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QUARTERLY BUSINESS CAPITAL EXPENDITURES

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This paper reports on the research underlying the business capital expenditure equations used in RDX1, the experimental aggregate model of the economy being developed in the Research Department of the Bank of Canada. The views expressed are the personal views of the authors and no responsibility for them should be attributed to the Bank.

PREFACE

This study explains the theory and empirical experiments underlying the two business fixed capital expenditure equations used in RDX1, an aggregate quarterly model of the Canadian economy. Econometric descriptions of behaviour are never final, even when the behaviour in question is fairly straightforward. In the field of investment behaviour, where decision-makers and researchers alike operate under conditions of considerable uncertainty, almost any equation must be regarded as a stopgap whose use is only justified under the pretext that it is temporary. Even while research is continuing it often makes sense to stop and chronicle the progress to date, in part to help others on the same route and in part to clarify the remaining problems. When one must produce some equation or other in a specified time, as we had to do for the RDX1 model, there is an added incentive to spell out progress to date so that the equation can be duplicated for the aggregate model.

To Ian Stewart and the rest of the group assembling the equations for the aggregate RDX1 model, we are grateful for the questions they raised that eventually led to a number of subtle flaws being removed from our data and specifications. If an independent group had not been trying to duplicate our equations on the basis of our written reports, a number of mistakes in both would have remained undiscovered. The experience has taught us to institute such duplication wherever our equations are to be put to use, and to write up our equations in such a way that other researchers should likewise be able to obtain the same results. Thus we have written our report describing our experiments in some detail, and in a serial manner. Even if the chronicle of our search may not always make gripping reading, at least our footsteps should be clear.

We would be grateful if other investigators would let us know when they succeed where we have failed.

The Research Department of the Bank of Canada, though not responsible for any of the views in this paper, did provide excellent research facilities, a stimulating environment and lots of encouragement for a search that had many discouraging moments.

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A. Introduction

Efforts to construct models of the capital investment process in Canada on a quarterly basis are of necessity somewhat constrained in their scope. In the first place, no disaggregation is possible beyond the level of non-residential construction and machinery and equipment expenditure, since quarterly data at a finer level do not exist. Even the aggregate quarterly figures are rather suspect, being built up from price and employment data for construction and from shipments data for machinery and equipment. Thus there are no 'real' figures at all on a quarterly basis.

There are two ways of dealing with this situation. One way is to proceed as though the quarterly capital expenditures figures were actual observations and hope that the errors in the variables are not large and not systematic enough to bias the resulting estimates seriously. This approach precludes disaggregated investment equations, but ties in straightforwardly with an aggregate quarterly model.

A second way of dealing with the problem is to look further afield for alternative sources of investment data, even if that involves moving out of a strict quarterly framework. In Canada, one has to go to the results of the annual investment survey to find a direct measure of investment put in place during a particular time period. The survey provides no information about the quarterly allocation of investment outlays but does allow disaggregation to the sector, the industry, or even the enterprise level, and provides forecast as well as actual capital expenditures for each calendar year. This survey information supplies an alternative route to aggregate quarterly investment equations and the only possible source of either quarterly or annual disaggregated capital expenditures equations. The way we envisage using this information in a quarterly model is to have equations explaining the most recent annual investment forecast, equations (called realizations functions) explaining the difference between the current annual actual and forecast expenditures, and a non-stochastic scheme for allocating the estimate of the current year's actual expenditures among the four quarters. The forecast equations and the realizations functions would be unusual in that, although the values of the independent variables would change each quarter, the dependent variables (being based on observed annual figures) would have the same values in four successive quarters. The success of this approach depends on the quality of the forecasts and realizations functions, and on the a priori plausibility of whatever scheme is used for the quarterly allocation of the estimated annual actual expenditures. There can be no straightforward contest between this approach and the first approach using the quarterly expenditures data, since there are no actual quarterly expenditures data to provide a standard of performance. The second approach is not likely to explain the existing quarterly expenditures series as well as the first approach. Nor is it intended to do so, since the second approach specifically rejects the assumption that the present quarterly series are the best approximation to investment actually put in place during the quarter. In pursuing the second approach, we have done a considerable range of experiments with realizations functions; to be reported in a separate paper. For the aggregate quarterly RDX1 model,[1] however, we are relying entirely on the first approach, both because of its simplicity and because of the apparent plausibility of our results.

