical separation of the production stages would result, in such a case, in cost saving.

Last, our findings are significantly different from what has been previously found by Kaserman and Mayo (1991), Kwoka (2002) and Nemoto and Goto (2004) working on the electric utility industry. They both found that vertical integration results in cost saving for almost all production levels, at the exception of the smallest ones. Kwoka (2002) reports for example that at the mean levels for distribution and generation outputs, the efficiency gain from integration is 42 percent. We do also find global economies of vertical integration but only for small levels of final output. One possible explanation is that the need for coordination between generation, transportation and distribution is much more important in the electric industry than in the water sector. It is for example well-know that a real-time management of power flows is required in order to guarantee energy balance in the network and to prevent failure of the system. In the same vein, as electricity flows across the network in accordance with the laws of physics, it can not be controlled through a command and control system. This may impose high externality costs in case of non-vertically integrated systems. The need for such a coordination between the different stages may be less stringent for a water network than for an electric system.

Our results also differ from those obtained for two other natural resource industries, namely the gas and the oil sectors. Oil and gas companies are usually active in several sectors of activity including exploration, production, transport, distribution, etc. But, an important motivation for the vertical integration of oil an gas companies is to mitigate the impact of intermediate good price cycles and, hence to reduce profit volatility, (Perruchet and Cueille 1991). Such an effect is not present in the water network industry as the water price does not strongly fluctuate. Before deriving the economic implications of these results, we still need to isolate the technological economies of vertical integration from the global ones.

Technological economies of vertical integration We now evaluate the level of technological economies of vertical integration. We proceed in the following way.

(1) We compute the estimated marginal cost of production for a non-vertically integrated producer utility for K different level of Y_1, $\{Y_{1_1}, \ldots, Y_{1_K}\}$.

(2) Given that the volumes $\{Y_{1_1}, \ldots, Y_{1_K}\}$ are sold by the non-vertically integrated producer to the non-vertically integrated retailer utility at their marginal cost, we compute associated final output $\{Y_{2_1}, \ldots, Y_{2_K}\}$ and the associated costs.

(3) We compute the production cost of a vertically-integrated utility assigned to sold to final users the different quantities $\{Y_{2_1}, \ldots, Y_{2_K}\}$.

(4) We compute the technological economies of vertical integration for $\{Y_{2_1}, \ldots, Y_{2_K}\}$ defined by equation (20).

In Figure 2, we have plotted the technological economies of vertical integration, as defined by equation (20). As mentioned previously, this measure is computed for different levels of final output. Remember that TVI ≤ 1 means that there are technological economies of vertical integration. First, there are technological economies of vertical integration only for small levels of final output (for a final output less than 200,000 Mgals). This means that, if marginal cost pricing is implemented on the upstream market, a vertically integrated structure is a cost effective solution only if the utility is small enough. The technological economies of vertical integration for small services can also be understood by considering the characteristics of their production and distribution costs. In case of a small size, the distribution service can capture the economies of scale at the production stage by integrating it. The aggregation of the average production

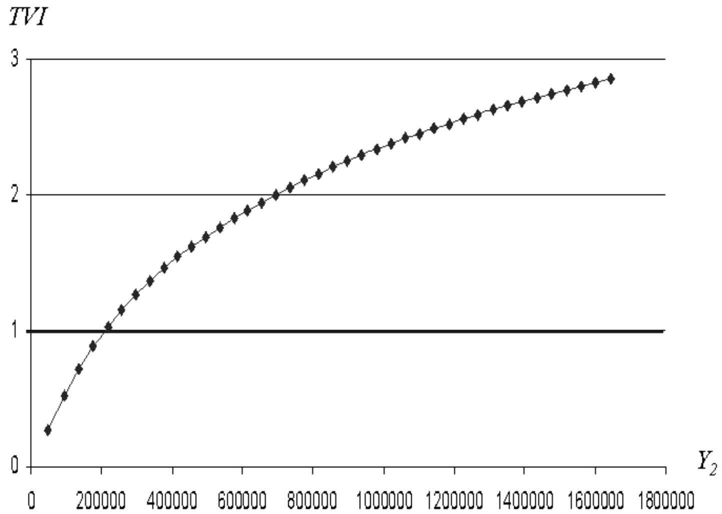

Figure 2: Technological Economies of Vertical Integration

and distribution cost functions allows to produce at a level of production with a overall average cost closer to its minimum.

