

An Evaluation and Comparison of Econometric Methods of
Forecasting Business Investment:
Summer's Q, Neoclassical, ARIMA, and VAR Models

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ABSTRACT

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Aggregate investment is a large and important component of GDP. The current level of investment not only determines current GDP, but it also plays a large part in determining future productivity gains and competitiveness as well. Thus, a correct model of the investment process is vital for both policy makers and forecasters.


Two distinct models of aggregate investment compete in the literature, the Neoclassical model and the Q model. The more traditional Neoclassical approach is currently used by most practitioners even though it has been rejected by most theorist (Lucas, 1976) in favour of the Q approach. The principle theoretical advantage of the Q model over the Neoclassical model is that it incorporates forward looking expectations. In theory, the backward looking expectations of the Neoclassical model leave it particularly vulnerable to the Lucas Critique.

This thesis compares the forecasting accuracy of a tax adjusted version of the Q model (Summer's Q), with two versions of the Neoclassical model, using quarterly Canadian data. In addition to the theory based models, a pair of time series models, an ARIMA model and a Vector Auto Regression (VAR) model are examined to assess the contribution of economic theory to the prediction of investment. Accuracy is measured with both Theil's U and Mean Absolute Percent Error (MAPE). The quantitative significance of the Lucas Critique is assessed with the CUSUM test which tests for model stability. The Neoclassical and Q models are also tested for model specification using a co-integration test and the Ramsey test.

A comparison of the theory based models with the time series models reveals that the VAR and ARIMA models outperform both theory based models in the prediction of investment in non-residential construction. This result casts doubt on the value of economic theory as an explanation of the investment process. Further, both Neoclassical models, and Summer's Q model, fail the co-integration test for investment in machinery and equipment.

A comparison between the two theory based models shows that in general, Summer's Q is superior to the Neoclassical models in both forecasting accuracy and model stability. Further, the superiority of the Q model may be due directly to the quantitative significance of the Lucas Critique. Evidence is provided by the CUSUM test which shows instability of the Neoclassical models during the forecast period. The backward looking expectations of the Neoclassical models leave them particularly vulnerable in times of changing expectations whereas the Q model incorporates changing expectations

immediately through the valuation of the stock market. Improvement in the modelling of expectations may lead to improvement in forecasting accuracy and model stability of the Neoclassical models.




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CHAPTER 1: INTRODUCTION

1.1 The Issue

Investment is a large and important component of GDP, therefore correct modelling of the investment process is vital for both policy analysis and economic forecasting. The primary concern of this thesis is the forecasting performance of business capital investment models using Canadian data. There are two distinct models of investment which compete in the literature. There is the more traditional Jorgenson approach and the more modern Q approach, both of which are based on optimizing frameworks. The Jorgenson approach continues to be used in most econometric models in spite of the fact that it has been rejected on theoretical grounds (Lucas, 1976) in favour of the Q approach.

The second, and closely related concern of this paper, is the determination of the quantitative significance of the Lucas critique (LC). This is directly related to the prediction of business investment because if the LC is as devastating quantitatively as it is theoretically, then the Neoclassical models will be inadequate for use in the prediction of business investment. The LC suggests that the Neoclassical model will be unstable in times of changing expectations. This, in turn, would lead to biased forecasts. To test the quantitative significance of the LC, I will use the CUSUM test which tests for model stability. Chirinko (1988) examined this issue using data from the United States. His

results showed that the CUSUM test was able to identify instability following from the Lucas Critique, but he concluded that its quantitative impact was not of major importance.

As well as looking at the Q approach and the Neoclassical approach, this paper will look at two autoregressive models to assess the contribution of economic theory to the forecasting of capital investment. The two additional models are the ARIMA model, and a vector autoregression (VAR) model as modeled by Chirinko (1988).

1.2 Objectives

This paper will examine five models of investment: 1) The Neoclassical profit max (derived from the assumption of profit maximizing behaviour of the firm); 2) The Neoclassical cost min (derived from the assumption of cost minimizing behaviour of the firm); 3) Summer's Q model which is a tax adjusted version of Tobin's Q to be discussed below; 4) Sim's vector autoregression (VAR); and 5) A Box Jenkins model (ARIMA).

Separate equations for each of the models will be estimated for investment in machinery and equipment, and non-residential construction so that 10 equations will be estimated in total. The estimation period will be 1973Q2 to 1984Q4.

Each of these equations will then be examined in five tests: 1) The CUSUM test which

tests for model stability; 2) Theil's U statistic which measures forecasting accuracy will be used for an eight quarter model simulation; 3) The mean absolute percentage error (MAPE) will also be used to examine the forecasting accuracy of the eight quarter model simulations as well as a series of eight one step ahead forecasts; 4) The Ramsey test will be used to test each equation for omitted variables; 5) The Neoclassical models and Summer's Q model will also be tested for co-integration using the $\hat{\rho}$ statistic for which the sampling distribution has been constructed empirically by Dickey (Dickey, 1979). All model simulations as well as the CUSUM test will be performed during the period 1985Q1 to 1986Q4.

1.3 The Theoretical Framework

The Q approach relates investment to the Q ratio. Originally developed by Tobin (Tobin, 1969), the Q ratio is the ratio of the market value of the firm to the replacement cost of its capital. The principal theoretical advantage of the Q model over the Neoclassical model is the way in which it incorporates future expectations into the investment process. As we will see, future expectations are represented quite differently in both models. Tobin's Q has forward looking expectations, whereas the Neoclassical model has backward looking expectations. This difference in essence is what makes the Neoclassical model vulnerable to the Lucas Critique.

If in fact the Lucas Critique is quantitatively significant, then the Neoclassical model

will be unstable and we would expect the Q model to perform better in both the CUSUM test and the eight quarter model simulations. That is, if the Neoclassical model is unstable over time then the forecasts during the model simulation will be biased.

1.4 The Lucas Critique

Lucas views policy as the force that generates future policy variables. Economic agents form expectations about the values of these future policy variables based on the current economic policy. These expectations are modelled in different ways by different econometric models, but in general, it is assumed that a single set of parameters related to some observed variables will accurately represent expectations of future variables. The problem with this approach is that when the force which is generating the expectations (i.e. Economic Policy) changes, the parameters of expectations will change as well. It is for this reason that models that do not adapt to the change in the parameters which describe future expectations will be of no use in analyzing simulations of proposed policy changes.

Lucas describes the traditional "theory of economic policy" as follows: The state of the economy at time t can be described by y_t , a vector of state variables, x_t a vector of forcing variables, and e_t a vector of random shocks. The motion of the economy can be described as

$$y_{t+1} = f(y_t, x_t, e_t)$$

The tasks of economists in the past has been to estimate the function f . The regular procedure is as follows. Find the function F such that

$$f(Y,X,E) = F(Y,X,B,E)$$

That is, propose a functional form F and proceed to estimate the fixed values of vector B . Note that this assumes that the econometrician can choose the correct functional form F . The resulting equation is then used for policy analysis simply by inserting the proposed changes in X and examining the resulting change in Y . Note that for an analysis of this sort, it is essential that neither F or B be altered by this change in X . Lucas then goes on to explain why this assumption is not valid.

Firstly, current practices of econometricians indicate implicitly that they are aware of potential problems due to the Lucas critique. For example, forecasters rarely use the data series prior to 1947. Within the theory of econometrics a larger sample is always better but there seems to be an aversion to the pre 1947 time series. Further evidence is provided by the constant upgrading of econometric models. That is, as X changes over time, it seems that there is an understanding that both F and B must be re-estimated. Both of these suggest that there is an implicit understanding that the vector B and the functional form F are not constant over time. This contradicts the central assumption of econometric theory that once F & B are known, that they will remain stable under arbitrary changes in X . This has devastating effects on the effectiveness of policy analysis because any policy analysis is in effect an analysis of changes in X .

The essence of the Lucas critique is thus that simulations with econometric models under alternative proposals of exogenous policy variables cannot provide guidance for policy decisions. This is because all simulations would be carried out based on a single set of parameters B and a functional form F which were estimated from the sample period. The vector B is assumed to be stable but as Lucas suggested, it will likely vary with each alternative policy. Therefore, any results gained from an analysis of this type will be meaningless.

1.5 Summary

This thesis is primarily concerned with a comparison between the Neoclassical models of investment and Summer's Q model of investment. The LC suggests that if expectations change, the parameters of the Neoclassical model will be unstable whereas the parameters of the Q model will not. Sim's VAR and ARIMA models will also be examined. The prediction accuracy of these additional models can be compared with the prediction accuracy of the Neoclassical models and Summer's Q model to measure the contribution of economic theory to the prediction of business investment.

The test results presented in this thesis show that in fact, Summer's Q is a more accurate predictor of investment than the Neoclassical models. Further, evidence from the CUSUM tests suggests that the forecasting superiority of the Q model is due in part to structural instability of the Neoclassical models.

Test results also show that the VAR and ARIMA models outperform both the Neoclassical models and Summer's Q model in the prediction of investment in non-residential construction. These results cast doubt on the adequacy of the theory based models as tools in the prediction of business investment.

CHAPTER 2: THE MODELS

2.1 The Neoclassical Models

The typical Neoclassical putty-putty investment model takes the form:

$$I_t^g = \mu(K_t^* - K_{t-1}) + \delta K_{t-1} \quad (1)$$

That is, gross investment I_t^g is equal to the sum of net investment $\mu(K_t^* - K_{t-1})$ plus replacement investment δK_{t-1} . The greek letter δ denotes the replacement rate. The letter μ is a co-efficient representing the proportion of adjustment from last years capital stock K_{t-1} to this years desired capital stock K_t^* that takes place in year t . This lagged adjustment response μ actually has two causes. Firstly there is the cost of implementing new capital. It may not be most beneficial to adjust immediately to the new desired capital stock due to adjustment costs. This will lead to the adjustment taking place gradually. Secondly, there are technical factors which may prohibit immediate adjustment. The nature of fixed capital is such that it takes time to implement it even when immediate implementation is desired.

2.1.1 Maximizing Profits

The variables which enter into the desired capital stock depend on whether one assumes cost minimizing or profit maximizing behaviour by the firm. If one assumes profit maximization, and output is modelled as a function of capital and labour, then the

derivation goes as follows:

Profits can be written as

$$R_t = P_t f(K_t, N_t) - c_t K_t - w_t N_t \quad (2)$$

where

R_t = profits at time t ;

P_t = the price of one unit of output at time t ;

K_t = capital stock at time t ;

N_t = quantity of labour at time t ;

c_t = the user cost of one unit of capital at time t ;

w_t = the wage rate at time t .

The profit maximizing firm will choose the amount of capital and labour such that these conditions are satisfied:

$$\frac{\partial R_t}{\partial N_t} = P_t f_N(K_t^*, N_t^*) - w_t = 0 \quad (3)$$

$$\frac{\partial R_t}{\partial K_t} = P_t f_K(K_t^*, N_t^*) - c_t = 0. \quad (4)$$

Assuming a Cobb Douglas constant returns to scale production function, output can be expressed as:

$$Y_t = AK_t^\alpha N_t^{(1-\alpha)} \quad (5)$$

where

Y_t = quantity of output at time t ;

A = a scale factor;

α = elasticity of output with respect to capital.

Given the production function above, the marginal product of capital, f_K , is

$$f_K = \alpha AK_t^{(\alpha-1)}N_t^{(1-\alpha)} \quad (6)$$

using (5)

$$f_K = \alpha Y_t / K_t \quad (7)$$

and substituting into (4) yields

$$\frac{\partial R_t}{\partial K_t} = P_t \alpha Y_t / K_t^* - c_t = 0 \quad (8)$$

Thus,

$$K_t^* = \alpha P_t Y_t / c_t \quad (9)$$

2.1.2 Minimizing Costs

Rather than maximize profits, one can minimize costs subject to a given level of output. Minimizing costs subject to an output constraint requires minimizing the following Lagrangian,

$$Z_t = w_t N_t + c_t K_t + \lambda(\bar{Y} - f(K_t, N_t)) \quad (10)$$

where \bar{Y} is the exogenous level of output.

The first order conditions for minimizing costs are thus

$$\frac{\partial Z_t}{\partial N_t} = w_t - \lambda f_N(K_t^*, N_t^*) = 0 \quad (11)$$

$$\frac{\partial Z_t}{\partial K_t} = c_t - \lambda f_K(K_t^*, N_t^*) = 0 \quad (12)$$

Taken together, Equations (11) and (12) imply that the ratio of the marginal products is equal to the ratio of the factor prices. That is:

$$\frac{w_t}{c_t} = \frac{f_N(K_t^*, N_t^*)}{f_K(K_t^*, N_t^*)} \quad (13)$$

Substituting this back into a Cobb Douglas production function and solving for K yields the following expression for desired capital stock:

$$K_t^* = \frac{\bar{Y}_t}{A} \left(\frac{1-\alpha}{\alpha} \frac{w_t}{c_t} \right)^{1-\alpha} \quad (14)$$

The optimal level of capital at time t is thus expressed differently depending on the

assumptions made about the behaviour of the firm. It can be shown however that the cost minimization and profit maximization solutions are identical when $P = \lambda$, where

$\lambda = \partial Z_f / \partial \bar{Y}_t$ is the long run marginal cost.¹

Note that from (4) we can see that the profit maximizing firm will desire capital until the marginal benefit of one additional unit of capital, $P_t f_K(K_t^*, N_t^*)$, is equal to the marginal cost of one additional unit of capital c_t . As we will see later, the Q model incorporates this same feature of the firms behaviour.

2.1.3 Net Investment Specification

Translating the standard Neoclassical model into a net investment specification involves substituting either the desired capital stock from either Equation (9) or (14) into the stock adjustment formulation (1).

Thus using (9), the profit maximizing version is:

$$I_t = \mu(\alpha P_t Y_t / c_t - K_{t-1}) + \delta K_{t-1} \quad (15)$$

This specification states that investment depends on the expected values of output, output

¹ Scotland, Francis, "Investment: A Survey of Models With Some Implications For The Effects of Monetary Policy." Technical Report #29, Bank of Canada Technical Reports. p.16

price, and the user cost of capital.

As mentioned earlier, the fundamental problem with estimation of the Neoclassical equations is the specification of expectations. Clearly, P_t , Y_t and c_t are not known at any time previous to t which is when investment decisions are made. Neoclassical theory solves this problem by assuming that firms base their expectations of the future on their observations of the past. These backward looking expectations can be represented as a distributed lag of past values so that the expected value of $P_t Y_t / c_t$ can be written as

$$(P_t Y_t / c_t)^e = \sum_{i=1}^n z_i P_{t-i} Y_{t-i} / c_{t-i} \quad (16)$$

where the z_i 's are fixed expectations parameters. This is restrictive however as noted by Bischoff (1969) in that it restricts the lag structure on the value of output ($P_t Y_t$) to be the same as the structure of the lags on user cost (c_t). A less restrictive model, and the one which is used in this thesis, is the following which allows for different lag structures on the price, output and user cost variables.

$$Y_t^e = \sum_{i=1}^{n1} B_{1i} Y_{t-i} \quad (17)$$

$$P_t^e = \sum_{i=1}^{n2} B_{2i} P_{t-i} \quad (18)$$

$$c_t^e = \sum_{i=1}^{n3} \beta_{3i} c_{t-i} \quad (19)$$

where β_{1i} , β_{2i} , and β_{3i} are fixed expectations parameters.

That is, it is assumed that expectations on the future value of a variable can be modelled as a stable function of past values of the variable of concern. As will be seen later, these expectations parameters then enter the estimated model in combination with an adjustment co-efficient μ , to form coefficients on the lagged values of price, output and user cost. Note that although less restrictive, the modification of the lag structure proposed by Bischoff does nothing to protect the Neoclassical theory from the LC. In fact, the only change is that now instead of having one faulty lag structure on $P_t Y_t / c_t$, we will now have three, one on Y_t , one on P_t , and one on c_t . Any announced change in future economic policy which alters expectations of future values of P , Q , or c , will not be captured in the previously estimated parameters representing investors expectations. The Neoclassical model is vulnerable to the LC regardless of the intricacy of the lag structure because its parameters of expectations are based only on the past.

Dividing equation (1) through by K_{t-1} gives

$$I_t^g / K_{t-1} = \mu (K_t^* / K_{t-1} - 1) + \delta \quad (20)$$

Recognizing that for values of K_t^* / K_{t-1} close to one,

$$\ln K_t^* - \ln K_{t-1} \approx K_t^* / K_{t-1} - 1, \quad (21)$$

we can write

$$I_t^g/K_{t-1} = \mu(\ln K_t^* - \ln K_{t-1}) + \delta \quad (22)$$

Hence substituting in for K_t^* from (9) gives

$$I_t^g/K_{t-1} = \mu(\ln(\alpha P_t Y_t / c_t) - \ln K_{t-1}) + \delta \quad (23)$$

Now, substituting from (17), (18), and (19) to incorporate the expectations of Y_t , P_t and c_t gives

$$I_t^g/K_{t-1} = (\delta + \mu \ln \alpha) + \sum_{i=1}^{n1} \mu \beta_{1i} \text{Ln} Y_{t-i} + \sum_{i=1}^{n2} \mu \beta_{2i} \text{Ln} P_{t-i} + \sum_{i=1}^{n3} \mu \beta_{3i} \text{Ln} c_{t-i} - \mu \text{Ln} K_{t-1} + \epsilon_t, \quad (24)$$

which can be written as

$$I_t^g/K_{t-1} = \alpha + \sum_{i=1}^{n1} \phi_i \text{Ln} Y_{t-i} + \sum_{i=1}^{n2} \theta_i \text{Ln} P_{t-i} + \sum_{i=1}^{n3} \psi_i \text{Ln} c_{t-i} - \mu \text{Ln} K_{t-1} + \epsilon_t. \quad (25)$$

This form recognizes that investment at time t will also include lags of adjustment from past years. Therefore, the lagged coefficients ϕ_i , θ_i , and ψ_i are a combination of expectations parameters, β_{1i} , β_{2i} , β_{3i} and the delivery lag parameter μ (Chirinko, 1986:140). The model in (25) is the one which is used for this paper.

The Neoclassical cost min version is essentially the same as above except that equation (14) is substituted in for desired capital stock. The primary difference between the two

is that in the cost min version the wage rate is used in place of the output price level.

Thus, given (14),

$$I_t = \mu \left(\frac{\bar{Y}_t}{A} \left(\frac{1-\alpha}{\alpha} \frac{w_t}{c_t} \right)^{1-\alpha} - K_{t-1} \right) + \delta K_{t-1} \quad (26)$$

The equation to be estimated is then

$$I_t/K_{t-1} = \alpha + \sum_{i=1}^{n1} \phi_i \text{Ln} Y_{t-i} + \sum_{i=1}^{n2} \theta_i \text{Ln} w_{t-i} + \sum_{i=1}^{n3} \psi_i \text{Ln} c_{t-i} - \nu \text{Ln} K_{t-1} + \epsilon_t. \quad (27)$$

The key variable in both versions is c_t , the user cost of capital. The correct specification of the user cost of capital is very important for the analysis of tax policy because all of the relevant tax variables enter the Neoclassical equation through the user cost. For the purposes of this paper I use a user cost developed by Nadeau(1991):

$$c = q \left(\frac{r + \delta - \bar{\mu}}{r} \right) (pRB + (1-p)RS) \quad (28)$$

where

$$q \equiv \pi_K (1 - ITC) (1 - \tau_c \tilde{D}) \quad (29)$$

and π_K is the supply price of capital goods, ITC is the rate of investment tax credit, τ_c is the tax rate on corporate income, and D is the present value of depreciation allowances on one dollar of investment. The net of tax rate of return required by investors to hold equity, denoted r , is determined as the net of tax opportunity cost of not investing funds in other assets of the same risk class. The expected inflation rate for the output price, denoted as $\bar{\mu}$, is proxied by the long run inflation rate for the output price. The debt/asset ratio for manufacturing corporations is denoted as p , RB is the rate of return on bonds, (i.e the cost of debt financing), and RS is the pre corporate tax rate of return to stock holders.

