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LOCAL GOVERNMENT INVESTMENT IN MUNICIPAL WATER AND SEWER INFRASTRUCTURE: *Adding Value to the National Economy*

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Mayors Briefing

Public infrastructure is the foundation for economic development. Access to roads, water, sewer, communication technologies, and electricity are all essential to the economy. Investment in both the infrastructure (***i.e.,*** the purchase of physical plant and equipment) and the operation and maintenance (e.g., labor, supplies) of these structures can expand the productive capacity of an economy, by both increasing resources and enhancing the productivity of existing resources.

This paper summarizes estimates of direct economic impacts of water and sewer investment. The estimates exhibit a wide range, but the consensus is that public infrastructure investment yields positive returns, and investment in water and sewer infrastructure has greater returns than most other types of public infrastructure.

- A recent study estimates that one dollar of water and sewer *infrastructure investment* increases private output (Gross Domestic Product, GDP) in the *long-term* by $6.35.

- With respect to *annual general revenue and spending* on operating and maintaining water and sewer systems, the US Department of Commerce's Bureau of Economic Analysis estimates that for each additional dollar of *revenue (or the economic value of the output)* of the water and sewer industry, the increase in *revenue (economic output)* that occurs in all industries is $2.62 in that year.

- The same analysis estimates that adding 1 job in water and sewer creates 3.68 jobs in the national economy to support that job.

However, there are many factors to consider when interpreting the results. Measures of the return on public infrastructure investment vary geographically and are affected by past investment. For example, if public water and sewer infrastructure is adequate and of high quality, the rates of return on further investment may be lower than it would be if infrastructure were inadequate. Optimal levels of investment also depend on the method used to generate additional funding. For example, if greater investment in public infrastructure is going to be funded by increased taxes, the effect of those taxes on the economy must be taken into account.

These conclusions are based on a review of 310 economic studies, books, and government and non-government reports. Although a large body of literature estimates the return on investments in public infrastructure, only a sub-set of the literature focuses on the returns to investment in water and sewer infrastructure. Some early studies estimated that returns were very large, while others indicated no meaningful returns on investment in public infrastructure. Over time, the methodologies used by researchers have evolved and the results have become more consistent. It has become clear that water and sewer investment can foster specialization and complement labor and private capital within an economy.

Specific types of investment may also generate *secondary or indirect benefits* such as fire protection and the increased provisioning of ecosystem services such as climate regulation, disturbance regulation, habitat, and cultural and recreational services. These services also have a positive effect on the economy. For example, protecting one hectare (10,000 square meters, or

2.471 acres) of a wetland for source water protection may yield a primary benefit of $4,177 annually in avoided treatment costs. However, the same wetland may yield an additional $10,246 annually in other ecosystem services. These secondary benefits are reviewed briefly, but are not the focus of this paper.

As the largest investors in water and sewer, municipalities have an interest in knowing the return on this investment. Overall, the reviewed literature indicate that water and sewer investment by local government creates significant value-added to the economy.

A. Introduction: The Need for Investment

The nation has considerable resources invested in drinking water and sewer services. Although local governments are major investors in this sector, other capital intensive services (i.e., transportation, communication, and electricity) compete for limited local resources. Beyond providing safe drinking water and environmental protection, water and sewer investments also contribute to economic growth in the local and national economies.

Infrastructure investment contributes to economic growth by expanding the productive capacity of a locality, region, state, or the nation as a whole. A new highway, for example, allows for increased transportation of people, goods, and services. But it does more. It creates opportunities for increased commerce as businesses will locate near the new road, providing additional jobs and output. Investments can enhance the productivity of existing infrastructure resources and increase the resource base of an economy through the addition of new infrastructure. Therefore public investment lowers the total production costs for private companies (Munnell 1992). Infrastructure investment can also contribute to economic growth through the expenditures associate with purchasing, installing, operating, and maintaining the infrastructure itself.

The goal of this paper is to describe the value-added from investment in municipal water and sewer. This paper reviews the body of relevant literature estimating the economic impact of water and sewer investment and presents our findings in the following five sections:

- Returns to Public Infrastructure Investment
- Returns to Annual Operations and Maintenance Spending
- Additional Indirect Impacts
- Additional Factors to Consider
- Conclusions

Local governments are the primary investors in water and sewer systems. According the US Census, state and local governments spent $36 billion on sewers and another $46 billion on drinking water in 2004-2005. In 2004, public spending on infrastructure reached a cumulative total of just over $312 billion, of which states and localities spent $238.7 billion, or 76 percent.[1] Water supply and sewer treatment projects took 32 percent of total state and local infrastructure investment, or $28.3 billion, in 2004 alone (CBO 2007). Of these combined state and local investments, the local government share of spending on sewer is over 95 percent, and over 99 percent for water supply (Anderson 2007). For example, of the $15.3 billion invested in sewer infrastructure by state and local governments in 2006, $14.7 billion or 96% came from local governments (Census 2008).

Despite these considerable and ongoing investments, the US Environmental Protection Agency projects that the nation's water systems will need to invest $276.8 billion through 2023 to

[1] In real dollars (i.e., adjusted for inflation), all types of infrastructure.

provide safe drinking water and $202.5 billion through 2028 to control wastewater pollution—figures that exclude needs related to growth (EPA 2005, EPA 2008).

Beyond investments in physical plant and equipment, spending on the operations and maintenance of water systems also is a major financial obligation for states and local governments. In 2004, spending by states and localities on water and sewer operations and maintenance was $51.2 billion. This represents a 34 percent share of their total operation and maintenance spending, second only to highway and roads (CBO 2007).

