



**NAHB**

**THE METRO AREA  
IMPACT OF HOME  
BUILDING IN THE CITIES  
OF BELTON AND TEMPLE  
IN TEXAS**

**COMPARING COSTS  
TO REVENUE FOR  
LOCAL GOVERNMENTS**

Prepared by the Housing Policy Department

September 2007

National Association of Home Builders  
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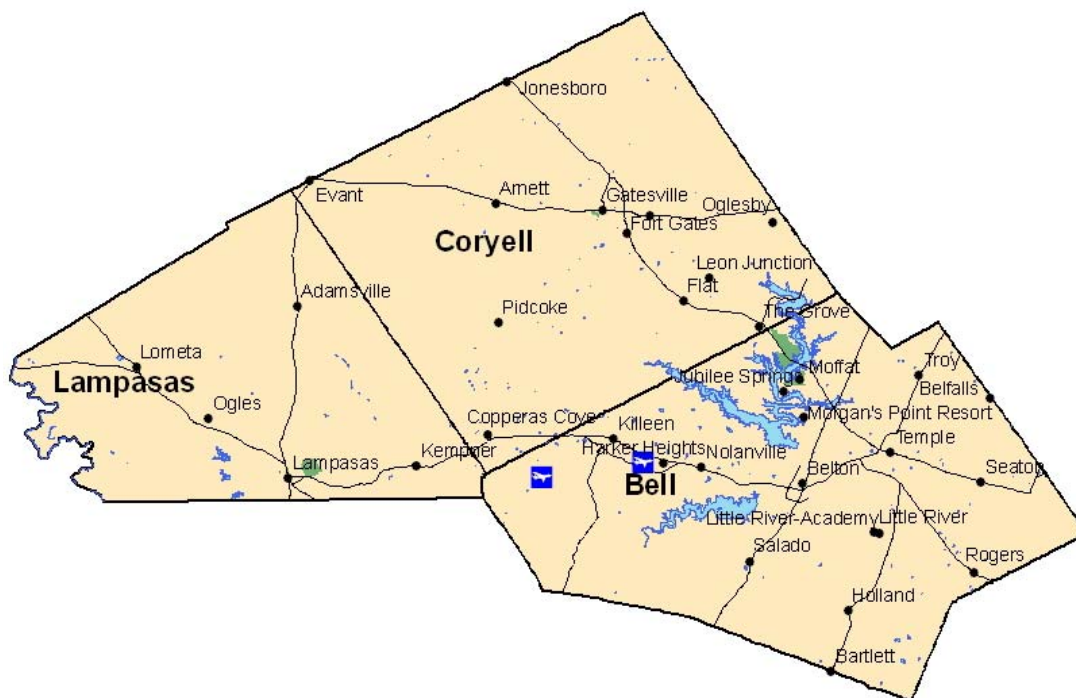
## **Introduction**

Home building generates local economic impacts such as income and jobs for local residents, and revenue to local governments. It also typically imposes costs on local governments—such as the costs of providing primary and secondary education, police and fire protection, and water and sewer service. Not only do these services require annual expenditures for items such as teacher salaries, they typically also require capital investment in buildings, other structures, and equipment that local governments own and maintain.

This report presents estimates of the metro area impacts of home building in the cities of Belton and Temple, Texas. The report presents estimates of the impacts of building 100 single family and 74 multifamily housing units, representative of construction in the cities of Belton and Temple in 2006. The number of 100 for single family construction was chosen to generate a report based on a convenient round number. The number 74 was then chosen to reflect the proportion of multifamily to single family construction that prevailed in the cities of Belton and Temple in 2006.

The local economic benefits generated by this level of home construction activity are reported in a separate NAHB document.<sup>1</sup> This report presents estimates of the costs—including current and capital expenses—that new homes impose on jurisdictions in the area and compares those costs to the revenue generated. The results are intended to answer the question of whether or not, from the standpoint of local governments in the area, residential development pays for itself.

Figure 1. Killeen-Temple-Fort Hood, TX MSA



<sup>1</sup> "The Metro Area Impact of Home Building in the Cities of Belton and Temple, Texas: Income, Jobs and Taxes Generated," completed by NAHB in September 2007.

The comprehensive nature of the NAHB model requires a local area large enough to include the labor and housing market in which the homes are built. Local benefits in the model, including revenue generated for local governments, include the ripple impacts of spending and taxes paid by construction workers and new residents, which occur in an economic market area. For a valid comparison, costs should be calculated for the same area. A local labor and housing market generally corresponds to a Metropolitan Statistical Area (MSA) as defined by the U.S. Office of Management and Budget (OMB).

Based on local commuting patterns, OMB has identified the Killeen-Temple-Fort Hood MSA as a metro area consisting of three counties (Bell, Coryell, and Lampasas) in Texas. The cities of Belton and Temple are both located in Bell County (see Figure 1). In this report, wherever the term local is used, it refers to the entire metro area.

### ***Costs Compared to Revenue: Total***

This section summarizes results for both single family and multifamily construction. Detail by structure type follows, but for many purposes a combined analysis of both types may be most appropriate. Market areas generally require a mix of housing types to accommodate residents of different income levels, different occupations, and who are at different stages in their professional careers. Although it's possible to analyze single family and multifamily construction separately, such an approach does not reflect the typically integrated character of residential development.

◆ In the first year, the 100 single family and 74 multifamily housing units built in the cities of Belton and Temple result in an estimated

- **\$1.2 million** in tax and other revenue for local governments<sup>2</sup>
- **\$271,000** in current expenditures by local government to provide public services to the net new households at current levels
- **\$4.1 million** in capital investment for new structures and equipment undertaken by local governments

The analysis assumes that local governments finance the capital investment by borrowing at the current municipal bond rate of 4.40 percent.<sup>3</sup>

◆ In a typical year after the first, the single family and multifamily units result in

- **\$778,000** in tax and other revenue for local governments
- **\$542,000** in local government expenditures to continue providing services at current levels

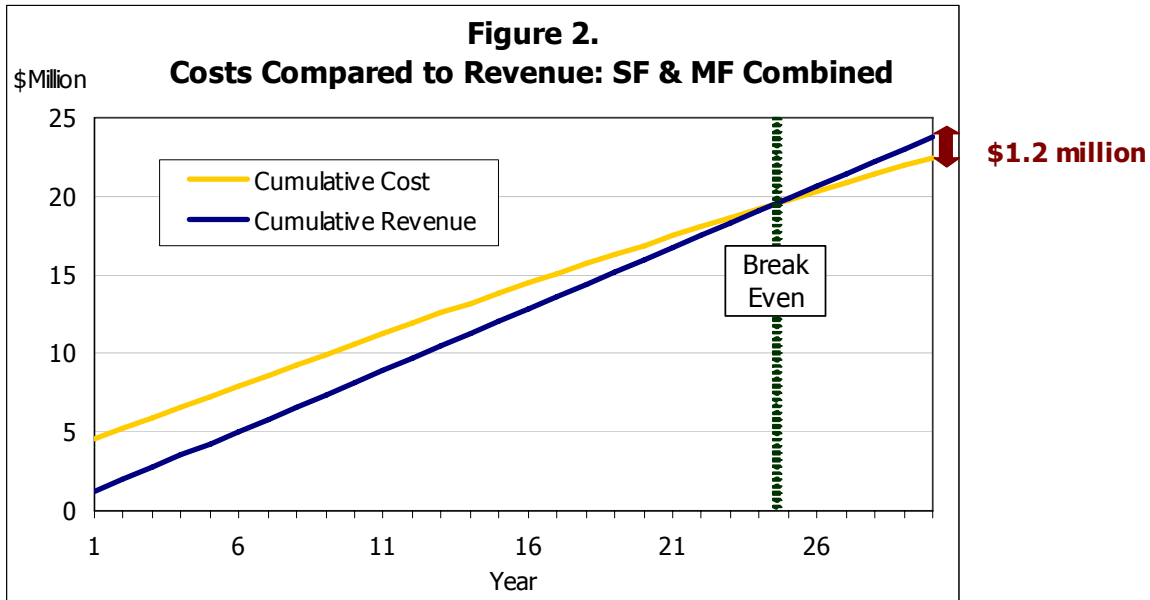
The difference is an "operating surplus" that is available to service or pay down debt.

