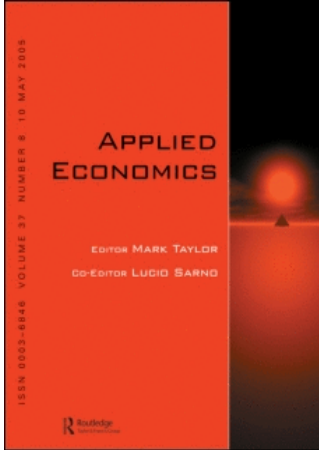


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Aggregate local public sector investment and shocks: Norway 1946–1990

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Local public sector investment is determined in an environment of shifting economic conditions. Investments are investigated using an intertemporal decision model allowing for tests of forward looking behaviour and adjustments to expected and unexpected shocks. The econometric analysis of the aggregate local public sector over the period 1946–1990 indicates that local and county governments are forward looking and have small adjustment costs to investment. In a full investment demand model, only unexpected changes of gross domestic product and unemployment are shown to be important in the short run. The central government has arranged stable revenue growth of the local public sector, but greater volatility in macroeconomic conditions has led to fluctuations in local public investment.

I. INTRODUCTION

Local public sector investments allow the expansion of service production in the future. Local governments must take into account future income growth and demand factors when their investment plans are decided and implemented. The handling of intertemporal decisions in public institutions is the subject of this study. The empirical basis of the analysis is the aggregate investment level in the Norwegian local public sector during the period 1946–1990.

Local public investment has amounted to about 50% of total public investment in recent years. Local and county governments organize about 2/3 of the public sector service production, but their services are more labour-intensive than those of central government. Gross local public investment is estimated to about NOK 14 billion (USD 2 billion) in 1995 or NOK 3.000 (USD 500) per capita.

The time path described in Fig. 1 shows long-term growth in real investment during the period 1946–1970. Since 1970, the investment level has stagnated and fluctuated in business-cycle fashion. Current local public revenue is the main source of financing of the investment. According to Fig. 1, local public revenue has grown with remarkable stability during the whole period. Interestingly, the erratic investment pattern has coincided with stable local public revenue growth. To understand the investment pattern, we must look at background macroeconomic factors that started fluctuating around 1970. Figure 2 shows

trends in two variables related to the business cycle. Gross domestic product has had stable growth in post World War II Norway, except for short periods of stagnation in the early 1960s, late 1970s and late 1980s. Unemployment was around 1% up to 1980, but has fluctuated thereafter. The macroeconomic variables indicate some turbulence since the late 1970s, but local public revenue has not been much affected. The fluctuation of local public investment with stable revenue growth since 1970 forms the main puzzle of this study.

Why has local public investment stagnated since 1970? The United States has experienced the same investment stagnation, which has been called ‘the infrastructure problem’ by Hulten and Peterson (1984). They show that state and local capital spending as a share of their total spending has declined from 30% in the mid-1960s to 15% in the early 1980s. Some observers refer to deterioration of roads, mass transit systems, water and sewage systems, etc. as evidence of problems related to bad decision making. In Norway, the deterioration of local public sector capital stock is manifested as declining quality of buildings, primarily schools and hospitals. Maintenance of buildings seems to suffer most. It is not self-evident that this deterioration is suboptimal. The school structure is changing over time due to demographics, and allowing some schools to run down may be a way of adjusting the capacity. Run down hospitals are typically replaced by new buildings, which may be a way of adapting to new technology. It cannot be concluded from

