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The Impact of the Declining Groundwater Supply in the Northern High Plains of Texas and Oklahoma on Expenditures for Community Services

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THE IMPACT OF THE DECLINING GROUNDWATER SUPPLY IN THE NORTHERN HIGH PLAINS OF TEXAS AND OKLAHOMA ON EXPENDITURES FOR COMMUNITY SERVICES

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ABSTRACT

Reduced availability of groundwater in the Northern High Plains of Texas and Oklahoma is expected to have repercussions throughout the regional economy due to the reduction in agricultural income. The decline in the economic base is expected to lead to an out-migration of population. It is presumed that the decrease in population and available income will result in reduced expenditures for community services.

This study establishes concepts for the empirical analysis and measurement of service expenditures. Linear model forms are applied using a cross-sectional data set to develop service expenditure functions. Projections of future expenditure levels for selected community sizes are made using the estimated functional relationships.

The results of these projections indicate that reduced service expenditures will accompany the decrease in population and income due to the decline of available groundwater. Per capita service expenditures are projected to increase over time as total expenditures decrease. Generally it is estimated that per capita service expenditures will be higher in smaller communities in future time periods. Both total expenditures and per capita expenditures are projected to increase more in smaller communities relative to larger communities. These results suggest that the effects of the declining groundwater supply will have a more adverse impact on smaller communities in the Northern High Plains of Texas and Oklahoma.

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INTRODUCTION

The Problem Setting

Economic activity in the High Plains of Northern Texas and Western Oklahoma is highly dependent on groundwater for irrigated agriculture. Irrigation has been practiced for approximately thirty years in the Southern High Plains of Texas. In the Northern High Plains, widespread irrigation has developed more recently. Irrigation and associated inputs have increased agricultural output appreciably. Cotton yields in the region are increased approximately twofold with irrigation, grain sorghum yields about sixfold and wheat yields some threefold, compared to dryland yields (Osborn and Harris).

Dependence of agricultural production on irrigation in this region is emphasized by Osborn and Harris. It was estimated that the value of total crop output from the Northern and Southern High Plains of Texas was $778.1 million in 1967. Of this total, $637.2 million was attributable to irrigated crops while dryland crops accounted for an output of $140.9 million. Total economic activity (direct and indirect) associated with the crop sectors was estimated to be $2.18 billion in 1967.

The continuation of this level of agriculturally based economic activity is not assured. Water is pumped primarily from the Ogallala aquifer. Recharge of this groundwater base is from surface water percolating to the water table from rainfall and application of groundwater. However, natural and artificial recharge is extremely small compared with annual withdrawal rates. This means the groundwater resource is exhaustible. Further, economic exhaustion will occur before physical exhaustion of the aquifer -- where economic exhaustion is defined as that level of water where the cost of pumping and application becomes greater than the value of the irrigation water.

Despite the declining water table, development of the aquifer continues with corresponding increases in irrigated acreage. However, beyond some peak level of irrigated acreage, the process can be expected to reverse with a reverting back to dryland production. This trend is evident in the Southern High Plains where the number of irrigated acres increased from 460,804 in 1949 to 1,380,978 in 1959. However, by 1969 the number of irrigated acres had decreased to 1,324,224. In the Northern High Plains, where irrigation development is more recent, a decrease in irrigated acres has not yet occurred. From 1949 to 1969, the number of irrigated acres on the Northern High Plains increased from 12,591 to 1,230,435 (U.S. Department of Commerce, 1952, 1961, 1972).

Agricultural output in the region can be expected to decline significantly as the transition from irrigated to dryland production occurs. Grubb has estimated that peak irrigated acreage in the region would occur in 1980. Using 1959 data and irrigated acreage projections to the year 2020, he estimated the direct benefits of irrigation on the

High Plains to be $20 per acre irrigated with indirect benefits of $35.32. He concluded that the resulting decline in output from reduced irrigated acreage would have a serious impact on the regional economy.

Relating the effect of declining irrigation to the region, Osborn and Harris estimate the value of irrigation production will decline from $637 million in 1967 to $244 million in 2015, a decrease of 61.6 percent. Although it was estimated that the value of dryland production would increase 63.8 percent, the total value of dryland production would be only 60.9 percent of the 1967 level. The total economic activity associated with crop sectors was estimated to decline from $2.18 billion in 1967 to $1.32 billion in 2015.

Another comprehensive study of the impact of a decline in groundwater was done by Hughes and Harmon on a portion of the Southern High Plains. They estimated a 64 percent reduction in cotton production, a 91 percent reduction in grain sorghum production, and 22 percent increase in wheat production by the year 2015 as compared to 1966. This brought a decline in aggregate value of agricultural product from $432 million in 1966 to $128 million in 2015. These studies indicate a substantial reduction in agricultual income can be expected with reduced groundwater supplies.

It is projected that annual pumpage of groundwater in this region will increase from 1967 to 1990 or 1995, after which it will decline (Wyatt). Ekholm has estimated that both population and gross output from the economy will increase with the increased pumpage of water, but should decrease after 1996.

The Research Problem

Due to the rural characteristics of the area and the dependence on agricultural production, the decline in agricultural output is expected to impact fairly directly on local communities. This could cause major long-term adjustments of the regional economy as the exhaustible water resource is depleted.

One important area of adjustment will be in the delivery of public services. Local communities are responsible for providing such services as water, sewer, police and fire protection. It is expected that an important impact of the decline in agricultural output will be changes in the population and household income in the communities and the region as a whole. These changes will alter the demand for and the ability to support local public services. Viable projections should be useful to community decision makers in planning for public service delivery adjustments.