The research question in this paper focuses on defining the economic impact of investment in water and sewer systems, including investment in infrastructure, operations, and maintenance. Infrastructure investment can come from both the reinvestment and replacement of existing infrastructure (existing assets), and investment in new infrastructure (adding assets at the margin). Beyond the replacement or addition of infrastructure, there are also economic impacts associated with operations and maintenance (the provisioning of the service). Therefore, local decision makers may consider three ways that investment in water and sewer could create added value in the economy.

1. Capital reinvestment in existing infrastructure (replacement, rehabilitation, etc.)
2. Capital investment in new infrastructure
3. Operation and maintenance of existing infrastructure

From an economic perspective, the distinction between these categories is important, especially with regard to the methodology for estimating their impact. Existing infrastructure stocks affect the marginal productivity of new infrastructure. Assuming diminishing returns, a small increase in the stock of infrastructure would have a small economic impact if a large stock of infrastructure is already in place. Similarly, a large increase in the infrastructure stock is expected to have a large economic impact if the previous stock was small. Despite the importance of marginal impacts, many empirical studies focus on the average productivity of public infrastructure and cannot be used to assess whether the existing stock is efficient or if investment in new infrastructure is necessary (Romp and de Haan 2005).

How Does Infrastructure Affect the Economy?

Infrastructure investment can boost productivity by enhancing the productivity of existing infrastructure resources and by increasing the resource base of an economy by adding new infrastructure.

Existing Infrastructure

- On a periodic basis, infrastructure needs to be rehabilitated or replaced. This *reinvestment* maintains the value of the existing assets. Reinvestment is primarily spending on physical plant and equipment. It also involves labor costs for construction.

- On a daily basis, systems incur expenses to *operate* and serve customers and perform routine *maintenance* to prevent wear and tear. Beyond productivity gains, economic impacts primarily come from spending on labor and supplies.

New Infrastructure

- Periodically *new infrastructure* is added to the existing stock. This represents growth at the margin of the infrastructure stock. Beyond productivity gains, economic impacts result from payments for the new infrastructure and payments for its installation.

Models of Economic Output (What is a *Production Function*?)

To estimate the effects of infrastructure investment on the economy a conceptual model is needed to determine how they interact.

- A *production function* is a mathematical equation of the relationship between production inputs (e.g., capital and labor) and outputs (e.g. Gross Domestic Product).
    - The Cobb-Douglas production function is a specific production function (named for economists Charles Cobb and Paul Douglas) that assumes that output is an exponential function of inputs. In general, output (Q) is given by $Q = AK^{\alpha}L^{\beta}$, where:

        A represents technology or productivity

        K represents the amount of capital (K can be divided into several types of capital)

        L is the amount of labor (which also can be divided into several categories)

        α and **β** relate capital and labor to output. They are elasticities; i.e., they show the percentage change in output for a percentage change in inputs. These parameters often are estimated using regression models.
    - Water and sewer infrastructure are typically modeled as a type of capital, or technology. The *investment elasticity* describes the relationship between investment in water and sewer infrastructure and output.
- An *input-output model* maps out the economy as a whole. It measures how the output from each sector is used as an input in other sectors of an economy. It describes the inter-sector relationships through a series of *multipliers*.
- Other types of models have different basic assumptions and are analyzed using specific techniques.

Evolution of the Economic Literature

Since the late 1980s, academic interest in the role of public investment and economic growth has been revived. This was largely motivated by declines in public investment in the early 1970s and falls in economic productivity growth at roughly the same time. Arguments by Aschauer (1989) and others that there were significant linkages between economic growth and public infrastructure investments fueled the discussion. Many of these studies were estimations of *Cobb-Douglas production functions* with time series data. (*Production functions* describe how inputs are combined to produce outputs. See the text box "Models of Economic Output.") However, many of the early studies were controversial because of their sensitivity to small changes in data and methodological issues (CBO 2007; OECD 2006). The wide range of estimates made the results of older studies difficult to interpret from a policy perspective. Key points of concern in these early studies focused on methodological and econometric difficulties including causality and correlation (Romp and de Haan 2005; Gramlich 1994).

- *Direction of causality*: While public infrastructure may affect productivity and output, economic growth can also shape the demand and supply of public infrastructure services. This may cause an upward bias if feedbacks within the model are not addressed.

- *Spurious (false) correlation*: Output and public infrastructure data often have a *unit root*, meaning that the value tomorrow is its value today plus an unpredictable change. This unpredictable change can be viewed as the result of irregular policy decisions to start, stop, or change infrastructure projects to meet evolving priorities with respect to public infrastructure. If statistical models fail to account for this random process, they will misestimate the relationship between public infrastructure investment and output.

To address these issues, researchers have employed a number of statistical techniques, including testing variables for co-integration, using vector autoregression models, and using panel data approaches to estimate the relationships between public infrastructure and output (Gramlich 1994). Most recent estimates are significantly lower than previous estimates, possibly indicating that the earlier results did not account for some feedback effects (OECD 2006).

Major Methodological Approaches

Estimates of investment elasticites and of input-output (I-O) multipliers are two approaches used to capture how changes in the water and sewer industry affect the broader economy.

- Investment elasticities measure the relationship between inputs and output. In general, e*lasticities* give the percentage change in one variable for a percentage change in another. For example, *price elasticities of demand* show the percentage change in the quantity consumer's demand for a percentage change in price. In the public infrastructure literature, *investment elasticities* show the percentage change in output for a percentage change in the value of public infrastructure assets. Output usually is measured as gross state product or national GDP.