Note that this expression for user cost incorporates many variables which can be either directly or indirectly altered by policy makers. For this reason, it follows from the LC that for any parameters which are estimated to represent expectations, a change in policy which directly or indirectly alters the expectations of any of the variables in c will therefore alter the parameters. Clearly, although easy to implement, the backward looking expectations leave the Neoclassical model vulnerable to the Lucas critique.

2.2 Key Assumptions and Caveats (Neoclassical)

One serious flaw in the Neoclassical models above, is that in reality, both the profit maximizing and the cost minimizing firms will choose output and capital stock simultaneously. The above expressions both take output as given and therefore do not

recognize the dependence of output on user cost. Unbiased simulations could be generated by solving the factor demand equations and the production function simultaneously. The alternative is to assume that output is determined exogenously as would be the case in a Keynesian view of the economy where output is determined by demand.

Any simulations performed for the purpose of policy analysis will underestimate the reaction of investment to the change in user cost since the change in output due to the change in user cost will not be captured in the simulation. This will not affect the ability of the Neoclassical models to forecast in this paper because the actual values of user cost and output are used in the forecast period.

Another caveat concerns the assumption that the expected values of price, wage rate, output, and user cost can be represented by distributed lags of past observations. Firstly, this implies that any change will be treated as though it were permanent even if it was announced as temporary. For example, backward looking expectations cannot discern between a tax change which is announced as temporary versus one which is announced as permanent. The Neoclassical model of investment would predict the same investment response for both. Secondly, any pre announced changes in tax policy would have no impact on investment since only past values of the user cost enter into the expectations structure.

Finally, another related point is that by using a distributed lag on past values of user cost to represent the expectations of future values, we are imposing the constraint that all elements of the user cost follow the same autoregressive process. Tax policy and interest rates may in fact follow very different patterns. The result of this method of treatment for expectations by the Neoclassical model is that the expectations parameters are likely to be unstable over time. This is particularly relevant to this paper since unstable expectations parameters would result in a poor performance in the CUSUM tests and a poor performance in forecasting since the forecasts would be biased due to incorrect expectations parameters.

2.3 The Q Model

While able to explain a great deal of the variation in the investment data, the Neoclassical specification is plagued by the inadequate treatment of expectations. A popular approach which deals with this problem is the Q theory, which was originally put forward by Tobin (1969). As mentioned earlier, the Q theory is appealing in that it overcomes the problem of backward looking expectations encountered with the Neoclassical model. It does this with explicit consideration of forward looking expectations. These enter the model through the valuation of the firm in the stock market, incorporating, in principle, the expectations of future variables which determine investment.

In theory, an efficient market will incorporate all available information as well as expectations of the future into the value of the firms' shares. As more capital is acquired by the firm, the value of the firm in the stock market will increase. If the expected marginal benefit of an additional unit of capital is greater than the expected marginal cost then the value of the firm will increase by more than the cost of the capital. Marginal Q is the ratio of the expected marginal benefit of one additional unit of capital to the expected marginal cost. Note that the profit maximizing firm will hire capital until the expected marginal benefit equals the expected marginal cost (i.e. when marginal Q equals 1).

In practice, marginal values are difficult to observe. This problem is solved by using average Q as a proxy. The theoretical justification for the use of average Q has been developed by Hayashi (1985).² Average Q is simply the ratio of the market value of the firm to the replacement cost of its capital:

$$Q_t^a = V_t/P_k K_t, \quad (30)$$

where V is the market value of the firm, P is the price of a unit of capital, and K is the capital stock. If this ratio is greater than one, the market valuation of capital exceeds its replacement cost. Whenever Q_t^a is greater than one, the market consensus is that the future prospects of the firm are such that they warrant further investment. As more capital is accumulated by the firm, the term Q_t^a will move toward one.

² "If the firm is a price taker with constant returns to scale in both production and installation, then marginal Q is equal to average Q." (Hayashi, 1988:214)

Summers (1981) created a tax adjusted Q which he found to provide somewhat more explanatory power than the original Q developed by Tobin. The tax adjusted Q can be written as

$$Q = \left(\frac{\frac{(V-B)(1-C)}{pKSTOCK(1-\theta)} - 1 + b + ITC + Z}{1 - \tau_c} \right) \quad (31)$$

where B is the present value of depreciation allowances on the current capital stock, τ_c is the corporate tax rate, C is the capital gains tax rate on an accrual basis, θ is the dividend tax rate, b is the portion of new debt financed via debt, and Z is the present value of depreciation allowances on one dollar of investment.

The general functional form used is³

$$I_t^G/K_{t-1} = \alpha + \sum_{i=0}^n \beta_i Q_{t-1-i} + e_t \quad (33)$$

The obvious advantage of this theory over the Neoclassical theory is that expectations at time t are now embodied in one variable Q_t , not in a mass of lagged parameters.

³ The reasons for including lagged values of Q are "(i) existing practice across a majority of Q studies and (ii) potential data misalignment, by which is meant that the national accountant's timing of investment rarely matches perfectly the timing of news on the stock market." (Sensenbrenner, 1991)

Furthermore, we would expect that the Q theory would not be vulnerable to the LC since any change in expectation patterns caused by a change in policy will be directly reflected in a change in the value of the firms shares in the stock market and thus in the value of Q. The lagged parameters on Q represent only adjustment lags and, therefore, should not be altered by a change in expectations.

Another advantage of the Q theory is that it incorporates the fact that firms make decisions on output and capital stock simultaneously rather than taking the level of output as given as in the Neoclassical model. This is an important point since a reduction in the cost of capital encourages firms to supply more output, this in turn motivates them to purchase more capital.

Past studies have found that residual serial correlation is a problem shared by both the Q model and the Neoclassical. The original Jorgenson framework does not predict autocorrelation of the residuals. The AR(1) term has been included in practice more out of necessity than theory. In contrast, the Q equation derived by Sensenbrenner (1991) incorporates investment inertia at the theoretical stage. To do this he assumes an intertemporal quadratic adjustment cost function. The assumption is that certain investment costs are shared across consecutive time periods, which gives rise to autocorrelated errors. The interpretation is that last periods investment paid for some of the costs (internal costs, such as adjustment and irreversibility costs) of this periods investment. Second, the intertemporal cost function allows for external investment costs

through gestation lags. Gestation lags in the investment process translate into order queues, with some firms explicitly paying a premium for the speedier delivery of their orders for investment goods, while other firms incur the opportunity cost of foregone profits. Premium or foregone profit are shown to depend on how strong current investment is relative to past investment.

The theoretical advantage of the Q theory over the Neoclassical theory has not stopped policy analysts from continuing to use the Neoclassical model. One reason for this is that before Summers (1981) developed his tax adjusted Q there was no direct link between policy variables and investment in the Q theory. Policy analysis was carried out more easily with the Neoclassical model of investment because tax variables and interest rates enter directly into the Neoclassical model through the user cost of capital.

2.4 Key Assumptions and Caveats (The Q Model)

The principle criticism of the Q theory is that short term fluctuations in the stock market value are unlikely to be related to the investment decisions of the firm. It is important to eliminate the random noise from the stock market data to get a true measure of the expectations of the future profitability of the firm. One method of removing the random noise, which is adopted in this study, is to use a moving average on the stock market values to smooth out the fluctuations (Scotland, 1981).

An additional problem concerns the measurement of the capital stock used in the denominator of average Q . The capital stock series used are generated assuming a fixed depreciation rate. "These rates may have become highly inaccurate in the face of the major structural shifts which have occurred since the early 1970s. The rapid rise in energy prices may have made part of the existing capital stock obsolete, forcing firms to retire machines designed initially to work best with low energy costs" (Chirinko, 1988). That is, any historical change in the depreciation rate would lead to biased estimates of the capital stock, which in turn would lead to biased estimates of Q . In the case of the energy shock, the capital stock series generated with a fixed depreciation rate would overstate the replacement value of the existing capital stock which enters in the denominator of Q . Fortunately, the severity of this bias may be insignificant. Arnold (1985), using U.S. data, found that the rise in energy prices caused only a small bias in the estimation of manufacturing capital stock in the U.S.

2.5 The Vector Auto Regression Model

This study examines a Vector Auto Regression Model (VAR) with the same variables used by Chirinko (1988). The six variables which he used are: the level of output, the financial value of the firm, and a lagged dependent variable (all scaled by the capital stocks of equipment plus structures), the nominal interest rate, a composite tax variable, and the relative price of investment goods. The latter three are actually the familiar components of the Neoclassical user cost of capital term. The financial value of the firm

is the same as that which was used in the Q theory, and the level of output is the same as that which was used in the Neoclassical theory.

Assuming that the error terms are uncorrelated between equations, each equation may be estimated separately without loss of estimation efficiency.⁴ Therefore, in this paper the investment equations will be estimated separately by ordinary least squares.

To stay consistent with the other equations which were estimated, the dependent variable used in the estimation of the VAR equations is the quantity of investment scaled by the previous periods capital stock of the same type, I_t/K_{t-1}

Following Chirinko (1988) the general functional form of the VAR equations is

$$\begin{aligned}
 I_t/K_{t-1} = & \alpha + \sum_{i=0}^{n1} \beta_i \frac{Y_{t-1-i}}{KSTOCK_{t-1-i}} + \sum_{i=0}^{n2} \theta_i \frac{V_{t-1-i}}{KSTOCK_{t-1-i}} + \sum_{i=0}^{n3} \phi_i \frac{I_{t-1-i}}{K_{t-2-i}} \\
 & + \sum_{i=0}^{n4} \varphi_i RLIND_{t-1-i} + \sum_{i=0}^{n5} \psi_i \frac{(1-ITC - \tau_c D)_{t-1-i}}{(1-\tau_c)_{t-1-i}} + \sum_{i=0}^{n6} \varpi_i \frac{PIME_{t-1-i}}{PINRC_{t-1-i}} + \epsilon_t
 \end{aligned} \tag{34}$$

where KSTOCK is the total stock of machinery and equipment and non-residential structures excluding energy and agriculture, RLIND is the average corporate bond rate, and PIME and PINRC are the investment price deflators for machinery and equipment

⁴ See Judge et al (1988:756).

and non-residential construction respectively.

2.6 The ARIMA Model

In the ARIMA (p,d,q) model, a time series is modelled as

$$y_t = \phi_1 y_{t-1} + \phi_2 y_{t-2} + \dots + \phi_p y_{t-p} + \epsilon_t - \theta_{t-1} \epsilon_{t-1} + \theta_{t-2} \epsilon_{t-2} \dots - \theta_q \epsilon_{t-q},$$

where p is the order of the autoregressive portion of the model and q is the order of the moving average component of the model. The letter d is for the level of differencing required to obtain stationarity. Separate equations are to be estimated for investment in machinery and equipment and non-residential construction. The series used in each case will be (I_t/K_{t-1}) , the same as the dependent variables used in the models described above.

The three steps required for the estimation of an ARIMA model are: identification, estimation, and diagnostic checking. The ARIMA model is of interest in this paper as a measure of the ability to forecast investment without any economic theory. The ARIMA model is different from the Neoclassical and the Q in that it requires no economic theory at all. It is merely an attempt to identify the stochastic process which generates values of the variable of concern. Unlike the regression models, a set of explanatory variables is not used. ARIMA models attempt to explain future values of a variable based only on past values of itself. Note that the ARIMA model is really a special case of the VAR discussed above but with only one variable, I_t/K_{t-1} , in the vector.

Also, in the case of the ARIMA model, the series is differenced if required to obtain a stationary series.

CHAPTER 3: ESTIMATION RESULTS

All models were estimated using quarterly data, seasonally adjusted at annual rates from 1973Q2 to 1984Q4. The starting date was chosen due to data limitations while the completion date was chosen to allow an eight quarter model simulation with the available data from 1985Q1 to 1986Q4. The data is described in detail in Appendix A. For all models, separate equations for investment in machinery and equipment and investment in non-residential construction were estimated. The reasons for the separation are twofold. Firstly, separate equations allow one to use separate user cost variables to distinguish between the cost of machinery and equipment and the cost of non-residential construction. Secondly, we would expect different adjustment lags and therefore different lagged coefficients for the two types of investment.

Both investment series were defined to exclude energy and agriculture since many of the factors affecting energy related capital formation and agricultural investment are non-market in nature (Scotland,1981:23). The Neoclassical and Q models were specified using the Cochrane Orcutt procedure to correct for first order autocorrelation of the errors. The Cochrane Orcutt procedure uses the autocorrelation as a source of additional information to provide more efficient estimation of the coefficients.

The equations which were chosen as optimal are displayed in appendix B. Tables B1 through B5 show the equations for machinery and equipment while the equations for non-

residential construction are displayed in tables B6 through B10.

A variety of F tests were used to pick the optimal lag length and polynomial order for each of the eight equations excluding the ARIMA models. A discussion of the F tests and their results is included in Appendix C.

3.1 Estimation of the Neoclassical Models

The only Neoclassical equation which fit according to theory is the Neoclassical profit max equation for machinery and equipment displayed in table B1 in appendix B. The sums of the coefficients are all as would be predicted by theory. That is, the equation confirms that an increase in either output price or output quantity will have the effect of increasing investment while an increase in the user cost of capital will have the effect of decreasing investment.

The Neoclassical cost min equation for machinery and equipment displayed in table B2 shows the sum of the lagged coefficients on the wage rate equal to -0.084 which is contrary to Neoclassical theory. Theory would suggest that an increase in the wage rate would cause investment to rise as firms substitute capital for labour as they move to the cost minimizing input combination on the production isoquant. The co-efficient on the lagged capital stock has the wrong sign at 0.003. The stock adjustment framework outlined earlier shows that the co-efficient should be negative.

The Neoclassical profit max equation for structures displayed in table B6 shows that the sums of the lagged coefficients on both output and output price are the wrong sign at -0.049 and -0.036 respectively. The co-efficient on the lagged capital stock is also the wrong sign at 0.464. As will be explained later, the size and sign of the co-efficient on the lagged capital stock variable have serious implications for the eight quarter model simulations.

The Neoclassical cost min equation for structures, displayed in table B2, is the worst of the Neoclassical equations. Once again, the sum of the lagged coefficients on the wage rate is the wrong sign, thus contradicting economic theory. It is also important to note that the co-efficient on the lagged capital stock is again the wrong sign and is relatively large at 1.41.

3.2 Estimation of the Q Model

The Q variable defines the ratio of the market value of the firm to actual replacement value of the existing capital stock, thus the market value of the firm cannot be divided into the value of machinery and equipment and non-residential structures. Therefore, the same Q variable is used to predict both types of capital investment.

The final equations chosen as optimal are shown in tables B3 and B8 in appendix B. Both of the Summer's Q equations exhibit a high degree of first order auto correlation

of the error terms with the co-efficient of correlation (ρ) equal to 0.908 for machinery and equipment and 0.978 for structures. As explained earlier, the inclusion of an AR(1) in the Q models has been justified by Sensenbrenner (1991) when adjustment costs are assumed to be intertemporal. The sum of the coefficients is positive in both cases as would be expected.

3.3 The Vector Auto Regression Model

The estimation of the VAR equations involves a format similar to that used by Chirinko (1988). The six variables which he used are: the level of output, the financial value of the firm, and a lagged dependent variable (all scaled by the capital stocks of equipment plus structures), the nominal interest rate, a composite tax variable, and the relative price of investment goods. Separate equations are estimated for machinery and equipment and structures. Chirinko used a lag of twelve quarters for each of the dependent variables and imposed a fourth order polynomial constraint on the distributed lags.

Due to the limited data, $n=43$, the starting point for the testing of the lag lengths in this thesis is six quarters. The results of the F tests show that this limitation is not a problem since the joint F test on the sixth lag of each of the variables fails to reject the null hypothesis that the sixth coefficients are jointly insignificantly different from zero. Further, the F tests also show that a fourth order polynomial distributed lag, which was

used by Chirinko, is too restrictive. The lag length and polynomial order chosen as optimal are a lag length of five and a polynomial order of five for both investment in machinery and equipment and structures. The F test results are displayed in appendix C.

The VAR model performs much better in the case of machinery and equipment than for non-residential construction. The sums of the coefficients are the correct sign on all variables in the machinery and equipment regression. In the case of non-residential construction the sums of the coefficients are the incorrect sign for the nominal interest rate, the tax variable, and the relative investment price deflators however none are significantly different from zero.

3.4 The ARIMA Model

The three phases of specifying an ARIMA model, identification, estimation, and diagnostic checking were performed as follows. For both investment in machinery and equipment and investment in non-residential construction the series was differenced until a stationary series was obtained. In both cases, due to a positive time trend, the level of differencing required was one. The next step in the identification phase required choosing the lengths of the AR and MA components of the process. In both cases it was evident from an examination of the partial autocorrelation functions (PACF) and the autocorrelation functions (ACF) that ARIMA 1,1,0 was the most likely model. A variety

of other ARIMA models were tried but the ARIMA 1,1,0 performed best in the diagnostic checking phase. To check the specification of the models the Modified Box-Pierce chisquare statistic was used. An additional criteria was that the estimated coefficients had to be significantly different from zero. The models chosen, as well as the corresponding modified Box-Pierce statistics for both machinery and equipment and non-residential construction are displayed in tables B5 and B10 respectively. Constant terms are not included as they proved to be insignificantly different from zero.

CHAPTER 4: TEST DESCRIPTIONS

4.1 Intra-Sample Tests

The two intra-sample tests which are used in this thesis are the Ramsey test and a co-integration test. These tests are performed during the pre-forecast period of 1973Q2 to 1986Q4.

4.1.1 The Ramsey Test

The Ramsey test is a test for omitted variables. The procedure used in this paper is outlined in Maddala (1988). Ramsey suggests the use of \hat{y}^2 , \hat{y}^3 , and \hat{y}^4 as proxies for z_t , where \hat{y} is the predicted value of y_t obtained from a regression of Y on X, and z_t represents any omitted variables. The following steps were followed:

1. Regress y_t on x_t to get \hat{y} .
2. Regress y_t on x_t , \hat{y}^2 , \hat{y}^3 , \hat{y}^4 and test the hypothesis that the coefficients on the powers of \hat{y} are zero using a joint F test.

The F statistic is calculated as

$$F[J,n-k] = \frac{(ESS_R - ESS_{UR})/J}{ESS_{UR}/(n-K)}$$

where J is the number of restrictions and n - k is the degrees of freedom in the

unrestricted regression. ESS_R and ESS_{UR} are the residual sum of squares for the restricted regression and the unrestricted regression respectively.

4.1.2 Co-integration Test

Both investment in machinery and equipment and non-residential construction are non-stationary time series, as are the explanatory variables examined in both the Neoclassical models and Summer's Q model. Regressing one non-stationary time series against another can lead to spurious results if the time series are not co-integrated. That is the results will indicate a long term relationship between the two variables when in fact none exists.

If two time series are co-integrated then they must obey an equilibrium relationship in the long run, although they may diverge substantially in the short run. Further, if two series are co-integrated then the residual series which results from regressing one on the other will be stationary (i.e the residual series will not follow a random walk). Therefore, the residuals which result from the regression of one random walk on another can be used to test for co-integration.