The present paper deals only with our experiments using the quarterly national accounts figures for machinery and equipment (M&E) and non-residential construction (NRC) as the dependent variables. Section B presents the model and discusses the basic data. Section C presents the results of our first phase experiments explaining gross capital expenditures. The experiments presented in Section D use the results of the first phase equations to construct net investment variables which are then used in attempts to find the influence of financial factors on the size and timing of investment outlays.

There are more data problems encountered at this stage, as the price data both for capital goods and for output are not reliable enough to provide any measure of the relative cost-of-capital services figuring prominently in the Fisherian theory of

[1]An experimental prototype model of the Canadian economy which is under development in the Research Department of the Bank of Canada.

optimal investment. Some efforts were made to work with existing price data but these were not successful. The data referring to the cost of finance also gave rise to conceptual and estimation problems.

Section E presents the final phase two equations and puts them through some preliminary forecasting tests. Section F describes some further experiments designed to improve the M&E equation and runs our final equations through further forecasting tests. The preferred equations are, as usual, a compromise between the type of structure that we would like to see on a priori theoretical grounds and the equations that our existing data would support with some degree of plausibility. Our final equations are quite satisfactory on any a priori criterion, but they are not perfect and they do not embody all the effects that we would like to see. This may be due to inadequacies of data, to mistaken specification, or to both.

B. The Model

1. Preliminary Structure

The model we have used for both non-residential construction and machinery and equipment investment is a flexible accelerator pattern with the basic equation:[2]

$$I^g_t = a + b(KGAP)_t + cK_{t-1} \qquad (1)$$

Here I^g_t is gross investment quarterly, K_{t-1} is the size of capital stock at the end of quarter $t-1$; so cK_{t-1} represents replacement investment and c is an estimate of the proportion of the capital stock that is replaced in each period. $(KGAP)_t$ is the accelerator term, representing the discrepancy between desired and actual capital stock, which then gives rise to new capacity-expanding investment in period t. Since time is required both for the investment decision to be taken and for the plant and equipment to be produced and installed, we assume that present expansionary investment put in place is composed of investment

[2]The definitions of all the variables used in the paper are set out in Appendix B.

related to a number of past periods' capital shortages, so:

$$(KGAP)_t = \sum_{i=0}^{n} W_i (K^*_{t-i} - K_{t-i-1}) \qquad (2)$$

$$\sum_{i=0}^{n} W_i = 1$$

A change has to be thought to have some permanence before it is used as a basis for planning additions to productive capacity. Although current information is probably more relevant to expectations than are long past values of variables, the past values may still have some importance in helping to decide whether current values are good indicators of the future. Thus, several past values of some variables are likely to have some importance when decisions are made about what expenditures should be undertaken. The relative importance of various lagged values presumably depends on the type of variable whose future values are being forecast by the decision maker. Once decisions have been made about what capital expenditures to undertake, the actual capital expenditures will be distributed among subsequent time periods. If it is possible to separate investment decisions from investment expenditures, then these two sorts of lag may be distinguished. In Canada, we have only the aggregate quarterly expenditures data to explain, so there is no chance of sorting the pre-decision formation of expectations from the post-decision time distribution of actual expenditures. Thus, all we can get from our data is a single lag distribution, which may be considered to be a convolution of the pre- and post-decision distributions. It is important to remember this fact, lest we be tempted to regard the W_i as the lag distribution of expenditures behind appropriations[3] (expenditure decisions), and b as a measure of the elasticity of expectations.

Since there will be times when we have to make assumptions

[3]"Appropriations" refer to allocations of funds by firms for specific investment projects, and provide the best evidence about the timing of investment decisions. If appropriations data are available, it is possible to estimate separately the time shape of the variables influencing investment decisions and the lag structure linking investment decisions and actual outlays. Almon [1] and Hart and Sachs [25] have attempted to explain the latter relationship using U.S. data, while Hart [12] has also made some efforts to explain appropriations themselves. There are no Canadian appropriations data, so we could not follow this routine.

about the separate time structures of the pre- and post-decision lag structures, it is worthwhile exploring the possibilities. Under what circumstances might it be possible to regard the W_i as the lag structure relating appropriations and actual expenditures?

1. If the structure of the W_i is very close to the lag structures explicitly relating the National Industrial Conference Board U.S. quarterly appropriations to actual expenditures, then we should be more willing to interpret the W_i in the same way, having regard to the dangers involved in assuming that U.S. experience is directly applicable to investment behaviour in Canada.