Objectives

The overall objective of this study is to assess the impact of the declining water supply in the Northern High Plains on the provision of selected community public services. The services studied include water, sewer, street maintenance, police and fire protection.

Specific objectives are:

1. To quantify the relationship between community service expenditures and various demographic and economic variables.
2. To apply the relationships developed above using projected values of the demographic and economic variables to determine the long-term effects on expenditures levels for community public services.

Study Area

The study area is comprised of 25 counties of the Northern Texas Panhandle and the three counties of the Oklahoma Panhandle as shown in figure 1. This region, hereafter referred to as the Northern High Plains, is basically a rural area with Amarillo as the only Standard Metropolitan Statistical Area (SMSA). The Amarillo SMSA serves as a regional trade center, and in the decade of 1960 to 1970 accounted for 40 percent of the region's population. The remaining 60 percent of the regional population is composed primarily of rural communities. Approximately thirty communities have populations between 1,000 and 5,000 with only eight communities exceeding 5,000 persons. There are numerous communities with less than 1,000 persons (The Dallas Morning News). Total regional population was 357,095 in 1970, which represented a 4.4 percent decline from 1960 (U.S. Department of Commerce 1963, 1973).

Principal agricultural commodities produced in this region are grain sorghum, wheat, corn and cattle. These products are an integral part of the region's economy. A large proportion of the production from the crops is directly attributable to irrigation. In 1969, 25

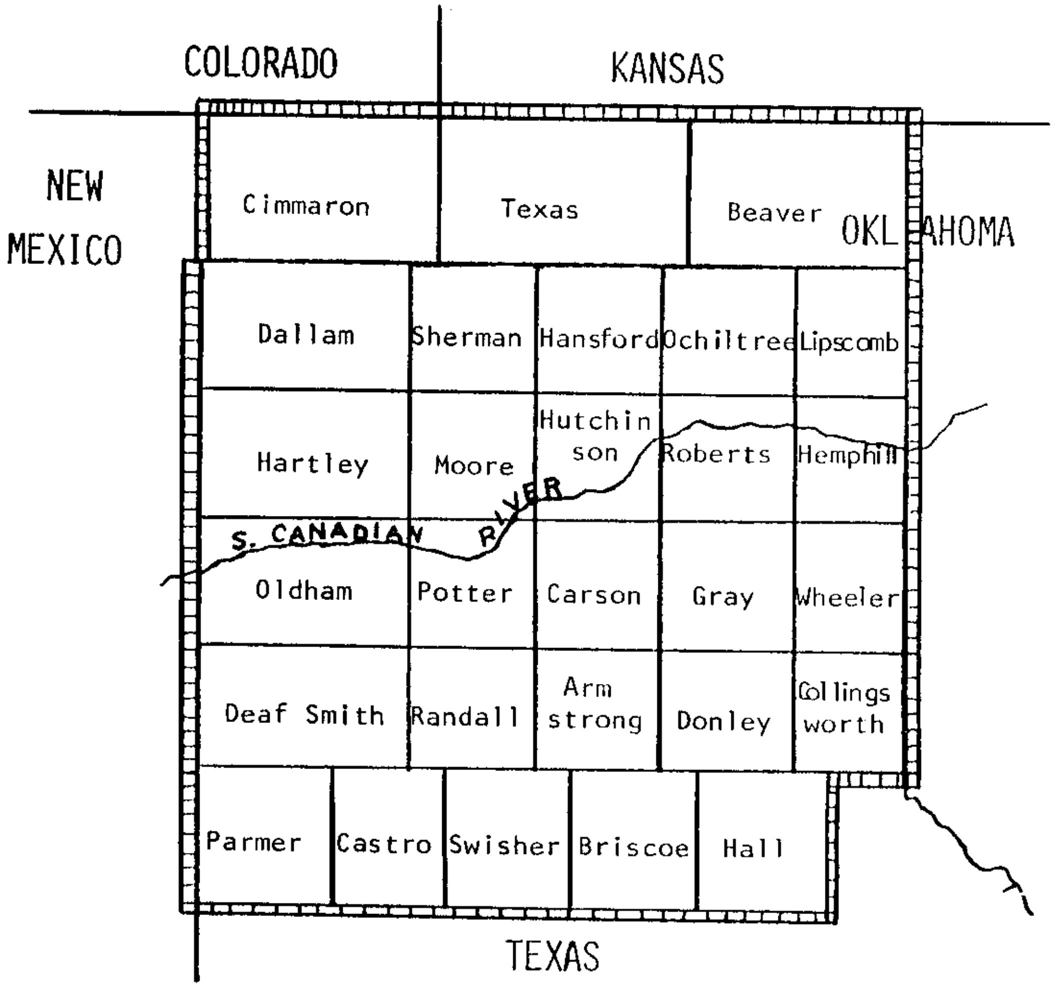

Figure 1. Northern High Plains of Texas and Oklahoma

percent of the crop acreage in the study area was irrigated (U.S. Department of Agriculture). In 1971, total agricultual income in the region was $820 million which accounted for over 20 percent of regional household income (U.S. Department of Agriculture; Texas Industrial Commission). Due to the dependence of agricultural activities on the exhaustible water resource base, it is important that estimates be made of the effects of changes in water availability.

THE MODEL AND METHOD OF ANALYSIS

To estimate the effect of the declining groundwater supply in the Northern High Plains on community services, it was necessary to develop a reliable relationship between groundwater supplies and public service expenditures. The services examined include municipal water, sewer, street maintenance, police, and fire protection.