The co-integration test is essentially a unit root test on the error terms where

$$H_0: \Delta \epsilon_t = c + \mu_t \quad : \text{random walk with drift}$$

$$H_1: (1-\rho B)\varepsilon_t = c + \mu_t \quad \text{where } |\rho| < 1 \quad \text{:stationary AR(1)}$$

The statistic

$$\hat{\tau}_c = \frac{\hat{\rho} - 1}{S(\hat{\rho})}$$

where $S(\hat{\rho})$ is the estimated standard error of $\hat{\rho}$, which is the co-efficient of the first order autoregressive error term, can be used in this case. The sampling distribution of $\hat{\tau}_c$ has been constructed empirically under the assumption that $H_0: \rho = 1$ is true. Critical values for the τ_c statistic are presented in Davidson and Mackinnon (1993:722).

4.2 Out of Sample Tests

All models are tested for both forecasting accuracy and model stability outside of the original estimation period of 1973Q2 to 1984Q4. An eight quarter model simulation with capital stock endogenous is undertaken with all models during the period from 1985Q1 to 1986Q4. The forecasting accuracy during the eight quarter model simulations is compared with the aid of Theil's U statistic and the MAPE.

The CUSUM test uses a sequence of one step ahead forecasts during the same period to measure model stability. The MAPE for the one step ahead forecasts, which are used for the CUSUM test, is also calculated to allow comparison of the one step ahead

forecasting accuracy of the competing models.

The one step ahead forecasts which are used for the CUSUM test are performed with the structure constant but with the parameters re-estimated at each time t over the 8 quarters from 1984Q4 to 1986Q3. The eight quarter model simulations are performed using the parameters held constant at the values which were chosen as optimal over the intra-sample period ending at 1984Q4. During the extra-sample simulation, the capital stock is endogenous so that any forecast errors feed directly into the simulated value of the capital stock. Further, for the Neoclassical and Q equations, the value of ρ estimated at time t is applied against the residual at time t when forecasting for the period $t+1$ for the CUSUM test. For the eight quarter model simulations the term

$$\rho^i \hat{\epsilon}_t$$

is added to the forecast value of I_{t+i}/K_{t+1+i} where time t in this case is 1984Q4.

To examine the contribution of the error correction in the forecasting process, additional eight quarter model simulations are performed without the above error adjustment for the Neoclassical models and Summer's Q model. These will be referred to as eight quarter unadjusted forecasts.

4.2.1 The Cusum Test

The CUSUM test is used because unlike other tests of model stability, the CUSUM does not require precise information as to when the structural change took place. The null hypothesis is that the coefficient vector B and the functional form F , as described in the Lucas Critique, are stable over time. The alternative is that they are not. The procedure is as follows. The recursive residuals are calculated by estimating a model over the sample period 1973Q2 to 1984Q4, then using this coefficient vector and the explanatory variables for 1985Q1, the one step ahead forecast error is calculated. This procedure is repeated sequentially with the sample period extended one period at a time until forecast errors are obtained for 1985Q1 to 1986Q4.

Following the procedure outlined in Greene (1990:225) the forecast errors (e_t) are divided by their standard error to provide normalized forecast errors w_t . It follows then that if the null hypothesis is true, that w_t is $N(0,1)$ and independently distributed. If the w_t are independent then there should be no persistent deviations away from zero. The CUSUM test statistic is then calculated as the cumulative sum of the normalized residuals.

4.2.2 Theil's U and MAPE Tests

One of the most common measures of out-of-sample evaluations is Theil's inequality measure, or U-statistic. This involves using the root mean squared forecast error, and standardizing it such that the value of U is bounded by zero on the lower end and by one

on the upper end.⁵ Theil's inequality coefficient is defined as:

$$U = \frac{\sqrt{(1/T) \sum (P_t - A_t)^2}}{\sqrt{(1/T) \sum (P_t)^2 + (1/T) \sum (A_t)^2}}$$

where P_t and A_t represent the predicted and actual values of the time series respectively, and the numerator is the root mean squared error of the predicted values. A value of $U=0$ implies that $P_t=A_t$ for all t , and the particular forecast provides a perfect fit. On the other hand, if $U=1$, this indicates the worst possible performance of the predictor P_t . Clearly then, the forecasts can be rated in relation to one another, with the lowest U -statistic indicating the forecast which performs best in the given out-of-sample evaluation.

In order to gain a better understanding of the forecast ability of each of the evaluated predictors, Theil's inequality coefficient can be decomposed as follows:⁶

$$(1/T) \sum (P_t - A_t)^2 = (P_\mu - A_\mu)^2 + (\sigma_P - \sigma_A)^2 + 2(1 - \rho)\sigma_P\sigma_A$$

where P_μ , A_μ , σ_P , and σ_A are the means and standard deviations of the series P_t and A_t respectively, and ρ is their correlation coefficient. This step allows an analysis of the sources of the forecast errors. The decomposition tests are then performed by separating the above equation into three parts, defined as proportions of inequality:

⁵ Pindyck and Rubinfeld (1981:364).

⁶ Pindyck and Rubinfeld (1981:365).

$$U^M = \frac{(P_{\mu} - A_{\mu})^2}{(1/T) \sum (P_t - A_t)^2}$$

$$U^S = \frac{(\sigma_P - \sigma_A)^2}{(1/T) \sum (P_t - A_t)^2}$$

$$U^C = \frac{2(1-\rho)\sigma_P\sigma_A}{(1/T) \sum (P_t - A_t)^2}$$

These proportions, U^M , U^S , and U^C are known respectively as the bias, the variance, and the covariance proportions of the inequality coefficient. It can be shown that $U^M + U^S + U^C = 1$. This decomposition analysis allows a more precise evaluation of the forecasts, using the definitions of U^M , U^S , and U^C as given by Pindyck and Rubinfeld (1981).

U^M , the bias proportion, is a measure of the systematic error of the forecast, because it measures the extent to which average values of the predicted and actual values of the series deviate from one another. Regardless of the total value of U , any large value of U^M (in excess of 0.2 for example) would indicate the presence of significant systematic bias in the forecast, meaning that revision of the model is necessary.

U^S is the variance proportion of U , and indicates the ability of the predictor to replicate the degree of variability in the variable that the predictor is attempting to

forecast. A large value of U^S indicates that either: 1) the actual series has varied considerably while the forecasted values have not, or 2) the forecasted values have varied considerably but the actual values of the series have not. In either case, a large value of U^S indicates that a better forecast may be needed.

U^C , the covariance proportion, measures what is known as the unsystematic error, or the remaining error after accounting for average variability and deviations from average values. Obviously, it is unreasonable to expect predicted values to forecast precisely the actual time series (such a case would result in a value of $U=0$). Therefore, for values of $U>0$, the best possible distribution of inequality among the three components would be $U^M=U^S=0$ and $U^C=1$, since the covariance proportion of any forecast error is the least troublesome.

CHAPTER 5: TEST RESULTS

5.1 The Ramsey Test

Table 1: Ramsey Test Results

Machinery & Equipment	T-RATIOS			Critical	Critical	Calc.
	\hat{y}^2	\hat{y}^3	\hat{y}^4	$F_{.01,3,*}$	$F_{.05,3,*}$	$F_{3,*}$
Neo Profit Max 24 DF	-.14	0.98	-1.36	4.72	3.01	2.99
Neo Cost Min 30 DF	-.14	0.04	0.15	4.51	2.92	1.25
Summers Q 33 DF	1.08	-1.10	1.09	4.40	2.88	1.59
VAR 8 DF	0.11	-0.00	-0.13	7.59	4.07	4.19
Structures						
Neo Profit Max 6 DF	-.66	0.67	-.63	9.78	4.76	3.94
Neo Cost Min 16 DF	-.45	0.55	-.62	5.29	3.24	1.09
Summers Q 31 DF	-.74	0.72	-0.71	4.51	2.92	.75
VAR 8 DF	-1.41	1.49	-1.56	7.59	4.07	6.95

* = degrees of freedom in the unrestricted regression.

The results above show that none of the coefficients of the powers of \hat{y} are significantly different from zero at the 5% level when examined individually. However, when the significance of the powers of \hat{y} are examined jointly, two of the eight models

fail the Ramsey test at the 5% level. Surprisingly, the inclusion of the powers of \hat{y} significantly improves the fit of both VAR models at the 5% level. The only other models close to failing the Ramsey test are the Neoclassical profit max equations in both machinery and equipment and non-residential construction.

5.2 Co-integration Test

The asymptotic critical value for the τ_c statistic at the 1 per cent level is -5.25 (Davidson and Mackinnon:1993:722)⁷. The results are presented in Table 2. At the $\alpha = 0.01$ level we reject the null hypothesis of a random walk for both Neoclassical models in non-residential construction. The only equation to fail the co-integration test in non-residential construction is Summer's Q. In machinery and equipment we fail to reject the null hypothesis for Summer's Q as well as both Neoclassical equations. This implies that, although Summer's Q has proved to be superior to the Neoclassical models in each of the other tests examined, the relationship between Summer's Q and investment may be spurious. It is important to note however that correlation of the error terms in the Q model is predicted by Sensenbrenner(1991) if one assumes an intertemporal adjustment cost function. Thus, if one accepts that adjustment costs are intertemporal, there is a bias toward failure to reject the null hypothesis when testing the Q equations

⁷ The table of critical values in Davidson and Mackinnon provides critical values for up to a maximum of 5 right hand side variables. The Neoclassical equations have more than 5 right hand side variables therefore the critical values should actually be larger (more negative) than -5.25.

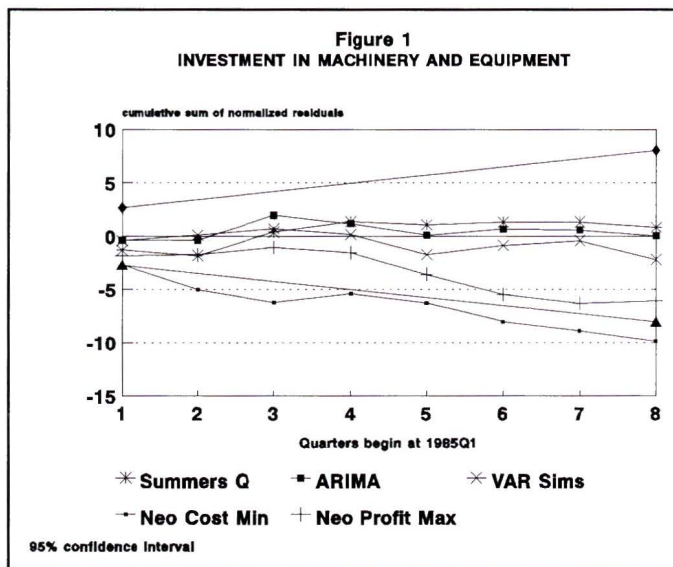
for co-integration.

Table 2: The Co-integration Test

Machinery & Equipment	$\hat{\rho}$	$S(\hat{\rho})$	$\hat{\tau}_c$
Neo Profit Max	0.3531	0.1609	-4.02
Neo Cost Min	0.6903	0.1164	-2.66
Summer's Q	0.9646	0.0401	-0.88
Structures			
Neo Profit Max	-0.9391	0.0627	-30.93
Neo Cost Min	0.0050	0.0219	-45.40
Summer's Q	0.9032	0.0739	-1.31

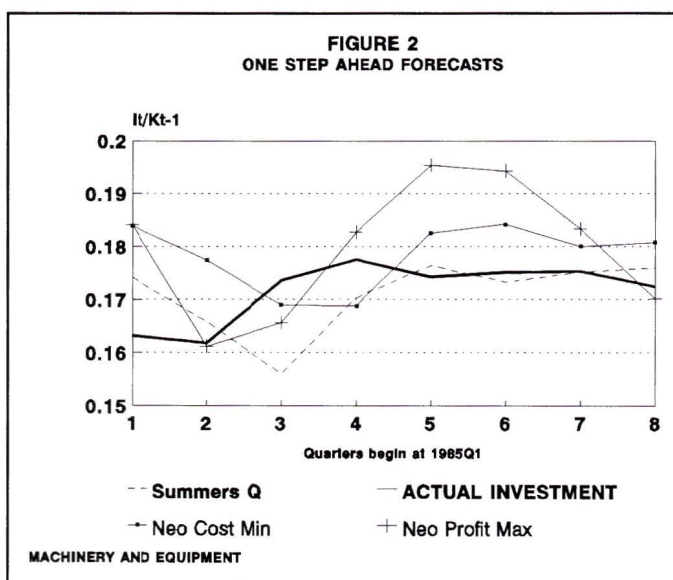
5.3 The Cusum Test

The results of the CUSUM test for machinery and equipment are displayed in Figure 1. The Neoclassical models both show signs of parameter instability. The Neoclassical cost min model fails the CUSUM test at the 5% level and although the profit max



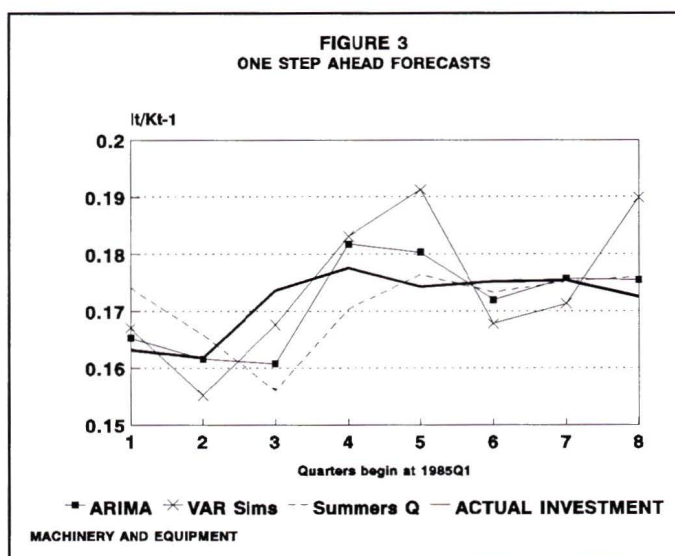
equation does not fail the CUSUM test it also appears to show signs of parameter instability. It should be noted that the 95% confidence level applies to the entire test period. That is, there is only a 5% probability that the sum of the normalized residuals will stray outside the boundary during the test period if the null hypothesis of model stability is true.

The Neoclassical models appear to consistently overestimate investment in the period examined.

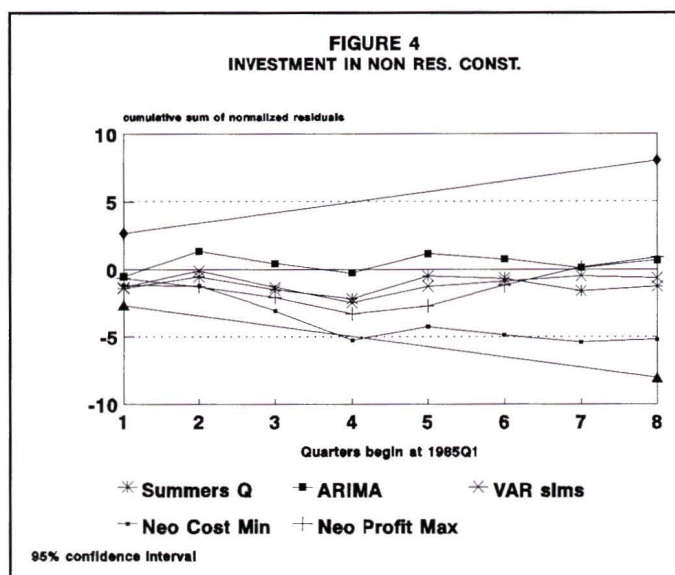


A closer examination of the actual one step ahead

forecasts in Figures 2 and 3 reveals that this is in fact the case. The Neoclassical cost min equation overpredicts investment in six of the eight quarters examined while the Neoclassical profit max model overpredicts by a relatively large amount in quarters 4,5,6 and 7.



The CUSUM was much closer to 0 for the Summer's Q equation due to the fact that Summer's Q showed no bias toward overprediction or underprediction during the test period. As shown in Figure 3, both the ARIMA and VAR models also showed no bias during the test period.



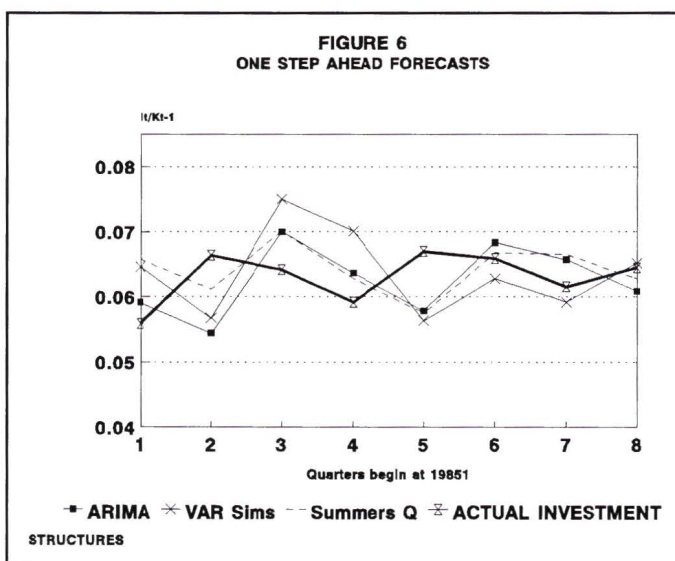
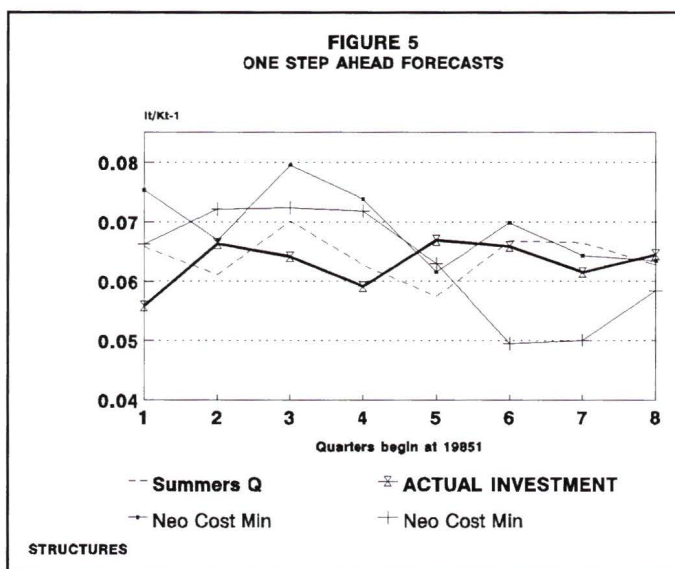
In the case of non-residential construction the Neoclassical cost min model again fails the CUSUM test. That is, the hypothesis of model stability is rejected at the 5% level.

As shown in Figure 4, all other models perform very well and the hypothesis of model stability is not rejected.

A close examination of the one step ahead forecasts in Figure 5 reveals that both the Neoclassical

profit max model and the Neoclassical cost min model overestimate investment in the first four quarters of the test with the degree of overestimation being most severe in the case of the cost min model.

Figure 6 shows that the Summer's Q, VAR, and ARIMA models follow very similar patterns throughout the test period and show no tendency toward overprediction or underprediction of investment.