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<sup>2</sup> This assumes that homes are occupied at a constant rate during the year, so that the year captures one-half of the ongoing, annual revenue generated as the result of increased property taxes and the new residents participating in the local economy.

<sup>3</sup> The analysis assumes that there is currently no excess capacity, that local governments invest in capital before the homes are built, and that no fees or other revenue generated by construction activity are available to finance the investment, so that all capital investment at the beginning of the first year is financed by debt. This is a conservative assumption that results in an upper bound estimate on the costs incurred by local governments. For information about the particular interest rate on municipal bonds used, see page 2 of the technical appendix.

- ◆ If it is assumed that the operating surplus is used first to service and then to pay down the debt, all debt incurred by investing in structures and equipment at the start of the first year can be entirely paid off by the end of the twenty-fifth year. After that, future operating surpluses will be available to finance other projects or reduce taxes. After 30 years, the homes will generate a cumulative **\$23.7 million in revenue** compared to **\$22.5 million in costs**, including annual current expenses, capital investment, and interest on debt (Figure 2).



### ***Costs Compared to Revenue: Single Family Construction***

This section summarizes results for single family construction only. The relevant assumptions about the single family homes built (including their average price, property tax payments, and construction-related fees incurred) are contained in the NAHB report, *The Metro Area Impact of Home Building in the Cities of Belton and Temple, Texas: Income, Jobs and Taxes Generated*.

- ◆ In the first year, the 100 single family homes built in the cities of Belton and Temple result in an estimated

- **\$846,000** in tax and other revenue for local governments
- **\$184,000** in current expenditures by local government to provide public services to the net new households at current levels
- **\$2.8 million** in capital investment for new structures and equipment undertaken by local governments

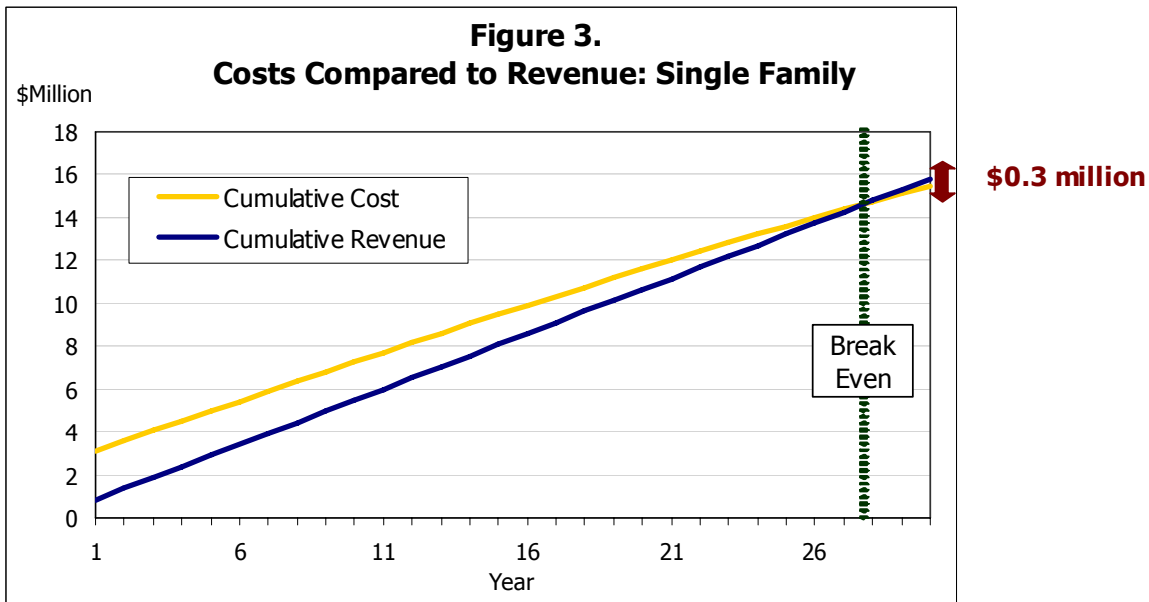
The analysis assumes that local governments finance the capital investment by borrowing at the current municipal bond rate.

- ◆ In a typical year after the first, the 100 single family homes result in
  - **\$516,000** in tax and other revenue for local governments
  - **\$367,000** in local government expenditures needed to continue providing services at current levels.

The difference is an "operating surplus."



If it is assumed that the operating surplus is used first to service and then to pay down the debt, all debt incurred by investing in structures and equipment at the beginning of the first year can be entirely paid off by the end of the twenty-eighth year. After that, the operating surpluses will be available to finance other projects or reduce taxes. After 30 years, the homes will generate a cumulative **\$15.8 million in revenue** compared to **\$15.5 million in costs**, including annual current expenses, capital investment, and interest on debt (Figure 3).



### ***Costs Compared to Revenue: Multifamily Construction***

This section summarizes results for multifamily construction only. As with the section on single family construction, relevant assumptions about the type units built can be found in *The Metro Area Impact of Home Building in the Cities of Belton and Temple, Texas: Income, Jobs and Taxes Generated*.