Interpreting Return on Investment and Spending

Investment

The relationship between infrastructure investment and economic output is captured by an *elasticity coefficient*. This represents what a one-percent change in infrastructure investment would have on economic output. For example, according to one estimate, a one percent increase in investment in water and sewer in Florida would increase output in Florida by approximately 0.2 percent. While that may seem small, it is in fact a very large impact. With annual gross state product (GSP) of $735 billion, the 0.2 percent increase in output is worth $1.4 billion.

Florida Economic Output (GSP)	Investment Elasticity	Impact of 1% Increase in the Stock of Water and Sewer Infrastructure
$ 734.5 billion	0.1959	$ 1.4 billion

Spending

One person's spending is another person's income. Therefore, when municipalities spend more on water and sewer infrastructure operations and maintenance these dollars contribute to workers wages and revenue for other businesses, which in turn spend the money in the economy.

This chain of spending results in a *multiplied* effect on the economy. These effects are captured by *multipliers* representing the impact of a one dollar investment on the economy. For example, for each additional dollar of water and sewer output in New Mexico there is $1.74 total increase in output that occurs in the economy as a whole.

- *Input-output multipliers* measure the economic impact of each sector of the economy on other sectors. The multiplier is the primary factor income to outside sectors (other industries) that sell to or buy from the water industry (direct beneficiaries of augmented water supply) (DOC 1997; Young 2005).

These two measures are used to quantify the impact that water and sewer infrastructure has on the economy. The elasticities show the effect that changes in investment have on the economy, while the I-O multipliers map out inter-industry interactions and capture the relationship between the water and sewer industry and other industries within a region, or the economy as a whole.

In a review of the theoretical and empirical literature on the link between public infrastructure investment and economic growth, Romp and de Haan (2005) identify the three major approaches economists have used to estimate elasticities.

- *Production-function approach*: An aggregated Cobb-Douglas production function is adapted to include the monetary value of the infrastructure stock. Most often infrastructure is a third factor in the production function (in addition to private capital and labor), or is incorporated into the production function as a part of the technological constraint (i.e., influences total factor productivity).

- *Cost-function approach*: The cost function for private sector firms are estimated assuming that public infrastructure is externally provided by the government as a free input. When firms optimize they decide the amount of the unpaid fixed input (public infrastructure) they want to use and the model satisfies the conditions of standard marginal productive theory – which the production-function approach violates.

- *Vector auto regression (VAR) models*: All variables are jointly determined with no *a priori* assumptions about causality (unlike the production function and cost-function approaches). VAR models test whether the causal relationship assumed in other approaches is valid, or whether feedback effects from output to infrastructure exist.

B. Returns to Public Infrastructure Investment

Effects of Investment in Public Infrastructure

Public infrastructure is the foundation for economic development. Access to roads, water, sewer, communication technologies, and electricity are all essential to the economy (Kemp 2005). Many different researchers have attempted to describe and quantify the effects that public infrastructure has on economic output. Most of this research was sparked by Aschauer's 1989 paper "Is Public Expenditure Productive," which concluded that reduced government spending on public infrastructure was one of the primary causes of the economic slowdown in the U.S. He used a production function in which state output is a product of labor, productivity, utilization, private capital, and public infrastructure. He found "core" public infrastructure (highways, mass transit, airports, electrical and gas facilities, water, and sewers) to have a profoundly positive effect on the productivity of state economies. The subsequent research on this topic builds on Aschauer's initial work, modifying the methodology, and either affirming or challenging the results. The economic output elasticities of public infrastructure are reported in Table 1, and other measures of the effect of public infrastructure on the economy are reported in Table 2.

Table 1: Investment Elasticities of Public Infrastructure

Source	**Measure**	**Region**	**Investment Elasticity/ Range**
Aschauer 1989	Output elasticity of net nonmilitary public infrastructure stock	National	0.39*
Munnell 1990	State output elasticity of public infrastructure stock	States	0.15*
Moomaw et al. 1995[1]	State output elasticities of aggregate public infrastructure	National	0.2398*
		Northeast	-0.1021 - 0.2612
		North Central	0.0652 - 0.1716
		South	0.0104 - 0.1918
		West	0.0006 - 0.2414
Tatom 1991	Business sector elasticity of public infrastructure	National	0.042[2]

* Statistically significant at the 5 percent level.
1. Only results for 1986 cross section are reported.
2. Not statistically different from 0.

Munnell (1990) uses a similar methodology as Aschauer to measure the effect of public infrastructure spending on state economic output. Her study confirms Aschauer's conclusions, that spending on public infrastructure has a positive effect on the productivity of the economy, but she finds slightly lower output elasticities of public infrastructure. Moomaw et al. (1995) expands on this technique to produce elasticities for all 50 states for 3 years. Again, the results support a positive correlation between public infrastructure and economic output in almost all cases.

Some researchers have since challenged the statistical method used to obtain these results. Tatom (1991) argues that Aschauer's study and those using similar methodologies ignore broken trends in productivity, fail to account for changes in energy prices, and contain non-stationary variables (i.e., they fail to account for trends in the data over time). Tatom concludes that if you take into account the above limitations the effect of public infrastructure stock on output is not statistically different from zero. (A statistically significant result is one that is unlikely to have occurred by chance. Statistical significance does not imply the difference is large or important; rather, it means it is not merely random noise.)