5.4 Theil's U and MAPE Tests

Table 3 shows Theil's U test and the MAPE tests for investment in machinery and

equipment. MAPE1 is the mean absolute percentage error for the one step ahead forecasts used in the CUSUM test. MAPE8 is the MAPE for eight quarter model simulations. Theil's U statistic and its components are also for the eight quarter model simulations. The ARIMA model is the most accurate in the one step ahead forecasts with a MAPE of 2.3%. Summer's Q model is second best at 3.51% with the VAR model third at 4.93%. The cost min version of the Neoclassical model and Neoclassical profit max are the least accurate at 5.92%, and 6.19% respectively.

Table 3: Theil's U and MAPE Tests (Machinery and Equipment)

M & E	Theils U	U ^M	U ^S	U ^C	MAPE8	MAPE1
Neo Profit Max	0.1538	0.64	0.32	0.04	27.67	6.19
Neo Cost Min	0.2123	0.68	0.30	0.02	42.91	5.92
Summers Q	0.0282	0.04	0.68	0.28	5.12	3.51
VAR	0.0418	0.18	0.49	0.33	6.03	4.93
ARIMA 1,1,0	0.0304	0.57	0.40	0.03	5.25	2.30
Neo P Max Unad.	0.1541	0.64	0.32	0.04	28.33	NA
Neo C Min Unad.	0.2475	0.71	0.28	0.01	53.79	NA
Summer's Q Unad	0.0449	0.43	0.39	0.18	7.91	NA

The most accurate model in the eight quarter simulation for machinery and equipment

is Summers's Q model as shown by the values of Theil's U statistic and MAPE8 at 0.0282 and 5.12 per cent respectively. In both cases the ARIMA model is a very close second with the U statistic and the MAPE8 at 0.0304 and 5.25 percent respectively. The VAR model is next, with the Neoclassical models performing the poorest as measured by both the MAPE8 and Theil's U statistic.

The MAPE is much larger for the Neoclassical models in the eight quarter model simulations than for the one step ahead forecasts. This is in contrast to Summer's Q model, the ARIMA model, and the VAR model which have fairly similar values for the MAPE1 and MAPE8. This is likely due in part to the instability of the Neoclassical models shown earlier in the CUSUM tests. That is, when calculating the one step ahead forecasts, the coefficient vector B was re-estimated at each quarter so that the coefficients could adjust partially to reflect the new expectations if they occurred. When performing the eight quarter model simulations the coefficient vector was fixed at the values estimated in the sample period of 1973Q2 to 1984Q4. Any change in expectations after 1984Q4, would result in a biased co-efficient vector B being used in the eight quarter model simulations for both Neoclassical models. This would result in biased forecasts which would lead to a much larger MAPE in the eight quarter model simulations than in the one step ahead forecasts. An examination of Table 1 reveals that this is in fact the case for investment in machinery and equipment. The values of UM , which measures the proportion of the errors attributable to bias, are very high for the Neoclassical profit max and cost min models at 0.64 and 0.68 respectively. The corresponding value for

Summers Q is very low at 0.04 as would be expected since any change in expectations would feed directly through the value of the stock market into the Q variable. The result is that since the change in expectations does not alter the coefficient vector B in the Summer's Q model, the eight quarter model simulations provide unbiased forecasts and hence the Q model is almost as accurate during the eight quarter model simulation as it is during the one step ahead forecasts.

Note that we would not expect the models to be as accurate in the eight quarter model simulations even if the true parameters remained unchanged during 1985Q1 to 1986Q4 because the one step ahead forecasts have the advantage of using the actual capital stock for each forecast. In the eight quarter model simulations, even an unbiased residual feeds directly into the capital stock, thus making the following period's forecast less accurate. This is explained in more detail below.

It is important to note that the eight quarter forecasts examine the forecast value of investment, not of the value of the dependent variable, which is investment scaled by the previous periods capital stock. This is because with the capital stock endogenous, a forecast of the ratio of investment to capital stock may be correct, when in fact the forecast for investment is incorrect. Therefore, the forecast value of I_t/K_{t-1} at each period is multiplied by the simulated K_{t-1} to get the forecast value of I_t . Note that if a forecast is too high in period t, the error will feed into that periods adjusted capital stock. This will then have the impact of increasing the investment forecast in period t+1 when the

forecast value of I_{t+1}/K_t is multiplied by K_t to get I_{t+1} . This may result in the investment forecasts exploding as one forecast error leads into the next. All models have the same dependent variable however so this should not put any particular model at a disadvantage.

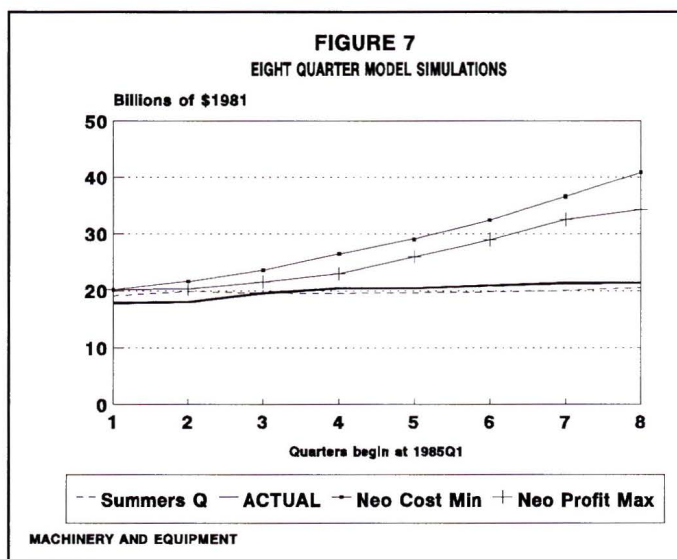
A related point regarding the Neoclassical models is that with 3 of the 4 equations having a positive co-efficient on the log of the lagged capital stock, there will be a strong tendency for the Neoclassical model errors to grow exponentially throughout the forecast. For example, the Neoclassical cost min equation for structures has a co-efficient on the lagged capital stock equal to 1.41. Suppose that at time t in the eight quarter model simulation, due to overprediction of investment in earlier periods, the simulated capital stock value is greater than the actual. The difference between the log of the simulated capital stock and the log of the actual capital stock, which is approximately equal to the per cent difference between the simulated capital stock and the actual capital stock, will lead to an error in the prediction of I_{t+1}/K_t equal to

$$1.41(Ln\hat{K}_t - LnK_t)$$

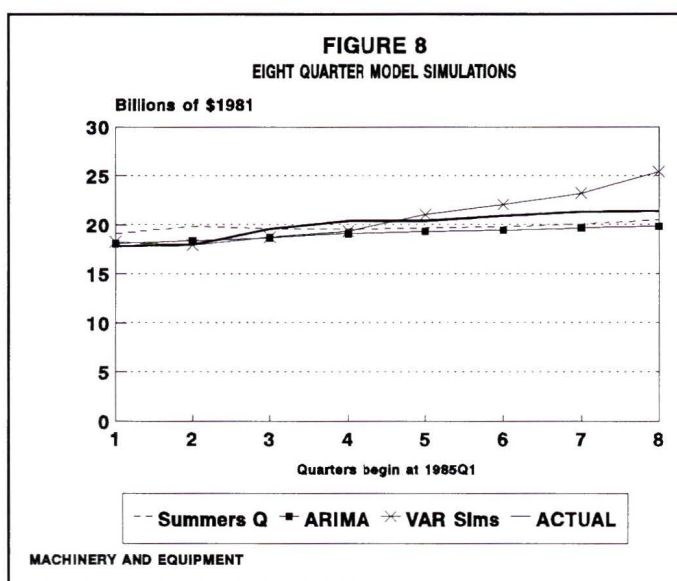
Thus a 10 per cent difference between the simulated capital stock and the actual capital stock in period t would result in overprediction of I_{t+1}/K_t by 0.141. With I_t/K_{t-1} equal to approximately 0.06 throughout the forecast period, this would result in approximately a 235 per cent error in the prediction of I_{t+1}/K_t . Further worsening the problem is that the forecast value of I_{t+1}/K_t is then multiplied by the simulated value of K_t thus magnifying the error. This then leads to an even greater error in the simulated value of

K_{t+1} and hence the next periods investment forecast as well.

An examination of the eight quarter model simulations shown in Figure 7 confirms the problems with the Neoclassical models. The Neoclassical models both tend to overestimate investment throughout the entire simulation period with a definite trend upward. Summer's Q model and the ARIMA model both are very close to the actual values, following a similar pattern of underprediction over the last four quarters.



Additional eight quarter simulations are performed with no error correction to test the contribution of the error correction to the prediction of investment. Given the high autocorrelation



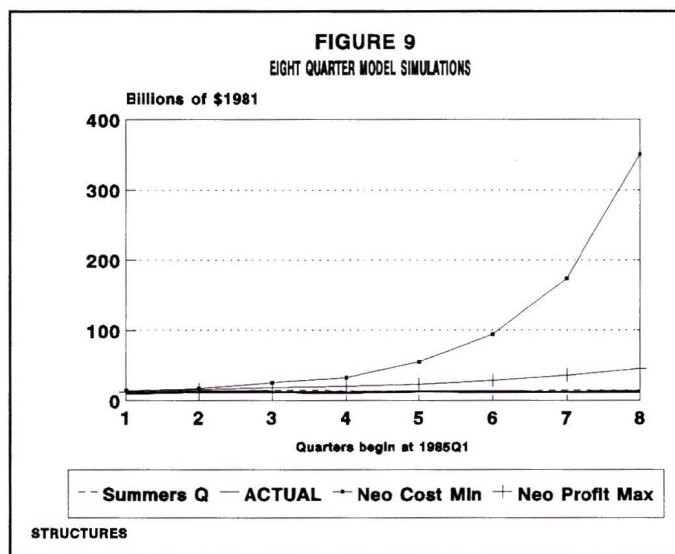
present in the Summer's Q equations one might expect it to be quite significant.

However, the eight quarter unadjusted model simulations show that, although Summer's Q does benefit more than the Neoclassical models from error correction, Summer's Q is still more accurate than the Neoclassical models even without error correction. Table 3 shows that for machinery and equipment, Summer's Q unadjusted is 7.91 per cent versus 28.33 and 53.79 per cent for the profit maximizing and cost minimizing versions respectively. Theil's U statistic is 0.0449 for Summer's Q versus 0.1541 for Neoclassical profit max and 0.2475 for the Neoclassical cost min model respectively.

The results for the investment in non-residential construction forecasts are shown in Table 4: Theil's U and MAPE Tests (Structures)

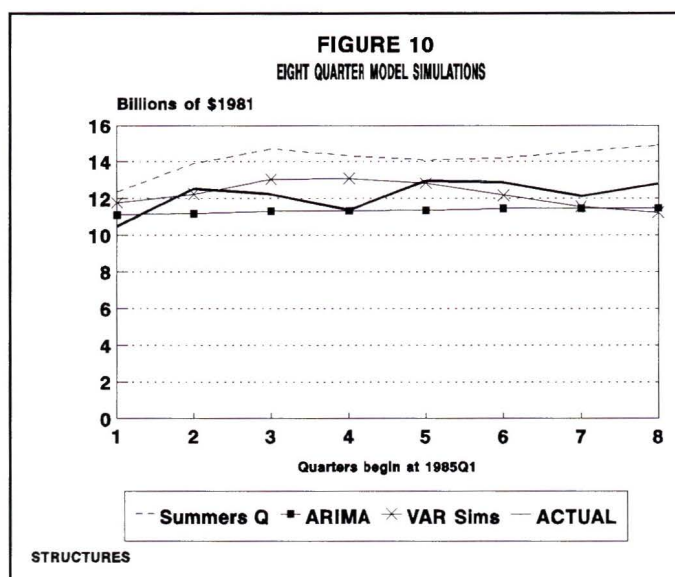
STRUCTURES	Theil's U	U ^M	U ^S	U ^C	MAPE8	MAPE1
Neo Profit Max	0.4119	0.59	0.37	0.33	102.49	14.88
Neo Cost Min	0.8715	0.34	0.65	0.01	662.9	13.13
Summers Q	0.0774	0.90	0.00	0.11	16.23	8.41
VAR	0.0426	0.00	0.02	0.99	7.46	11.40
ARIMA 1,1,0	0.0473	0.54	0.40	0.06	8.00	8.80
Neo P Max Unad.	0.4092	0.59	0.38	0.03	100.92	NA
Neo C Min Unad.	0.8716	0.34	0.65	0.01	663.1	NA
Summer's Q Unad	0.1008	0.94	0.00	0.06	22.09	NA

Table 4. The ARIMA model and Summer's Q are the most accurate in the one step ahead forecasts. Summers Q is most accurate, outperforming the ARIMA model with a MAPE1 of 8.41% versus 8.8% for the ARIMA model. Sim's VAR model is next best



with a MAPE1 of 11.4 per cent. The Neoclassical cost min and profit max models are the least accurate at 13.13 per cent and 14.88 per cent respectively.

Figures 9 and 10 display the eight quarter model simulation results. The VAR model is the most accurate during the eight quarter model simulations. The ARIMA model is a close second with Summer's Q a distant third. Once again, the Neoclassical



models are the least accurate with both showing exponential growth throughout the simulation period. Recall that the Neoclassical cost min model failed the CUSUM test. This is evidence of instability of the coefficients therefore we would expect it to perform

poorly in the eight quarter model simulation. The CUSUM test, illustrated in figure 4, shows that a structural change in the parameters of the cost min model results in consistent overprediction of investment in non-residential construction during the one step ahead forecasts. During the eight quarter model simulations each error is compounded exponentially due to the large positive co-efficient on the log of the lagged capital stock.

The eight quarter unadjusted simulations show that error correction definitely plays a larger part in Summer's Q model than in the Neoclassical models. The performance of the Neoclassical models is virtually the same with or without error correction. The MAPE8 for Summer's Q model rises from 16.23 per cent to 22.09 per cent when the error adjustment is not made.

CHAPTER 6: CONCLUSIONS

The Neoclassical models are disappointingly poor predictors of investment in both the one step ahead forecasts and the eight quarter model simulations. The primary reason for this seems to be the instability of the Neoclassical model's coefficients. Evidence of this is provided by the CUSUM tests in Figures 1 and 3. The Neoclassical cost min model failed the CUSUM test in both machinery and equipment and non-residential construction. The Neoclassical profit max model also showed a tendency to overpredict investment although this was not significant at the 5% level. The poor performance of the Neoclassical models in the CUSUM tests provides evidence that the LC may be quantitatively significant. That is, given that the CUSUM test was performed during a period of tax reform by the newly elected Conservative government, failure of the CUSUM test is evidence that the Neoclassical models are unstable in times of changing expectations.

A further explanation of the poor performance of the Neoclassical models is provided by an examination of the estimated equations displayed in Appendix B. Three of the four Neoclassical equations have the incorrect sign on at least one of the sums of the coefficients or on the lagged capital stock. That is, the historical relationships between the variables included in the Neoclassical models, and the investment series itself, are often contrary to Neoclassical theory. In econometric practice, the applied econometrician would likely attempt different lag lengths or sample periods in an attempt

to achieve the correct sign on each variable. The necessity of this common practice of "data mining" to obtain appropriate coefficients is in itself strong evidence that the Neoclassical theory is not an adequate explanation of investment behaviour.

Summer's Q provides the most accurate forecast of investment in machinery and equipment in the eight quarter model simulations. However, the ARIMA model is the most accurate in the one step ahead forecast with a MAPE of 2.3% versus 3.5% for Summer's Q. The Neoclassical cost min and the Neoclassical profit max models are the least accurate at 5.92% and 6.19% respectively. The performance of the ARIMA model relative to the theory based models casts doubt on the value of economic theory in the prediction of investment.

The strength of the time series models is also evident in non-residential construction. Summer's Q is only slightly more accurate than the ARIMA model in the one step ahead forecasts with MAPE's of 8.4% and 8.8% respectively. Once again the Neoclassical cost min and the Neoclassical profit max models are the least accurate at 13.1% and 14.9% respectively. In the eight quarter model simulations, for investment in structures, the ARIMA model and the VAR model are the most accurate while the Neoclassical model forecasts tend to explode upward. This occurs in large part due to the co-efficient on the lagged capital stock variable which is incorrectly positive.

Both Neoclassical models, as well as Summer's Q model, fail the co-integration test

at the 1 per cent level for machinery and equipment. Summer's Q is the only model to fail the co-integration test for non-residential construction. In both cases the co-efficient on the error term is significantly larger for Summer's Q than that of the Neoclassical models. This might lead one to believe that the relationship between Summer's Q and investment is spurious and that much of the predictive power of the Summer's Q equations is due to the co-efficient on the error term. However, when an eight quarter forecast is performed with no error correction, Summer's Q still significantly outperforms both Neoclassical models. The unadjusted eight quarter model simulations show that error correction plays a more significant role in the prediction of investment by Summer's Q than the Neoclassical models. However, it can be argued that this follows directly from the argument by Sensenbrenner(1991) regarding intertemporal adjustment costs. That is, the error terms will be correlated if one assumes an intertemporal adjustment cost function and it follows that the autocorrelation of the errors will be a significant contributor to the prediction of investment.

Taken together, the results from the CUSUM test, the eight quarter model simulations, and the Ramsey test, indicate that Summer's Q model is superior to the Neoclassical models in the prediction of investment. This is likely due in part to the problem of backward looking expectations. That is, evidence from the CUSUM test indicates that the LC is quantitatively significant. Further, the parameters estimated for the Neoclassical models often have the incorrect sign thus casting doubt on the adequacy of the Neoclassical theory. As a result, Summer's Q model provides a more accurate

forecast of business investment than the Neoclassical models.

Unfortunately, to the extent that an accurate forecast of the stock market is more difficult to obtain than the prediction of the Neoclassical variables, the value of Summer's Q as a tool for forecasting may be limited. The persistent use of the Neoclassical models of investment in econometric models is likely because the independent variables are relatively easy to forecast, and they can be easily used for policy analysis. However, the poor performance of the Neoclassical model and the instability of its coefficients seriously limits the value of its predictions. If one interprets the CUSUM test results as evidence of the significance of the LC, then improvement of the modelling of expectations should provide significant improvements in the performance of Neoclassical models.

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APPENDIX A: THE DATA

Investment and Capital stock series

IMEXEA Investment in machinery and equipment excluding energy and farm investment. Constructed as IMEXE - IMEA.

IMEA Business Investment in Machinery and Equipment in Agriculture.

Source: Current Analysis Group. - Research Dept.

Generated in 'COMPLX' at the Bank of Canada
From National Income and Expenditure Accounts
and Research Dept. data.
(Unpublished)
\$millions (1981 dollars)

IMEXE Business Investment in Machinery and Equipment
Excluding Energy Investment.

Source: Current Analysis Group. - Research Dept.

Generated in 'COMPLX' at the Bank of Canada
From National Income and Expenditure Accounts
and Research Dept. data.
(Unpublished)
\$millions (1981 dollars)

IME Business Investment in Machinery and Equipment

Source: Current Analysis Group. - Research Dept.

Generated in 'COMPLX' at the Bank of Canada
From National Income and Expenditure Accounts
and Research Dept. data.
(Unpublished)

\$millions (1981 dollars)

INRCXEA Investment in Non-residential Construction excluding energy and farm investment. Constructed as IMEXE - IMEA.

INRCA Business Investment in Non-Residential Construction in Agriculture.

Source: Current Analysis Group. - Research Dept.
Generated in 'COMPLX' at the Bank of Canada
From National Income and Expenditure Accounts
and Research Dept. data.
(Unpublished)
\$millions (1981 dollars)

INRCXE Business Investment in Non-Residential Construction Excluding Energy Investment.