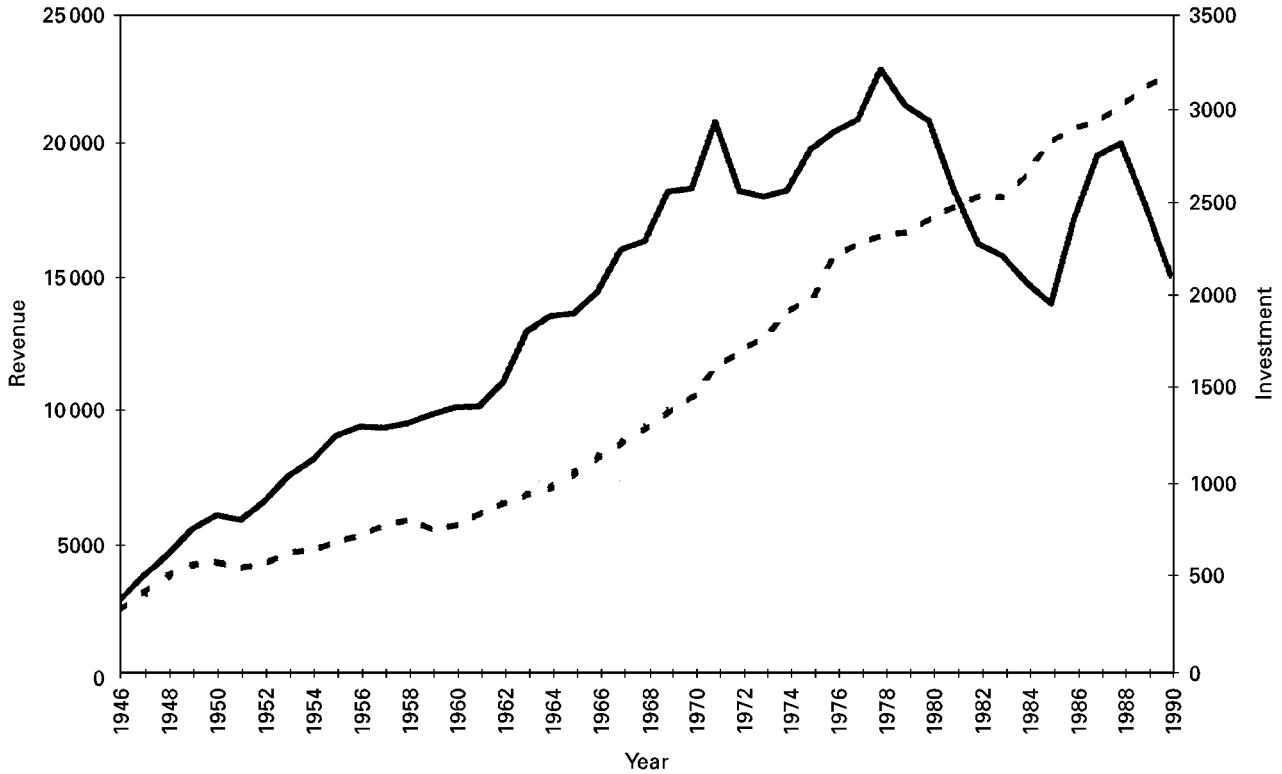


Fig. 1. Investment (—) and revenue (----) in Norwegian local public sector (in real 1985-NOK)