One way to address some of these concerns is to view public infrastructure as a technology that constrains the other inputs in the production function rather than as an independent input. Duggal et al. (1999) uses this approach and finds similar output elasticities of public infrastructure as Aschauer (1989). Bougheas et al. (2000) takes this technique one step further and views infrastructure as a technology that reduces the cost of intermediate inputs in the production of final goods. Bougheas et al. conclude that these reduced costs foster specialization, which increases productivity within the economy. Both these studies affirm that public infrastructure investment can expand the productive capacity of an economy, both by increasing resources and by enhancing the productivity of existing resources (Munnell 1992).

Over time, a consensus has emerged that public infrastructure stimulates economic growth; however most recent studies show that the impact is not as large as Aschauer first reported (Romp and de Haan 2005). Demetriades and Mamuneas (2000) concludes that in the long run, public infrastructure investment is positively correlated with input demands and output supply; in the short run the correlation is also positive but less powerful. This positive correlation has many possible causes. Public infrastructure is a gross-complement to both labor and private capital (Demetriades and Mamuneas 2000).

Table 2: Other Measures of the Effect of Public Infrastructure on the Economy

Source	**Measure**	**Region**	**Investment Elasticity/ Range**
Aschauer 1989	Total factor productivity of core infrastructure[1]	National	0.24[*]
Duggal et al. 1998	Output elasticity of core public infrastructure	National	0.27
Bougheas et al. 2000	Relationship between infrastructure and degree of specialization	National for manufacturing industry	2.8613
Demetriades & Mamuneas 2000	**Output supply** elasticity of public infrastructure	National Short - Run	1.000
		National Long-Run	1.030
Demetriades & Mamuneas 2000	**Input demand** elasticity of public infrastructure	National Short - Run	Labor: 1.129 Capital: 0.026
		National Long-Run	Labor: 0.798 Capital: 0.309

* Statistically significant at the 5 percent level.

1. Core infrastructure consists of highways, mass transit, airports, electrical and gas facilities, water, and sewers.

Public infrastructure expenditures provide cost-saving benefits that exceed the associated investment costs due to substitutability between public infrastructure and private input. This is especially true in the manufacturing industry (Morrison and Schwartz 1996). Public spending on infrastructure also has a positive effect on the productivity of private capital investment (Munnell 1990).

The fluctuations in the output elasticities that have been reported by these studies have several explanations. First and foremost, the rate of return depends on the level of previous investment in public infrastructure. If an economy has already made large investments in highways or water and sewer then the return on further investment will be lower than in an economy that has not spent as much developing this infrastructure (Moomaw et al. 1995). There is also a balance that needs to be struck between public infrastructure and private capital. Aschauer (1989) attempts to quantify this relationship; he reports that a ratio of $0.44 of core public infrastructure to $1.00 of private capital is optimal for growth in an economy (the ratio is $0.31 to $1.00 for all other public infrastructure).

Effects of Investment in Water and Sewer Infrastructure

A subset of the literature estimating the value-added of public infrastructure investment focuses on water and sewer infrastructure. These papers are not focused on answering questions related to the role of water and sewer per se; rather they are focused on presenting a disaggregated view of public infrastructure as a whole with water and sewer as one component of that whole. The literature provides insight into both the effect of water and sewer investment on the economy and how investment in water and sewer compares to other types of public infrastructure. The investment elasticities of water and sewer infrastructure are presented in Table 3.

In an effort to overcome some of the methodological problems associated with early studies, Evans and Karras (1994) used panel data and a production function approach to estimate how government capital and services contribute to private productivity. (Panel data track cross-sectional data of multiple localities over time). The authors find that educational services have positive productivity but no evidence that other services or capital (including water and sewer) are productive—the coefficient for the water and sewer infrastructure stock was not statistically significant. Using a pooled cross-section approach, Moomaw et al. 1995 estimate the relationship between the value of assets of water and sewer infrastructure and GSP both on a national and a state-by-state basis. The results indicate that, in general, states get greater returns from investing in water and sewer systems than from investing in highways. Table 3 shows the results for the nation, the high and low range of states in each of the four regions considered.

Several studies have found that the nature of variables could lead to misestimating the strength of the relationship among them. Unless special statistical techniques are used, correlations we observe among variables may be meaningless. (See the discussion of spurious correlation under "Evolution of the Economic Literature"). These studies employ VAR models to estimate the relationship between public infrastructure investment and output and use techniques to address spurious correlation. Batina (1998) examined the cointegration properties of aggregate data on output, labor, private and public infrastructure and used dynamic statistical models to test for effects over time and directionality. The author found that public infrastructure has a strong and long lasting effect on output and private sector variables, and vice versa. However, when public infrastructure is disaggregated into real spending on highways and streets and water and sewer systems the magnitude of the public infrastructure coefficients is much smaller.

Table 3: Investment Elasticities of Water and Sewer Infrastructure

Source	Measure	Region	Investment Elasticity/ Range
Evans & Karras 1994	Net stock of water an sewer infrastructure on GSP	48 States	0.011[1]
Moomaw et al. 1995[2]	Net stock of water an sewer infrastructure on GSP	National	0.1686*
		Northeast North Central South West	0.0003 to 0.2467 0.0567 to 0.2452 0.0434 to 0.3312 0.0991 to 0.3045
Batina 1998	Real spending on water and sewer on an Industrial Production Index	National	0.0004
Pereira 2000	Investment in sewage and water supply system infrastructure on (1) Private GDP (2) Private Investment (3) Private Employment	National	(1) 0.00856[3] [-0.00579 to 0.01074] (2) -0.01159[3] [-0.01233 to -0.00473] (3) 0.01239[3] [-0.05814 to 0.01673]
Pereira 2001	Investment in sewage and water supply system infrastructure on private investment	National	0.0129

* Statistically significant at the 5 percent level.