In the first year, the 74 multifamily housing units built in the cities of Belton and Temple result in an estimated

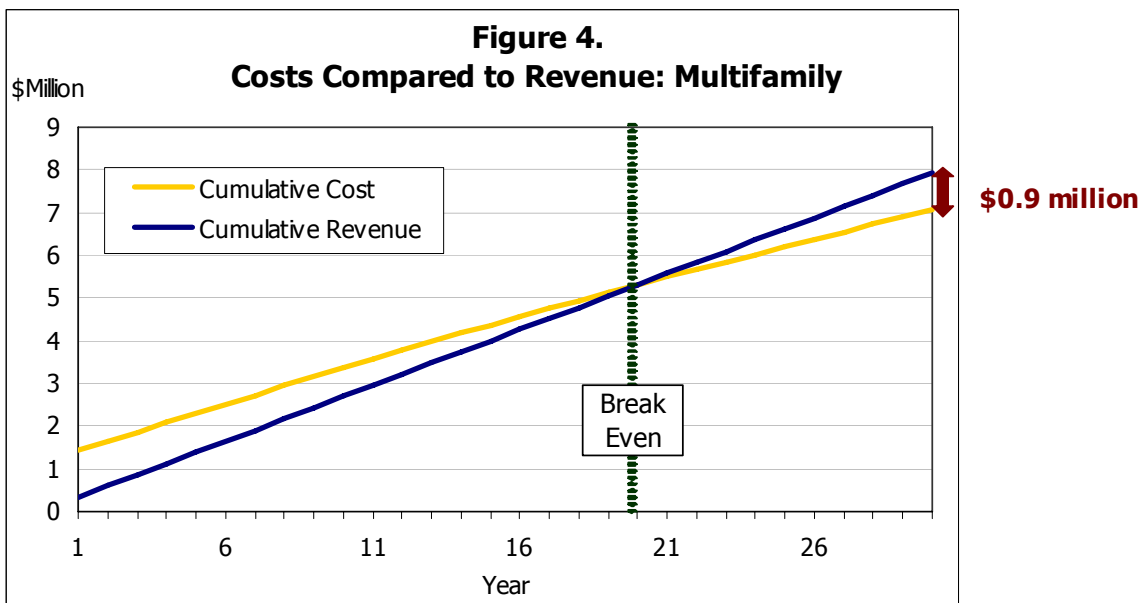
- **\$338,000** in tax and other revenue for local governments
- **\$88,000** in current expenditures by local government to provide public services to the net new households at current levels
- **\$1.3 million** in capital investment for new structures and equipment undertaken by local governments

The analysis assumes that local governments finance the capital investment by borrowing at the current municipal bond rate.

- ◆ In a typical year after the first, the 74 multifamily units generate
  - **\$262,000** in tax and other revenue for local governments
  - **\$175,000** in local government expenditures needed to continue providing services at current levels.

The difference is an “operating surplus” that can be used to service or pay down the debt.

- ◆ If it is assumed that the operating surplus is used first to service and then to pay down the debt, all debt incurred by investing in structures and equipment at the beginning of the first year can be entirely paid off by the end of the twentieth year. After that, future operating surpluses will be available to finance other projects or reduce taxes. After 30 years, the units will generate a cumulative **\$7.95 million in revenue** compared to **\$7.05 million in costs**, including annual current expenses, capital investment, and interest on debt (Figure 4).



**Method Used to Estimate Costs**

The method for estimating local government revenue generated by home building is explained in the NAHB documents, *The Metro Area Impact of Home Building in the Cities of Belton and Temple, Texas: Income, Jobs and Taxes Generated* and *NAHB’s Local Impact of Home Building Model: Technical Documentation*. This section describes how costs are estimated.

The general approach is to assume local jurisdictions supply residents of new homes with the same services that they currently provide, on average, to occupants of existing structures. The amount that any jurisdiction spends is available from the Census of Governments, where all units of government in the U.S. report line item expenses, revenues, and intergovernmental transfers once every five years to the Governments Division of the U.S. Census Bureau. Census of Governments accounts can be aggregated for every local government in the Killeen-Temple-Fort Hood metro area and then used to produce total annual expenses per single family and multifamily housing unit (Table 1):

Table 1.  
Total Annual Local Government Expenses per Housing Unit  
(in 2006 Dollars)

	Single Family	Multifamily
Education	\$1,845	\$1,074
Police Protection	\$298	\$221
Fire Protection	\$160	\$119
Corrections	\$123	\$91
Streets and Highways	\$98	\$68
Water Supply	\$220	\$115
Sewerage	\$71	\$37
Health Services	\$243	\$181
Recreation and Culture	\$108	\$80
Other General Government	\$468	\$349
Electric Utilities	\$31	\$23
Total	\$3,665	\$2,358

Not surprisingly, cost per housing unit varies substantially across the major service categories. Education accounts for the largest share of annual expenses, followed at a distance by general government functions, police protection, health services, and water supply.

In deriving the above estimates, water supply and sewerage expenses are allocated based on gallons of water consumed per day by single family and multifamily households. Streets and highway expenses are allocated based on average number of vehicle trips generated on weekdays. Education is allocated based on average number of children age 5 through 18. The other government services listed in Table 1 are assumed to be proportional to population, so costs associated with those services are allocated based on household size.<sup>4</sup>

There are several factors present in most parts of the country that tend to reduce education expenses per housing unit. The first is the average number of school-aged children present in the units. According to the American Housing Survey, there is, on average, only a little over one school-aged child for every two households in the U.S. The number is about 0.6 per household for single family and under 0.4 per household for multifamily. So education costs per housing unit are lower than costs per pupil, simply because there is less than one pupil per household.

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<sup>4</sup> Information about vehicle trips comes from *Trip Generation*, published by the Institute of Transportation Engineers. Information about water consumption comes from *Analysis of Summer Peak Water Demands*, a study undertaken by the City of Westminster, Colorado Department of Water Resources and Aquacraft, Inc. Water Engineering and Management. Information about household size and number of children comes from the American Housing Survey, conducted by the U.S. Census Bureau for the Department of Housing and Urban Development.

Beyond that, a share of households typically send their children to private schools. According to the National Center for Education Statistics (NCES), the share is 12.6 percent of all school-aged children nationally. As public monies are very rarely used to pay for private instruction, this tends to further reduce K-12 public school expenses, although the extent to which that occurs varies from place to place. Moreover, according to the NCES another 1.7 percent of students nationwide, ages 5 to 17, with a grade equivalent of kindergarten through grade 12, are homeschooled, which further acts to reduce the cost of public education.

Finally, state governments in the form of intergovernmental transfers pay for some public school expenses. In the latest Census of Governments, local governments in aggregate across the Killeen-Temple-Fort Hood metro area spent about \$490 million in current expenses on education. However, 66 percent of this was offset by \$322 million in state-to-local intergovernmental transfers for education.

In addition to current expenses, providing services to residents requires that local governments make capital expenditures for items such as schools and other buildings, equipment, roads, and other structures.

Estimating these costs is more complicated than estimating current expenses. The basic procedure is to estimate a traditional economic model, where costs are a function of labor and capital, with state level data, for which information about the capital stock can be derived (for more detail, see the technical appendix). The results are then applied to a local area, where information is available for every variable except capital. The local capital stock then emerges as a residual in the calculation. As with current expenses, the amount of capital in each category is the amount necessary to accommodate an average single family or average multifamily housing unit (Table 2).

Table 2.  
Local Government Capital per Housing Unit  
(in 2006 Dollars)

	Single Family	Multifamily
Schools	\$19,152	\$11,142
Hospitals	\$845	\$629
Other Buildings	\$2,215	\$1,648
Highways and streets	\$3,251	\$2,253
Conservation & development	\$108	\$80
Sewer systems	\$935	\$490
Water supply	\$1,067	\$558
Other structures	\$208	\$155
Equipment	\$376	\$280
Total	\$28,157	\$17,234

To implement these numbers, several conservative assumptions are made to avoid understating costs. In contrast to the way current expenses were handled, intergovernmental transfers are generally not taken into account here—it is assumed that local governments undertake all

capital investment without any help from the states. The exception is highways and streets, for which the amount of current expenditures per dollar of capital is typically quite low. It is further assumed that none of this demand for capital can be met through current excess capacity. Instead, local governments invest in new structures and equipment at the start of the first year, before any homes are built. To the extent that this is not true—that, for instance, some revenue from impact or other fees is available to fund part of the capital expenditures—interest costs would be somewhat lower than reported here.