Source: Current Analysis Group. - Research Dept.
Generated in 'COMPLX' at the Bank of Canada
From National Income and Expenditure Accounts
and Research Dept. data.
(Unpublished)
\$millions (1981 dollars)

INRCXE Business Investment in Non-Residential Construction

Source: Current Analysis Group. - Research Dept.
Generated in 'COMPLX' at the Bank of Canada
From National Income and Expenditure Accounts
and Research Dept. data.
(Unpublished)
\$millions (1981 dollars)

KMEXEA Stock of non-farm machinery and equipment excluding energy stocks.

Source: Current Analysis Group. - Research Dept
Generated in 'COMPLX' at the Bank of Canada
From National Income and Expenditure Accounts and Research Department data
(Unpublished)
\$millions (1981 dollars)

KME Stock of machinery and equipment

Source: Current Analysis Group. - Research Dept
Generated in 'COMPLX' at the Bank of Canada
From National Income and Expenditure Accounts and Research Department data
(Unpublished)
\$millions (1981 dollars)

KNRCXEA Stock of non-farm non-residential construction excluding energy stocks.

Source: Current Analysis Group. - Research Dept
Generated in 'COMPLX' at the Bank of Canada
From National Income and Expenditure Accounts and Research Department data
(Unpublished)
\$millions (1981 dollars)

KNRC Stock of non-residential construction

Source: Current Analysis Group. - Research Dept
Generated in 'COMPLX' at the Bank of Canada
From National Income and Expenditure Accounts and Research Department data
(Unpublished)
\$millions (1981 dollars)

Independent Variables

1 Neoclassical Models

CME Imputed rental price for machinery and equipment.
Source: constructed by Nadeau, (1991)

Recall that user cost was calculated as:

$$c = q \left(\frac{r + \delta - \bar{\mu}}{r} \right) (pRB + (1-p)RS)$$

where q is defined as

$$q \equiv \pi_K (1 - ITC) (1 - \tau_c \tilde{D})$$

π_K The supply price of capital goods. See PIME and PINRC.

ITC The rate of investment tax credit.
Source: Nadeau (1991)

τ_c the tax rate on corporate income. A weighted average of combined federal and provincial highest marginal statutory tax rates on corporate income.

\tilde{D} the present value of depreciation allowances on one dollar of investment. See CPVME and CPVNR.

r the net of tax rate of return required by investors to hold equity, which is determined as the net of tax opportunity cost of not investing funds in other assets of the same risk class. Set equal to $RLIND(1-\tau_p)$ where RLIND denotes an average of the rates on 10 industrial bonds. (McLeod, Young and Weir) and τ_p is the highest marginal personal income tax rate.

δ	the depreciation rate of the capital stock. See DELTAMEX and DELTANRX.
$\bar{\mu}$	the expected inflation rate for the price of output taken as the long run inflation rate for the price of output. Set to 5.6% as per Nadeau (1991).
p	debt/asset ratio for manufacturing corporations. Generated from Statistics Canada- Corporation Financial Statistics data.
RB	rate of return on bonds, i.e the cost of debt financing. Source: Nadeau (1991b)
RS	the pre tax rate of return to stock holders. Source: Nadeau (1991b)
CNR	Imputed rental price for non-residential construction. Source: Generated by scaling CME.

Note that π_k , \tilde{D} , and δ will be different in the case of non-residential construction than in the user cost term calculated by Nadeau (1991) for machinery and equipment. To allow for this difference the CNR series was calculated by scaling the CME series as follows:

$$\left(\frac{PINRC(1 - \tau_c CPVNR) \frac{r + DELTANRX - \bar{\mu}}{r}}{PIME(1 - \tau_c CPVME) \frac{r + DELTAMEX - \bar{\mu}}{r}} \right) CME$$

CPVME	Present tax value of depreciation allowances for machinery and equipment.
-------	---

Source: Current Analysis Group. - Research Dept
Generated in 'COMPLX' at the Bank of Canada From
National Income and Expenditure Accounts and Research
Department data
(Unpublished)
percent

CPVME	Present tax value of depreciation allowances for non-residential construction.
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Source: Current Analysis Group. - Research Dept
Generated in 'COMPLX' at the Bank of Canada
From National Income and Expenditure Accounts and Research
Department data
(Unpublished)
percent

DELTAMEX RATE OF DEPRECIATION OF MACHINERY AND EQUIPMENT
EXCLUDING ENERGY AND AGRICULTURE

Source: Current Analysis Group. - Research Dept
Generated in 'COMPLX' at the Bank of Canada
(Unpublished)

DELTANRX RATE OF DEPRECIATION OF NON-RESIDENTIAL CONSTRUCTION
EXCLUDING ENERGY AND AGRICULTURE

Source: Current Analysis Group. - Research Dept
Generated in 'COMPLX' at the Bank of Canada
(Unpublished)

PGPP PRICE DEFLATOR FOR GROSS DOMESTIC BUSINESS PRODUCT

Source: Current Analysis Group. - Research Dept
Generated in 'COMPLX' at the Bank of Canada
From National Income and Expenditure Accounts and
Research Department data
(Unpublished AND Published)
1981 = 1.0

PIME PRICE DEFLATOR FOR BUSINESS INVESTMENT IN MACHINERY
AND EQUIPMENT

Source: Current Analysis Group. - Research Dept
Generated in 'COMPLX' at the Bank of Canada
From National Income and Expenditure Accounts and
Research Department data
(Published)
1981 = 1.0

PINRC PRICE DEFLATOR FOR BUSINESS INVESTMENT IN NON-RESIDENTIAL CONSTRUCTION

Source: Current Analysis Group. - Research Dept
Generated in 'COMPLX' at the Bank of Canada
From National Income and Expenditure Accounts and
Research Department data
(Published)
1981 = 1.0

UGPP Gross Private Business Product (Excluding agriculture and non-commercial business)

Source: Current Analysis Group. - Research Dept
Generated in 'COMPLX' at the Bank of Canada
From National Income and Expenditure Accounts and
Research Department data
(Published)
\$millions (1981 dollars)

WNIC WAGES AND SALARIES OF INDUSTRIAL COMPOSITE EXCLUDING COMMUNITY SERVICES, GOVERNMENT AND AGRICULTURE.

Source: Current Analysis Group. - Research Dept
Generated in 'COMPLX' at the Bank of Canada
From Statistics Canada Data
(Published)
DOLLARS PER WEEK

Summer's Q

Q was estimated as

$$Q = \left(\frac{\frac{(V-B)(1-C)}{pKSTOCK(1-\theta)} - 1 + b + ITC + Z}{1 - \tau_c} \right)$$

where

$$B_t = \frac{\tau_c \delta^T \frac{(1-\theta)}{(1-c)} KDEP_t e^{-\delta T}}{\left(\frac{\rho + \pi}{1-C}\right)^2}$$

V Generated as:

$$V = .25 \sum_{i=0}^3 (YCR_{t-i} + YDIVII_{t-i} + YDIVF_{t-i}) TSEPE_{t-i}$$

- YCR Retained corporate profits.
Source: National Income and Expenditure Accounts (published)
\$millions (current dollars)
- YDIVF Dividends paid to foreign shareholders by Canadian corporations.
Source: National Income and Expenditure Accounts (published)
\$millions (current dollars)
- YDIVII Dividends paid to Canadian residents by Canadian corporations.
Source: National Income and Expenditure Accounts (published)
\$millions (current dollars)
- TSEPE Toronto stock exchange price to earnings ratio
Source: CANSIM
- B The present value of depreciation allowances on the current depreciable capital stock generated as.

$$B_t = \frac{\tau_c \delta^T \frac{(1-\theta)}{(1-c)} KDEP_t e^{-\delta T}}{\left(\frac{\rho + \pi}{1-C}\right)^2}$$

τ_c The tax rate on corporate income. A weighted average of combined federal and provincial highest marginal statutory tax rates on corporate income. It was calculated using the formula:

$$\tau_c = \tau_{cf} \cdot (1 + S_{cf} \cdot y - A_c) + \tau_{co}$$

where

τ_{cf} : highest marginal statutory rate on corporate income - federal rate.

S_{cf} : federal surtax applicable on income from large non-mining and non-manufacturing industries.

y : proportion of non-mining and non-manufacturing industries.
Sources: Statistics Canada - Corporation Financial Statistics.

A_c : federal abatement = 10%.

τ_{co} : highest marginal statutory rate on corporate income-Ontario rate.

δ^T The tax depreciation rate at time T. This was generated as

$$\delta^T = \frac{CCAC\$}{KDEP\$}$$

where

$$KDEP\$_t = K\$_{t-1} + I\$_t - CCAC\$_t$$

where K\$ and I\$ are the nominal values of total capital stock and investment respectively.

CCAC\$ CAPITAL CONSUMPTION ALLOWANCE, CORPORATIONS.

Source: Current Analysis Group. - Research Dept
Generated in 'COMPLX' at the Bank of Canada From
National Income and Expenditure Accounts and Research

Department data
(Unpublished)
\$millions (Current dollars)

- C Capital gains tax rate on an accrual basis. It was constructed by Nadeau (1991) using the formula:

$$\tau_g = \frac{1+g - [(1-\mu)((1+g)^T-1)+1]^{1/T}}{g}$$

where μ is the capital gains tax rate, T is the number of periods the asset is held, and g is the growth rate in value of the asset. For the years 1973q2-1984, the capital gains tax rate m used 0.5(τ_p). For the years 1985-1986, m was calculated as:

$$\mu = 0.05 \cdot (1-x) \cdot \tau_p$$

where x is the percentage of capital gain incomes exempt from taxation for taxpayers with incomes over \$100,000 (based on 1984 data corrected for inflation). The variable T was taken from Nadeau (1986) and specified as 3.76 years. The growth rate g used is the average percentage increase of the values of the Standard and Poor's Stock Price Index over the years 1956 to 1984; it was calculated as 6.65%.

- Θ the highest marginal statutory rate on dividend income as constructed by Nadeau (1991).
- π Rate of inflation of the consumer price index. Constructed from PCPI

PCPI CONSUMER PRICE INDEX

Source: Current Analysis Group. - Research Dept
Generated in 'COMPLX' at the Bank of Canada
From Statistics Canada Data
(Unpublished)
1981 = 1.0

ρ

The real fixed required real rate of return by equity holders the net of tax rate of return required by investors to hold equity, which is determined as the net of tax opportunity cost of not investing funds in other assets of the same risk class. Set equal to $RLIND(1-\tau_p) - \pi$ where $RLIND$ denotes an average of the rates on 10 industrial bonds. (McLeod, Young and Weir), τ_p is the highest marginal personal income tax rate and π is the overall inflation rate.

- b The portion of new investment financed via debt
Source: Nadeau (1991)
- ITC The effective rate of investment tax credit
Source: Nadeau (1991)
- Z The present value of depreciation allowances on one dollar of current investment. This was generated as a weighted average of CPVME and CPVNR.

pKSTOCK Generated as the replacement value of existing capital stock:

$$pKSTOCK_t = PINRC_t KNR C_t + PIME_t KME_t + PKIB_t KIB_t$$

PINRC PRICE DEFLATOR FOR NON FARM BUSINESS INVENTORY STOCK

Source: Current Analysis Group. - Research Dept
Generated in 'COMPLX' at the Bank of Canada
From National Income and Expenditure Accounts and
Research Department data
(Published)
1981 = 1.0

KIB NON-FARM BUSINESS INVENTORY STOCK

Source: Current Analysis Group. - Research Dept
Generated in 'COMPLX' at the Bank of Canada
From National Income and Expenditure Accounts
and Research Department data
(published)
\$millions (1981 dollars)

RLIND The average corporate bond rate.
Source: Generated in 'COMPLX' at the Bank of Canada from
National Income and Expenditure Accounts and research
department data
(published)

APPENDIX B: THE INVESTMENT EQUATIONS

Table B1: Neoclassical Profit Max (Machinery and Equipment)

1973Q2 - 1984Q4

$$\hat{I}_t/K_{t-1} = \begin{matrix} -7.15 \\ (2.51) \end{matrix} + \sum_{i=0}^{n1} \phi_i LnY_{t-1-i} + \sum_{i=0}^{n2} \theta_i LnP_{t-1-i} + \sum_{i=0}^{n3} \beta_i Lnc_{t-1-i} - \begin{matrix} 0.036 \\ (0.11) \end{matrix} LnK_{t-1}$$

$$\hat{\epsilon}_t = \begin{matrix} 0.372\hat{\epsilon}_{t-1} \\ (.15) \end{matrix}$$

$$R^2 = 0.988 \quad \bar{R}^2 = 0.984$$

	ϕ_i		θ_i		β_i	
i=0	0.030	(0.077)	0.043	(0.072)	-0.039	(0.008)
1	0.109	(0.066)	0.275	(0.046)	-0.057	(0.010)
2	0.222	(0.061)	0.467	(0.065)	-0.061	(0.010)
3	0.096	(0.100)	0.392	(0.090)	-0.052	(0.008)
4	0.198	(0.084)	0.027	(0.065)	-0.028	(0.012)
5			-0.449	(0.025)	-0.009	(0.024)
6			-0.655	(0.063)		
7			-0.007	(0.070)		
sum	0.656		0.092		-0.229	

Table B2: Neoclassical Cost Min (Machinery and Equipment)

1973Q2 - 1984Q4

$$\hat{I}_t/K_{t-1} = \frac{-8.43}{(2.19)} + \sum_{i=0}^{n1} \phi_i \text{Ln}Q_{t-1-i} + \sum_{i=0}^{n2} \theta_i \text{Ln}W_{t-1-i} + \sum_{i=0}^{n3} \beta_i \text{Ln}c_{t-1-i} + \frac{0.003}{(0.098)} \text{Ln}K_{t-1}$$

$$\hat{\epsilon}_t = \frac{0.954\hat{\epsilon}_{t-1}}{(.047)}$$

$$R^2 = 0.955 \quad \bar{R}^2 = 0.945$$

	ϕ_i		θ_i		β_i	
i=0	0.173	(0.089)	-0.084	(0.033)	-0.068	(0.026)
1	0.089	(0.061)			-0.053	(0.019)
2	0.150	(0.092)			-0.038	(0.014)
3	0.092	(0.067)			-0.023	(0.013)
4	-0.012	(0.100)			-0.079	(0.017)
5	0.248	(0.125)			0.007	(0.024)
6						
7						
sum	0.741		-0.084		-0.116	

Table B3: Summer's Q (Machinery and Equipment)

1973Q2 - 1984Q4

$$\hat{I}_t/K_{t-1} = \underset{(0.407E-01)}{0.898E-01} + \sum_{i=0}^4 \beta_i Q_{t-1-i}$$

$$\hat{\epsilon}_t = \underset{(.033)}{0.978} \hat{\epsilon}_{t-1}$$

$$R^2 = 0.948 \quad \bar{R}^2 = 0.940$$

	β_i	
i=0	0.032	(0.018)
1	0.005	(0.023)
2	-0.014	(0.024)
3	-0.003	(0.024)
4	0.035	(0.019)
sum	0.053	

Table B4: Vector Auto Regression (Machinery and Equipment)

1973Q2 - 1984Q4

$$\hat{I}JK_{t-1} = \frac{0.088}{(0.186)} + \sum_{i=0}^{n1} \beta_i \frac{Y_{t-1-i}}{KSTOCK_{t-1-i}} + \sum_{i=0}^{n2} \theta_i \frac{V_{t-1-i}}{KSTOCK_{t-1-i}} + \sum_{i=0}^{n3} \phi_i \frac{I_{t-1-i}}{K_{t-2-i}} \\ + \sum_{i=0}^{n4} \varphi_i RLIND_{t-1-i} + \sum_{i=0}^{n5} \psi_i \frac{(1-ITC-\tau_c D)_{t-1-i}}{(1-\tau_c)_{t-1-i}} + \sum_{i=0}^{n6} \varpi_i \frac{PIME_{t-1-i}}{PINRC_{t-1-i}}$$

$$R^2 = 0.994 \quad \bar{R}^2 = 0.979$$

	β_i		θ_i		ϕ_i	
i=0	-0.279	(0.225)	0.024	(0.016)	1.109	(0.388)
1	0.174	(0.205)	0.016	(0.017)	-0.350	(0.465)
2	-0.056	(0.289)	-0.028	(0.018)	-0.303	(0.447)
3	-0.053	(0.332)	0.026	(0.018)	-0.280	(0.364)
4	0.322	(0.299)	0.003	(0.011)	0.665	(0.295)
sum	0.107		0.041		0.841	
	φ_i		ψ_i		ϖ_i	
i=0	-0.002	(0.003)	0.003	(0.121)	0.069	(0.195)
1	0.004	(0.004)	-0.003	(0.112)	-0.154	(0.201)
2	-0.002	(0.003)	-0.186	(0.127)	0.098	(0.181)
3	-0.004	(0.003)	0.015	(0.162)	-0.225	(0.187)
4	-0.002	(0.003)	0.067	(0.155)	0.176	(0.146)
sum	-0.005		-0.104		-0.035	

Table B5: ARIMA (Machinery and Equipment)

1973Q2 - 1984Q4

let $y_t = (1-B)(I_t/K_{t-1})$

$$\hat{Y}_t = \frac{0.761}{(0.097)} \hat{Y}_{t-1}$$

 $R^2 = 0.486$

Modified Box-Pierce Chisquare statistic

Lag	12	24	36
Chisquare	9.1 (DF=11)	18.4 (DF=23)	20.4 (DF=35)
Chisquare(.99)	24.73	42.98	57.81

Table B6: Neoclassical Profit Max (Structures)

1973Q2 - 1984Q4

$$\hat{I}_t/K_{t-1} = \frac{-4.62}{(9.26)} + \sum_{i=0}^{n1} \phi_i \text{Ln}Y_{t-1-i} + \sum_{i=0}^{n2} \theta_i \text{Ln}P_{t-1-i} + \sum_{i=0}^{n3} \beta_i \text{Ln}c_{t-1-i} + \frac{0.464}{(0.883)} \text{Ln}K_{t-1}$$

$$\hat{\epsilon}_t = \frac{-0.963\hat{\epsilon}_{t-1}}{(.044)}$$

$$R^2 = 0.992 \quad \bar{R}^2 = 0.968$$

	ϕ_i		θ_i		β_i	
i=0	0.169	(0.057)	0.204	(0.106)	-0.053	(0.015)
1	-0.279	(0.067)	-0.420	(0.168)	0.026	(0.019)
2	0.272	(0.069)	0.365	(0.093)	-0.087	(0.016)
3	0.015	(0.035)	-0.081	(0.072)	0.042	(0.017)
4	-0.086	(0.056)	0.022	(0.038)	0.017	(0.007)
5	0.099	(0.058)	0.225	(0.078)	-0.021	(0.011)
6	-0.259	(0.077)	-0.267	(0.100)	0.072	(0.016)
7	0.296	(0.090)	0.165	(0.101)	-0.069	(0.015)
8	-0.176	(0.097)	-0.078	(0.143)	0.036	(0.014)
9			-0.172	(0.023)	-0.075	(0.009)
sum	-0.049		-0.036		-0.113	

Table B7: Neoclassical Cost Min (Structures)