2. If the definition of K^* includes all the past values, appropriately weighted, of the variables influencing current investment decisions, then the case becomes stronger for treating b as a scale factor indicating the elasticity of expectations with respect to the weighted combination of past values of the variables affecting K^*. If it were possible to so interpret b, then the W_i would be left to represent only the lag between appropriations and actual expenditures.

Our definition of K^* involves only Y_t as a proxy for future output, while it is likely that a weighted average of several recent values would provide a more appropriate measure.[4] If, for example, the appropriate way of measuring expected future output were to use all past values with geometrically declining weights, then our W_i are the weights resulting from the convolutions of two lag structures. What could we say, in this case, about the relationship between the two component distributions? Not much, beyond saying that the actual lag distribution of expenditures behind appropriations must reach a peak sooner, and be more compact, than the associated distribution of W_i.

The important conclusion from this discussion is that no empirical tests within our present framework will allow us to tell how our single lag distribution relating past experience to current expenditures can be split into pre-decision and post-decision dis-

[4]This implies regressive expectations. Extrapolative expectations are also possible, in which case the appropriate value for expected future output would be an extrapolation based on recent output values.

tributions. This fact becomes important when we are including policy variables in our investment equation. If, for example, a policy variable enters K^* in the same way as does Y_t, we are thereby assuming that lagged values of the policy variable enter into the formation of expected future values with exactly the same weighting pattern as past values of Y enter into the determination of expectations about future output.[5] This problem is avoided in those instances where it is appropriate to include policy variables linearly (i.e. independently of KGAP) in the investment equation.

Whatever difficulties we may have in deciding how to interpret b and the W_i in our model, we can be sure that different sizes of b and patterns of W_i could lead to damped or explosive oscillatory movements in the size of the discrepancy between K_t^* and K_{t-1}, and hence in the level of investment.[6] The smaller is b in our

[5]This will not be true if the policy variable also affects the lag distribution relating appropriations and actual expenditures. In this case, there is still a fixed way in which expectations are assumed to be formed about future values of the policy variable, except that it is no longer the same as the way in which past Y_t influences expectations about future output.

[6]For example, assume that b=1, W_2=1, W_i=0, i≠2, and the system is in equilibrium, with replacement investment always equal to depreciation. In period 0 desired capacity changed by 1.

	New capacity desired (end of period)	Investment
0	1	0
1	1	0
2	0	1
3	-1	1
4	-1	0
5	0	-1

....and so on to infinity

But if b=.5 we get the sequence

0	1	0
1	1	0
2	.5	.5
3	0	.5
4	- .25	.25
5	- .25	0
6	- .125	- .125
7	0	- .125
8	.0625	- .0625

....and the sequence converges rapidly.

Clearly a different structure of W_i is needed to remove the oscillatory pattern, but the smaller value of b leads to a more plausible behaviour pattern. Businessmen do not react immediately to all of an apparent capital shortage; they initiate a few projects and wait to see if the shortage persists.

model, the more likely it is that the model will predict a fairly smooth pattern of investment expenditures in response to a sustained change in K_t^*. If the W_i in each case are representative only of the lags between decisions and actual expenditures, we would expect the b for the M&E equations to be higher than for NRC equations. This is so because the faster depreciation rate on M&E means that the forecasts relevant for M&E investment are shorter term than those on which NRC decisions are based, and hence the relevant M&E output forecasts are more likely to be closely related to current output.

The composition of K_t^* is of course one of the key aspects of the model, for it is on the desired level of capital stock capacity that all the variables of 'neoclassical' investment theory are focused. If one assumes that the level of capital services supplied is proportional to the size of the capital stock,[7] then the desired level of capital services is that at which the marginal productivity of capital is equal to its net rental value; the latter taking into account purchase price, expected life, tax factors, and the firm's internal rate of discount. Working within a production function context, the marginal productivity of capital services can be derived from the level of output. For our initial experimentation, however, given the weakness of our data on the prices of capital and output, the lack of variance in the tax policy series, and our simple lack of knowledge about firms' internal discount rates, we decided to start with a much simpler formulation. We assumed that firms had some desired capital/output ratio, which could be approximated by the formula $\sum_{i=1}^{12} (K/12Y)_{t-i}$ where Y is some measure of the level of output of the economy and K is the capital stock. This implies that over a three year period, if this is long enough to eliminate the cycle, investors are generally satisfied with their capital/output ratios. This historical experience embodies all the tax, price, and discount-rate factors bearing on the desired level of K and assumes that on the average