Model

The relationship quantified in this study is total community service expenditures (TE) as a function of community population (P) and area income (Y). That is

(1) $$TE = f(P,Y)$$

In equation (1) Y can be expressed as

(2) $$Y = Y_a + Y_n$$

where Y_a = total income to agricultual enterprises

Y_n = non-agricultural income

Further, assuming that the relationships between different sectors of the economy have and will remain relatively constant, then Y_n can be separated into

(3) $$Y_n = M(Y_a) + Y_o$$

where M = multiplier reflecting indirect effect of agricultural activity on sources of non-agricultural income, i.e., $M(Y_a)$ is income related to (induced by and stemming from) agricultural activities.

Y_o = income not affected by agricultural income

The important issue for purposes of this study is that agricultural income (Y_a) and hence Y_n will be negatively affected by the decline in the supply of available groundwater. In the main it is safe to assume that Y_o will not be affected by the declining water supply. Therefore, assuming no change in Y_o it would be possible to show the effects of the declining water supply on the regional economy using this framework. Since forecasted values to the year 2010 for Y and P have been generated in a regional input-output simulation study by Ekholm, all that was needed to operationalize the model was to specify and fit equation (1).

Several assumptions are implicit in this framework. First it was assumed that the study communities are relatively homogeneous with regard to economic characteristics, income sources and resource base implying comparable spending patterns for services. Secondly, it was presumed that the level of services provided is at a point which the governing agency considers to be optimum given their community's "demand" situation and political support (Brunn and Jones).[1]

Finally it was assumed that, in the long run, the level of public services will follow the same course on the declining side that it did in increasing. In the short run, if an economic decline occurred, a city might be forced to maintain a high level of expenditures due to depreciation schedules and over-capitalization. However, as the marginal value of facilities falls to salvage value, or the facilities wear out, the communities should be able to cut expenses back to a point comparable to the long-run growth curve.

Method of Analysis

Ordinary least squares multiple regression was used to estimate the parameters of the model. The computer routine used was the regression procedure of the Statistical Analysis System (SAS). Although both linear functions and curvilinear functions including power and quadratic forms were specified, only the results using the linear model specifications are discussed in this report. Results of other model forms are presented in Williford.

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[1]Public services have been regarded as commodities which express some characteristics of both public and private goods, and which may be analyzed using traditional economic concepts (Jones and Gessaman; Jones; Hirsch). Due to the difficulties in defining service output units, most analysis has focused on the measurement of expenditure levels which has aroused some controversy (Schmandt and Stephens; Tiebout; Breton; Glover). Using expenditures in relationships as a function of selected demographic and economic factors, various researchers have examined changes in expenditure patterns between different communities and attempted to determine the minimum cost community size in service provision (Hyman; Morris, Hall and Jones; Hitzhusen; White and Tweeten; Ricker and Tyner). A more thorough review of background literature is contained in a M.S. thesis by Williford.

DATA: SOURCES AND DEVELOPMENT

Two approaches were used to establish a community service expenditure function, one utilizing time series data and the other cross-sectional data. Discussion in this report is limited to the use of the cross-sectional data; the time series analysis was inconclusive. The time series results are presented and discussed in Williford.

The Data

The cross-sectional data set was information from 47 communities of the Texas High Plains for 1970. Communities were included both from the Northern High Plains and the Southern High Plains because irrigated agricultural development in the Southern High Plains preceded that of the Northern High Plains by approximately thirty years, and parallels the expected course in the Northern High Plains. The communities were classified according to population size, but variations in factors such as income and population change were expected to show differences in the situations of similar size communities.

The community expenditures for water and sewer, streets, police, and fire protection as well as a total service expenditure figure were obtained by telephone interview with each of the 47 communities. Because some communities did not report certain information, there are some gaps in the observations.

The independent variables of the cross-sectional data include city population, percent change in city population, and per capita county income. All these values were obtained from the Texas Industrial Commission. City population was obtained by the Texas Industrial Commission from the Department of Commerce (1963, 1973). The percent change in city population was calculated by subtracting the 1960 city population from the 1970 city population and dividing the difference by the 1960 city population. Both population increases and decreases occurred over the 47 communities during this 10 year period.

Percent change in city population was included to provide some insight into the growth situation of the individual communities. It was assumed that a community experiencing a great deal of growth in the past decade would have to expand the services offered and in turn expenditures made on services. Conversely a community whose population had declined in the decade should have capital facilities in excess of that currently needed. In attempting to maintain these facilities, the expenditures would be expected to be non-proportional to community size. Thus the coefficient for percent change in city population was expected to be negative.

County per capita income data were obtained from the Texas Industrial Commission from the Department of Commerce (1973). A city income figure could not be located; therefore, county income was used. It is assumed that the county per capita income is applicable to all communities of the county. The 47 communities are similar in their economic activities. There is no large industrial or tourism development. Most of the income sources are either agricultural or service industries. The 1970 cross-sectional data including observations for the smallest community, largest communtiy, and the range of values over all communities for each variable are given in table 1.

Projections

The determination of the effects of the declining groundwater supply on future community service levels in Northern High Plains communities is one portion of a project undertaken by the Water Resource Institutes of Texas and Oklahoma. Separate portions of the research were done at Texas A&M, Texas Tech, and Oklahoma State Universities.