From this Figure, the vertical organization of Wisconsin water utilities can be discussed. First, for 81 VI water utilities (47% of the sample), the volume of water sold to final users is smaller than 200,000 Mgals. As these services belong to a zone with technological economies of vertical integration, their vertical organization is optimal. Notice however that, for the average VI Wisconsin water utility, the TVI index is equal to 1.55: if the regulator is able to enforce marginal cost pricing, vertically separated utility may result in important efficiency gain. Second, for 14 NVI distribution utilities (88% of the sample), the volume of water sold to final user is greater than 200,000 Mgals. The vertical organization of most of NVI distribution utilities is cost efficient. To conclude, the technological economies of vertical integrations help understanding why the average VI utility in the Wisconsin is smaller (both in terms of water delivery or customer number) than the NVI distribution utility.

These result are difficult to compare with the economies of vertical integration reported by Kwoka (2002) and by Kaserman and Mayo (1991) for the electric network industry because these papers do not distinguish the global and technological economies. However given the high level of global economies reported by these papers, it is likely that applying our framework to their data would result in finding technological economies of vertical integration for large electric utilities, an opposite conclusion to what we find for water utilities. We believe that specialization of inputs by production stage (or asset specialization) is much more important than coordination across stages for large water utilities than for large electric utilities.[13] This may explain why large water utilities are characterized by important technical diseconomies of vertical integration whereas large electric utilities are more likely to present economies. The higher network efficiency of NVI distribution utilities (see Table 1) may be viewed as a result of the stage specialization.

These results have some important policy implications in term of the water industry organization. Based on efficiency considerations there is no clear answer to the debate about separation of production & treatment and transportation & distribution stages. In case of a small water network, a vertically integrated structure should be preferred. But separation of stages is a more cost effective solution in the case of large water utilities if marginal cost pricing can be enforced on the upstream market. In the case of separation of production stages, one important task of the water regulation authority will be to promote and ensure enough pricing efficiency on the upstream market. It is likely that, given the limited number of production utilities, such a market will suffer from a lack of competition.

Conclusion

As a matter of general principle, public policies should seek to isolate the natural monopoly elements in an industry and to prevent the firms entrusted with activities with natural monopoly characteristics from extending their monopoly power beyond the segment of the market where these characteristics exist. In network industries characterized by multi-stage production processes, achieving this objective requires to analyze the cost structure of vertically-integrated firms. The question of vertical integration addressed in this paper is not a simple issue as many factors need to be carefully analyzed. These factors include technical, technological and economic constraints to separation. The potential benefits of vertical separation have to be carefully balanced against the loss of scope and scale economies, the costs of sector restructuring, and the possible loss of some internalization of externalities. If these factors (in particular, economies of scope) are significant enough, there may be a case for the continuation of a vertically-integrated monopoly. If not, a vertical separation could be desirable. If parts of an industry must remain

[13] A good example of coordination requirement between production and distribution in the electric industry is power pools. Power pools are agreements among independent utilities aiming at coordinating certain activities (joint scheduling of shutdowns for instance). To our knowledge, there are no similar agreements in the water sector. The main reason for connecting to water networks is to secure water sources. Technological economies of vertical integration from a better coordination of stages are likely small in the water industry.

vertically integrated, vertical conduct regulation or measures of partial vertical separation will be needed to establish conditions for effective competition.

Identifying sources of economies of vertical integration is crucial in order to define the economic policy that must be implemented. Economies of vertical integration may result from technological effects as a better coordination across stages or the non-duplication of fixed costs, but it can also be the consequence of market imperfections at upstream stages of the production process. By estimating separately the cost functions of vertically integrated and non-vertically integrated structures, we have proposed a framework that allows to distinguish the technological economies of vertical integration from the impact of market imperfections.

These issues related to the vertical integration of water utilities have been investigated by estimating the production and distribution cost functions for some North American water utilities. More precisely, we have considered a sample of Wisconsin water utilities where the most common firm is an integrated utility responsible for all aspects of service provision in the area under its jurisdiction. The traditional view is that water utilities constitute as a whole a natural monopoly that must be regulated. However by considering separately the production and the distribution stages, we have shown that there are in fact some evidences that disintegration of these two stages may lead to cost savings (at the exception of the smallest services). Moreover, the returns to scale at the production and distribution stages are constant. Competition could have at each stage some welfare improving effects. However, introducing competition can raise serious difficulties, in particular for the network itself which can not be duplicated.