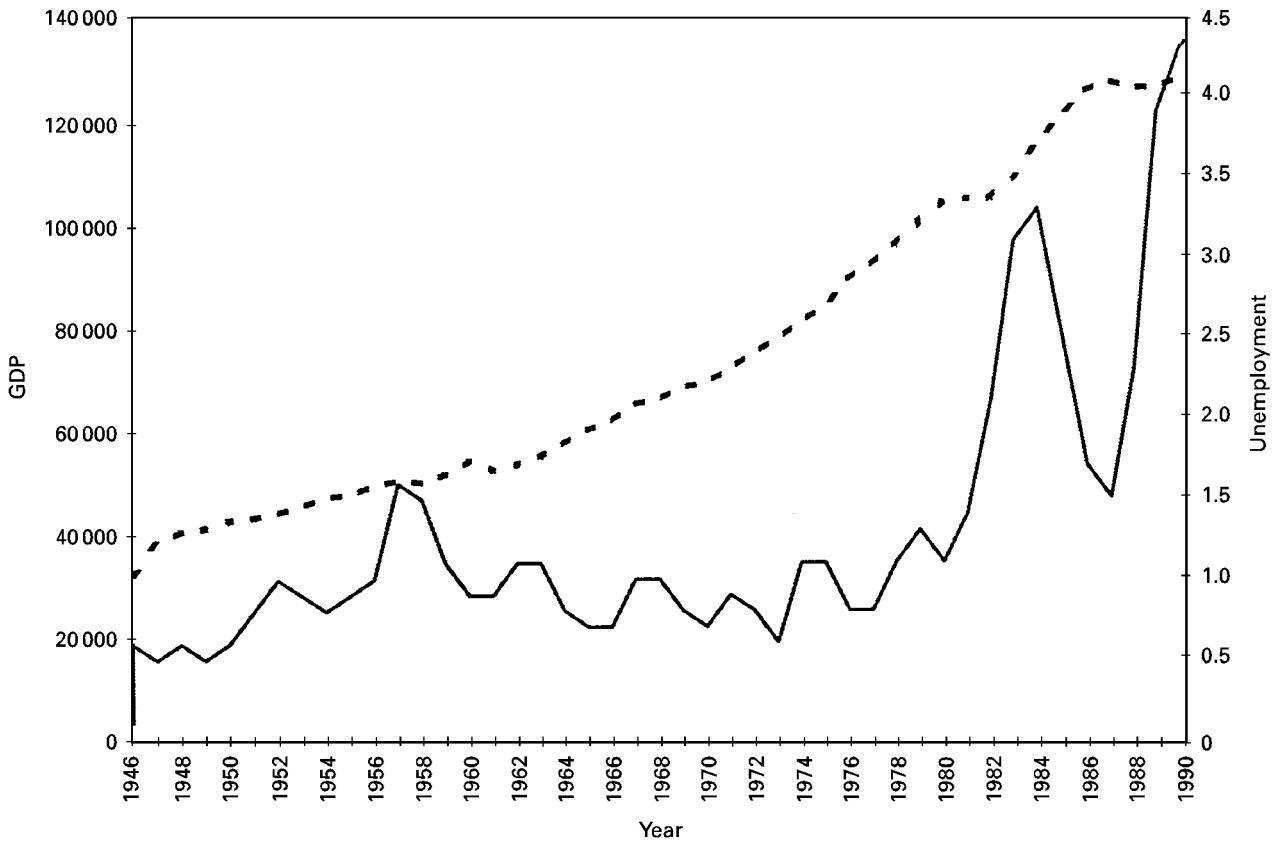


Fig. 2. GDP (----) and unemployment (—) in Norway (1946–1990) (GDP in real 1985-NOK, unemployment in per cent)

direct observation that bad decision making explains the stagnating investment level.

The slowdown and stagnation of local public investment growth since 1970 can be understood in very different contexts. Here we concentrate on a framework of intertemporal optimization with rational expectations. In this context, the slowdown may be the sensible response to reduced future revenue growth or demographic shift. Local and county governments have based their investment plans on expectations about future economic and social conditions, and investments are typically predicted to develop *pari passu* to revenue growth. Slowdown and stagnation may follow news about changes in permanent revenue growth and demographics. Changes in the age composition of the population may motivate a reorientation of the service production towards more labour-intensive services; e.g. care for the elderly is less capital intensive than education for children.

Local public spending is typically analysed in a static model emphasizing the tradeoff between tax price and service production (see the survey by Rubinfeld, 1987). A few studies have addressed inertia and adjustment costs in the determination of public service production. Dunne *et al.* (1984) apply a dynamic version of the AIDS model to analyse the demand for public services. Borge and Rattso (1995) use a partial adjustment framework to investigate local government responses to demand and supply shifts. Poterba (1994) looks at reactions to unexpected shocks. This literature does not handle expectation formation explicitly and is not concerned with investment issues.

The present study follows the intertemporal approach of Holtz-Eakin and Rosen (1993). Compared to their study, two modifications are made. First, we apply a general error-correction framework to investigate short-run and long-run dynamics. Second, the investment function is expanded to take into account business cycle fluctuation. Other studies addressing intertemporal aspects of local public sector decision making include Holtz-Eakin *et al.* (1994), Poterba (1995) and Dahlberg and Lindström (1998). This analysis looks at aggregate local public investment and ignores politics.

The theoretical foundation for the investment analysis is based on a Euler model of optimal capital stock adjustment, and is discussed in Section II. The econometric formulation and data are presented in Section III. The intertemporal assumptions regarding expectations formation are empirically tested in Section IV, while the full investment demand model is developed in Section V and estimated in Section VI. Concluding remarks are offered in Section VII.