A Northern High Plains regional simulation model was adapted from a model developed by Osborn. The modification and application of this model was done by Ekholm at Oklahoma State University. In the Ekholm study, the simulation model was applied using estimates of available groundwater and regional input-output data to estimate, by year, the changes in population, output, income, and employment for the area. The projected change in population and value of income from Ekholm's study were used to estimate the expected effects on service expenditures. The projected area population and per capita income data are listed in table 2. The data show that population is expected to increase until 1981, after which it declines, while per capita disposable income increases through 2010.

Table 1. Population, Income, and Service Expenditures for 47 Northern and Southern High Plains Communities, 1970.

Variable	Unit	Smallest Community	Largest Community	Range over all Communities
City population[a]	persons	578	21,726	578 - 21,726
Percent change in city population	percent	31.96	-11.91	-32.12 - 75.30
County per capita income[a]	dollars	3,071	3,655	2,442 - 3,952
Water and sewer expenditures[b]	dollars	2,170	426,218	2,170 - 426,218
Street expenditures[b]	dollars	125	208,314	125 - 208,314
Police expenditures[b]	dollars	2,925	214,568	1,200 - 214,568
Fire expenditures[b]	dollars	51	239,712	51 - 239,712
Total service expenditures[b]	dollars	5,271	1,088,812	5,271 - 1,088,812

[a]Source: Texas Industrial Commission.

[b]Obtained by telephone interview from individual communities.

Table 2. Projected Population and Disposable Per Capita Income, Northern High Plains, 1967-2010[a].

Year	Population	Disposable Per Capita Income (1967 dollars)
1967	362,361	3,010
1968	363,084	3,081
1969	365,099	3,157
1970	370,857	3,219
1971	378,455	3,270
1972	386,732	3,333
1973	397,111	3,372
1974	407,135	3,411
1975	415,977	3,462
1976	425,097	3,486
1977	433,541	3,497
1978	439,177	3,510
1979	442,337	3,528
1980	443,570	3,553
1981	443,958	3,579
1982	443,649	3,602
1983	442,120	3,633
1984	440,256	3,666
1985	438,455	3,702
1986	436,943	3,739
1987	436,430	3,772
1988	436,393	3,804
1989	436,577	3,835
1990	436,755	3,865
1991	436,806	3,893
1992	436,388	3,922
1993	435,498	3,953
1994	434,449	3,985
1995	433,340	4,019
1996	432,263	4,043
1997	429,699	4,061
1998	425,348	4,082
1999	419,532	4,110
2000	413,050	4,144
2001	406,563	4,181
2002	400,317	4,213
2003	393,751	4,244
2004	386,859	4,279
2005	379,884	4,315
2006	373,060	4,354
2007	366,502	4,394
2008	360,297	4,433
2009	354,352	4,473
2010	348,629	4,511

[a]Source: Ekholm.

The community service expenditure function was specified with service expenditures as a function of income and population. Applying the models developed with the cross-sectional data, it was assumed that on the average, the area communities' population would change by the same percentage as Ekholm's figures, with per capita income the same as that estimated by Ekholm. Even though communities from the Southern High Plains were used in establishing the relationships, the projections are applicable only to Northern High Plains communities.

COMMUNITY SERVICE EXPENDITURE FUNCTIONS

Since development of a functional relationship between community service expenditures and income and population is the nucleus of this study, a detailed description of model development is appropriate. Expenditures for the individual services as well as total expenditures were used as the dependent variables and were regressed on community population (X_1), per capita county income (X_2), and percent change in community population (X_3). The models were fitted in linear form using ordinary least squares.

The regression results are presented in table 3. The calculated "t" values are given below each coefficient. Also listed are the R^2 and F values as well as the number of observations. R^2's for all models were .79 or greater. The coefficients on X_1 were significant at the .01 level for all expenditure categories. The coefficients on X_2 and X_3 were significant at the .05 level for all categories except street and police expenditures.

Table 3. Estimated Community Service Expenditure Functions Using Linear Models.

Model[a]	Regression Coefficients[b]				R^2	F	N
	Intercept	X_1	X_2	X_3			
Total expenditures	-177,734.73	49.103	56.146	-1,312.05	.92	175.31	47
		(20.96)	(2.044)	(-2.929)			
Water and sewer expenditures	-100,549.05	19.142	37.725	-857.219	.79	55.54	47
		(11.296)	(1.899)	(-2.645)			
Street expenditures	-3,472.185	9.957	1.453	-50.005	.80	50.67	42
		(11.835)	(.148)	(-.301)			
Police expenditures	-16,788.609	11.762	3.673	-47.696	.93	187.86	46
		(22.536)	(.602)	(-.468)			
Fire expenditures	-46,082.496	8.104	10.731	-402.958	.81	57.62	45
		(11.711)	(1.327)	(-3.024)			

[a] Linear Model $Y = a + b_1X_1 + b_2X_2 + b_3X_3$

[b] X_1 = 1970 community population; X_2 = 1970 per capita county income; X_3 = percent change in community population, 1960-1970.

Expenditure Estimates by Community Size

Estimated total and per capita expenditures for individual and combined service categories are presented in table 4. These estimates were obtained by setting X_2 and X_3 at their sample means--$3,000 and five percent, respectively--and setting X_1 at alternative population levels (first column of table 4).

Implication of the results presented in tables 3 and 4 are discussed for each service category in turn. In addition, elasticity values of the total service expenditure functions were calculated at the smallest and largest population levels. Along with per capita expenditures, the elasticity value suggests whether per capita community service costs can be expected to increase (elasticity greater than one) or decrease (elasticity less than one) as population increases. One problem associated with linear functions is that they exhibit either decreasing or increasing per capita expenditures, but not both.