1. Not statistically significant at the 5 percent level.
2. Only results for 1986 are reported.
3. Central case and range presented. Elasticities represent total percentage-point changes in private sector variable for each long-term accumulated percentage-point change in public investment once all dynamic feedback effects among the different variables have been considered.

Periera (2000) used VAR models to examine the relationship between aggregate and decomposed types of public investment and private GDP, investment and employment. In general, Periera found that faster growth in private GDP yields greater public investment (more tax revenue) and negative growth in employment yields greater public investment (perhaps because it is used as a countercyclical tool). However, the opposite is true for water and sewage investment. When the economy slows down, public investment goes to infrastructure like streets, mass transit, and electric—not water and sewer. When private investment grows, public investment in water and sewer grows as well. The paper also focuses on the effect on public investment on the private sector. It found public investment has a positive effect on private output. Of the five sub-components considered (highways and streets, energy infrastructure and mass transit, water and sewer, public buildings, and conservation structures), water and sewer had the third greatest impact with respect to private GDP. It had the fourth greatest impact with respect to private employment and private investment. In all three cases, energy infrastructure and mass transit had the greatest positive impact. However, when the measures of elasticity are converted to marginal productivity (i.e., the dollar value of the increase in output) per dollar invested water and sewer has the second highest[2] marginal productivity (Table 4).

[2] Energy and mass transit infrastructure has a substantially larger marginal productivity.

Table 4: Effect of Public Investment on Private Output and Private Investment

Source	Measure	Marginal Productivity	Rate of Return
Pereira 2000	Effect of public sewage and water supply systems investment on private **output (GDP)**	\$6.35[1]	9.7%[2]
Pereira 2001	Effect of public sewage and water supply systems investment on private **investment**	\$0.25[2]	

1. Read long-term accumulated marginal productivity as: One dollar spent on sewage and water supply systems increases private output in the long-term by \$6.35.
   Calculated as Elasticity (0.00856) multiplied by the Output to Public Investment ratio for years 1988-1997. Designed to reflect the relative scarcity of the different types of public investment.
2. Rate of return assumes a life horizon of twenty years.

Building on the 2000 study, Periera (2001) examined the effects of different types of public investment on aggregated and disaggregated private investment. At the aggregated level, public investment in water and sewer infrastructure has lower long term elasticities than all other types of infrastructure except for highways and streets. However, when the elasticity is converted to measure marginal productivity its impact on private investment is greater than both highways and streets, and public buildings (Table 4). Like private output, the impact of public investment in energy and mass transit infrastructure yields higher returns than all other types of infrastructure.

The methodological variation among the studies helps explain the variation in elasticities and marginal products. Appendixes 1 and 2 summarize the variables and techniques used by the reviewed papers. Although this variation makes it impossible to summarize the elasticities using an average (i.e., to say the average effect is X), the finding of a small positive relationship between water and sewer infrastructure investment and economic activity should be considered robust explicitly because of the variability in methodologies used to produce this consistent result.

C. Returns to Annual Operations and Maintenance Spending

Infrastructure is not the only type of investment that municipalities can make in water and sewer. New infrastructure investment and reinvestment in existing infrastructure through replacement and rehabilitation are not constant expenditures for water and sewer systems. Rather they are likely to occur once a year, or every few years. On the other hand, the operation and maintenance of existing infrastructure is a continuous investment for water and sewer systems. As a municipal expenditure, the returns on annual operations and maintenance spending are also important to consider.

The US Department of Commerce Bureau of Economic Analysis (BEA) calculates input-output (I-O multipliers) for 473 industries, including the water and sewer industry.[3] The goal of I-O multipliers is to account for inter-industry relationships. BEA calculates the multiplier based on

[3] Defined as water, sewage and other systems by NAICS code 2213.

I-O benchmark data. These benchmark data estimate the goods and services purchased by an industry (water and sewer), and whether industry output (goods and services) are purchased by other industries (DOC 1997). The primary output of the water and sewer industry is clean water. Producing this output requires infrastructure (new and rehabbed), water treatment supplies, and labor (operating and maintaining infrastructure). Because output is used as an input for households (wages and water) and industry (water), increases in water and sewer output has a direct impact on other sectors of the economy. BEA estimates that across the United States as a whole, for each additional dollar's worth of output of the water and sewer industry in a year, the dollar value of the increase in output that occurs in all industries is $2.62 in the same year (final-demand output multiplier, Table 7).

Table 7: Input-Output Model Results

	Final-demand Output (dollars)[1]	**Direct-effect Employment (number of jobs)[2]**
United States	2.62	3.68
Low State	1.22	1.97
High State	2.19	3.06

Bureau of Economic Analysis, 2008

1. ***Final demand output is the increase in the economic value of the output of all industries due to a one dollar increase in the economic value of the output of the water and sewer industry.***
2. ***Direct effect employment is the increase in number of jobs in all industries due to the addition of one job in the water and sewer industry.***

The BEA I-O multipliers also breakdown effects in and among regions. A state-by-state comparison shows variation across states (Appendix 3). The lowest state multiplier is Washington DC, where output increase in all industries is $1.22 for each additional dollar of water and sewer output in a year. The highest state multiplier is Texas, with a multiplier of $2.19. The national multiplier is greater than the highest state multiplier because it captures spillovers among states and regions and therefore does not represent the average state but the whole nation.