II. INTERTEMPORAL RESTRICTIONS OF INVESTMENT MODEL

When local governments take decisions regarding resource use, investments and financial allocations, they are assumed

to consider future changes in economic and social conditions. The creation of production capacity links up to the expected stream of revenues and the expected changes in the demand for local government services. Our theoretical starting point is the simplest possible rational model of future oriented planning as suggested by Holtz-Eakin and Rosen (1993).

We assume that the local governments produce an aggregate service, G_t , which is the argument in the utility function of the representative government in period t . The representative local government is assumed to maximize the expected present value of the utility of the local public service:

$$E_t \sum_s (1/(1 + \pi))^s U(G_{t+s}) \quad (1)$$

E_t is the expectation given the information available at the beginning of period t , and the discounting is based on the time preference rate π . Preferences are assumed constant over time. The utility function is best interpreted as a stable community preference function. How this preference function is established is beyond the scope of this study. Thus no general optimality conditions can be derived from the model results.

The aggregate service is produced by combining labour L and real capital K . To simplify the analysis, the production function is separable in labour and real capital. The decision problem of the government is to allocate available resources to labour and investment in real capital I_t in each period. The production function combines end of period capital stock K_{t-1} and current labour input L_t :

$$G_t = F(L_t, K_{t-1}) \quad (2)$$

Real capital evolves according to the perpetual inventory identity (d is a constant depreciation rate):

$$K_t = (1 - d)K_{t-1} + I_t \quad (3)$$

The dynamics of the investment process will depend on the capital stock adjustment process. In general, the movement towards the desired stock of real capital is influenced by adjustment costs. Such costs imply that the unit cost of new capital q increases with the size of the investment level:

$$q_t = q(I_t) \quad q' > 0 \quad (4)$$

With this formulation, the price of one unit of capital in period t depends on the adjustment of the capital stock from period $t - 1$ to period $t + 1$.

In Norway, local governments are responsible for national welfare services. Income tax revenue sharing and grants are the main sources of financing these expenditures. Consequently we treat the current revenues of the local public sector as exogenous. The local units operate within an intertemporal budget constraint where the exogenously given, but uncertain, revenue stream Y_t covers the outlays

for labour and investment. The intertemporal budget balance is:

$$\sum_s (1/(1+r))^s (Y_{t+s} - w_{t+s}L_{t+s} - q_{t+s}I_{t+s}) = 0 \quad (5)$$

The formulation assumes that the real interest rate, r , is constant. The price w_t is the gross price of labour. The budget constraint assumes that the government can choose a time path of current spending and investment spending using financial markets to cover deviations from the current revenue stream. This is a crucial assumption. According to law, Norwegian local governments must balance current spending inclusive of interest payments with current revenue. They are allowed to choose any investment level given this restriction. In practice, local governments finance most of the investments by current surpluses, as shown by Borge (1995) and Rattsø (1996). It seems realistic that local governments are able to take advantage of the flexibility embodied in the above budget constraint.

The representative government determines the time path of local public consumption by the choice between labour and investment. This decision implies deficits and surpluses dependent on the variation in the current revenue. The government maximizes the expected utility stream given the production function and the budget constraint. The optimal time path of the capital stock is described by the Euler equation (equivalent to Holtz-Eakin and Rosen, 1993, Equation 2.6):

$$\begin{aligned} & E_t(dU/dG_{t+2} dF/dK_{t+1})/E_t(dU/dG_{t+1} dF/dK_t) \\ &= E_t(1+r)q_{t+1} - (1-d)q_{t+2})(1+\pi)/ \\ & E_t((1+r)q_t - (1-d)q_{t+1})(1+r) \end{aligned} \quad (6)$$

As usual, the expected marginal rate of substitution between utilities derived from capital in two following periods is equal to the expected intertemporal relative prices. The prices are determined by the interest rate, adjustment costs, the depreciation rate and the rate of time preference.