To compare the streams of costs and revenues over time, we assume that half of the current expenses and half of the ongoing, annual revenues are realized in the first year. This would be the case if construction and occupancy took place at an even rate throughout the year. Revenues in the first year also include all of the one-time construction impacts such as impact and permit fees.

The difference between revenues and current expenses in a given year is an operating surplus. At the start of the first year, capital investment is financed through debt by borrowing at the current municipal bond interest rate,<sup>5</sup> and the interest accrues throughout the year. Each year after that, the operating surplus is used first to pay the interest on the debt, if any exists, then to pay off the debt at the end of the year. The results are shown for the 100 single family homes in Table 3, for the 74 multifamily units in Table 4, and for single family and multifamily combined in Table 5.

The difference between revenues (the third column) and all costs, including interest on the debt, is shown in the last column. Again, the assumption is that any operating surplus is being used to service the debt, and then to retire as much debt as possible at the end of the year. For either single family or multifamily construction considered separately, as well as for the combined case that analyzes single family and multifamily construction together, revenue net of costs and interest is negative in the first year, but turns positive beginning in year two.

Revenues are eventually sufficient to pay off all debt by the end of year twenty-eight for single family construction, and by the end of year twenty for multifamily construction. In the combined case, where it is assumed net income on multifamily construction is available to pay down single family debt after year twenty, all debt can be paid off by the end of year twenty-five. After that, net income generated by the 100 single family and 74 multifamily units is roughly \$235,000 per year.

A relatively small amount of new capital investment occurs in years eleven and twenty-one, because capital equipment purchased at the start of the first year becomes fully depreciated and needs to be replaced at ten year intervals. All other capital investment consists of structures of various types, which have service lives much longer than a single decade.

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<sup>5</sup>The interest rate on municipal bonds is the monthly Bond Buyer 20-year General Obligation Municipal Bond Index available on the Federal Reserve Board's Web site: [http://www.federalreserve.gov/releases/h15/data/Monthly/H15\\_SL\\_Y20.txt](http://www.federalreserve.gov/releases/h15/data/Monthly/H15_SL_Y20.txt).

Table 3. Results for 100 Single Family Homes

Year	Current Expenses	Revenue	Operating Surplus	Capital Investment Start of Year	Debt Outstanding End of Year	Interest on the Debt	Revenue Net of Costs and Interest
1	183,500	846,332	662,832	2,816,000	2,277,096	123,927	-2,277,096
2	367,000	515,817	148,817	0	2,228,490	100,211	48,606
3	367,000	515,817	148,817	0	2,177,744	98,072	50,745
4	367,000	515,817	148,817	0	2,124,766	95,839	52,979
5	367,000	515,817	148,817	0	2,069,456	93,507	55,310
6	367,000	515,817	148,817	0	2,011,712	91,073	57,744
7	367,000	515,817	148,817	0	1,951,426	88,532	60,285
8	367,000	515,817	148,817	0	1,888,488	85,879	62,938
9	367,000	515,817	148,817	0	1,822,780	83,109	65,708
10	367,000	515,817	148,817	0	1,754,180	80,217	68,600
11	367,000	515,817	148,817	38,000	1,720,561	77,199	33,619
12	367,000	515,817	148,817	0	1,647,462	75,719	73,098
13	367,000	515,817	148,817	0	1,571,147	72,502	76,315
14	367,000	515,817	148,817	0	1,491,473	69,144	79,674
15	367,000	515,817	148,817	0	1,408,293	65,637	83,180
16	367,000	515,817	148,817	0	1,321,452	61,977	86,841
17	367,000	515,817	148,817	0	1,230,790	58,155	90,663
18	367,000	515,817	148,817	0	1,136,137	54,165	94,652
19	367,000	515,817	148,817	0	1,037,319	50,000	98,818
20	367,000	515,817	148,817	0	934,153	45,651	103,167
21	367,000	515,817	148,817	38,000	864,446	41,110	69,707
22	367,000	515,817	148,817	0	753,671	38,043	110,775
23	367,000	515,817	148,817	0	638,021	33,168	115,650
24	367,000	515,817	148,817	0	517,282	28,078	120,739
25	367,000	515,817	148,817	0	391,230	22,765	126,053
26	367,000	515,817	148,817	0	259,630	17,217	131,600
27	367,000	515,817	148,817	0	122,238	11,426	137,392
28	367,000	515,817	148,817	0	0	5,379	143,438
29	367,000	515,817	148,817	0	0	0	148,817
30	367,000	515,817	148,817	0	0	0	148,817

Table 4. Results for 74 Multifamily Housing Units

Year	Current Expenses	Revenue	Operating Surplus	Capital Investment Start of Year	Debt Outstanding End of Year	Interest on the Debt	Revenue Net of Costs and Interest
1	87,500	337,492	249,992	1,276,000	1,082,163	56,155	-1,082,163
2	175,000	261,691	86,691	0	1,043,095	47,624	39,067
3	175,000	261,691	86,691	0	1,002,309	45,905	40,786
4	175,000	261,691	86,691	0	959,728	44,110	42,581
5	175,000	261,691	86,691	0	915,272	42,236	44,455
6	175,000	261,691	86,691	0	868,860	40,280	46,412
7	175,000	261,691	86,691	0	820,406	38,237	48,454
8	175,000	261,691	86,691	0	769,820	36,105	50,587
9	175,000	261,691	86,691	0	717,007	33,878	52,813
10	175,000	261,691	86,691	0	661,870	31,554	55,137
11	175,000	261,691	86,691	21,000	625,306	29,128	36,564
12	175,000	261,691	86,691	0	566,133	27,519	59,173
13	175,000	261,691	86,691	0	504,357	24,915	61,777
14	175,000	261,691	86,691	0	439,861	22,196	64,495
15	175,000	261,691	86,691	0	372,527	19,358	67,334
16	175,000	261,691	86,691	0	302,230	16,394	70,297
17	175,000	261,691	86,691	0	228,839	13,301	73,391
18	175,000	261,691	86,691	0	152,219	10,071	76,621
19	175,000	261,691	86,691	0	72,227	6,699	79,992
20	175,000	261,691	86,691	0	0	3,179	83,513
21	175,000	261,691	86,691	21,000	0	0	65,691
22	175,000	261,691	86,691	0	0	0	86,691
23	175,000	261,691	86,691	0	0	0	86,691
24	175,000	261,691	86,691	0	0	0	86,691
25	175,000	261,691	86,691	0	0	0	86,691
26	175,000	261,691	86,691	0	0	0	86,691
27	175,000	261,691	86,691	0	0	0	86,691
28	175,000	261,691	86,691	0	0	0	86,691
29	175,000	261,691	86,691	0	0	0	86,691
30	175,000	261,691	86,691	0	0	0	86,691