[7]Jorgenson [14] [15] [17], Hall and Jorgenson [11], Bischoff [2], Resek [23] and others make this assumption in relating the determination of investment to an explicit production function. The validity of the assumption is questioned by Tobin [27], but in the absence of independent utilization data there would seem to be no alternative.

over a long enough period desired capital stock has in the past been equal to actual capital stock. Applying this ratio to the current level of output yields:

$$K_t^* = \sum_{i=1}^{12} (K/12Y)_{t-i} \, (Y_t) \tag{3}$$

On examining the residuals from our initial experiments, however, we observed that the twelve quarter average appeared to be too short to take in the Canadian business cycle. Longer period movements in output tended to shift the desired capital/output ratio around in a cyclical manner. This being the case, we fitted a trend capital/output ratio by a type of trend-through-peaks approach, leading to:

$$K_t^* = (K/Y)^T \, Y_t \tag{3'}$$

Experimentation with both forms indicated that the latter was clearly superior. This could be because it is not sensitive to the longer cycles; it could also be that by fitting it on a trend-through-peaks we allow historical capital/output ratios to embody the cost-of-capital-services variables that we could not measure explicitly without requiring the assumption that desired capital/output ratios are equal to the average for recent years.

2. The Measurement of Capital Stock

The use of the accelerator model rests on the assumption that data exist on the size of the capital stock, since the capital stock at end of last period enters into replacement investment through the rate of depreciation and into capacity-expanding investment through the accelerator term. But, of course, data on the size of the capital stock in Canada on a quarterly basis do not exist. There are estimates of the total stock on an annual basis up to 1955 [13], and for manufacturing [24] up to 1960. Thus, it is necessary to compute stock figures using the quarterly investment flows built onto a base year stock figure. This procedure in turn requires certain assumptions about the length of life of capital assets and the depreciation patterns associated with them.

For a number of reasons, both theoretical and computational, we chose to use an exponential decay rate depreciation pattern of the form:

$$K_1 = K_0 + I_1 - \rho K_0 \qquad (4)$$

Here I is gross investment, K_0 and K_1 are net capital stocks at the end of periods 0 and 1, and ρ is the rate of depreciation. This form has the advantage that we can use the same measure of capital stock both in our accelerator term KGAP and in our replacement investment term, an equality previously taken on faith. But as Griliches points out ([9] p. 123), replacement investment is equal to the depreciation of the gross capital stock, while the accelerator term depends on the supply of capital services available or on the net capital stock. Only if one uses an exponential depreciation rate is the replacement proportionate to the net stock of capital, so that the same K_t can be used in both parts of the equation.

Further theoretical and empirical support for the exponential rate is marshalled by Jorgenson. (See [17] pp. 139-140.) He cites a theorem in renewal theory to the effect that replacement will be proportional to accumulated capital stock independent of individual equipment replacement patterns provided that the capital stock is constant or is growing at a constant rate — in the probabilistic sense. (See Parzen [21] pp. 180-1 or Feller [8] pp. 285-293.) The latter assumption may be acceptable. In addition, there is the finding of Meyer and Kuh ([19] pp. 91-94) that no significant "echo effect" exists in U.S. investment flows; there is no 'bunching' at regular lagged intervals following high levels of investment.

At the computational level, the exponential rate has the advantage that it can be derived from the flow data and a base period figure by successive application of (4). Thus a stock series for any given ρ can be calculated rapidly by computer, while straight-line assumptions would be more tedious. This is not merely an argument for the easy life; given the present state of our ignorance on the length of life of capital assets it is a significant advantage to have a generating procedure that enables us to search rapidly over a range of possible depreciation rates and to choose that which seems most satisfactory. This, in turn, requires a criterion of choice, and again our model has the advantage of providing such a criterion. It assumes that replacement investment is some proportion c of net capital stock. But replacement investment equals depreciation, which is some proportion ρ of net capital stock. Consequently we need only calculate several stock series for different ρ, plug them into an estimating equation of the form (1), and choose the value of ρ for which the estimated value c and the assumed value ρ converge to equality. This decision rule is of little help if convergence is not observed, but fortunately for us, convergence was found to be regular and quite satisfactory. An acceptable rate for non-residential construction was found quite swiftly, while for machinery and equipment a wider band was searched. Table 1 lists the values of ρ which were tested, together with the depreciated value of an investment of 1 after several terms of years under the various depreciation rates.