If adjustment costs are constant and independent of the investment level, the intertemporal relative price is equal to the constant ratio between the rate of the time preference and the real interest rate, and the optimal path of the capital stock follows the rule:

$$\begin{aligned} & E_t(dU/dG_{t+2} dF/dK_{t+1})/E_t(dU/dG_{t+1} dF/dK_t) \\ &= (1+\pi)/(1+r) \end{aligned} \quad (7)$$

The expected marginal rate of substitution between services in adjacent periods is constant. The best prediction of K_{t+1} is consequently K_t . Under certain conditions, K behaves according to a random walk. This is equivalent to Hall's (1978) result in a permanent income consumption model, where he showed that the marginal utility of consumption is a martingale.

Hall approaches the empirical problem of relating past observed income to expected future income to estimate the

permanent income model and takes advantage of the stochastic implications of the theory. He shows that the theory implies that marginal utility, and under linear structure also consumption, obeys a random walk. Hall derives two testable implications of the random walk hypothesis: consumption lagged more than 1 period has no predictive power for current consumption, and consumption is unrelated to any other economic variable that is observed in earlier periods. As shown by Holtz-Eakin and Rosen (1993), both implications can be related to the investment model and are tested below.

The Euler equation defines a relationship between the capital stock at different points in time that can be approximated linearly:

$$K_t = a_0 + a_1 K_{t-1} + a_2 K_{t-2} + a_3 K_{t-3} + \dots + u_t \quad (8)$$

If the production function is separable between labour and real capital and adjustment costs are zero, the evaluation of the optimal capital stock will only take into account the change from K_{t-1} to K_t . It follows that investigation of the dynamics in the time series for K offers information about the underlying model.

If adjustment costs depend on the level of investment, the dynamics are different. The investment volume depends on the difference between the capital stocks of this period and the last period, K_{t-1} and K_t . The determination of K_{t-1} must take into account adjustment costs both from the previous period and to the next period, that is K_{t-2} and K_t . Symmetrically, the determination of K_t must consider K_{t-1} and K_{t+1} . Altogether three lags are involved with adjustment costs.

So far the model has addressed the determination of capital stocks, while our empirical model is based on investment data. The model of capital stock determination must be transformed to a model of investment flows. This transformation is simplified by the assumption that the depreciation rate d is zero. Since depreciation is defined as net of maintenance, the assumption is not that dramatic. In this case, the Euler equation can be rewritten:

$$I_t = a_1 I_{t-1} + a_2 I_{t-2} + a_3 I_{t-3} + \dots + du_t \quad (9)$$

A positive depreciation rate implies non-linearity and additional lag and error terms.

III. ECONOMETRIC TEST OF INTERTEMPORAL ASSUMPTIONS

The model assumes that local governments are future oriented and optimize intertemporally, and these assumptions put restrictions on the lag structure of the investment series. The first test of the intertemporal restrictions of the Euler equation investigates the lag structure of an autoregression for investment and is documented in Table 1. The autoregression of the investment series should have only

Table 1. Autoregression of Euler equation

	AR (4)	AR (3)	AR (2)	AR (1)
Constant	182.89* (67.18)	169.74* (64.51)	162.56* (59.10)	182.05* (44.38)
<i>Inv-1</i>	1.226* (0.180)	1.215* (0.205)	1.220* (0.195)	0.926* (0.031)
<i>Inv-2</i>	-0.213 (0.271)	-0.271 (0.294)	-0.291 (0.181)	
<i>Inv-3</i>	-0.403 (0.289)	-0.018 (0.173)		
<i>Inv-4</i>	0.316 (0.196)			
R^2 -adj	0.931	0.932	0.939	0.941
DW	2.015	1.936	1.954	1.377
Durbin h	-0.421	1.896	-0.107	1.978
<i>N</i>	41	42	43	44

Dependent variable: real investment, NOK per capita. Standard error in parentheses.

*Significant at the 5% level.

Model reduction

Model	SC (Schwarz criterion)
AR (4)	10.7125
AR (3)	10.6872
AR (2)	10.5727
AR (1)	10.5456

one lag when there are no adjustment costs and only three lags with adjustment costs. If this is not rejected the dynamics of the investment series is consistent with the forward looking behaviour assumed.