Combined Expenditures

Data on combined community service expenditures were available from 47 communities. The model was statistically acceptable with estimated expenditures consistent with observed values within the population levels of the sample. All coefficients of the model were significant at the 95 percent probability level and the R^2 was .92. The total expenditure function from the linear model shows a constant slope or change in the absolute level of expenditures as population increases.

Table 4. Estimated Total and Per Capita Service Expenditures for Selected Community Sizes, Northern High Plains of Texas and Oklahoma.

Population	Combined Expenditures Total	Combined Expenditures Per Capita	Water and Sewer Expenditures Total	Water and Sewer Expenditures Per Capita	Street Expenditures Total	Street Expenditures Per Capita	Police Expenditures Total	Police Expenditures Per Capita	Fire Expenditures Total	Fire Expenditures Per Capita
	- - - - - -	- - - - - -	- - - - - -	- - - - - -	- - dollars	- - - - - -	- - - - - -	- - - - - -	- - - - - -	- - - - - -
500	8,695	17.39	17,911	35.82	5,616	11.23	--	--	--	--
1,000	33,246	33.25	27,481	27.48	10.594	10.59	5,764	5.76	--	--
2,500	106,901	42.76	56,195	22.48	25,529	10.21	23,407	9.36	4,356	1.74
5,000	229,658	45.93	104.050	20.81	50,421	10.08	52,812	10.56	24,616	4.92
7,500	352,414	46.99	151,905	20.25	75,314	10.04	82,217	10.96	44,876	5.98
10,000	475,171	47.52	199,760	19.98	100,206	10.02	111,622	11.16	65,136	6.51
12,500	597,928	47.83	247,615	19.81	125,099	10.01	141,027	11.28	85,396	6.83
15,000	720,685	48.05	295,470	19.70	149,992	10.00	170,432	11.36	105,656	7.04
17,500	843,442	48.20	343,325	19.62	174,884	9.99	199,837	11.42	125,916	7.20
20,000	966,199	48.31	391,180	19.56	199,177	9.99	229,242	11.46	146,176	7.31
22,250	1,088,956	48.40	439,035	19.51	224,669	9.99	258,647	11.50	166,436	7.40
25,000	1,211,713	48.47	486,890	19.48	249,562	9.98	288,052	11.52	186,696	7.47

[a] Model specification used for estimation of expenditures is presented in table 3.

The estimated per capita expenditure values indicate increasing per capita costs. Per capita expenditures increase from $17.39 at a population of 500 to $48.47 at a population of 25,000. The elasticity measure of the combined total expenditure curve also indicates increasing per capita costs since the curve is elastic. The elasticities range from 2.82 at a population of 500 to 1.01 at 25,000.

Water and Sewer Expenditures

The expenditures for these services were combined since most communities maintain one department which is responsible for both. As with total expenditures, data were available from 47 communities.

The estimated linear function is presented in table 3. The R^2 values indicate that 79.49 percent of the variation in expenditures was explained by the models. All coefficients were statistically significant at the 5 percent level.

The estimated total expenditures for water and sewer services are presented in table 4. Expenditures rose from $17.911 at population 500 to $486,890 at 25,000. This function had a positive intercept causing the curve to be inelastic over the estimated range. Decreasing per capita expenditures throughout the sample populations were shown by the elasticity values which ranged from .53 at a population of 500 to .98 at 25,000. This is illustrated in table 4 as per capita expenditures fall from $35.82 to $19.48 at population levels 500 and 25,000, respectively.

Street Expenditures

Data on street expenditures were available from 42 communities. The population coefficient was highly significant, but the coefficients for per capita income and percent population change were not significant. The R^2 value indicates that approximately 80 percent of the variation in expenditures was explained by the model.

The function had a positive intercept when per capita income and percent change in population were held constant. Estimated total street expenditures were $5,615 for a population of 500 and $249,562 at 25,000. Elasticity of the function rose from .89 at 500 population to .997 at 25,000. This is reflected in the decrease of per capita expenditures from $11.23 at 500 population to $9.98 at 25,000.

Police Expenditures

Data for estimating police expenditures were obtained from 46 communities. The model was statistically satisfactory, having acceptable R^2 and F values. The population coefficient was significant at the one percent probability level. The coefficients for all the other variables were not significant at an acceptable probability level.

With income and population change held constant, the linear fucntion indicated that no expendiutres for law enforcement would be forthcoming until a population slightly above 500 was reached. Total police expenditures were estimated to increase over larger populations from $5,764 at 1,000 to $288,052 at 25,000.

The elasticities of the total police expenditure function ranged from 2.04 at 1,000 population to 1.02 at 25,000. The per capita expenditures were estimated to increase from $5.76 at 1,000 population to $11.52 at 25,000.

Fire Expenditures

There were 42 fire department expenditure observations. All statistical values were acceptable with the exception of the estimated "t" value for the coefficient on per capita income.

With per capita income and percent population change held constant, the linear function had a negative intercept which showed no fire expenditures until a population of over 1,000. As shown in table 4, total fire expenditures ranged from an estimated $4,356 at a population of 2,500 to $186,696 for a community of 25,000. The elasticity ranged from 4.64 to 1.09 over the sample size communities. Per capita expenditure estimates rose from $1.74 at 2,500 population to $7.47 at a community of 25,000.

Findings

In considering application of the model and associated implications, the computed elasticity measures yield information about the shape of the community expenditure functions. The model used to estimate total expenditures in this study indicate that most services have an elastic expenditure function; i.e., per capita expenditures increase over larger populations. These elasticity measures indicate the shape of the average or per capita service expenditure curve.