But focusing only on global economies of vertical integration to assess the optimal structure of an industry can be misleading as global economies of vertical integration may result from market imperfection or from technological effects. We have shown that there are no evidence for technological economies of vertical integration (at least for large utilities) between the production and distribution stages. This means that if marginal cost pricing can be enforced on the upstream market for the intermediary good, vertically disintegrated utilities should be promoted. This result for the water network industry appears to be different from what has been previously found by the applied literature for the electric industry, see Kaserman and Mayo (1991), Kwoka (2002) and Nemoto and Goto (2004) among others. We believe that for the water network industry, the specialization of inputs by production stage (or the asset specificity) generates more cost savings than the coordination across stages; a situation that may not hold for electric utilities. This may explain why most of the water utilities in our sample are characterized by important technical diseconomies of vertical integration. Finally, it is interesting to notice that some countries are already engaged into a vertically disintegration process. This is for example the case in the Portugal where multi-municipal companies have been created in 1993 in order to provide the municipalities with treated bulk water and/or treatment of the collected wastewater.

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A Description of data sources

Labor The technical and financial annual reports give labor expenses at 5 steps of the production process: Source of supply (SS), Pumping (P), Treatment (T1), Transmission (T2), Customers account (CA) from 1997 to 2000. In order to estimate the two-stage cost function, we need to define for each water utility and at the P&T and T&D stages the unit cost of labor.

The unit cost of labor is derived from the Occupational Employment Statistics (OES) Survey published each year by the US Bureau of Labor Statistics, Department of Labor. This survey gives the mean hourly wage for the 11 Metropolitan Areas (MA) of the Wisconsin and for various occupations. We have matched each water utility with the corresponding Metropolitan Area. Then, we have matched each step (SS, P,T1, T2 and CA) with the OES corresponding occupation.

For each water utility, the P&T unit cost of labor is then the sum of the unit labor costs for SS, P and T1 weighted by the expenses for these three categories. The T&D labor cost corresponds to the sum of the unit labor costs for T2 and CA weighted by the expenses for these two categories. Both labor prices w_{Ls} $s = 1, 2$ are in $US\$/hours$.

Energy and Purchased water The price of energy w_E is defined as the expenses for fuel or power purchased divided by the quantity of energy used in thousands of kilowatts per hour ($MkWh$). The unit price of energy is thus defined in US$ per $MkWh$. The price of purchased water w_{Y_1} is defined as the ratio of purchased water expenses to the quantity of water purchased in thousands of gallons (Mgals). The unit price for the water input is in US$ per Mgals.

Operation supplies and expenses, Maintenance and Chemical The main difficulty for defining OSE and M unit prices is that the expenses associated to these inputs are very heterogeneous. In order to construct a price index associated to each input, w_{OESs} and w_{Ms} for $s = 1, 2$, we have divided the corresponding expenses by the output of the stage considered, Y_s in millions of gallons (MMgals). Price indexes are defined in US$ per unit of output. The implicit assumption is that the unobserved quantity of OES and M increases proportionally with the level of output. For the chemical input CH we do not observe any physical measure of the quantity used by the water utility. A price index is construct by dividing expenses for chemical by Y_1 in MMgals. The price of chemical is defined in US$ per MMgals.

B Input shares and cost descriptive statistics

Table B.1: Cost descriptive statistics for VI utilities, 684 observations

Variable	Mean	Min.	Max	Stdev.
VC	310281	13552	3243731	381930
S_{L1}	0.15	0	0.52	0.11
S_{OSE1}	0.04	0	0.41	0.05
S_{M1}	0.08	0	0.62	0.08
S_{E1}	0.17	0	0.69	0.08
S_{C1}	0.07	0	0.28	0.06
S_{L2}	0.18	0	0.73	0.13
S_{OSE2}	0.08	0	0.49	0.08
S_{M2}	0.24	0	0.68	0.12

Table B.2: Cost descriptive statistics for NVI production utilities, 68 observations

Variable	Mean	Min.	Max.	Stdev.
VC	1409974	27149	11985558	2683902
S_{L1}	0.320	0.110	0.578	0.139
S_{OSE1}	0.054	0.001	0.206	0.049
S_{M1}	0.171	0.003	0.468	0.091
S_{E1}	0.309	0.072	0.629	0.134
S_{C1}	0.146	0.000	0.395	0.108