The analysis is based on annual data for total nominal investment in the local public sector during the period 1946–1990 deflated by the national account price index of investment goods. Data are documented in the appendix.

The autoregressions show that only one lag has a significant effect. This result is consistent with forward looking behaviour and no adjustment costs. Table 1 shows the estimated autoregressions with four to one lags, AR (4) to AR (1). The reported estimates imply that lags of two years or more have no significant effect. The statistical basis of reducing the model to AR (1) is provided by the Schwarz criterion, which is derived from a Bayesian procedure for seeking the most probable model. According to this procedure, the model with the smallest test value is to be preferred. AR (1) has the smallest criterion value, 10.5456.

The second test investigates the role of other lagged variables. If local and county governments exhibit forward looking behaviour, all information about historical determinants of investment should be included in the one-year investment lag. Last period's investment captures all forecastable information concerning this year's investment. It follows that no exogenous variables with two lags or more should have any effect. This exclusion restriction is tested with vector autoregression models. Table 2 examines the

Table 2. Test of lag structure

	VAR (4)	VAR (3)	VAR (2)	VAR (1)
Constant	241.27 (67.61)	180.651 (69.15)	165.099 (67.50)	205.151 (59.85)
<i>Inv-1</i>	1.152 (0.207)	1.140* (0.194)	1.184* (0.208)	0.960* (0.077)
<i>Inv-2</i>	-0.185 (0.216)	-0.215 (0.230)	-0.243 (0.178)	
<i>Inv-3</i>	-0.317 (0.294)	0.008 (0.144)		
<i>Inv-4</i>	0.293 (0.214)			
<i>GDP-1</i>	-0.002 (0.025)	0.010 (0.019)	0.018 (0.019)	-0.001 (0.003)
<i>GDP-2</i>	0.051 (0.037)	0.026 (0.029)	-0.019 (0.019)	
<i>GDP-3</i>	-0.050 (0.038)	-0.038 (0.022)		
<i>GDP-4</i>	-0.001 (0.022)			
R^2 -adj	0.939	0.939	0.939	0.941
DW	2.064	2.007	2.102	1.442
Durbin h	-0.192	0.078	-1.455	1.852
<i>N</i>	41	42	43	44

Dependent variable: real investment, NOK per capita. Standard error in parentheses.

*Significant at the 5% level.

Model reduction

Model	SC (Schwarz criterion)
VAR (4)	10.8317
VAR (3)	10.7638
VAR (2)	10.7085
VAR (1)	10.6159

effects of lagged values of gross domestic product. Gross domestic product is the main background variable determining the revenue conditions of the local public sector. The most general vector autoregression VAR (4) assumes four lags of investment and gross domestic product. According to the Schwarz criterion, the general VAR model can be reduced to the VAR (1) model without loss of explanatory power. At the 5% level of significance, no variable with two lags or more has a significant effect on local public investment. However, the three-year lagged gross domestic product has a negative effect on investment at the 10% level.

We conclude that the time series properties of the investment series are consistent with a forward looking model.

IV. OPERATIONALIZATION OF INVESTMENT DEMAND MODEL

The permanent income approach can be used to formulate an explicit investment demand model. The maximization of expected utility from local public services under the

conditions stated above implies an investment plan dependent on expectations about future revenues and other variables affecting community preferences for local public services over time. A similar plan for the use of labour emerges as a part of the optimization. In a stable growth context, the level of investment will basically follow a trend. According to the model, any deviation from the trend must result from unexpected and permanent changes in preferences or revenue. In effect, forecasts about future changes in revenue cannot have any influence on investment since they are already incorporated in the investment plan.