Application of the model resulted in the conclusion that for most individual services and for total service expenditures, increasing per capita costs over larger populations are prevalent. Of course, a limitation of this analysis is the basic characteristics of the linear function used which cannot be identifying both increasing and decreasing per capita costs.

PUBLIC SERVICE PROJECTIONS WITH A DECLINING RESOURCE BASE

The service expenditure models were applied to project the service expenditures for various sized communities in the Northern High Plains through the year 2010. Ekholm's projections of area population and disposable income per capita were used as input to the models. Population was assumed to start at a given level in 1968 and change by the same rate as Ekholm's projected area population. Thus both future population and percent change in population for the communities were available.

The values of expenditures projected using these variables are not purported to show the expectations of actual individual communities. They are presented as an expected path of service expenditures over time for "average" area communities of a particular size category. The projections of expenditures for the individual services as well as those for combined service expenditures were estimated for five alternative size communities.

Service Expenditure Projections

Projections of service expenditures were made for communities with initial populations of 2,500, 5,000, 10,000, 15,000, and 20,000 in 1968. The estimates of community expenditures for the individual services and for all services combined are given in table 5. Estimated per capita expenditures are given in table 6.

The estimated expenditures for services in the early years were very close to the expenditure values of comparable size communities in the sample. For all community sizes except that with an initial population of 2,500, the estimates showed a period of increased service expenditures followed by a relatively stable period after which expenditures were projected to decline. Results of the projections in terms of total expenditures and per capita expenditures are discussed in turn.

Combined Service Expenditures

For a community with a 1968 population of 2,500, projections of expenditures for all services combined increased continuously over time by approximately 53 percent, from $140,321 in 1978 to $214,051 in 2010. The estimates for a community of 20,000 population in 1968 showed an intitial increase of 3.6 percent, from $1,179,635 in 1978 to $1,222,448 in 1990, followed by a decline of 15 percent of $1,039,031 from 1990 to 2010.

Per capita expenditures for all services combined exhibited increases over larger communities early, but showed lower costs for

Table 5. Projected Serivce Expenditures for Communities with 1968 Populations of 2,500, 5,000 , 10,000, 15,000 and 20,000, Northern High Plains of Texas and Oklahoma, 1978 to 2010.[a]

Year	Population[b]	Combined Service Expenditures	Water and Sewer Expenditures	Street Expenditures	Police Expenditures	Fire Expenditures
		- - - - - -	- - - - - -	dollars	- - - - - -	- - - - - -
				2,500 population in 1968		
1978	3,025	140,321	71,769	30,697	30,692	7,636
1980	3,056	145,963	75,099	31,134	31,277	8,872
1985	3,022	171,291	92,241	31,722	32,101	15,918
1990	3,011	189,087	104,180	32,199	32,904	20,398
1995	2,987	196,161	109,274	32,169	33,174	21,736
2000	2,847	201,816	114,910	31,167	32,186	23,635
2005	2,619	209,274	122,911	29,490	30,462	26,403
2010	2,404	214,051	129,018	27,799	28,810	28,093
				5,000 population in 1968		
1978	6,049	288,809	129,654	60,808	66,260	32,142
1980	6,110	295,924	133,558	61,543	67,198	33,622
1985	6,039	319,435	149,993	61,762	67,587	40,368
1990	6,017	336,690	161,721	62,130	68,261	44,759
1995	5,971	342,685	166,393	61,881	68,271	45,918
2000	5,692	341,514	169,369	59,494	65,649	46,691
2005	5,236	337,777	173,006	55,547	61,243	47,611
2010	4,806	331,997	174,997	51,716	57,063	47,559
				10,000 population in 1968		
1978	12,097	585,784	245,425	121,028	137,397	81,155
1980	12,218	595,845	250,478	122,360	139,040	83,121
1985	12,077	615,918	265,572	121,882	138,606	89,299
1990	12,030	631,947	276,822	122,001	138,986	93,488
1995	11,937	635,633	280,594	121,284	138,443	94,266
2000	11,378	620,713	278,210	115,110	132,528	92,770
2005	10,464	594,487	273,080	107,603	122,735	89,978
2010	9,602	567,495	266,803	99,470	113,473	86,426

Table 5 (continued)

Year	Population[b]	Combined Service Expenditures	Water and Sewer Expenditures	Street Expenditures	Police Expenditures	Fire Expenditures
		- - - - - - - - -	- - - - - - - -	dollars	- - - - - - - -	- - - - - - - -
				15,000 population in 1968		
1978	18,145	882,759	361,196	181,248	208,533	130,168
1980	18,327	895,815	367,416	183,187	210,894	132,628
1985	18,116	912,451	381,171	182,013	209,637	138,239
1990	18,046	927,350	391,980	181,903	209,746	142,242
1995	17,905	928,680	394,834	180,708	208,639	142,631
2000	17,066	900,011	387,090	172,745	199,430	138,866
2005	15,696	851,394	373,231	159,698	184,273	132,379
2010	14,405	803,337	358,742	147,293	169,966	125,349
				20,000 population in 1968		
1978	24,191	1,179,635	476,928	241,448	279,647	179,165
1980	24,433	1,195,638	484,297	243,985	282,713	182,112
1985	24,151	1,208,788	496,693	242,103	280,621	187,147
1990	24,058	1,222,558	507,062	241,764	280,459	190,963
1995	23,870	1,221,579	509,106	240,101	278,799	190,971
2000	22,753	1,179,260	495,950	229,371	266,321	184,953
2005	20,926	1,108,203	473,344	211,773	245,789	174,762
2010	19,205	1,039,031	450,326	195,087	226,424	164,249

[a] Model specification is presented in table 4.