Table B.3: Cost descriptive statistics for NVI distribution utilities, 64 observations

Variable	Mean	Min.	Max.	Stdev
VC	1010424	286355	3172686	791313
S_{L2}	0.05	0	0.17	0.04
S_{Y_1}	0.70	0.33	0.87	0.13
S_{OSE2}	0.19	0.05	0.38	0.08
S_{E2}	0.06	0	0.41	0.10

C Cost functions estimates

Table C.1: Cost function for VI utilities (GMM)

Variable (in log)	Est.	Stdev.	T-stat.	Parameter	Est.	Stdev.	T-stat.
Constant	9.721	0.370	26.07	$w_{M1} \cdot w_{M2}$	–0.004	0.002	–1.82
w_{OSE1}	0.025	0.003	7.79	$w_{E1} \cdot w_{C1}$	–0.002	0.003	–0.70
w_{M1}	0.060	0.004	16.17	$w_{E1} \cdot w_{L2}$	0.004	0.008	0.50
w_{E1}	0.063	0.017	3.83	$w_{E1} \cdot w_{OSE2}$	–0.012	0.004	–2.89
w_{C1}	0.071	0.015	4.68	$w_{E1} \cdot w_{M2}$	–0.003	0.006	–0.46
w_{L2}	0.312	0.013	24.60	$w_{C1} \cdot w_{L2}$	–0.007	0.007	–1.03
w_{OSE2}	0.179	0.007	25.10	$w_{C1} \cdot w_{OSE2}$	–0.006	0.004	–1.67
w_{M2}	0.168	0.005	32.28	$w_{C1} \cdot w_{M2}$	–0.014	0.004	–3.71
$w_{OSE1} \cdot w_{OSE1}$	0.015	0.002	8.68	$w_{L2} \cdot w_{OSE2}$	–0.043	0.011	–3.94
$w_{M1} \cdot w_{M1}$	0.036	0.003	14.33	$w_{L2} \cdot w_{M2}$	–0.027	0.012	–2.31
$w_{E1} \cdot w_{E1}$	0.026	0.004	6.83	$w_{OSE2} \cdot w_{M2}$	–0.027	0.006	–4.68
$w_{C1} \cdot w_{C1}$	0.030	0.003	8.98	Y_2	0.631	0.046	13.71
$w_{L2} \cdot w_{L2}$	0.066	0.033	1.97	$Y_2 \cdot Y_2$	0.015	0.048	0.30
$w_{OSE2} \cdot w_{OSE2}$	0.101	0.009	11.80	$Y_2 \cdot w_{OSE1}$	0.002	0.005	0.38
$w_{M2} \cdot w_{M2}$	0.090	0.005	16.78	$Y_2 \cdot w_{M1}$	0.009	0.005	1.82
$w_{OSE1} \cdot w_{M1}$	0.000	0.001	–0.02	$Y_2 \cdot w_{E1}$	0.021	0.011	1.86
$w_{OSE1} \cdot w_{E1}$	0.000	0.002	–0.12	$Y_2 \cdot w_{C1}$	–0.001	0.008	–0.08
$w_{OSE1} \cdot w_{C1}$	0.000	0.002	0.00	$Y_2 \cdot w_{L2}$	–0.071	0.020	–3.52
$w_{OSE1} \cdot w_{L2}$	–0.004	0.004	–0.97	$Y_2 \cdot w_{OSE2}$	0.031	0.011	2.82
$w_{OSE1} \cdot w_{OSE2}$	–0.005	0.003	–1.71	$Y_2 \cdot w_{M2}$	0.013	0.007	1.85
$w_{OSE1} \cdot w_{M2}$	–0.003	0.002	–1.24	$Length$	0.168	0.088	1.92
$w_{M1} \cdot w_{E1}$	–0.005	0.002	–2.79	$CAP1_P$	0.011	0.029	0.37
$w_{M1} \cdot w_{C1}$	–0.002	0.001	–1.35	$CAP1_{WT}$	0.170	0.108	1.57
$w_{M1} \cdot w_{L1}$	–0.014	0.004	–3.84	$User$	0.082	0.060	1.35
$w_{M1} \cdot w_{OSE2}$	–0.006	0.002	–2.58	Rt	–0.411	0.097	–4.23

Notes : N=171, T=4, $\bar{R}^2 = 0.96$.