This approach, however, has sidestepped the whole question of technical progress. We have assumed above that depreciation means actual physical deterioration; but of course this is not true. Particularly for machinery and equipment there is a constant improvement in the quality of new machines and our capital stock series should take account of this fact. If the value of ρ is assumed to include both physical deterioration and the rate of 'embodied' technical progress, then our net capital stock is a Solow-type 'vintage' capital stock [26] in which capital of different ages is weighted according to its productivity. This is clearly the concept needed in our accelerator term, in which the desired capital stock is related to the level of output. Here, desired capital is actually the desired productive services of capital, and consequently we wish to use a stock series whose components are productivity-weighted. But we face a problem in the replacement term, in that our convergence test now assumes that the faster the rate of technical progress, the faster the rate at which old capital loses value through obsolescence (assuming a constant rate of physical deterioration), and the larger is replacement investment as a proportion of last-period's capital stock. But technical progress implies that less capital is now needed to produce a given level of capital services, so that for given output the value of the capital stock falls. If, for example, output is being held constant, then the faster the value of the capital stock falls (through increased productivity) the larger the proportion of investment which we call 'replacement' invest-

Table 1 Depreciated Value of an Investment of 1, Various Depreciation Rates

Per Quarter ρ	Years 5	10	15	20	25	30	50	60
NRC								
.0075	.8606	.7406	.6374	.5485	.4720	.4062	.2228	.1650
.0090	.8346	.6965	.5813	.4851	.4049	.3379	.1639	.1142
.0100	.8180	.6691	.5473	.4477	.3662	.2996	.1341	.0897
.0125	.7778	.6050	.4706	.3660	.2847	.2214	.0811	.0491
M&E								
.0250	.6024	.3629	.2186	.1317	.0793	.0478	.0063	.0023
.0350	.4903	.2404	.1179	.0578	.0283	.0139	.0008	.0002
.0400	.4419	.1953	.0863	.0381	.0168	.0074	.0003	.0001
.0450	.3979	.1583	.0629	.0250	.0099	.0039	.0001	.00002
.0470	.3817	.1457	.0556	.0212	.0080	.0031	.0001	.00001
.0485	.3698	.1368	.0506	.0187	.0069	.0026	.00005	.000007
.0500	.3585	.1285	.0461	.0165	.0059	.0021	.00003	.000004
.0550	.3223	.1039	.0335	.0108	.0035	.0011	.00001	.000001
Maximum Depreciation Rates Permitted Under Canadian Income Tax Laws								
.05 per annum class 3 assets (including most NRC)	.7738	.5988	.4634	.3586	.2775	.2147	.0770	.0461
.20 per annum class 8 assets (including most M&E)	.3277	.1074	.0352	.0115	.0038	.0012	.0000	.0000

ment. It is true that under such circumstances our accelerator variable would be negative and the actual level of net investment would probably also be negative; but what sense can one make of a large positive 'replacement investment' term when the value of the net stock is falling, a term whose coefficient increases the faster is the fall? It is clear that technical progress obscures the meaning of the convergence test which was our primary criterion for the value of ρ.

This problem does not appear to have been faced in the current investment literature, and it tends to leave one in a cleft stick. One can assume that the depreciation rates found by the convergence test are actual physical deterioration, and that technological progress is not significant. Then the appropriate value for capital stock in KGAP would be less than we have assumed due to the increase in productivity which we have assumed away. Moreover one may find that $c = \rho$ for values that are hard to explain on the ground of physical deterioration alone. Alternately one may accept the fact that embodied technological progress takes place, and that our value of ρ is both a deterioration and an obsolescence factor. This removes the bias in capital stock as a component of KGAP but forces us to assume that 'replacement' investment is replacement of both obsolete and worn-out equipment, not up to existing levels but up to some datum capacity level that grows at the same rate as the embodied technical progress rate, such that the dollar value of capital stock is held constant.