[b] Population estimates based on a study by Ekholm.

Table 6. Projected Per Capita Service Expenditures for Communities with 1968 Populations of 2,500, 5,000, 10,000, 15,000, and 20,000, Northern High Plains of Texas and Oklahoma, 1978 to 2010.[a]

Year	Population[b]	Combined Service Expenditures	Water and Sewer Expenditures	Street Expenditures	Police Expenditures	Fire Expenditures
		- - - - - - - - - -	- - - - - - - - - -	dollars	- - - - - - - - - -	- - - - - - - - - -
				2,500 population in 1968		
1978	3,025	46.39	23.73	10.15	10.15	2.52
1980	3,056	47.76	24.57	10.19	10.24	2.90
1985	3,022	56.68	30.52	10.50	10.62	5.27
1990	3,011	62.80	34.60	10.69	10.93	6.77
1995	2,987	65.57	36.58	10.77	11.11	7.28
2000	2,847	70.89	40.36	10.95	11.31	8.30
2005	2,619	79.91	46.93	11.26	11.63	10.08
2010	2,404	89.04	53.67	11.56	11.98	11.69
				5,000 population in 1968		
1978	6,049	47.75	21.43	10.05	10.95	5.31
1980	6,110	48.43	21.86	10.07	11.00	5.50
1985	6,039	52.90	24.84	10.23	11.19	6.68
1990	6,017	55.96	26.88	10.33	11.35	7.44
1995	5,971	57.39	27.87	10.36	11.43	7.69
2000	5,692	60.00	29.76	10.45	11.53	8.20
2005	5,236	64.51	33.04	10.61	11.70	9.09
2010	4,806	69.08	36.41	10.76	11.87	9.90
				10,000 population in 1968		
1978	12,097	48.42	20.29	10.01	11.36	6.71
1980	12,218	48.77	20.50	10.02	11.38	6.80
1985	12,077	51.00	21.99	10.09	11.48	7.39
1990	12,030	52.53	23.01	10.14	11.55	7.77
1995	11,937	53.25	23.51	10.16	11.60	7.90
2000	11,378	54.55	24.45	10.21	11.65	8.15
2005	10,464	56.81	26.10	10.28	11.73	8.60
2010	9,602	59.10	27.79	10.36	11.82	9.00

Table 6 (continued)

Year	Population[b]	Combined Service Expenditures	Water and Sewer Expenditures	Street Expenditures	Police Expenditures	Fire Expenditures[a]
		- - - - - - - -	- - - - - - - -	dollars	- - - - - - - -	- - - - - - - -
				15,000 population in 1968		
1978	18,145	48.65	19.91	9.99	11.49	7.17
1980	18,327	48.88	20.05	10.00	11.51	7.24
1985	18,116	50.37	21.04	10.05	11.57	7.63
1990	18,046	51.39	21.72	10.08	11.62	7.88
1995	17,905	51.87	22.05	10.09	11.65	7.97
2000	17,066	52.74	22.68	10.12	11.69	8.14
2005	15,696	54.24	23.78	10.17	11.74	8.43
2010	14,405	55.77	24.90	10.23	11.80	8.70
				20,000 population in 1968		
1978	24,191	48.76	19.72	9.98	11.56	7.41
1980	24,433	48.94	19.82	9.99	11.57	7.45
1985	24,151	50.05	20.57	10.03	11.62	7.75
1990	24,058	50.82	21.08	10.05	11.66	7.94
1995	23,870	51.18	21.33	10.06	11.68	8.00
2000	22,753	51.83	21.80	10.08	11.71	8.13
2005	20,926	52.96	22.62	10.12	11.75	8.35
2010	19,205	54.10	23.46	10.16	11.79	8.55

[a] Model specification is presented in table 4.

[b] Population estimates based on a study by Ekholm.

larger communities in the later years. For a community with a 1968 population of 2,500, per capita expenditures were projected to increase 91.9 percent, from $46.39 in 1978 to $89.04 in 2010. A 1978 to 2010 per capita expenditure increase of 11 percent, from $48.76 to $54.10, was estimated for a community with an initial population of 20,000.

Water and Sewer Expenditures

Water and sewer service expenditures ranked first in percent of the total of individual service expenditures for smaller communities. This category was projected to comprise from 51 to 60 percent of total service expenditures in a community with a 1968 population of 2,500. In a community with an initial population of 20,000, these expenditures were projected to make up 40.5 to 43.5 percent of the sum of individual service expenditures over time.

The path of water and sewer expenditures over time also varied among different sized communities as is shown by the values in table 5. In smaller communities, through size 5,000, the estimates of expenditures generally rose through time, while in larger communities there was a decline indicated sometime after 1995. For a community of 2,500 population in 1968, water and sewer expenditures were estimated to increase by 80 percent from 1978 to 2010. In a community of 20,000 these expenditures were projected to increase by 3.6 percent from 1978 to about 1995, and then decline by 15 percent from 1995 to 2010.

For all size communities, water and sewer per capita expenditures were projected to increase throughout the time period from 1978 to 2010. For a community of 2,500 population in 1968, a 126 percent increase, from $23.73 to $53.67 in 2010, was projected. An 11 percent increase, from $19.72 in 1978 to $23.46 in 2010, was projected for a community with an initial population of 20,000.