Table 5. Combined Results for 100 Single Family and 74 Multifamily Units

Year	Current Expenses	Revenue	Operating Surplus	Capital Investment Start of Year	Debt Outstanding End of Year	Interest on the Debt	Revenue Net of Costs and Interest
1	271,000	1,183,824	912,824	4,092,000	3,359,259	180,082	-3,359,259
2	542,000	777,509	235,509	0	3,271,585	147,835	87,673
3	542,000	777,509	235,509	0	3,180,053	143,977	91,532
4	542,000	777,509	235,509	0	3,084,493	139,949	95,560
5	542,000	777,509	235,509	0	2,984,728	135,743	99,765
6	542,000	777,509	235,509	0	2,880,572	131,353	104,156
7	542,000	777,509	235,509	0	2,771,832	126,769	108,740
8	542,000	777,509	235,509	0	2,658,307	121,984	113,525
9	542,000	777,509	235,509	0	2,539,786	116,988	118,521
10	542,000	777,509	235,509	0	2,416,049	111,772	123,737
11	542,000	777,509	235,509	59,000	2,345,867	106,326	70,182
12	542,000	777,509	235,509	0	2,213,596	103,238	132,271
13	542,000	777,509	235,509	0	2,075,504	97,417	138,092
14	542,000	777,509	235,509	0	1,931,334	91,339	144,169
15	542,000	777,509	235,509	0	1,780,820	84,995	150,514
16	542,000	777,509	235,509	0	1,623,682	78,371	157,138
17	542,000	777,509	235,509	0	1,459,629	71,456	164,053
18	542,000	777,509	235,509	0	1,288,356	64,236	171,273
19	542,000	777,509	235,509	0	1,109,546	56,698	178,810
20	542,000	777,509	235,509	0	922,866	48,829	186,680
21	542,000	777,509	235,509	59,000	786,971	40,614	135,895
22	542,000	777,509	235,509	0	586,096	34,633	200,875
23	542,000	777,509	235,509	0	376,380	25,793	209,716
24	542,000	777,509	235,509	0	157,435	16,564	218,945
25	542,000	777,509	235,509	0	0	6,928	228,580
26	542,000	777,509	235,509	0	0	0	235,509
27	542,000	777,509	235,509	0	0	0	235,509
28	542,000	777,509	235,509	0	0	0	235,509
29	542,000	777,509	235,509	0	0	0	235,509
30	542,000	777,509	235,509	0	0	0	235,509



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**TECHNICAL  
APPENDIX ON  
ESTIMATING  
CAPITAL  
OWNED AND  
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## **Technical Appendix on Estimating Local Capital**

This appendix explains the method used to estimate the age and dollar value of local government capital by function (education, water and sewer services, etc.). The general approach is to estimate economic relationships using state-level data and then apply parameters from the state-level estimates to local data.

First, a cost share equation based on conventional production theory is described for the structures associated with each function of government. In the equations age of capital is used as a proxy for technologic change. Age of capital, in turn, is estimated as a function of population growth.

The following derivations apply to any one of the ten categories of state and local government capital—e.g., highways or school buildings—tracked in the Bureau of Economic Analysis (BEA) wealth data files. For simplicity, the notation suppresses an explicit reference to capital type. In cases where some detail of the model pertains to a particular type of capital or function of local governments, the text will make that clear.

Let  $y$  = output;  $L$  = labor,  $w$  = the price of labor, and  $r$  = the price of capital, and consider a general translog cost function:<sup>6</sup>

$$(1) \quad c_{it} = \beta_0 + \beta_w \ln w_{it} + \beta_r \ln r_{it} + \beta_y \ln y_{it} + \beta_a a_{it} + \frac{1}{2} \beta_{ww} (\ln w_{it})^2 + \beta_{wr} \ln w_{it} \ln r_{it} \\ + \frac{1}{2} \beta_{rr} (\ln r_{it})^2 + \beta_{wy} \ln w_{it} \ln y_{it} + \beta_{ry} \ln r_{it} \ln y_{it} + \beta_{wa} a_{it} \ln w_{it} + \beta_{ra} a_{it} \ln r_{it} \\ + \beta_{yy} (\ln y_{it})^2 + \beta_{ya} a_{it} \ln y_{it} + \beta_{aa} a_{it}^2$$

In the case where the firm is a government,  $y_{it}$  is essentially unmeasurable, so it seems reasonable to assume linear homogeneity in output. This simplifies the translog specification considerably:

$$(2) \quad c_{it} = \beta_0 + \beta_w \ln w_{it} + \beta_r \ln r_{it} + \ln y_{it} + \beta_a a_{it} + \frac{1}{2} \beta_{ww} (\ln w_{it})^2 + \beta_{wr} \ln w_{it} \ln r_{it} \\ + \frac{1}{2} \beta_{rr} (\ln r_{it})^2 + \beta_{wa} a_{it} \ln w_{it} + \beta_{ra} a_{it} \ln r_{it} + \beta_{aa} a_{it}^2$$

Specification (2) still requires an estimate of  $\ln y_{it}$ . However, application of Shephard's Lemma generates the following two-equation system:

$$(3) \quad s_{L, it} = w_{it} L_{it} / c_{it} = \partial \ln c_{it} / \partial \ln w_{it} = \beta_w + \beta_{ww} \ln w_{it} + \beta_{wr} \ln r_{it} + \beta_{wa} a_{it} \\ (4) \quad s_{K, it} = r_{it} K_{it} / c_{it} = \partial \ln c_{it} / \partial \ln r_{it} = \beta_r + \beta_{wr} \ln w_{it} + \beta_{rr} \ln r_{it} + \beta_{ra} a_{it}$$

By estimating cost shares rather than the cost function itself, the ability to estimate  $\beta_0$ ,  $\beta_a$ , and  $\beta_{aa}$  (essentially nuisance parameters) is lost. Also lost is some precision, in the sense that a lower-order approximation is being estimated.<sup>7</sup> The advantage is relief from the need to supply values for the unobservable  $y_{it}$ .

<sup>6</sup> See, for example, Walter Diewert and Terry Wales (1987), "Flexible Functional Forms and Global Curvature Conditions," *Econometrica*, 55, 43-68.

<sup>7</sup> See Henri Theil, *The System-Wide Approach to Microeconomics*, University of Chicago Press, 1980, page 151.

Economic theory implies several restrictions.

Symmetry:  $\beta_{wr}$  is the same in both equations

Linear homogeneity in input prices:  $\beta_w + \beta_r = 1$ ;  $1/2 \beta_{ww} + \beta_{wr} + 1/2 \beta_{rr} = 0$ ;  $\beta_{wa} + \beta_{ra} = 0$ .

The restrictions are imposed in the usual way. One of the factor prices ( $w_{it}$ ) is used as a numeraire; and only one share equation ( $s_{L, it}$ ) is estimated, leaving parameters of the second, if needed, to be recovered by simple algebra. The resulting estimating equation is

$$(5) \quad s_{L, it} = w_{it} L_{it} / (w_{it} L_{it} + r_{it} k_{it}) = \beta_w + \beta_{wr} \ln (r_{it} / w_{it}) + \beta_{wa} a_{it} + \beta_I' I_{it}$$

where  $I_{it}$  is a vector of indicator variables that may be added to equations for some government functions to account for outliers among specific states and time periods. More detail is provided when the regression results are discussed.