Employment multipliers indicate another aspect of the direct impact of water and sewer investment. BEA estimates that for each additional job created in the water and sewer industry, 3.68 jobs are created in all industries (direct-effect employment multiplier, Table 7). Wyoming has the lowest multiplier of 1.97 jobs, while Pennsylvania has the highest, with 3.06 jobs created in all industries from one additional job in water and sewer.

D. Additional Indirect Impacts

Beyond the direct economic impacts already discussed, several indirect impacts should also be considered. With respect to drinking water, we consider additional indirect impacts as those beyond the delivery of potable water to the public (necessary for life) and business (necessary as a factor of production). Indirect economic impacts come in terms of fire suppression, public health gains, and the provisioning of ecosystem services. Most indirect impacts from sewer investment come from the improved provisioning of ecosystem services.

Fire suppression is a secondary benefit from drinking water distribution pipelines. From a water delivery perspective, hydrants are used to maintain water quality when regularly "flushing" pipelines to remove stagnant water. These hydrants can also be used as a local source of water by firefighters (instead of bringing water to the fire) with economic impacts stemming from minimized losses to property and wages from businesses that would otherwise be burned.

Although a system's water may be potable, investments focused on improving the quality of the drinking water itself are commonplace and are focused on protecting/improving public health. An indirect economic impact from improved public health is a reduction in lost wages (from workers taking unpaid sick days), and improved workplace productivity (because workers are not sick at work). To the extent better public health results in less treatment in hospitals and clinics**,** spending on health care sector will be reduced..

Table 8: Average Value of Ecosystem Services From Land Types (Costanza et al. 1997)

	Ecosystem Services (1994 US$ per hectare per year)							
	Gas & Climate Reg-ulation	**Distur-bance Reg-ulation**	**Water Reg-ulation** (flow)	**Water Supply** (storage)	**Water Purific-ation**	**Habitat**	**Rec-reation**	**Cultural**
Temperate/ boreal forests	$ 88		$ 0		$ 87		$ 36	$ 2
Grass/ rangelands	$ 7		$ 3		$ 87		$ 2	
Wetlands	$ 133	$ 4,539	$ 15	$ 3,800	$ 4,177	$ 304	$ 574	$ 881
Lakes/ rivers			$ 5,455	$ 2,177	$ 665		$ 230	

Note: Open cells indicate a lack of available information.

An additional positive indirect economic impact comes from protecting the quantity and quality of source water. Often, systems purchase land to create protection zones with the goal of keeping pollution sources away from the source of drinking water, or to capitalize on the water purification properties of the ecosystem itself. Regardless of the objective, land purchases have indirect benefits in terms of ecosystem services. Ecosystem services are defined as the benefits humans derive from ecosystem functions (including habitat, and biological properties or processes) of which water purification is just one. The economic value of these services can be estimated using a variety of techniques (NRC 2005). Costanza et al. (1997) calculated the average annual per hectare value of 17 ecosystem services for marine and terrestrial biomes.[4] Although source water protection land purchases could include any number of terrestrial biomes, biomes like temperate forests, grass/rangelands, and wetlands provide important services. In these biomes, important contributors to the total value of ecosystem services (in addition to water purification) can include climate regulation (CO_2 sequestration), flood/drought control, habitat, food production, and recreational and cultural services. For example, protecting one hectare of a wetland for source water protection can yield a primary benefit of $4,177 annually in avoided treatment costs. (The wetland effectively treats the water and thus reduces the need for

[4] Based on a survey of published studies and original calculations.

traditional treatment facilities. One hectare is 10,000 square meters or 2.471 acres.) However, the same hectare may yield an additional $10,246 annually in other services. (This is the sum of the wetlands row in Table 8, excluding waste treatment.) A sample of the average annual per hectare value of the services provided by these land types is listed in Table 8.

With respect to sewer investment, most indirect economic benefits come as a result of improved water quality. Improved water quality decreases negative pressures on ecosystems and can result in the provisioning of more ecosystem services (including those listed above), and in the case of freshwater, an economic benefit to drinking water systems through decreased treatment costs.

E. Additional Factors to Consider

The preceding sections have described literature examining the relationship between water and sewer investment and its value added in the economy. As a result of challenges to early results, methodologies have evolved and current studies yield more consistent results. However, several factors still need to be considered when interpreting the literature and its application to current policy decisions.

The economic impact of infrastructure is likely to depend on how additional investment is financed. Increases in taxes are widely considered to reduce the rate of economic growth. Therefore, an increase in public infrastructure stimulates economic growth only if the impact of public infrastructure outweighs the adverse impact of higher taxes needed to finance the investment, and outweighs the adverse impact of spending cuts in other area such as operations and maintenance (Romp and de Haan 2005).

Economic benefits also depend on the geographic source of the money and the geographic area of benefit under consideration. Young (2005) argues when the benefits of project investments are localized but costs are paid by the national government, total economic benefits across the national economy are zero. In a properly functioning competitive economy (fully employed resources) a new investment yields no net benefits beyond its own net income. Expansion in secondary sectors in one region is offset by a fall in activity and profits elsewhere over the long-run. Therefore, from a national perspective the multiplier effects of local water projects financed by federal dollars would be offset by the multiplier effects of foregone alternative public investment (Young 2005).