1973Q2 - 1984Q4

$$\hat{I}_t/K_{t-1} = \frac{-16.51}{(2.25)} + \sum_{i=0}^{n1} \phi_i \text{Ln}Y_{t-1-i} + \sum_{i=0}^{n2} \theta_i \text{Ln}W_{t-1-i} + \sum_{i=0}^{n3} \beta_i \text{Ln}c_{t-1-i} + \frac{1.41}{(0.20)} \text{Ln}K_{t-1}$$

$$\hat{\epsilon}_t = \frac{0.024\hat{\epsilon}_{t-1}}{(.164)}$$

$$R^2 = 0.956 \quad \bar{R}^2 = 0.917$$

	Q		W		c	
i=0	-0.001	(0.042)	-0.105	(0.067)	-0.035	(0.009)
1	0.039	(0.036)	-0.052	(0.035)	-0.028	(0.006)
2	0.110	(0.035)	-0.137	(0.037)	-0.029	(0.007)
3	0.034	(0.019)	-0.200	(0.040)	-0.005	(0.007)
4	-0.050	(0.032)	-0.102	(0.042)	0.036	(0.007)
5	-0.002	(0.018)	0.087	(0.050)	0.041	(0.009)
6	0.076	(0.036)	0.132	(0.055)		
7	0.064	(0.025)	-0.100	(0.053)		
8	-0.127	(0.067)	-0.130	(0.050)		
9	-0.055	(0.051)				
sum	0.070		-0.606		-0.020	

Table B8: Summer's Q (Structures)

1973Q2 - 1984Q4

$$I_t/K_{t-1} = 0.504E-01 + \sum_{i=0}^5 \beta_i Q_{t-1-i} + \epsilon_t$$

(0.743E-02)

$$\hat{\epsilon}_t = 0.908\hat{\epsilon}_{t-1}$$

(.065)

$$R^2 = 0.864 \quad \bar{R}^2 = 0.842$$

	β_i	
i=0	0.011	(0.006)
1	0.007	(0.008)
2	-0.005	(0.008)
3	-0.011	(0.008)
4	0.000	(0.007)
5	0.017	(0.007)
sum	0.0176	

Table B9: Vector Auto Regression (Structures)

1973Q2 - 1984Q4

$$\hat{I}_t K_{t-1} = \frac{-0.131}{(0.119)} + \sum_{i=0}^{n1} \beta_i \frac{Y_{t-1-i}}{KSTOCK_{t-1-i}} + \sum_{i=0}^{n2} \theta_i \frac{V_{t-1-i}}{KSTOCK_{t-1-i}} + \sum_{i=0}^{n3} \phi_i \frac{I_{t-1-i}}{K_{t-2-i}} \\ + \sum_{i=0}^{n4} \varphi_i RLIND_{t-1-i} + \sum_{i=0}^{n5} \psi_i \frac{(1-ITC-\tau_c D)_{t-1-i}}{(1-\tau_c)_{t-1-i}} + \sum_{i=0}^{n6} \varpi_i \frac{PIME_{t-1-i}}{PINRC_{t-1-i}}$$

$$R^2 = 0.976 \quad \bar{R}^2 = 0.910$$

	β_i		θ_i		ϕ_i	
i=0	-0.014	(0.070)	0.631	(0.790)	0.851	(0.281)
1	-0.034	(0.100)	1.336	(1.108)	-0.342	(0.328)
2	0.177	(0.098)	-1.18	(0.890)	-0.163	(0.381)
3	-0.077	(0.126)	-0.109	(0.997)	0.186	(0.370)
4	0.043	(0.104)	1.03	(0.703)	-0.225	(0.288)
sum	0.094		1.706		0.307	

	φ_i		ψ_i		ϖ_i	
i=0	0.0003	(0.001)	-0.010	(0.060)	0.008	(0.061)
1	-0.0001	(0.002)	-0.003	(0.051)	-0.019	(0.068)
2	-0.0004	(0.001)	0.015	(0.044)	0.006	(0.067)
3	-0.0009	(0.001)	0.027	(0.061)	-0.029	(0.085)
4	0.0023	(0.001)	0.010	(0.052)	0.025	(0.050)
sum	0.001		0.004		-0.009	

Table B10: ARIMA (Structures)

1973Q2 - 1984Q4

let $y_t = (1-B)I_t/K_{t-1}$

$$\hat{Y}_t = \frac{0.455}{(0.133)} \hat{Y}_{t-1}$$

R2 = 0.183

Modified Box-Pierce Chisquare statistic

Lag	12	24	36
Chisquare	22.6 (DF=11)	41.8 (DF=23)	54.2 (DF=35)
Chisquare(.99)	24.73	42.98	57.81

A variety of other specifications were also tested but did not perform any better than the model above.

APPENDIX C: LAG LENGTH AND POLYNOMIAL ORDER TESTS

The following tests were performed following the format described in Judge (1988:723) for choosing the optimal lag length and polynomial order. The lag length tests were as follows

$$H_{oi}: N = M-i, \text{ that is, } \beta_{M-i+1} = 0 \text{ versus } H_{ai}: N = M-i+1, \text{ that is, } \beta_{M-i+1} \neq 0$$

where N is the optimal lag length and M is the maximum lag length being tested. The maximum lag length being tested is ten therefore this is done sequentially beginning at a lag length of ten and moving down one at a time. Each null hypothesis is tested conditional on the previous one being true. The likelihood ratio statistic for testing the i th null hypothesis H_{oi} can be written as

$$\lambda_i = \frac{SSE_{M-i} - SSE_{M-i+1}}{\hat{\sigma}_{M-i+1}^2}$$

where

$$\hat{\sigma}_n^2 = \frac{SSE_n}{T-n-2}$$

Note that $T - n - 2$ is the number of coefficients estimated. These are the intercept, β_0

and β_1 to β_n . The sample period is kept constant using the first 10 observations as presample observations in all tests. For example, there are $n = 47$ observations available. Since I assumed an upper bound of 10, the first 10 values are used as presample values and thus the remaining sample has size $T = 37$. For example, the first F test which appears in Table C1 tests the significance of the tenth lag on output. At this point the lags on price and user cost are also set at ten. Under the column with the heading ESS is the residual sum of squares. Under the σ^2 column is the estimated variance of the residuals. Under the DF column is the degrees of freedom. In this example $DF = 37 - 10 - 10 - 10 - 2$. The three tens are for the ten lags on output, price and user cost. The last two are the intercept and the coefficient on the lagged capital stock. 5.75 is the F statistic which was calculated using the formula above to test the significance of the tenth lag on output. In this case we fail to reject H_0 until finally a lag length of five on output is chosen as optimal. The lag length is then held at five on output while the optimal lag length for price is chosen next. Once the optimal lags are determined for all variables the optimal lag lengths with no polynomial order restrictions are used as the starting point for the sequential testing for the optimal polynomial order on each of the regressors. That is, we start with the polynomial degree on Q set equal to the optimal lag length N and reduce it sequentially. The polynomial degree that corresponds to the last null hypothesis which cannot be rejected is the one which is chosen as optimal.

Table C1: Neoclassical Profit Max Lag Length and Polynomial Order Tests (M & E).

A lag length of 10 on each of the regressors was chosen as the starting point. The decision criteria adopted was the F statistic with a 95 % confidence level.

LAG Q	ESS	$\hat{\sigma}^2$	DF	F	F _{.05}
10	.1048 E-04	.2096 E-05	5	3.05	6.61
9	.1688 E-04	.2814 E-05	6	.00	5.99
8	.1689 E-04	.2413 E-05	7	2.93	5.59
7	.2397 E-04	.2996 E-05	8	4.21	5.32
6	.3657 E-04	.4064 E-05	9	.69	5.12
5	.3936 E-04	.3936 E-05	10	26.23	4.96
4	.1427 E-03	.1297 E-04	11		
LAG P					
10	.3936 E-04	.3936 E-05	10	.136	4.96
9	.3989 E-04	.3619 E-05	11	4.42	4.84
8	.5589 E-04	.4658 E-05	12	54.56	4.75
7	.3100 E-03	.2385 E-04	13		
LAG C					
10	.5589 E-04	.4657 E-05	12	0.67	4.75
9	.5902 E-04	.4540 E-05	13	0.09	4.67
8	.5944 E-04	.4246 E-05	14	.25	4.60
7	.6050 E-04	.4034 E-05	15	.06	4.54
6	.6073 E-04	.3796 E-05	16	6.31	4.49
5	.8440 E-03	.4965 E-05	17		
Q POLY					
5	.4306 E-03	.2392 E-04	18	.01	4.41
4	.4309 E-03	.2268 E-04	19	.19	4.38
3	.4354 E-03	.2177 E-04	20	.46	4.35
3	.4454 E-03	.2121 E-04	21	8.79	4.32
1	.6319 E-03	.2872 E-04	22		
P POLY					
8	.4454 E-03	.2121 E-04	21	.30	4.32
7	.4518 E-03	.2054 E-04	22	.01	4.30
6	.4519 E-03	.1965 E-04	23	.77	4.28
5	.4670 E-03	.1946 E-04	24	6.77	4.26
4	.5987 E-03	.2395 E-04	25		
C POLY					
6	.4670 E-03	.1946 E-04	24	.78	4.26
5	.4822 E-03	.1929 E-04	25	.28	4.24
4	.4877 E-03	.1876 E-04	26	3.29	4.23
3	.5495 E-03	.2035 E-04	27	2.61	4.22
2	.6025 E-03	.2152 E-04	28	8.40	4.20
1	.7833 E-03	.2701 E-04	29		

Table C2: Neoclassical Cost Min Lag Length and Polynomial Order Tests (M & E).

A lag length of 10 on each of the regressors was chosen as the starting point. The decision criteria adopted was the F statistic with a 95 % confidence level.

LAG Q	ESS	$\hat{\sigma}^2$	DF	F	F _{.05}
10	.6246 E-03	.1249 E-03	5	3.23	6.61
9	.1029 E-02	.1716 E-03	6	0.00	5.99
8	.1030 E-02	.1471 E-03	7	0.25	5.59
7	.1067 E-02	.1333 E-03	8	0.30	5.32
6	.1107 E-02	.1230 E-03	9	5.33	5.12
5	.1762 E-02	.1762 E-03	10		
LAG W					
10	.1107 E-02	.1230 E-03	9	2.54	5.12
9	.1419 E-02	.1419 E-03	10	0.07	4.96
8	.1429 E-02	.1299 E-03	11	0.26	4.84
7	.1462 E-02	.1219 E-03	12	0.36	4.75
6	.1506 E-02	.1158 E-03	13	1.46	4.67
5	.1675 E-02	.1196 E-03	14	1.63	4.60
4	.1870 E-02	.1247 E-03	15	1.87	4.54
3	.2103 E-02	.1314 E-03	16	3.80	4.49
2	.2602 E-02	.1531 E-03	17	3.73	
1	.3175 E-02	.1764 E-03	18		
LAG C					
10	.3175 E-02	.1764 E-03	18	3.05	4.41
9	.3712 E-02	.1954 E-03	19	0.01	4.38
8	.3715 E-02	.1858 E-03	20	0.13	4.35
7	.3740 E-02	.1781 E-03	21	1.22	4.32
6	.3960 E-02	.1800 E-03	22	10.74	4.30
5	.5892 E-02	.2562 E-03	23		
POLY Q					
6	.2049 E-02	.7882 E-04	26	0.41	4.23
5	.2082 E-02	.7712 E-04	27	0.22	4.22
4	.2099 E-02	.7497 E-04	28	7.06	4.20
3	.2629 E-02	.9065 E-03	29		
POLY C					
6	.2099 E-02	.7497 E-04	28	0.00	4.20
5	.2099 E-02	.7239 E-04	29	1.03	4.18
4	.2173 E-02	.7244 E-04	30	1.99	4.17
3	.2317 E-02	.7474 E-04	31	1.64	4.12
2	.2440 E-02	.7623 E-04	32	0.41	4.08
1	.2471 E-02	.7488 E-04	33		

Table C3: Summer's Q Lag Length and Polynomial Order Tests (M & E).

A lag length of 10 was chosen as the starting point. The decision criteria adopted was the F statistic with a 95 % confidence level.

LAG SQ	ESS	$\hat{\sigma}^2$	DF	F	F _{.05}
10	.2395 E-02	.9212 E-04	26	0.15	4.23
9	.2409 E-02	.8921 E-04	27	0.53	4.21
8	.2456 E-02	.8772 E-04	28	0.006	4.20
7	.2457 E-02	.8471 E-04	29	0.163	4.18
6	.2471 E-02	.8235 E-04	30	0.03	4.17
5	.2473 E-02	.7979 E-04	31	3.38	4.17
4	.2743 E-02	.8572 E-04	32	1.90	4.17
3	.2906 E-02	.8806 E-04	33	0.88	4.17
2	.2984 E-02	.8775 E-04	34		
POLY SQ					
5	.2842 E-02	.7894 E-04	36	4.31	4.17
4	.3180 E-02	.8595 E-04	37		

Table C4: VAR Lag Length and Polynomial Order Tests (M & E).

A lag length of 6 on each of the dependent variables was chosen as the starting point due to data limitations. Further, joint hypothesis tests were used in this case to test the lag lengths of all dependent variables simultaneously. The decision criteria adopted was the F statistic with a 95 % confidence level.

LAG VAR	ESS	$\hat{\sigma}^2$	DF	F	F _{.05}
6	.1925 E-03	.4812 E-03	4	2.47	6.16
5	.3112 E-03	.3112 E-03	10	8.88	3.22
4	.5874 E-03	.3671 E-03	16		
POL VAR					
5	.3142 E-03	.2857 E-04	11	9.50	3.10
4	.5856 E-03	.3445 E-04	17		

Table C5: Neoclassical Profit Max Lag Length and Polynomial Order Tests (Structures).

A lag length of 10 on each of the regressors was chosen as the starting point. The decision criteria adopted was the F statistic with a 95 % confidence level.

LAG Q	ESS	$\hat{\sigma}^2$	DF	F	<u>F.05</u>
10	.1109 E-04	.2218 E-05	5	1.52	6.61
9	.1446 E-04	.2410 E-05	6	6.25	5.99
8	.2953 E-04	.4076 E-05	7		
LAG P					
10	.1446 E-04	.2411 E-05	6	24.53	5.99
9	.7360 E-04	.1051 E-04	7		
LAG C					
10	.1446 E-04	.2411 E-05	6	28.52	5.99
9	.8323 E-04	.1189 E-04	7		
Q POLY					
9	.1446 E-04	.2411 E-05	6	0.60	5.99
8	.1591 E-04	.2273 E-05	7	9.93	5.59
7	.3850 E-04	.4813 E-05	8		
P POLY					
10	.1591 E-04	.2273 E-05	7	0.01	5.59
9	.1593 E-04	.1991 E-05	8	8.79	5.32
8	.3343 E-04	.3714 E-05	9		
C POLY					
10	.1593 E-04	.1991 E-05	8	0.29	5.32
9	.1651 E-04	.1834 E-05	9	17.05	5.12
8	.4778 E-04	.4778 E-05	10		

Table C6: Neoclassical Cost Min Lag Length and Polynomial Order Tests (Structures).

A lag length of 10 on each of the regressors was chosen as the starting point. The decision criteria adopted was the F statistic with a 95 % confidence level.

LAG Q	ESS	$\hat{\sigma}^2$	DF	F	F _{.05}
10	.1172 E-04	.2344 E-05	5	6.95	6.61
9	.2802 E-04	.4670 E-05	6		
LAG W					
10	.1172 E-04	.2344 E-05	5	4.60	6.61
9	.2251 E-04	.3751 E-05	6	6.94	5.99
8	.4852 E-04	.6932 E-05			
LAG C					
10	.2251 E-04	.3751 E-05	6	4.41	5.99
9	.3907 E-04	.5581 E-05	7	0.02	5.59
8	.3918 E-04	.4897 E-05	8	0.14	5.32
7	.3986 E-04	.4429 E-05	9	4.12	5.12
6	.5806 E-04	.5806 E-05	10	9.07	4.96
5	.1107 E-03	.1007 E-04	11		
POLY Q					
10	.5804 E-04	.5804 E-05	10	0.02	4.96
9	.5815 E-04	.5287 E-05	11	0.18	4.84
8	.5909 E-04	.4924 E-05	12	2.80	4.75
7	.7288 E-04	.5606 E-05	13	0.03	4.67
6	.7303 E-04	.5216 E-05	14	10.01	4.60
5	.1253 E-03	.8351 E-05	15		
POLY W					
9	.7303 E-04	.5216 E-05	14	0.32	4.60
8	.7471 E-04	.4981 E-05	15	1.00	4.54
7	.7955 E-04	.4972 E-05	16	0.43	4.49
6	.8169 E-04	.4806 E-05	17	6.48	4.45
5	.1129 E-03	.6270 E-05	18		
POLY C					
6	.8169 E-04	.4806 E-05	17	0.50	4.45
5	.8409 E-04	.4672 E-05	18	1.32	4.41
4	.9024 E-04	.4750 E-05	19	5.73	4.38
3	.1175 E-03	.5873 E-05	20		

Table C7: Summer's Q Length and Polynomial Order Tests (Structures).

A lag length of 10 was chosen as the starting point. The decision criteria adopted was the F statistic with a 95 % confidence level.

LAG SQ	ESS	$\hat{\sigma}^2$	DF	F	F _{.05}
10	.2326 E-03	.8947 E-05	26	0.65	4.23
9	.2384 E-03	.8831 E-05	27	0.06	4.21
8	.2390 E-03	.8536 E-05	28	0.55	4.20
7	.2438 E-03	.8405 E-05	29	1.03	4.18
6	.2524 E-03	.8413 E-05	30	7.28	4.17
5	.3136 E-03	.1012 E-04	31		
POLY SQ					
6	.2877 E-03	.8463 E-05	34	9.38	4.17
5	.3671 E-03	.1049 E-04	35		

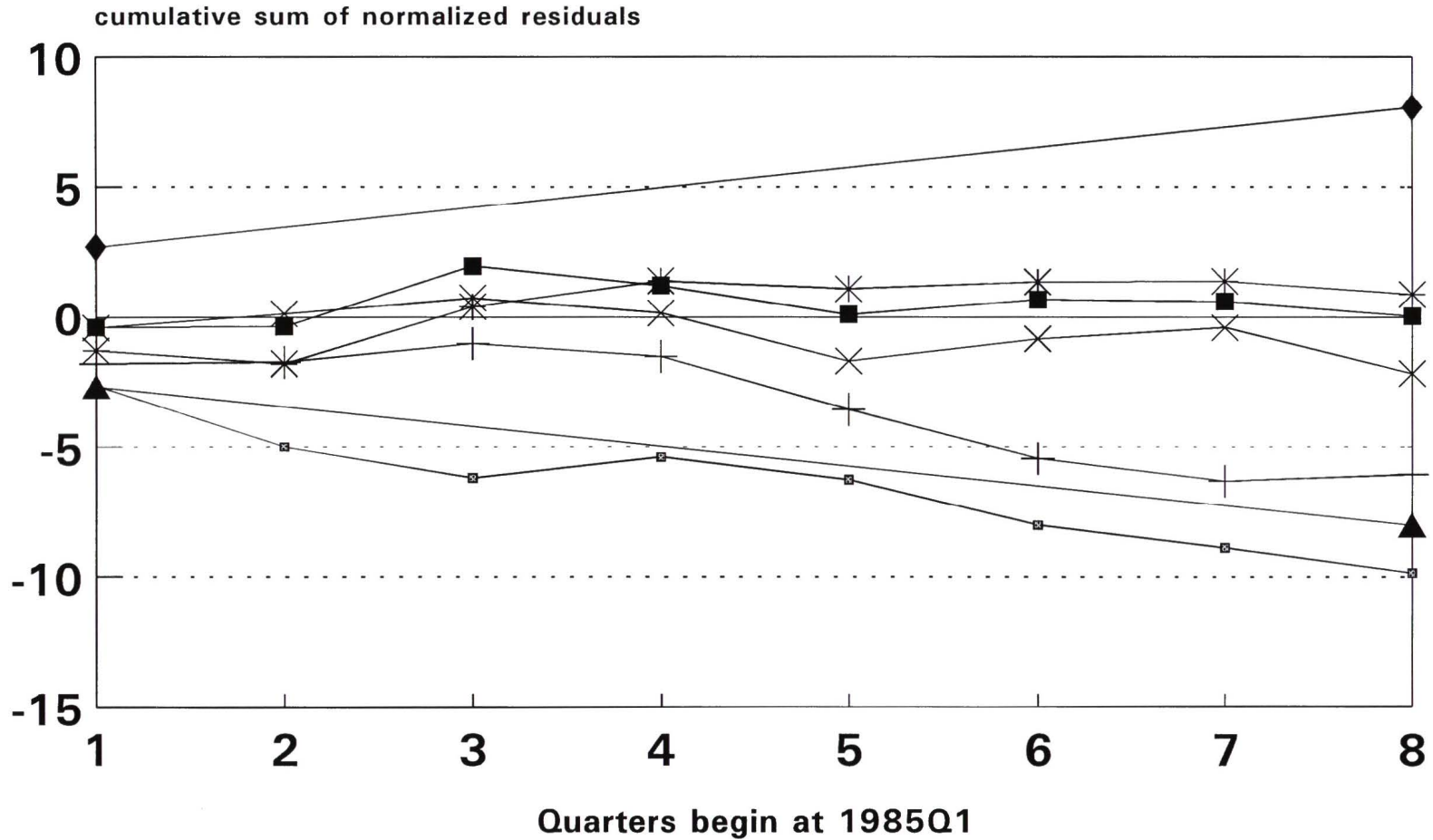
Table C8: VAR Lag Length and Polynomial Order Tests (Structures).