Model (5) can be estimated with any standard regression package, provided state-level annual data for  $L$ ,  $w$ , and  $r$  can be specified. Series beginning in 1987 for the first two are available from the Government Division of the U.S. Census Bureau. For  $r$ , standard practice is followed by assuming cost of capital is the sum of three terms: maintenance (meaning, in this case, all non-labor operating costs), interest, and depreciation.

$$(6) \quad r_{it} = x_{it} / k_{it} + \phi_{it} + *_{it}$$

where  $x_{it}$  is the difference between total current expenditures and labor costs,  $\phi_{it}$  is an interest rate for appropriate types of tax-exempt public-purpose government bonds, and  $*_{it}$  is the national depreciation rate from BEA's wealth accounts.

To estimate the cost share equations, the same annual interest rate series  $\phi_t$  is used for all states. Because the preferred series not available until 1990, two different sources are used to construct the 1987–2001 annual interest rate series  $\phi_t$ . From 1987 through to the end of 1989, the JP Morgan Revenue Bond Index (RBI) is used. The JP Morgan RBI data are monthly. An annual interest rate is constructed by taking the average of the 12 monthly observations for each calendar year.

From 1990 to the present the Merrill Lynch 20 Year AAA GO series is used. The Merrill Lynch data are provided weekly. An annual interest rate is constructed by taking the average of the 52 observations in each calendar year.

To insure that there is no discontinuity in the series, the annual interest rate from the JP Morgan RBI index for the years 1987 1988 and 1989 is multiplied by the average of the annual ratio of the Merrill Lynch 20 Year AAA GO series divided by the JP Morgan RBI index the for the years 1990 to the present. That ratio turned out to be 0.93. The reason the ratio is less than one is largely because the Merrill Lynch index has a duration that is on average 5 years shorter than the JP Morgan RBI Index.

The final index was chosen following consultation with bonds specialists at both JP Morgan and Merrill Lynch. Although there are hundreds of thousands of unique muni-bonds, and most are rarely if ever traded, the experts felt that a 20 year maturity seemed appropriate and that the ML GO AAA series was probably best for this purpose.

In order to make the cost share equations operational, it's necessary to apportion equipment among the other nine types of capital for which it's possible to approximately match capital with expense and employment data by function of government. In general, a year-zero approach is employed, basing the analysis on the ratio of structures to equipment when both are brand new.

Suppressing the cross-sectional (state) subscript, capital  $k$  required for a specific local government function is the sum of structures  $k_s$  and equipment  $k_e$ :

$$(7) \quad k_t = k_{st} + k_{et}$$

where  $k_{st} = k_{s0}(1-*_s)^{a_s}$ ,  $k_{et} = k_{e0}(1-*_e)^{a_e}$

or, equivalently,

$$(8) \quad k_{s0} = k_{st}(1-*_s)^{-a_s}, \quad k_{e0} = k_{et}(1-*_e)^{-a_e}$$

Brand new equipment is allocated to brand new structures based on the relative total year-zero values of structures. From this, a ratio  $z$  can be derived, which will be the same for all local government functions (or structure types):

$$(9) \quad z = k_{e0}/k_{s0} = k_{et}(1-*_e)^{-a_e} k_{st}^{-1}(1-*_s)^{a_s}$$

The average  $z$  ratio for 50 states plus the District of Columbia in the most recent year for which we can compute it (1998) is .11642. This number is used below to help derive estimates of government-owned equipment and structures for a particular local area.

The blended ages and depreciation rates for total capital (structures and equipment) were used to compute the independent variables in the estimating equations. The nine equations (one for each function of government) were estimated, using data for the period where complete state-level government employment and finance data were available—1987 through 1998. The procedure converged quickly (in four iterations). Results are shown in Table 3.

Fit of the model was improved by including a number of indicator variables, up to three per equation. These are identified as I1, I2, and I3 in Table A1 and defined in Table A2.

Not all of the cost equations contain an indicator variable, and each indicator captures only a small number of states. Several variables simply indicate that an observation is for the state of Alaska, and it seems reasonable to suppose that the technology of providing some government services in Alaska would be different than in many other states. In the case of housing, New York appears to be an isolated outlier, and again that is not especially surprising. Other indicators capture a small number of states in New England or the Rocky Mountain area. The conservation series showed a clear break between 1991 and 1992 in Arizona. The Census Bureau instituted some procedural changes involving the collection and reporting of government finance data beginning in 1992.

**Table A1. Regression Results: Cost Share Equations**

	$\beta_w$	$\beta_{wr}$	$\beta_{wa}$	I1	I2	I3	Adj R <sup>2</sup>
Residential	-0.5454 (.0001)	-0.1082 (.0001)	0.0051 (.0158)	0.1531 (.0001)	0.2150 (.0001)		.453
Education	-0.3801 (.0001)	-0.1391 (.0001)	0.0156 (.0001)				.545
Hospital	0.5682 (.0001)	-0.1413 (.0001)	-0.0247 (.0001)	-0.1793 (.0001)			.506
Other Buildings	0.3970 (.0001)	-0.1655 (.0001)	-0.0368 (.0001)				.784
Streets & Highways	-0.0345 (.4529)	-0.0723 (.0001)	-0.0110 (.0001)	0.2072 (.0001)			.598
Conservation	0.1846 (.0165)	-0.0524 (.0001)	-0.0017 (.6021)	0.3443 (.0001)	-0.2017 (.0001)	0.1210 (.0001)	.483
Sewer	-0.4148 (.0001)	-0.0861 (.0001)	0.0018 (.1985)				.522
Water	-0.0336 (.5780)	-0.1077 (.0001)	-0.0169 (.0001)				.413
Other Structures	-0.2342 (.0021)	-0.1112 (.0001)	-0.0111 (.0004)	0.39629 (.0001)			.566

**Table A2: Indicator Variables for Cost Share Equations**

Capital type	Variable	Condition for I=1
Residential	I1	state=AK
	I2	state=NY
Hospital	I1	state=AZ, NH, or VT
Streets & Highways	I1	state=AK
Conservation	I1	state=AK
	I2	state =NY or CT; or state=AZ and year < 1992
	I3	state=ID, MT, ND, or WY
Other Structures	I1	state= NE, NY, or WA

In the equations above, age of the capital stock appears as an explanatory variable. This is not readily available, even at the state level. A commonly used approach employs perpetual accounting, investment, and depreciation rates to base-year estimates.<sup>8</sup> The procedure used here begins with that approach, but then relates the investment rates to population growth rates, one of the few items for which consistent time series are available for individual U.S. counties.

From BEA national wealth data, the following are available or can easily be computed:

\* = real annual rate of depreciation (defined broadly, as BEA does, to include a normal rate of obsolescence and retirement of assets)

> = monthly depreciation rate, a simple algebraic transformation of \*.

$N_t$  = real, net (of depreciation) rate of investment in year  $t$ ,  $t=1946, \dots, 2000$ .