In the aggregate, the rate of embodied technological progress is slower than the rate of growth of output, since output is a function of the growing quantities of inputs as well as the increasing (embodied and disembodied) efficiency of capital goods. Thus when we assume 'replacement' investment to be large enough to keep productive capacity growing at a rate equal to the rate of embodied technical progress, we are still leaving a considerable amount of gross investment to be explained by movements of the variables influencing K^*. The corresponding assumption at the level of the firm is that regular gross investment outlays are made in amounts more than sufficient to maintain the productive capacity of the firm's plant but less than required to maintain the firm's share of the growing market. We are, therefore, supposing that decisions to invest so as to maintain a constant share of a growing market are not made automatically (as are the 'replacement' decisions) but in relation to what is happening in the markets for goods and finance. Whether it is most appropriate to assume that the amount of investment sufficient to increase capacity at a rate equal to the rate of embodied technical progress is the amount of investment not related to recent changes in the incentives to invest, cannot be settled a priori. In principle, there is no reason why all gross investment should not be influenced by the driving variables in the investment equation, but we are never surprised to find that any particular functional form we use in fitting the equation contains a term that is either a fixed constant or a fixed proportion of the lagged capital stock. It is often helpful to regard this fixed proportion as replacement investment, particularly if it helps us to derive an approximate series for the capital stock. One must be careful, however, not to rely too much on the implied distinction between replacement and expansionary investment expenditures.

Whatever decay rate is selected, the above procedure requires that we develop a base year stock from which to build our series. We calculated the bench mark value for both NRC and M&E in 1957 constant dollars, net capital stock as of mid-1949. Since our data set begins in 1947, we have in fact chosen K_{10} and must work back to K_0 and forward to K_{76} for each capital stock series. For manufacturing stock at this date we took Rymes' Set 1 estimates ([24] p. A6) based on the midpoints of the assumed range of "lives". Estimates in index form (1949=100) for most other non-manufacturing industries were published by the Dominion Bureau of Statistics [5]; the absolute numbers for these industries were supplied by the Business Finance Division of D.B.S.

These industries do not, however, include the industrial sector Finance, Insurance, and Real Estate or the Commercial Services subdivision of the service sector. For these, estimates are available in the work of W.C. Hood and A.D. Scott. (See [13] Appendix Table 6B-3, pp. 435-444.) Their estimates are in 1949 dollars, and no adequate deflation method being available we assume that their estimated proportion of industry accounted for by Finance, Insurance and Real Estate and Commercial Services in 1949 could be extended to the D.B.S. data. These two components made up 6.80% of construction-type stock and 3.73% of machinery and equipment. Extending these proportions to our data requires us to assume also that they would apply to the 1957 dollar values as well; this could be awkward if there have been marked differences between price movements in these sectors and in private industry as a whole. Such differences are unlikely to be large, however, and the smallness of these two sectors makes it improbable that our bench mark could be significantly affected.

The stock bench mark figures are:

Net Capital Stock at Mid-1949
(millions of 1957 dollars)

	NRC	M&E
Manufacturing*	3,785	2,963
Agriculture**	1,206	1,569
Forestry	148	74
Fishing & Trapping	8	94
Mining, Quarrying, & Oil Wells	557	251
Construction	79	255
Transport, Storage & Communication	4,342	1,809
Public Utilities	2,314	680
Trade	1,337	377
Sub-total	13,776	8,072
	(93.20%)	(96.27%)
Finance, Insurance, Real Estate, & Commercial Services	1,005	312
	(6.80%)	(3.73%)
Total	14,781	8,384

* M&E includes $250 million Capital Items Charged to Operating Expenses.

** M&E includes farmers' personal and farm commercial vehicles.

Since the flows cumulated on this bench mark are the National Accounts investment flows, it is clearly desirable that bench mark coverage corresponds to flow coverage. Unfortunately correspondence is not quite exact because D.B.S. stock data are on the Standard Industrial Classification, which differs slightly from the National Accounts basis. The National Accounts basis includes in the personal sector "all private organizations which are not established for the purpose of making a gain, e.g. charitable institutions, municipal hospitals, and universities." (See [4] p. 117, para. 98.) Investment by such institutions is included in the Business Gross Fixed Capital Formation category. On the other hand, non-commercial institutions directly administered by any level of government, e.g. municipal schools and federal and provincial hospitals, are included in the government sector. (See [4] p. 135, para. 178.) Investment by such institutions does not enter into the flow series. But capital stock data are not broken down in this manner; the Standard Industrial Classification lumps all such institutions into the Community Services sub-sector no matter which authority administers them. Hood and Scott give one overall stock figure for "Institutions." Allocation by the relative shares of government and non-government institutions in gross investment for 1949 is also impossible, since no breakdown of the National Accounts data is available, and examination of the figures in *Private and Public Investment in Canada* makes it clear that their breakdown of Private Institutions by function does not correspond to the National Accounts division by administering agency. (See [3] any recent year.) Since no juggling of the figures seemed likely to yield a satisfactory split, it appeared best to exclude institutions entirely from the bench mark. The capital in question is very hard to value in terms of its capitalized service production, and new investment is unlikely to be responsive to economic stimuli in any case. It would be preferable to exclude non-commercial institutions from the flow series as well, but existing data do not permit this. Moreover, in terms of the aggregate model, this would simply generate a further and not very important exogenous sector. On balance it is unlikely that this small inconsistency would have any material impact on our estimates.