A lag length of 6 on each of the dependent variables was chosen as the starting point due to data limitations. Further, joint hypothesis tests were used in this case to test the lag lengths of all dependent variables simultaneously. The decision criteria adopted was the F statistic with a 95 % confidence level.

LAG VAR	ESS	$\hat{\sigma}^2$	DF	F	F _{.05}
6	.2873 E-04	.7184 E-05	4	2.74	6.16
5	.4849 E-04	.4849 E-05	10	6.45	3.22
4	.7977 E-04	.4986 E-05	16		
POL VAR					
5	.5138 E-04	.4671 E-05	11	8.27	3.10
4	.8972 E-04	.5277 E-05	17		

Figure 1

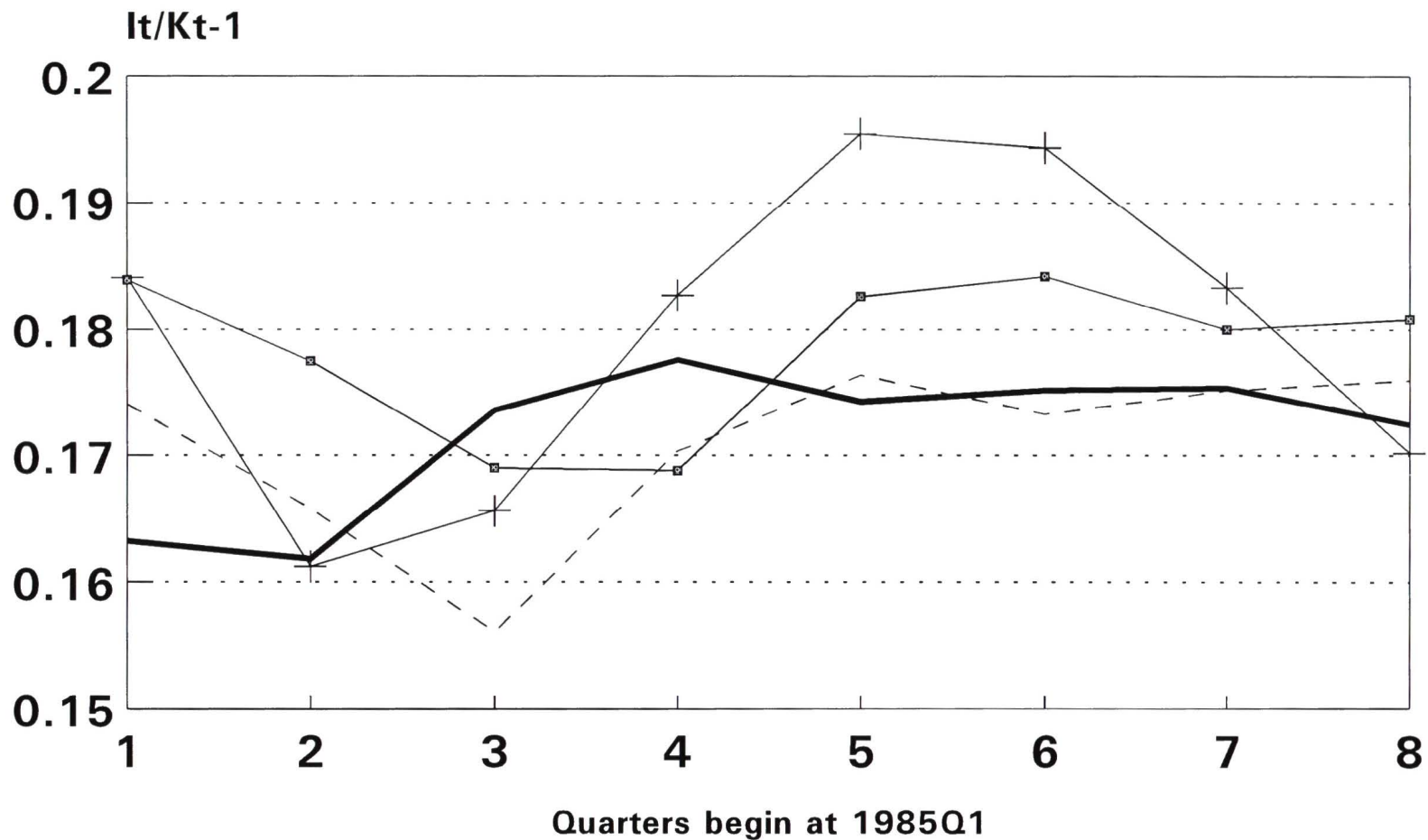
INVESTMENT IN MACHINERY AND EQUIPMENT



* Summers Q ■ ARIMA ✕ VAR Sims
 ◻ Neo Cost Min + Neo Profit Max

95% confidence interval

FIGURE 2
ONE STEP AHEAD FORECASTS



-- Summers Q

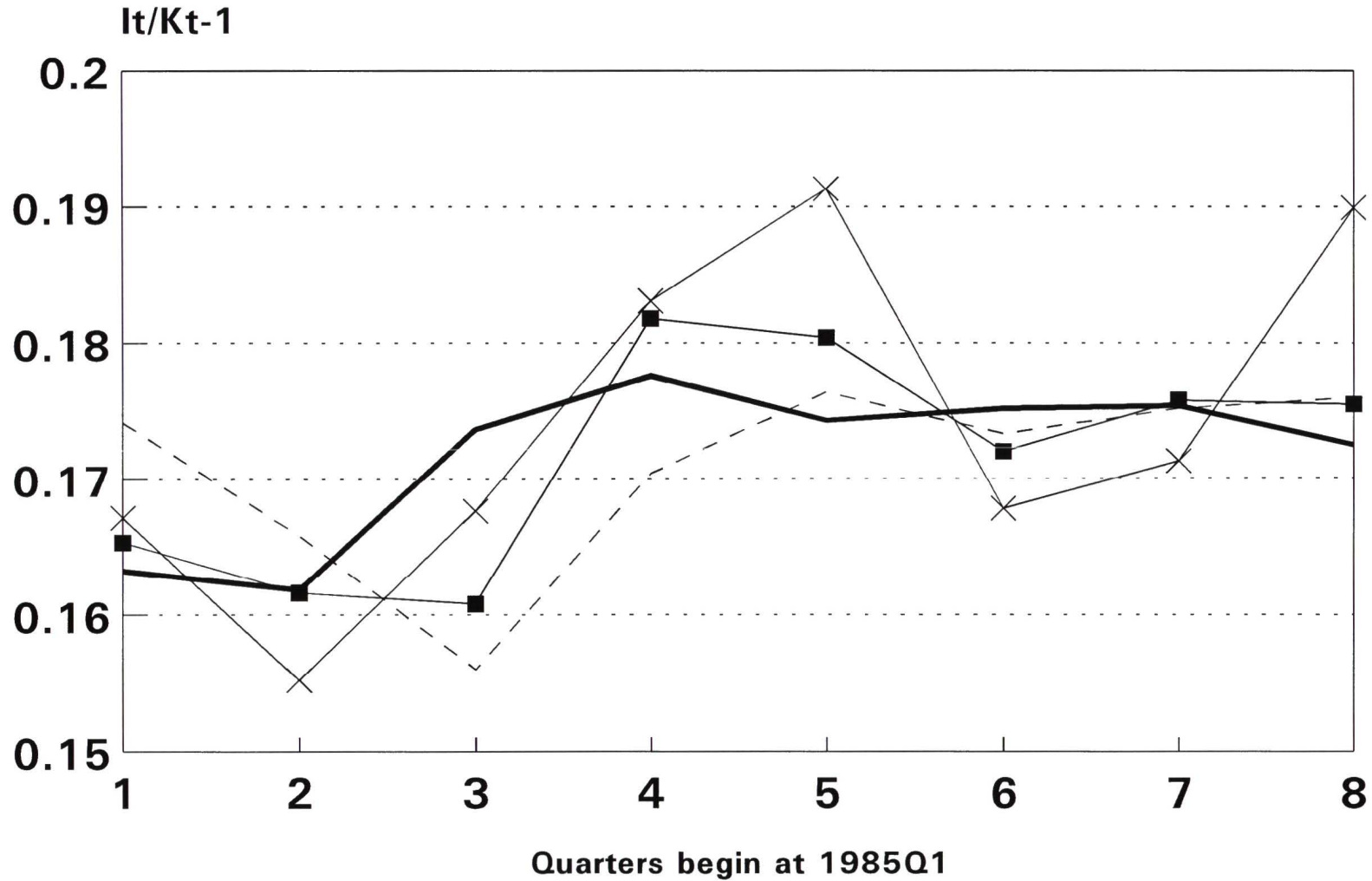
— ACTUAL INVESTMENT

-□- Neo Cost Min

+ Neo Profit Max

MACHINERY AND EQUIPMENT

FIGURE 3
ONE STEP AHEAD FORECASTS



ARIMA

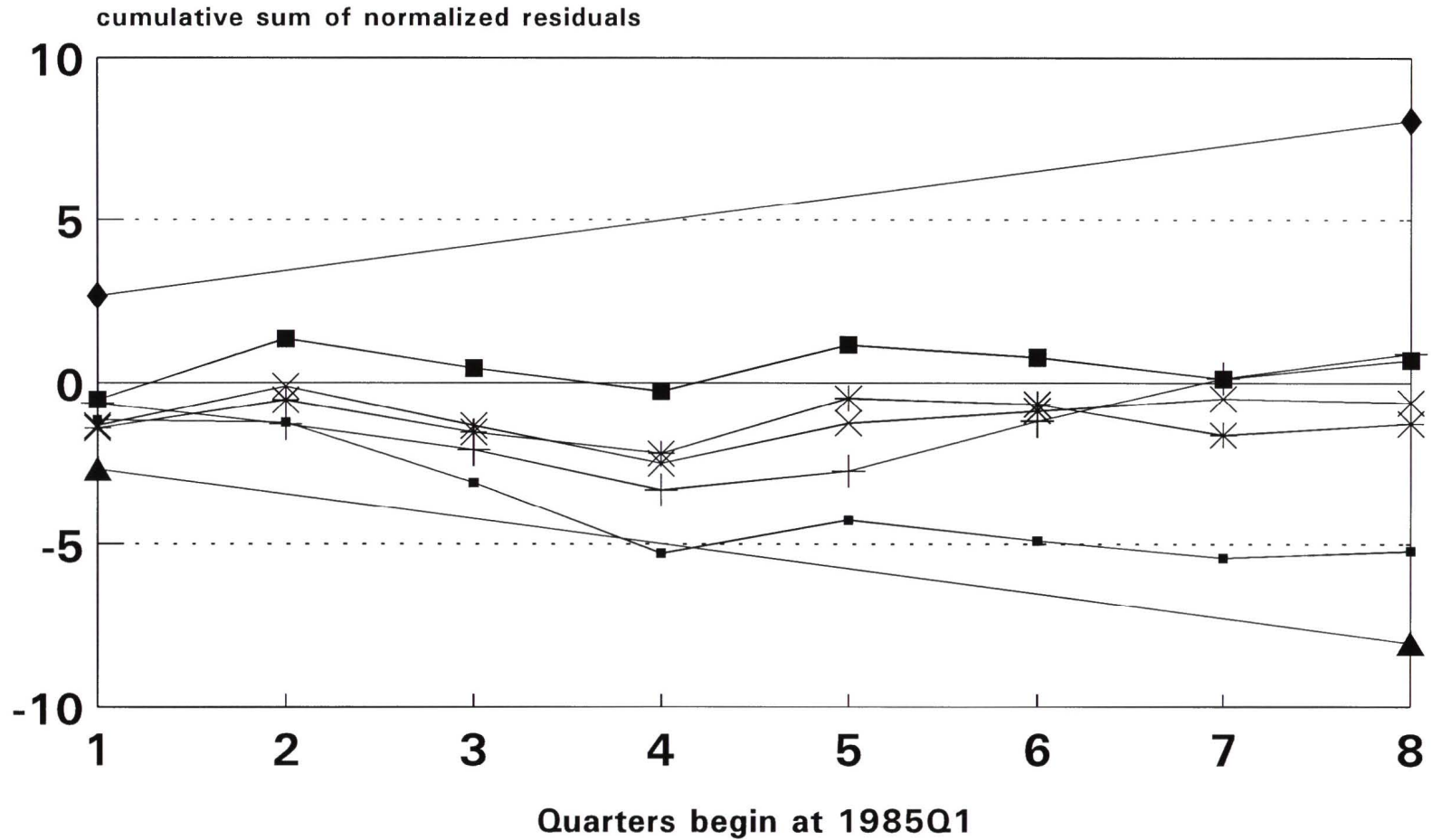
VAR Sims

Summers Q

ACTUAL INVESTMENT

MACHINERY AND EQUIPMENT

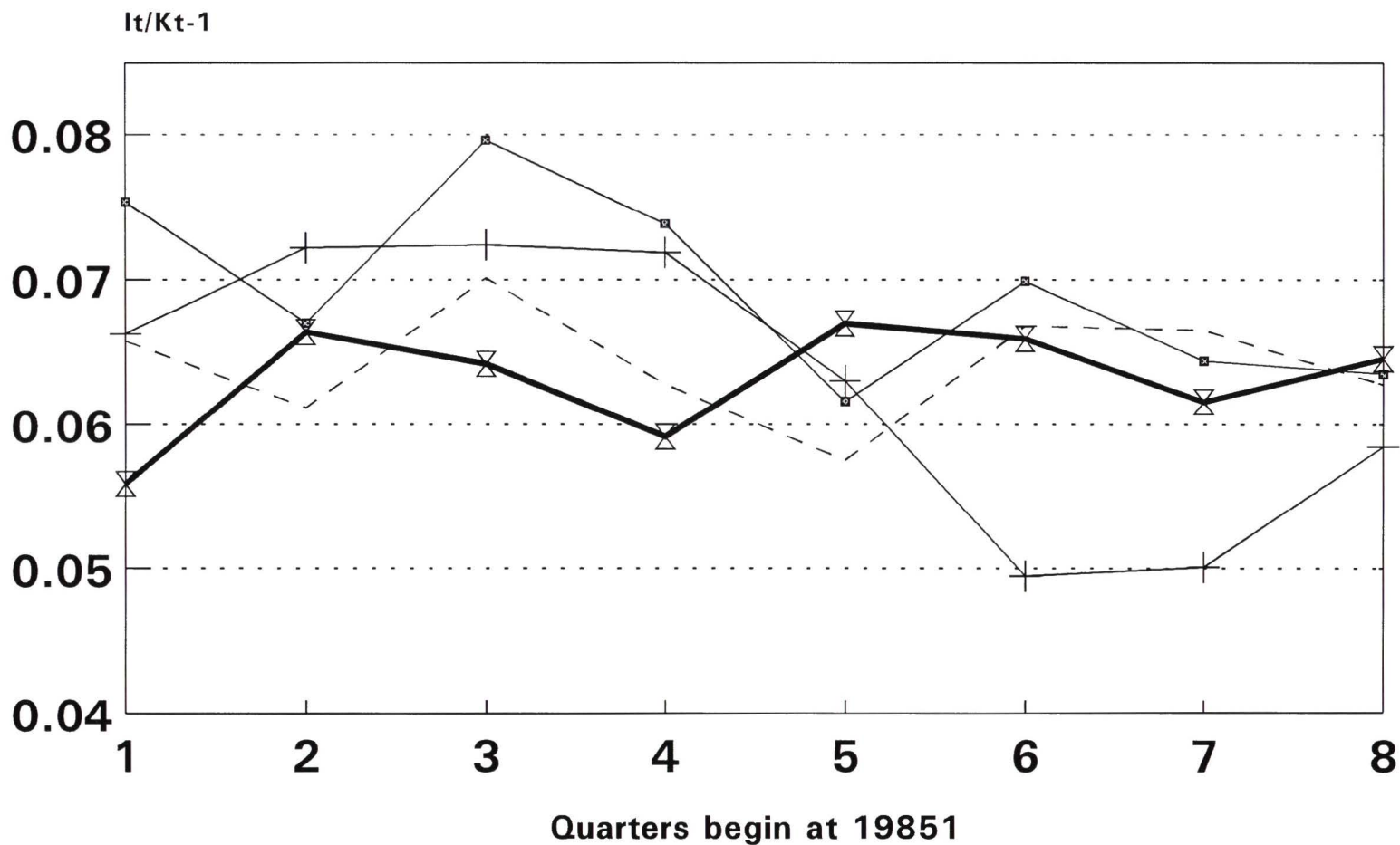
FIGURE 4
INVESTMENT IN NON RES. CONST.