Street Expenditures

Expenditures for street services were projected to comprise a greater degree of importance in relation to other services over time in larger communities. In a community of 2,500 population in 1968, street expenditures in 1978 represent 22 percent of total expenditures as compared to 13 percent in 2010. The projections suggest street expenditures will decline from 20.5 percent of total expenditures to 19 percent in a community with a 1968 population of 20,000 in 2010.

For a community of 2,500 population in 1968, street expenditures were projected to increase by 4.9 percent of 1978 expenditures in 1990, and then decline by 13.7 percent of the 1990 value in 2010. A 1.1 percent rise in 1990 and a corresponding 20 percent decline in 2010 was indicated for a community with an initial population of 20,000. A 13.9 percent increase in per capita street expenditures, $10.15 to $11.56, was estimated for the smaller community, but only a 1.8 percent rise was shown in the larger community, $9.98 to $10.16.

Police Expenditures

Police expenditures were projected to comprise a greater portion of total individual service expenditures for larger community sizes over the time than smaller communities. In a community with a 1968 population of 2,500, police expenditures were projected to make up 22 percent of the total expenditures in 1978, but drop to 13 percent by 2010. In a community with an initial population of 20,000, the estimates of police expenditures declined from 23.8 percent of total expenditures in 1978 to 21.9 percent in 2010.

In a community of 2,500 population in 1968 police expenditures were projected to increase 8.1 percent from 1978 to 1995, and decline by 13.2 percent of the 1995 value to 2010. For a community of 20,000 population in 1968 the estimates of expenditures increased 1.1 percent from 1978 to 1980 followed by a decline of 19.9 percent from 1980 to 2010.

Per capita police expenditures were projected to increase by 18 percent, from $10.15 in 1978 to $11.98 in 2010, for a community with population 2,500 in 1968. For a community of 20,000 the increase was estimated at only 2 percent from 1978 to 2010, from $11.56 to $11.79. The model projections indicated higher per capita expenditures in early years for larger community sizes, but lower per capita expenditures in later years.

Fire Expenditures

In a community of 2,500 population in 1968 fire expenditures were projected to account for 5 percent of total service expenditures in 1978 and increase to 13 percent in 2010. In a community of 20,000 population in 1968 the estimates of fire expenditures comprised from 15.2 to 15.9 percent of total expenditures over time.

Fire expenditures in a community of 2,500 initial population were projected to increase 268 percent from 1978 to 2010. This large increase for smaller communities results because, on balance, the influence of decreasing population is overriden by increasing income. The estimates for a community of 20,000 rose 6.6 percent from 1978 to 1995 and declined 14 percent from 1995 to 2010.

A 364 percent increase in per capita fire expenditures, from $2.52 in 1978 to $11.69 in 2010, was estimated for a community with an initial population of 2,500. The larger community, initial size of 20,000, was projected to experience a 15.4 percent increase, from $7.41 to $8.55.

Interpretation of Results

Estimates of expenditures generally exhibited a gradual increase followed by a slow decline over time. Further, the estimates indicate that the decline of the groundwater resource will have a more adverse impact on smaller communities relative to public service provision. It was projected that smaller communities will be less able to reduce service expenditures as population declines. This is probably due to a disproportionately high investment in capital structures which these smaller communities will be forced to maintain. For example, it was projected that the smaller communities must allot up to 60 percent of combined expenditures to water and sewer services which require a large capital investment. The larger communities were projected to spend a lesser percentage of total expenditures on water and sewer than smaller communities.

It was estimated that the largest percentage reduction in expenditures will occur in street services, indicating that this is the most expendable service for smaller communities. The increased importance of fire protection to smaller communities was indicated by the projected 268 percent increase in expenditures over time, while it was estimated that larger communities will reduce fire expenditures.

SUMMARY AND CONCLUSIONS

Summary

The objectives of this study were to quantify a community service expenditure function, and to use this function to project the effects of the declining groundwater supply in the Northern High Plains on expenditures for community services. Selected population and income values were used as the independent variables for the estimation of the level of service expenditures.

A cross-sectional data set for 1970 was collected from 47 communities ranging in population from 578 to 21,726. Estimated functional relationships using these data proved acceptable by selected statistical criteria (R^2, t tests, and F tests). Expenditure functions were developed for water and sewer, streets, police, fire and the total of all four services. The independent variables used in the model were community population, county per capita income, and percent change in community population from 1960 to 1970.

Projections of service expenditures in various sized Northern High Plains communities were made using values for independent variables estimated in a regional simulation study by Ekholm. Ekholm's study estimated regional population and regional per capita income through 2010. Population of various community sizes was assumed to start at a given level in 1968 and change by the same rate as the projected regional population estimates of Ekholm. Per capita income was presumed to be at the same level as the projected population values. Using these independent variables, the levels of service expenditures for communities of 2,500, 5,000, 10,000, 15,000, and 20,000 population in 1968 were projected from 1978 through 2010.

Conclusions

The estimated expenditure projections showed combined service expenditures, water and sewer expenditures, and fire expenditures to increase continuously through 2010 in smaller communities. Larger communities were estimated to reduce service expenditures as population declined. As population declined over time, smaller communities were projected to have higher per capita expenditures for all services.

The projections indicated that smaller communities would experience a greater adverse impact. With a decline in population due to a loss of the resource base, it was estimated that smaller communities would be less able to reduce service expenditures. This is primarily due to the predominance of capital intensive services in relation to other services in small communities. Even with a declining need and public support for these services, the large investment needed to provide even minimum service output obligates the community to high per capita service cost. For larger communities projections of per capita service expenditures were lower than those in smaller communities as population declined over time.

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