Table C.2: Cost function for NVI production utilities (Within-Sure)

Variable (in log)	Est.	Stdev.	T-stat.
Y_1	1.053	0.074	14.22
w_{L1}	0.001	0.052	0.02
w_{OSE1}	0.040	0.013	3.06
w_{M1}	0.255	0.014	17.62
w_{E1}	0.367	0.045	8.21
w_{C1}	0.337	0.036	9.40
$CAP1_P$	-0.664	0.285	-2.33
$CAP1_{WT}$	0.174	0.163	1.07
$Y_1 \cdot Y_1$	0.238	0.056	4.25
$w_{L1} \cdot w_{L1}$	0.073	0.021	3.51
$w_{OSE1} \cdot w_{OSE1}$	0.021	0.003	6.74
$w_{M1} \cdot w_{M1}$	0.117	0.005	23.16
$w_{E1} \cdot w_{E1}$	0.056	0.014	4.04
$w_{C1} \cdot w_{C1}$	0.084	0.012	6.92
$Y_1 \cdot w_{L1}$	-0.061	0.025	-2.44
$Y_1 \cdot w_{OSE1}$	0.009	0.008	1.08
$Y_1 \cdot w_{M1}$	0.024	0.007	3.47
$Y_1 \cdot w_{E1}$	0.042	0.023	1.85
$Y_1 \cdot w_{C1}$	-0.014	0.017	-0.83
$w_{L1} \cdot w_{OSE1}$	0.003	0.005	0.71
$w_{L1} \cdot w_{M1}$	-0.031	0.005	-5.85
$w_{L1} \cdot w_{E1}$	0.011	0.014	0.73
$w_{L1} \cdot w_{C1}$	-0.056	0.013	-4.38
$w_{OSE1} \cdot w_{M1}$	-0.001	0.003	-0.24
$w_{OSE1} \cdot w_{E1}$	-0.020	0.004	-4.86
$w_{OSE1} \cdot w_{C1}$	-0.004	0.004	-0.99
$w_{M1} \cdot w_{E1}$	-0.054	0.005	-11.23
$w_{M1} \cdot w_{C1}$	-0.031	0.004	-7.61
$w_{E1} \cdot w_{C1}$	0.007	0.009	0.75

Notes : N=17, T=4, $\bar{R}^2 = 0.769$

Table C.3: Cost function for NVI distribution utilities (Within-Sure)

Variable (in log)	Est.	Stdev.	T-stat.
Y_2	0.916	0.038	24.31
w_{L2}	0.013	0.020	0.66
w_{Y_1}	0.795	0.022	36.58
w_{OSE2}	0.180	0.013	14.00
w_{M2}	0.012	0.012	1.01
$Length$	-0.069	0.085	-0.81
$User$	0.079	0.044	1.81
Rt	-0.963	0.031	-31.44
$Y_2 \cdot Y_2$	-0.044	0.034	-1.31
$w_{L2} \cdot w_{L2}$	0.012	0.008	1.51
$w_{Y_1} \cdot w_{Y_1}$	0.119	0.010	12.10
$w_{OSE2} \cdot w_{OSE2}$	0.094	0.007	14.27
$w_{M2} \cdot w_{M2}$	0.001	0.003	0.17
$Y_2 \cdot w_{L2}$	-0.018	0.010	-1.81
$Y_2 \cdot w_{Y_1}$	0.026	0.011	2.31
$Y_2 \cdot w_{OSE2}$	-0.014	0.007	-1.97
$Y_2 \cdot w_{M2}$	0.005	0.009	0.60
$w_L \cdot w_{Y_1}$	-0.012	0.007	-1.65
$w_{L2} \cdot w_{OSE2}$	-0.001	0.005	-0.25
$w_{L2} \cdot w_{M2}$	0.001	0.003	0.39
$w_{Y_1} \cdot w_{OSE2}$	-0.099	0.006	-17.03
$w_{Y_1} \cdot w_{M2}$	-0.008	0.004	-1.81
$w_{OSE2} \cdot w_{M2}$	0.006	0.004	1.62

Notes : N=16, T=4, $\bar{R}^2 = 0.932$.