<sup>8</sup> As in Douglas Holtz-Eakin, "State-Specific Estimates of State and Local Government Capital," *Regional Science and Urban Economics*, Vol. 23, No. 2, April 1993, pp. 185-210.

From data compiled by the Governments Division of the Census Bureau, and ratios employed by BEA to analyze this data, the following can be computed for state  $i$  and  $t=1977, \dots, 1999$ :

$vn_{it}$  = real investment in new assets state  $i$  in year  $t$ .

$ve_{it}$  = real investment in existing assets state  $i$  in year  $t$ .

$v_{it}$  = real investment in state  $i$  in year  $t = vn_{it} + ve_{it}$ .

$x_{it}$  = current expenditures associated with the relevant type of capital state  $i$  in year  $t$ .

From standard Census Bureau data it is possible to compute

$\Pi_{it}$  = population growth in the state relative to the national rate; i.e.,

$$\Pi_{it} = \frac{\Delta \rho_{it}}{\rho_{it-1}} \left[ \frac{\sum_i \Delta \rho_{it}}{\sum_i \rho_{it-1}} \right]^{-1}$$

The starting point consists of initial end-of-year estimates of the real capital stock,  $k_{i76}^0$ , determined by allocating capital to each state according to its share of current expenditure,  $x_{i77}$ . This procedure, the one employed for example by Holtz-Eakin (1993), is used here only for the purpose of supplying initial values to be modified in subsequent iterations.

Perpetual inventory accounting can be used to calculate the following recursively for  $t=1977, \dots, 1999$ :

$$(10) \quad k_{i,t+1}^0 = k_{it}^0 (1-\delta) + v_{it+1} (1-\delta)^6$$

This assumes that investment made during period  $t+1$  depreciates an average of 6 months by the end of the period. Then relative (to the national rate) net real rates of investment can also be computed:

$$(11) \quad \equiv_{it}^0 = \left[ \frac{v_{it} - \delta k_{it-1}^0}{k_{it-1}^0} \right] N_t^{-1}$$

The goal is to obtain estimates of parameters  $\forall_j$  and  $2_q$  in the following regression relationship:

$$(12) \quad \equiv_{it}^0 = \sum_{j=1}^J \alpha_j^0 \rho_{it-j}^0 + \sum_{q=1}^Q \beta_q D_q$$

where  $J$  is the longest lag considered and the  $D_q$  are indicator (dummy) variables. The hypothesis underlying this specification is that a state's rate of investment (relative to the national rate) is a function of past rates of its population growth (also relative to the national rate), with indicator variables to account for anomalies in some states due to peculiarities that are difficult to observe and quantify. Inspection of the pair wise correlations between  $\equiv_{it}$  and  $\Pi_{it-j}$  reveal that they begin to decline at or before the lag reaches eight years, depending on the type of capital. Thus, model specification for each type of capital began by tentatively considering population growth effects up to  $J=8$ . The final specification varies from case to case.

As a practical matter, the final specifications employ averages of population growth rates lagged over several years. Over the course of several experiments, the sum of the coefficients on the population variables never changed substantially when an average was substituted for a series of individual lags. Coefficients on individual lags tended to fluctuate widely and lack statistical significance, due to collinearity. The use of averages thus aids interpretation without impacting the marginal impacts predicted by the equations in a meaningful way.

Three indicator variables were used in all but the hospital capital equation, which employed four. In most cases, indicator variables flag relatively few states (Table A3).

**Table A3: Indicator Variables for Relative Investment Rate Equations**

Capital Category	DVERYHI=1	DHIGH=1	DLOW=1	DVERYLOW=1
1 Equipment	DC, WY	AZ, CO, MT, UT	AR, NH, RI	
2 Residential Buildings	DC, HI, MA, NY	CT, DE, RI	CO, FL, ID, NM, TX, UT, VT, WY	
3 Educational Buildings	WY	HI, NM, TX	CA, VT, WI	
4 Hospital Buildings	WY	AL, FL, GA, HI, IA, ID, KS, NY, OH, WA	AR, CT, DE, IL, KY, ME, OR, UT, WI, WV	AZ, VT
5 Other Buildings	DC, WY	HI, MD	AR	
6 Highways and Streets	WY	DC, IA, MN, MT, ND, NE	AR, ME, NH, SC, VT	
7 Conservation & Development	HI, WY	AZ, LA, MT	AL, NY, OK, TN, VA	
8 Sewer Systems & Structures	DC, NY, WA	MA, MD, NJ, OH, RI, WI	AR, NC	
9 Water Supply Facilities	CO, DC, SD, WY	FL, NV	DE, NH	
10 Other Structures	DC	NE	NH	

Given initial estimates, it's possible to begin the perpetual inventory accounting process at an earlier date. If we assume that the World War II period was atypical and restrict ourselves to post-war population data, an 8-year lag in (12) implies that 1954 is the first year for which we can obtain state investment estimates. Hence, state capital stocks in 1953 are estimated by allocating the national capital stock in that year according to its share of the U.S. population, then estimating state investment in the years from 1954 through 1976 recursively according to

$$(13) \quad v_{it}^0 = k_{it-1}^0 (* + N_t \equiv_{it}^0)$$

where  $\equiv_{it}^0$  is estimated from (12). In words, (13) says that investment is enough to cover depreciation, plus another term which is the net national rate of investment multiplied by a relative factor specific to state *i*. It is then possible to combine (13) with (10) to derive estimates of the capital stock for the years 1954 through 1976 in most states. (Lack of complete data for in earlier years pushes the first estimate for Alaska forward to 1962.)

In this way revised estimates  $k_{i76}^1$  are derived, and these can be used to restart the process by repeating steps (10) through (13). This results in successively revised estimates  $k_{it}^1$  and  $\bar{\pi}_{it}^1$  for  $t=1977, \dots, 1999$ ; parameters  $v_j^1$  and  $z_{qi}^1$ ;  $v_{it}^1$  for  $t=54, \dots, 76$ ; and  $k_{i76}^2$ . This ends the first iteration.

This process can be repeated until either a convergence criterion is satisfied. The particular criterion used was an average absolute percentage change in the  $k_{i76}$  no greater than  $10^{-10}$  between iterations.

The procedure was carried out for all 10 BEA categories of state and local government capital. Each of the ten equations converged in fewer than 10 iterations. The final estimates are shown in Table A4.