Our empirical investigation addresses the separation between expected and unexpected determinants of investment. The plan defines an investment demand function that is generally dependent on the time paths of the exogenous variables of the model, notably the determinants of the revenue stream and the wage path. Changes over time in the real interest rate add to this list, although kept constant in the theoretical model. The revenue stream can be understood either as a Friedman-type permanent income or a Modigliani-type wealth. Here we apply a permanent income concept and relate investment to permanent revenue, Y^p . Other determinants such as demographics are included in a vector

Z^p of expected values. The desired capital stock in linear form is:

$$K_t = b_0 + b_1 Y_t^p + b_2 Z_t^p + b_3 K_{t-1} + v_t \quad (10)$$

Again the capital stock model must be transformed into an investment flow. This is straightforward when the net depreciation rate is assumed equal to zero:

$$I_t = b_1 dY_t^p + b_2 dZ_t^p + b_3 I_{t-1} + v_t - v_{t-1} \quad (11)$$

In Equation 11, the investment demand is influenced by the change in permanent revenue. By definition, any change in permanent revenue is unexpected and requires adjustment of the investment plan. The Z^p vector includes all other determinants of investment demand as changes in expected values.

In the empirical implementation, we have tried to represent the budget constraint and take into account business cycle factors. Borge and Rattsø (1997) show that gross domestic product and unemployment are important determinants of local public revenue. In addition to the effect of GDP and unemployment, demographics have been investigated. The age composition of the population influences the composition of local public services, as shown by Borge and Rattsø (1995) for Norway, and Cutler *et al.* (1993) and Poterba (1997) for the United States. When different services have different capital intensities, the overall investment level can be influenced. The relevant measure of the age composition, the share of elderly in the population, has grown steadily during the period studied. However, since the partial correlation with GDP is as high as 0.986, we have not been able to separate out a demographic effect.

The time series properties of the variables are checked using Dickey–Fuller tests. Investment, gross domestic product and unemployment rate are each I (1) in level form and I (0) in difference form. Over the very long run we expect the unemployment rate to be stationary, but it has drifted up since World War II. Here the econometric models are formulated in general error correction form to separate between short-run and long-run effects and are estimated using standard ordinary least squares (OLS).

Empirical implementation of the investment demand model necessitates an identification of expected versus unexpected determinants. Consistent with the rational expectation approach, we assume that the local public sector knows the mechanisms that generate gross domestic product and unemployment and that this information is used in their forecasts. The forecasting equations for gross domestic product and unemployment are based on an autoregressive model using distributed lags and the full sample. The equations are documented in the appendix.

Given the forecasting equations, expected values are updated annually. Unexpected values are defined as the gap between the actual observation and the expected value. Feenberg *et al.* (1989) discuss the rationality of US state revenue forecasting using more advanced methods.

Table 3. *Investment demand*

	Naive model	Expectation model
Constant	180.178* (61.48)	228.397* (76.15)
Δ Investment-1	0.140 (0.17)	0.089 (0.16)
Δ GDP	0.025 (0.014)	
Δ GDP, expected		- 0.007 (0.010)
GDP, unexpected		0.044* (0.015)
Δ Unemployment	- 150.162* (64.12)	
Δ Unemployment, expected		- 65.97 (49.48)
Unemployment, unexpected		- 307.65* (88.31)
Investment-1	- 0.175* (0.08)	- 0.238* (0.09)
GDP-1	0.005 (0.003)	0.008* (0.003)
Unemployment-1	- 178.108* (58.42)	- 227.64* (60.60)
R^2 -adj.	0.316	0.378
DW	1.963	1.927
Durbin's h	0.287	0.377
Log of likelihood function	- 275.055	- 259.672

Dependent variable: Δ real investment, NOK per capita.
Heteroscedastic-consistent standard error in parentheses.

*Significant at the 5% level.

V. DETERMINANTS OF INVESTMENT

The analysis concentrates on two models. The first is consistent with the intertemporal theory and distinguishes between expected and unexpected changes in gross domestic product and unemployment. The future-oriented model implies that only unexpected values of these determinants should play a role. To check the results also a naive model including actual values of changes in gross domestic product and unemployment is estimated.

The results are reported in Table 3 and they are consistent with the forward looking model. Only unexpected changes in gross domestic product and unemployment influence local public sector investment. Investment goes up by 4.4% of an unexpected rise in gross domestic product, which amounts to an elasticity of about 1.7 at mean. When unemployment unexpectedly rises by 0.1 percentage point, investment goes down by NOK 30 per capita; an elasticity at mean of 0.2. Local public investment is procyclical with respect to unexpected components of the cycle. Expected changes in gross domestic product and unemployment have no influence on the investment level. Based on US data, Holtz-Eakin and Rosen (1993) conclude that only unexpected resource flows influence municipal construction spending. Our result is consistent with their finding. It is also in accordance with the analysis of Rattso (1996), who shows that unexpected shocks, measured as deviations from budgeted deficits, influence local government investment.