Despite the challenges associated with identifying the appropriate level of new infrastructure investment from an economic perspective, it may be desirable to fall back on estimates of need from an engineering perspective. As cited previously, the EPA Drinking Water Needs Survey and Assessment (2005) estimates that the nation's water systems will need to invest $276.8 billion through 2023 to provide the same level of service to current customers—excluding costs solely for operation and maintenance, dams, reservoirs, future growth, and fire flow. However, Gramlich (1994) challenges the basic premise of these types of engineering needs assessments, arguing that studies of this type are based on an arbitrary initial period where infrastructure was presumed to be adequate. Without economic reasoning, there are no adjustments for excessive or underutilized initial infrastructure, and no recognition that citizens may want to trade off the benefits of greater infrastructure against the costs. These criticisms are not necessarily applicable to this survey, because it is not purely an engineering study; it is also a political statement and reflects tradeoffs and decisions made by federal, state, and local government. But studies that do not account for the economic value of the assets and tradeoffs stakeholders need to make may misstate the economic return to these assets.

F. Conclusions

The economic literature supports several conclusions about the returns to public spending on infrastructure. First, although not all studies find a growth-enhancing effect, there is a general consensus in the literature that spending often displays positive economic returns. Second, according to most studies the impact is much lower than the findings of earlier studies (e.g., Aschauer 1989). Third, both the average return and the range of return vary based on the type of infrastructure and the amount of infrastructure already in place. In other words, the larger the stock and the better its quality, the lower the impact of new infrastructure will be (CBO 2007; Romp and de Haan 2005).

Policymakers have a perverse incentive to invest in new public infrastructure projects that are politically more attractive than continuing or improving maintenance activities (Romp and de Haan 2005). However, the economic impacts of annual operations and maintenance spending should not be forgotten. Additionally, indirect impacts from some types of investment, especially benefits from ecosystems services, should be considered. Ultimately, understanding the full spectrum of investment options and the direct and indirect impacts of each type of investment can help inform municipal decision makers and help ensure that economic, environmental, and social goals are achieved.

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Appendix 1: Methodological Summary of Public Infrastructure Studies

Source	Dependent Variable (Units)	Independent Variables (Units)	Technique
Aschauer 1989	Private business economic output	• Private labor • Private capital • Nonmilitary public capital • Private business economy total factor productivity • Capacity utilization rate in manufacturing	Cobb-Douglas (log levels)
Munnell 1990	Gross state product	• The level of technology • Private capital stock • Employment on nonagricultural payrolls • Stock of state and local public capital • State unemployment rate	Cobb-Douglas (log levels)
Moomaw et al. 1995	Gross state product	• Labor (nonagricultural employment) • Private capital stocks • Public capital stocks	Cobb-Douglas (log levels)
Tatom 1991	Business sector production	• Public sector capital • Business sector hours • Relative price of energy	Cobb-Douglas with first difference regression (log levels)
Bougheas et al. 2000	Gross domestic product	• Number of manufacturing establishments • Core infrastructure • Twenty intercept dummies	Modification of the Romer specialization model (log levels)
Duggal et al. 1998	Gross Domestic Product (reduced by the portion originating from housing, adjusted upward by the portion of deflated government interest payments that can be attributed to the debt incurred due to government expenditures on new infrastructure)	• Core public infrastructure • Labor (total employee hours worked in nonagricultural establishments) • Capital stock (excluding military and infrastructure capital) • Interest rate • Real user cost of capital for equipment and structures • Comparative price variable (ratio of the GDP deflator and the nominal wage rate multiplied by the ratio of the GDP deflator to the nominal user cost of equipment) • Index of producer prices for 28 sensitive materials	Non-linear model (log levels)
Demetriades & Mamuneas 2000	Manufacturing Gross Domestic Product	• Technology • Fixed factors (capital) • Variable inputs	Non-linear SUR[1] with a system of simultaneous equations

Notes:
1. Seemingly Unrelated Regression (SUR)

Appendix 2: Methodological Summary of Water and Sewer Studies

Source	Dependent Variable (Units)	Independent Variables (Units)	Technique
Evans & Karras 1994	GSP[1]	• Number of workers in private industry • Net stock of private capital • State unemployment rate • Net stock of highway capital * • *Net stock of water and sewer capital* * • Net stock of other infrastructure capital * • Current educational services • Current highway services • Current health and hospital services • Current police and fire services • Current sewer and sanitation services	Cobb-Douglas, Translog; Panel Data (log dollars, fixed effects)
Moomaw et al. 1995	GSP	• Private capital • Aggregate public capital • Labor[1] • Net stock of highway capital * • *Net stock of water and sewer capital* * • Net stock of other infrastructure capital *	Production Function, Pooled Cross Section=*Panel Data* (log dollars, difference from mean=*fixed effects*)
Batina 1998	Industrial Production Index[2]	• Aggregate employment • Private Capital • Real spending on highways and streets • *Real spending on water and sewer*	VAR model; Error correction model (log dollars, difference from mean per std. dev.)
Pereira 2000[3]	Private GDP; private investment; private employment	• Aggregate public investment • Highways and street infrastructure • Electric and gas, transit system, airfield infrastructure • *Sewage and water system infrastructure* • Public buildings • Conservation and development structures, civilian equipment	VAR model (first-difference, log dollars; full time equivalents)
Pereira 2001	Private investment	• Aggregate public investment • Highways and street infrastructure • Electric and gas, transit system, airfield infrastructure • *Sewage and water system infrastructure* • Public buildings Conservation and development structures, civilian equipment	VAR model (first-difference, log dollars)

Note: Data transformations and units in parenthesis.
* Federal Reserve Bank of Boston data used by Munnell (1990)
1. Excluding agricultural industries.
2. Substantiate, Index is unit-less
3. First difference of log-levels estimates the growth rates of the original variables.