**Table A4. Final Regression Results: Dependent Variable=Relative Investment Rate**

	Equipment	Residential	Education	Hospital	Buildings nec
Iterations to Convergence	8	6	6	6	6
<b>Final Regression Coefficients (p-values):</b>					
Constant	-0.2590 (.0003)	0.5460 (.0001)	-0.0227 (.8295)	0.3663 (.0001)	0.5439 (.0001)
<i>Lagged relative population growth rates:</i>					
Population lag 1	0.4337 (.0001)		0.3852 (.0001)		0.1336 (.0001)
Population lag 2-5	0.1707 0.0212	0.0662 (.1225)			
Population lag 2-8			0.6865 (.0001)		0.0961 (.0002)
Population lag 6-8		0.0805 (.0532)		0.1270 (.0009)	
<i>State indicator variables:</i>					
DVeryhi	5.6639 (.0001)	2.9842 (.0001)	7.2485 (.0001)	4.1282 (.0001)	1.7082 (.0001)
DHigh	1.2733 (.0002)	0.7862 (.0001)	1.6538 (.0001)	1.4240 (.0001)	1.3839 (.0001)
DLow	-1.3392 (.0001)	-0.8119 (.0001)	-1.2254 (.0003)	-0.8407 (.0001)	-0.6383 (.0001)
DVerylow				-1.7778 (.0001)	
Adjusted R <sup>2</sup>	.432	.426	.311	.323	.402

**Table A4. Continued**

	Streets 6	C&D 6	Sewer 6	Water 6	Other 8
Iterations to Convergence	6	6	6	6	8
<b>Final Regression Coefficients (p-values):</b>					
Constant	0.8370 (.0001)	0.0938 (.0617)	0.4386 (.0001)	0.2036 (.0001)	0.2754 (.0016)
<i>Lagged relative population growth rates:</i>					
Population lag 1				0.1967 (.0001)	0.2253 (.0030)
Population lag 2		0.0950 (.0371)			
Population lag 2-5	0.2462 (.0001)				
Population lag 5			0.0516 (.1461)		
Population lag 2-8				0.4270 (.0001)	0.5368 (.0001)
Population lag 3-8		0.2653 (.0001)			
Population lag 6-8	0.0770 (.0318)		0.0701 (.0594)		
<i>State indicator variables:</i>					
DVeryhi	4.955 (.0001)	2.387 (.0001)	1.348 (.0001)	2.270 (.0001)	13.405 (.0001)
DHigh	1.340 (.0001)	1.223 (.0001)	1.025 (.0001)	0.396 (.0206)	5.981 (.0001)
DLow	-0.684 (.0006)	-0.785 (.0001)	-0.745 (.0001)	-0.126 (.0001)	-2.172 (.0001)
Adjusted R <sup>2</sup>	.502	.338	.268	.496	.528

The estimated pre-1977 investment series can be spliced onto the 1977-1999 data and the results used to estimate the average age of capital, by type, in each state. The procedure is as follows. First, set the average age of capital in state equal to the national average for 1953. Then, use perpetual accounting to recursively calculate the average age in subsequent years:

$$(14) \quad a_{i,t+1} = [(a_{i,t} + 1) k_{i,t}(1-\delta) + \frac{1}{2} v n_{i,t+1}(1-\delta)^6 + a p_t v e_{i,t+1}(1-\delta)^6] / K_{i,t+1}^0$$

where  $a p_t$  is the average age of the relevant type of private capital, in accord with the method used by BEA which assumes that existing assets purchased by governments are "typical".

The process of deriving estimating capital stock estimates for a particular local area begins by adapting the average age equation (14) to location m:

$$a_{m,t} = [(a_{m,t-1} + 1) k_{m,t-1}(1-\delta) + g_t v_{m,t}(1-\delta)^6] / [k_{m,t-1}(1-\delta) + v_{m,t}(1-\delta)^6]$$

where  $g_t = \frac{.5 \sum_i v n_{i,t} + p a \sum_i v e_{i,t}}{\sum_i v_{i,t}}$ , that is, the average end-of-the year age of total assets (including both new and used) purchased by all states in the country during the period.

Then (13) is substituted into the average age formula and the capital factor is eliminated in order to obtain

$$(15) \quad a_{mt} = \frac{(a_{mt-1} + 1)(1 - \delta) + g_t (\delta + N_t \eta_{mt})(1 - \varepsilon)^6}{1 - \delta + (\delta + N_t \eta_{mt})(1 - \varepsilon)^6}$$

Equation (13) can be used to estimate  $\bar{m}_t$  from local relative population growth factors  $\Pi_{mt}$ . Starting with the national average age for 1954 as initial estimate of the average age of the capital stock in  $m$ , (15) can be applied to calculate  $a_{mt}$  recursively for subsequent years.

The result is a recipe for estimating the age of the capital stock for a particular local area. To be implemented, the recipe requires only data on local population growth.

Given the age estimate—along with estimates of the parameters  $\beta_{wr}$ ,  $\beta_{wrr}$  and  $\beta_{wa}$  from the cost share equations, capital depreciation rates  $*_t$  from BEA, a current rate on tax-exempt bonds  $\phi_{mt}$ , and values for  $w_{mt}$ ,  $L_{mt}$  and  $x_{mt}$  that can be obtained for any unit of government from data bases maintained by the U.S. Census Bureau—capital  $k_{mt}$  is the only unknown in the local cost share equation

$$(16) \quad [w_{mt} L_{mt} + x_{mt} + (\phi_{mt} + *_t) k_{mt}] \cdot [\beta_w + \beta_{wr} \ln((x_{mt}/k_{mt} + \phi_{mt} + *_t)/w_{mt}) + \beta_{wa} a_{mt} + \beta'_I I_{mt}] = w_{mt} L_{mt}$$

However, it's necessary to account for the fact that capital in (16) consists of both structures and equipment. Equations (7), (8), and (9) imply that

$$(17) \quad k_{mt,s} = \gamma_{mt} k_{mt} \quad \text{and} \quad k_{mt,e} = (1 - \gamma_{mt}) k_{mt} \quad \text{where}$$

$$(18) \quad \gamma_{mt} = [1 + z(1 - *_e) a_{mt,e} (1 - *_s)^{-a_{mt,s}}]^{-1}$$

By using the 1998 state average value (.11642) for  $z$ , it's possible to compute  $\gamma_{mt}$  from BEA's depreciation rates and the estimated ages of structures and equipment. In turn,  $\gamma_{mt}$  can be used to compute

$$(19) \quad a_{mt} = a_{mt,s} k_{mt,s} / k_{mt} + a_{mt,e} k_{mt,e} / k_{mt} = \gamma_{mt} a_{mt,s} + (1 - \gamma_{mt}) a_{mt,e}$$

and

$$(20) \quad *_t = \gamma_{mt} *_t,s + (1 - \gamma_{mt}) *_t,e$$

for the blended age and depreciation rate of capital, respectively. Substitution into (16) yields a formula that can be applied in practice:

$$(21) \quad [w_{mt} L_{mt} + x_{mt} + (\phi_{mt} + \gamma_{mt} *_t,s + (1 - \gamma_{mt}) *_t,e) k_{mt}] \cdot [\beta_w + \beta_{wr} \ln((x_{mt}/k_{mt} + \phi_{mt} + \gamma_{mt} *_t,s + (1 - \gamma_{mt}) *_t,e)/w_{mt})] + \beta_{wa} (\gamma_{mt} a_{mt,s} + (1 - \gamma_{mt}) a_{mt,e}) + \beta'_I I_{mt}] = w_{mt} L_{mt}$$

This is the formula used to estimate  $k_{mt}$ , the dollar value of a particular type of government capital in a particular local area. Because capital appears twice in the nonlinear expression, a closed form solution for it does not exist. Finding the solution is a one-dimensional problem, however, so  $k_{mt}$  can be recovered through elementary numerical methods.