The estimates of Holtz-Eakin and Rosen imply that if the municipalities unexpectedly receive NOK 1000 per capita in higher revenue, investment will go up by about NOK 60 per capita. Poterba (1995), in his study of capital spending in the US states, finds an effect of grants equivalent to per capital NOK 100 higher investment with NOK 1000 higher grants, but much smaller effects for other sources of revenue. If we concentrate on the income tax revenue sharing effect of higher GDP, GDP per capita must go by about NOK 6000 to have NOK 1000 more tax revenue to the local public sector. When the higher revenue is unexpected, our estimates imply that investment will go up by about NOK 250. The investments of Norwegian local governments are more responsive to revenue changes than in the United States.

For comparison, a naive model applying actual values of gross domestic product and unemployment is estimated. The size of the estimated short-run coefficients of gross domestic product and unemployment are about the average of the coefficients of expected and unexpected values in the forward looking model. The effect of actual change in gross domestic product is only significant at the 10% level.

The expectations model in Table 3 implies the following long-run relationship between investment, gross domestic

product and unemployment:

$$INV = 0.0336 GDP - 956.5 UNEMP$$

In the historical data, local public investment is about 2.6% of gross domestic product on average. Given the historical values of investment and GDP, the long-run investment share of GDP is consistent with an unemployment rate of about 0.5.

We started out in Section I with the empirical puzzle that local public investment fluctuated during a period of stable local public revenue growth. Investments have responded to greater volatility in macroeconomic conditions since 1970. The local public revenue continued to grow steadily in this more turbulent period of the Norwegian economy. We conclude that local and county governments expected lower revenue with higher unemployment, but the central government never allowed this unemployment to affect the local public revenue growth.

VI. CONCLUDING REMARKS

Local government investment is determined in an environment of substantial uncertainty. The paper analyses local public sector investment in a model that focuses on decision makers' expectations about future events and how they respond to shocks.

Using Euler-equation methods, we find that one cannot reject the hypothesis that local governments are forward looking and that investment involves small adjustment costs. In a structural investment demand model, only unexpected changes of gross domestic product and unemployment are important in the short run, again consistent with the forward looking model of local public investment. The local public investment has been affected by fluctuating macroeconomic conditions even when local revenues have grown steadily. Stabilization of local revenue growth has not led to stable investment growth.

The aggregate investment studied here is the sum of investments in various services in many local and county governments. It is of interest in future analysis to take into account the cross-sectional variation. We have concentrated on a model of intertemporal optimization. A more disaggregated approach will allow for testing of alternative decision models involving local politics.

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APPENDIX: DATA DESCRIPTION

All economic variables are real 1985-NOK per capita. Data cover period 1946–1990.

Average and standard deviation in parentheses:

Investment: 1953 (782)

Δ Investment: 36.43 (191.82)

GDP: 74 298 (29 531)

Unemployment: 1.28 (0.9)

Autoregressive forecasting function applied to gross domestic product is (standard error in parentheses):

$$GDP_t = 491.82 + 1.497 GDP_{t-1} - 0.671 GDP_{t-2} \\ (671.40) \quad (0.161) \quad (0.259) \\ + 0.187 GDP_{t-3} \\ (0.138)$$

R^2 -adj = 0.997, DW = 2.052, Durbin h = - 0.816, $N = 42$

Autoregressive forecasting function applied to unemployment is (standard error in parentheses):

$$UNEMP_t = 0.065 + 1.728 UNEMP_{t-1} \\ (0.095) \quad (0.186) \\ - 1.522 UNEMP_{t-2} + 0.791 UNEMP_{t-3} \\ (0.318) \quad (0.206)$$

R^2 -adj = 0.881, DW = 2.295, Durbin h = - 1.716, $N = 42$