* Summers Q ■ ARIMA * VAR sims
 ■ Neo Cost Min + Neo Profit Max

95% confidence interval

FIGURE 5
ONE STEP AHEAD FORECASTS



-- **Summers Q**

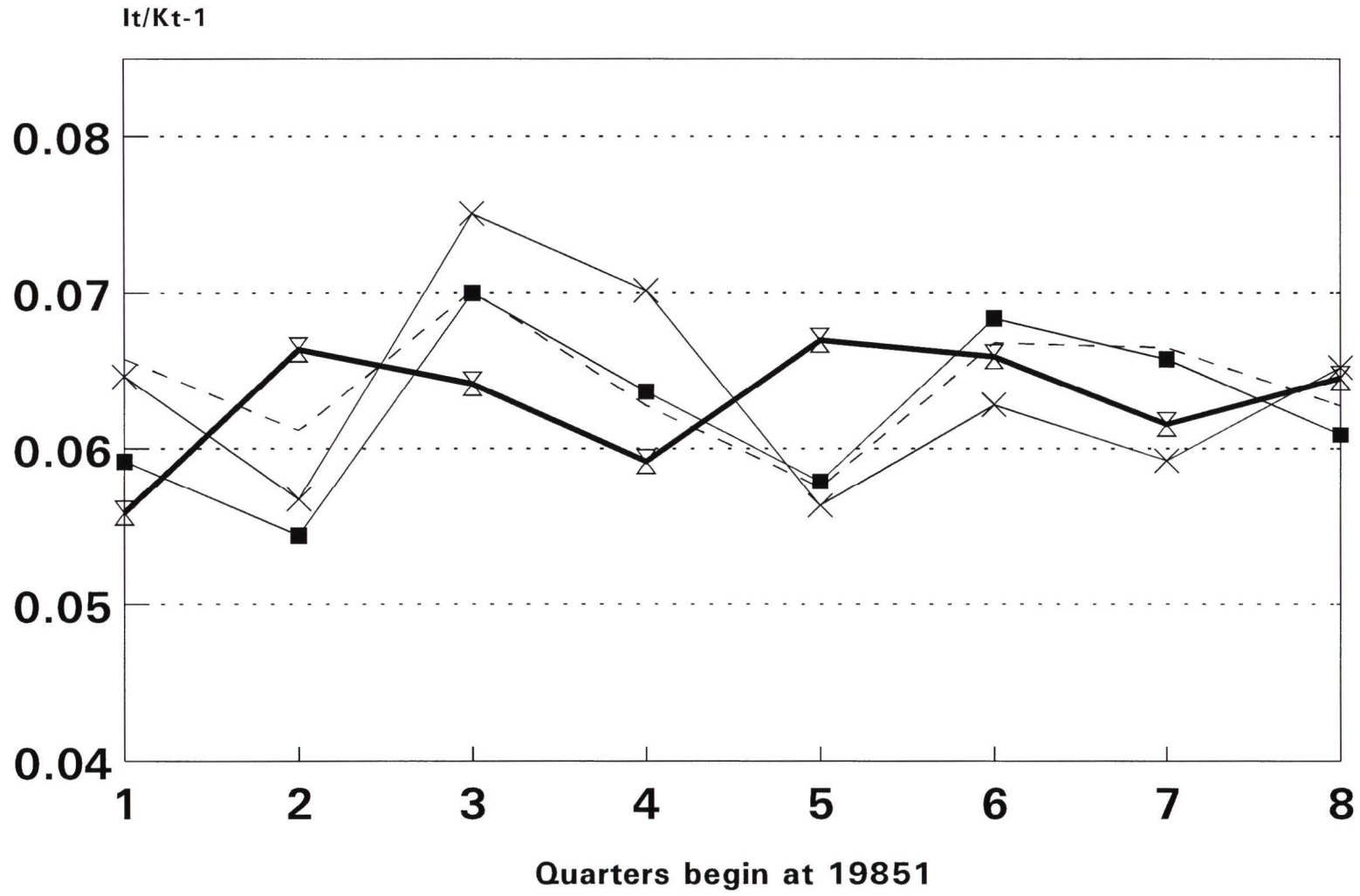
⊠ **ACTUAL INVESTMENT**

▣ **Neo Cost Min**

+ **Neo Cost Min**

STRUCTURES

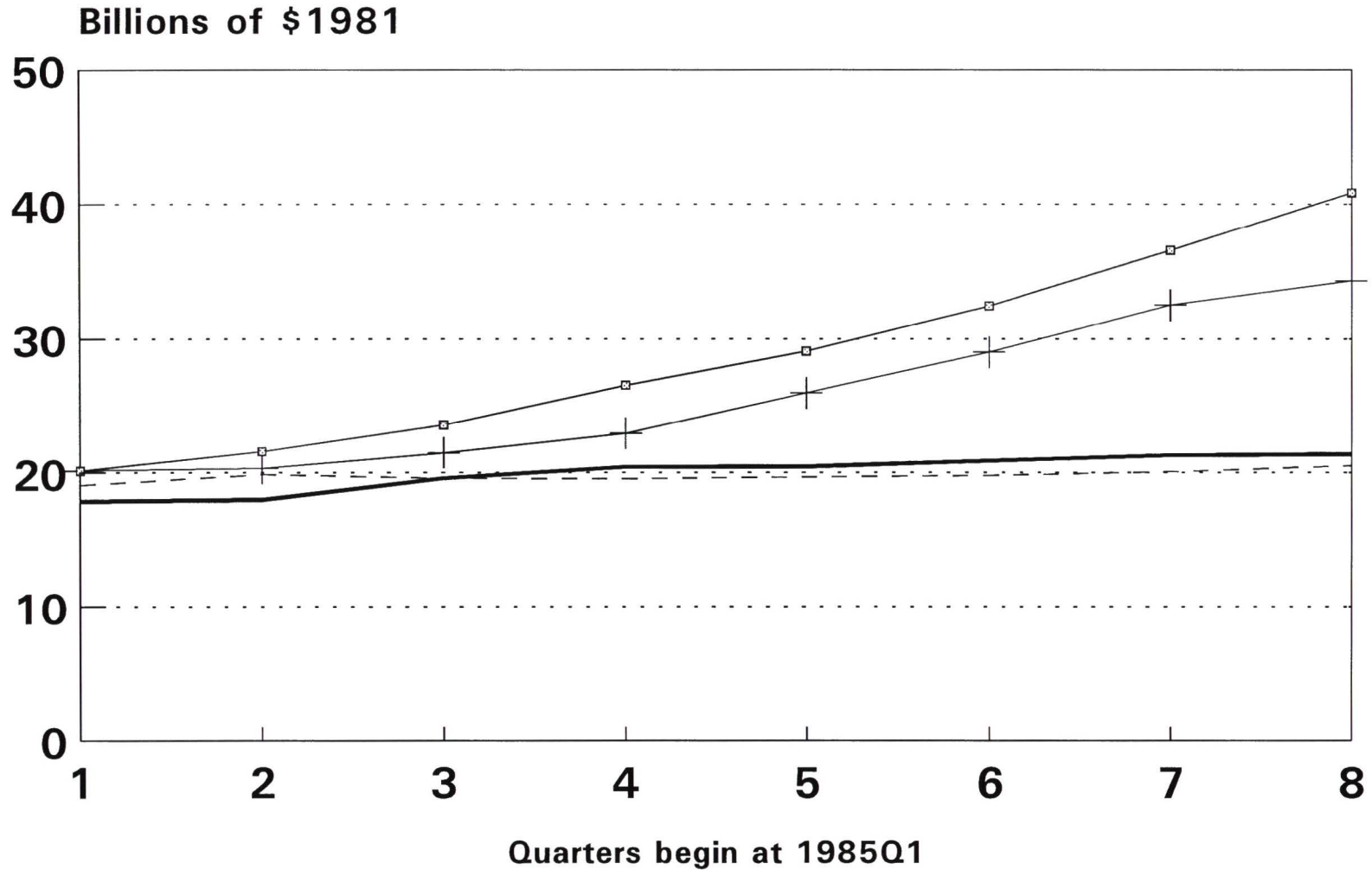
FIGURE 6
ONE STEP AHEAD FORECASTS



■ ARIMA × VAR Sims - - Summers Q ▽ ACTUAL INVESTMENT
STRUCTURES

FIGURE 7

EIGHT QUARTER MODEL SIMULATIONS

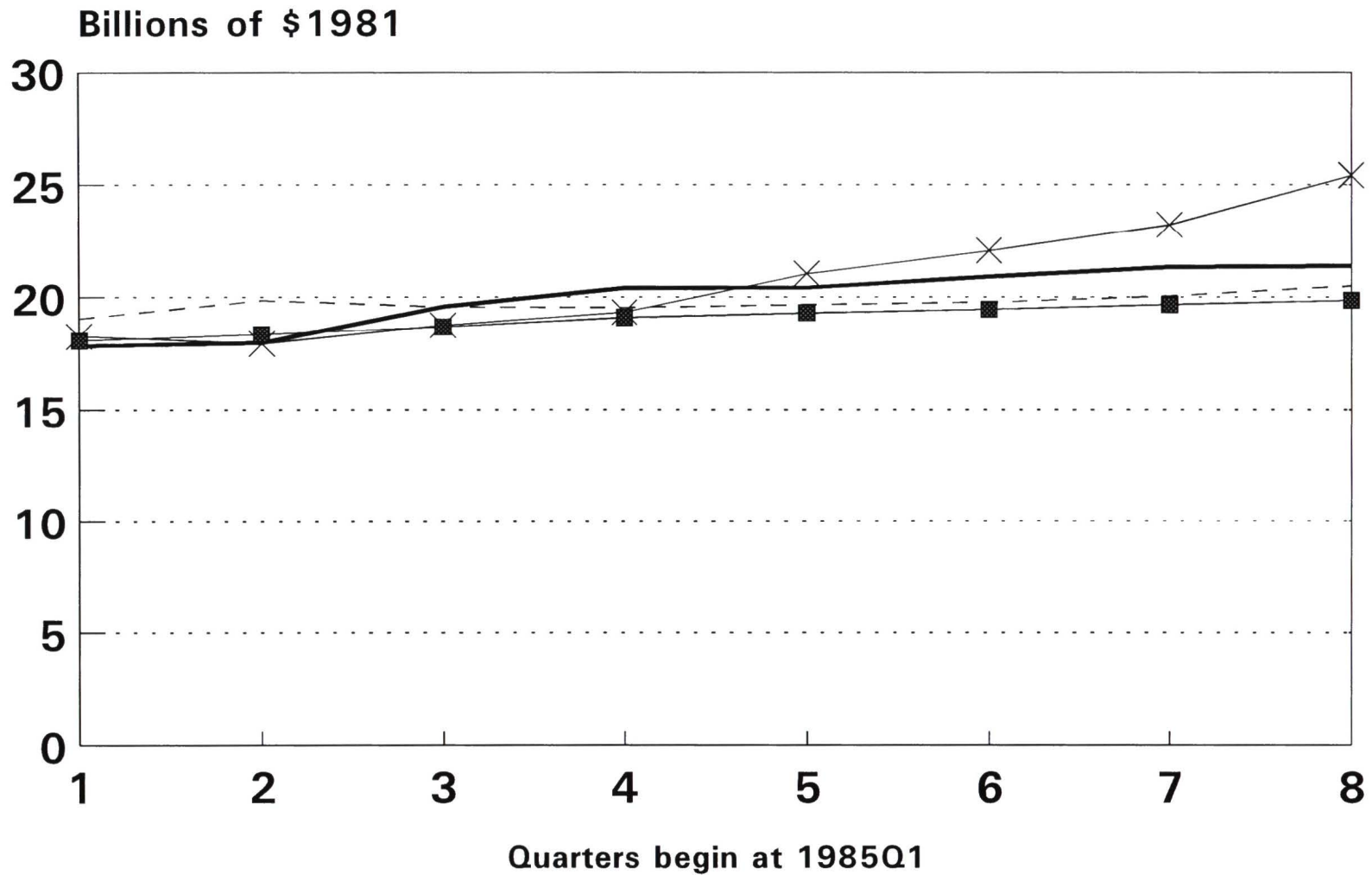


-- Summers Q — ACTUAL —□— Neo Cost Min + Neo Profit Max

MACHINERY AND EQUIPMENT

FIGURE 8

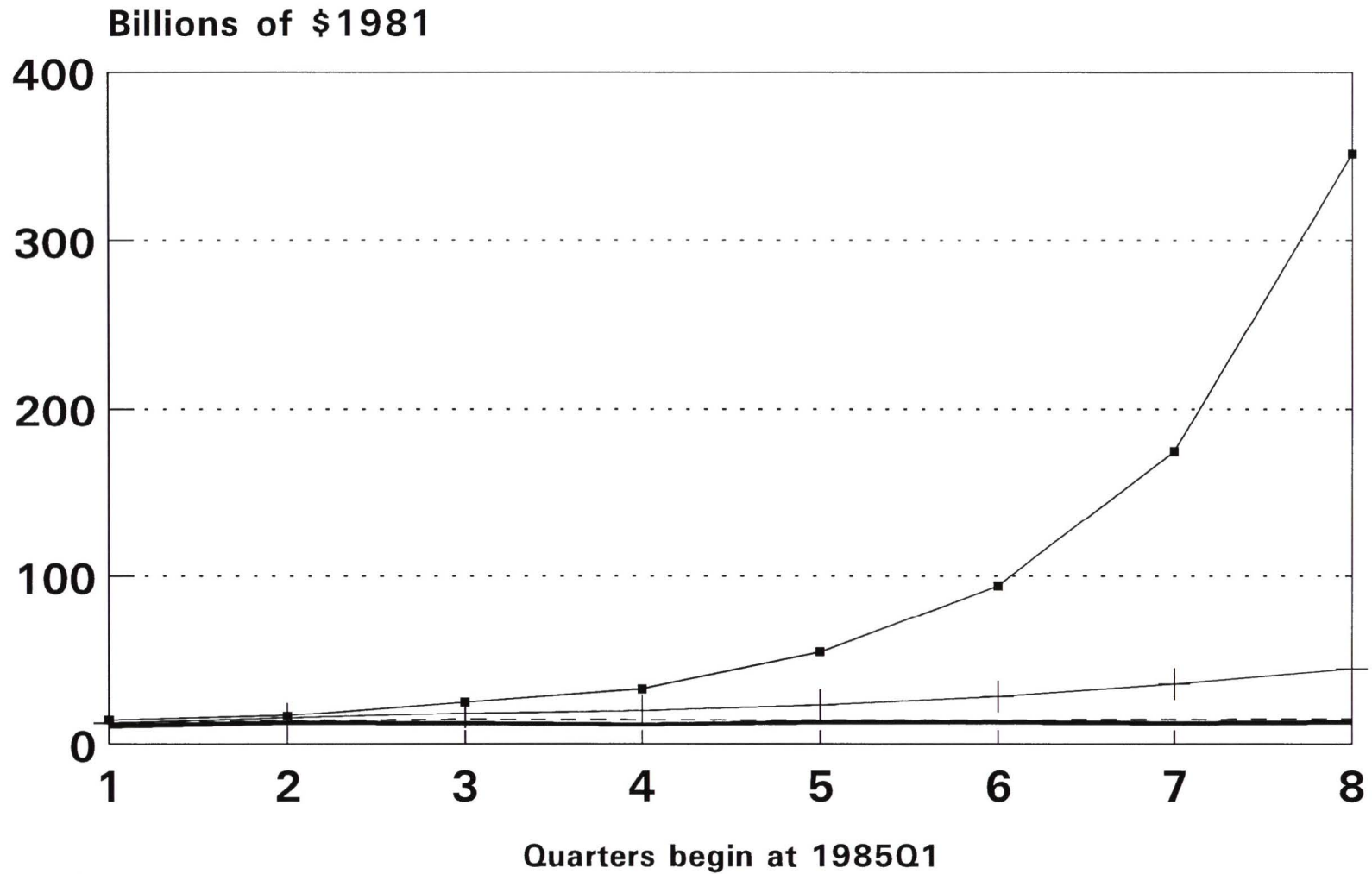
EIGHT QUARTER MODEL SIMULATIONS



-- Summers Q ■ ARIMA × VAR Sims — ACTUAL

MACHINERY AND EQUIPMENT

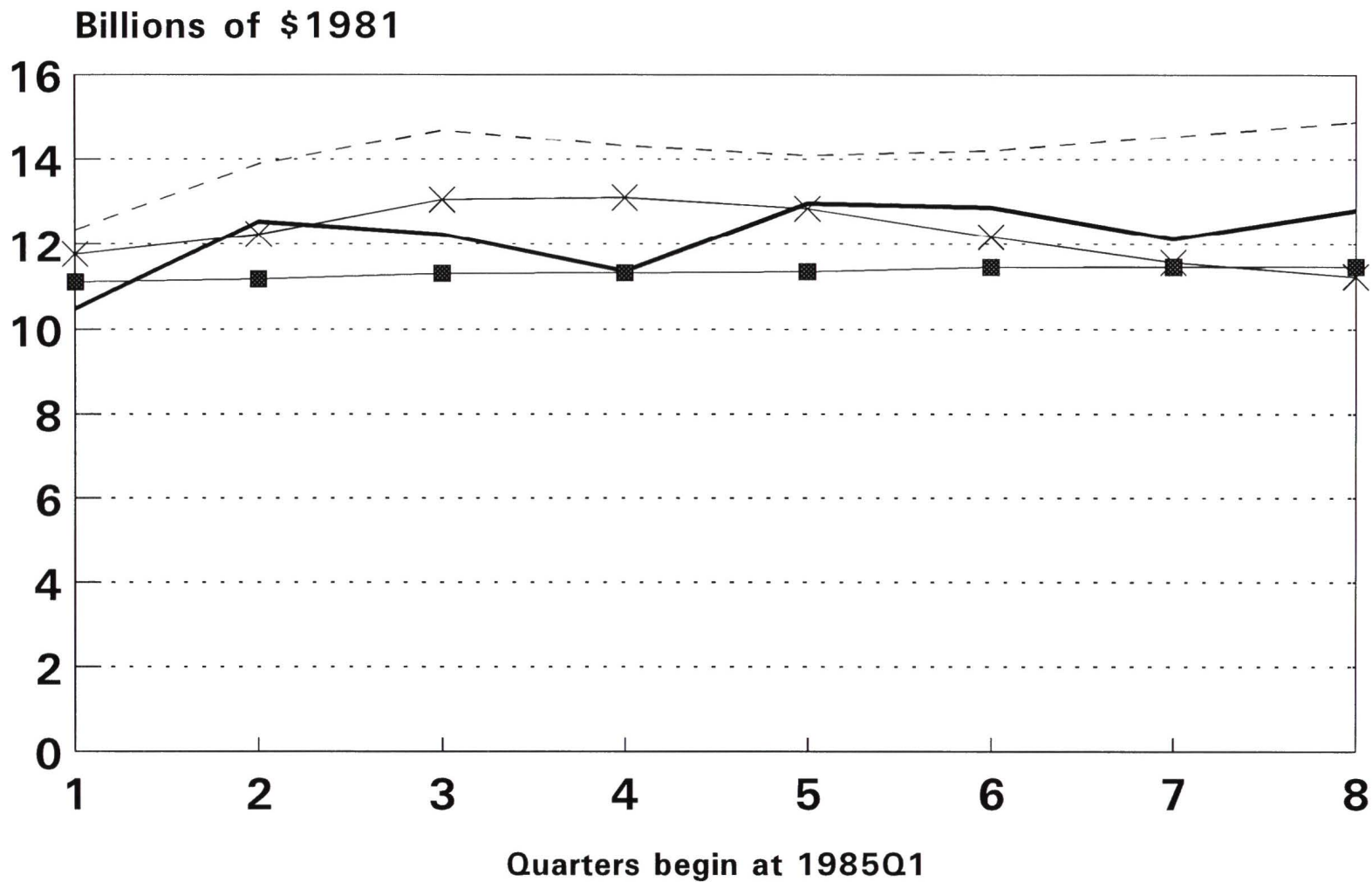
FIGURE 9
EIGHT QUARTER MODEL SIMULATIONS



-- Summers Q — ACTUAL -■- Neo Cost Min + Neo Profit Max

STRUCTURES

FIGURE 10
EIGHT QUARTER MODEL SIMULATIONS



-- Summers Q ■ ARIMA × VAR Sims — ACTUAL

STRUCTURES

VITA

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Phillips, Hager, and North Ltd Bursary	1991
Teaching Award	1991
Dean's Scholarship, University of Victoria	1990
Jimmy Condon Scholarship	1984-89
University of Calgary Athletic Award	1986

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Title of Thesis: An Evaluation and Comparison of Econometric Methods of Forecasting Business Investment: Summer's Q, Neoclassical, ARIMA, and VAR models

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JAMES ANTHONY PARKER

April 16, 1993