Appendix 3: Additional Data

Output Elasticities of Water and Sewer Capital

State	1970	1980	1986	Average
Northeast				
Maine	0.0193	0.0317	0.0510	0.0340
New Hampshire	-0.0182	0.0878	0.0309	0.0335
Vermont	-0.0431	0.0828	0.0003	0.0133
Massachusetts	0.1009	0.1156	0.1636	0.1267
Rhode Island	-0.0537	0.2165	0.0125	0.0584
Connecticut	0.0739	0.0950	0.1255	0.0981
New York	0.2036	0.1357	0.2467	0.1953
New Jersey	0.1456	0.0046	0.1964	0.1155
Pennsylvania	0.1969	0.1298	0.2323	0.1863
North Central				
Ohio	0.2029	0.1384	0.2291	0.1901
Indiana	0.1766	0.1957	0.2069	0.1931
Illinois	0.2084	0.2318	0.2452	0.2285
Michigan	0.1865	0.1312	0.2261	0.1813
Wisconsin	0.1235	0.1495	0.1815	0.1515
Minnesota	0.1448	0.2109	0.1667	0.1741
Iowa	0.1348	0.1635	0.1531	0.1505
Missouri	0.1357	0.1282	0.1769	0.1469
North Dakota	0.0862	0.1660	0.1399	0.1307
South Dakota	0.0530	0.1373	0.0567	0.0823
Nebraska	0.0925	0.1202	0.1358	0.1162
Kansas	0.1456	0.1720	0.1799	0.1658
South				
Delaware	-0.0099	0.0250	0.0434	0.0195
Maryland	0.0921	0.0317	0.1393	0.0877
Virginia	0.1111	0.1492	0.1735	0.1446
West Virginia	0.1235	0.1529	0.1620	0.1461
North Carolina	0.1334	0.2272	0.1912	0.1839
South Carolina	0.1010	-0.0319	0.1576	0.0756
Georgia	0.1332	0.1717	0.1924	0.1658
Florida	0.1563	0.2054	0.2259	0.1959
Kentucky	0.1205	0.1586	0.1689	0.1493
Tennessee	0.1304	0.0667	0.1761	0.1244
Alabama	0.1359	0.1743	0.1844	0.1649
Mississippi	0.1064	0.1615	0.1366	0.1348
Arkansas	0.0942	0.1307	0.1348	0.1199
Louisiana	0.2628	0.2623	0.2808	0.2686
Oklahoma	0.1611	0.2179	0.2020	0.1937
Texas	0.2979	0.2640	0.3312	0.2977
West				
Montana	0.1016	0.1650	0.1219	0.1295
Idaho	0.0448	0.0689	0.0682	0.0606
Wyoming	0.1348	0.1771	0.1815	0.1645
Colorado	0.0993	0.1492	0.1505	0.1330
New Mexico	0.1181	0.1694	0.1432	0.1436
Arizona	0.1155	0.1317	0.1457	0.1310
Utah	0.0402	0.3261	0.0991	0.1551
Nevada	0.0668	0.1293	0.1184	0.1048
Washington	0.1371	0.1713	0.1821	0.1635
Oregon	0.0933	0.1987	0.1359	0.1426
California	0.2349	0.2763	0.3045	0.2719

Moomaw, 1995

I-O Multipliers for NAICS#2213: Water, Sewage and Other Systems

State	Final-demand Output (dollars)	Direct-effect Employment (number of jobs)
Alabama	1.9208	2.2696
Alaska	1.6906	2.5252
Arizona	1.8694	2.6873
Arkansas	1.8188	2.1756
California	2.0954	3.0412
Colorado	2.0707	2.9177
Connecticut	1.7766	2.4339
Delaware	1.6951	2.4626
District of Columbia	1.2217	2.1049
Florida	1.8916	2.6769
Georgia	2.0499	2.8369
Hawaii	1.7905	2.3658
Idaho	1.7824	2.5363
Illinois	2.1203	2.9168
Indiana	1.9382	2.8644
Iowa	1.8188	2.4243
Kansas	1.8856	2.1848
Kentucky	1.8873	2.2695
Louisiana	1.9262	2.3918
Maine	1.7704	2.9238
Maryland	1.871	2.6308
Massachusetts	1.8345	2.6434
Michigan	1.8681	2.8475
Minnesota	1.9567	3.0231
Mississippi	1.8073	2.1563
Missouri	1.9458	2.7198
Montana	1.799	2.2744
Nebraska	1.7917	2.8904
Nevada	1.7068	1.9783
New Hampshire	1.799	2.5424
New Jersey	1.9422	2.7631
New Mexico	1.742	2.1527
New York	1.7388	2.3404
North Carolina	1.9456	2.391
North Dakota	1.7818	2.3501
Ohio	1.9808	2.7746
Oklahoma	1.9697	2.6782
Oregon	1.8572	2.3589
Pennsylvania	2.0715	3.0623
Rhode Island	1.6896	2.7112
South Carolina	1.8924	2.6654
South Dakota	1.7227	2.2269
Tennessee	1.9696	2.4195
Texas	2.1932	3.0116
Utah	2.0065	2.4586
Vermont	1.6734	2.1866
Virginia	1.8967	2.4436
Washington	1.9318	3.0085
West Virginia	1.6907	2.4267
Wisconsin	1.8986	3.0604
Wyoming	1.638	1.9736
United States	**2.6179**	**3.6772**

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