Closing the model now requires only some specification of the lag pattern in equation (2), again a matter on which we had no a priori information. There are two ways in which a lag pattern can be chosen; either by some maximizing process generating the lags within the model, or by pre-selection of a range of plausible lags and testing of the resulting equation. The first type of approach is exemplified by the Koyck transform and more generally by the Jorgenson rational distributed lag [16], the latter providing considerable flexibility in the final choice of pattern. Such a scheme, however, requires the inclusion in the estimating equation of one or more lagged values of the dependent variable. If the equation residuals are autocorrelated, as the investment series are, the resulting parameter estimates are particularly unreliable.

In the first place, the coefficients on the independent variables are asymptotically biased as shown by Malinvaud [18]. In addition the standard errors of both the coefficients and the dependent variable are severely understated as shown by the early Monte Carlo tests of Cochrane and Orcutt [6]. Nor can one rely on the standard autocorrelation tests, since the residuals of the fitted equation are not so autocorrelated as the true residuals, making the Durbin/Watson statistic biased towards 2.0. (See Nerlove and Wallis [20].) This problem is apparent in the fitted equation itself, since it has frequently been observed that Canadian quarterly investment functions, including a lagged investment term, yield very good fits with coefficients near 0.9 on lagged investment and very little significance on anything else. We have checked this formulation with a Jorgenson-type lag and confirmed the phenomenon; it therefore appears that no meaningful structure can be located from a quarterly investment equation with a lagged dependent variable.

We therefore fell back on an a priori specification of a range of lags, shown in Table 2 and charted in Appendix B. These lags will hereafter be referred to as labelled in the table. The long lag pattern conforms roughly to the lag between appropriations and expenditures derived by Almon [1] for Total Manufacturing in the U.S., the others are merely attempts to search over a broad band. Early experiments indicated that the PP group of lags involving a two-quarter start-up lag produced markedly inferior results; they were dropped very early on, and no results are reported. It was expected that the machinery and equipment equations would tend to fit better with the shorter lags while the longer lags would produce better results on the non-residential construction accelerator; this is in fact what was found.

The polynomial technique of fitting distributed lags used by Shirley Almon [1] provides an alternative method of deriving lag weights from the equation itself, which avoids both the lagged dependent variable and the use of several highly collinear lagged values of the independent variables. We did not use it for our main analysis largely because the computational capacity to apply the technique became available only late in the project. In addition, our use of seasonally unadjusted data limited the useful-

Table 2 Pre-Specified Lag Patterns Tested

These lag distributions are charted in Appendix B*

Label \ Quarter	t	t-1	t-2	t-3	t-4	t-5	t-6	t-7	t-8	t-9	t-10	t-11
SLAG	0.0	0.25	0.50	0.25								
MLAG	0.0	0.10	0.15	0.30	0.25	0.15	0.05					
LLAG	0.0	0.06	0.11	0.16	0.17	0.16	0.13	0.11	0.07	0.04		
PSLAG	0.0	0.0	0.25	0.50	0.25							
PMLAG	0.0	0.0	0.10	0.15	0.30	0.25	0.15	0.05				
PLLAG	0.0	0.0	0.06	0.11	0.16	0.17	0.16	0.13	0.11	0.07	0.04	
PPSLAG	0.0	0.0	0.0	0.25	0.50	0.25						
PPMLAG	0.0	0.0	0.0	0.10	0.15	0.30	0.25	0.15	0.05			
PPLLAG	0.0	0.0	0.0	0.06	0.11	0.16	0.17	0.16	0.13	0.11	0.07	0.04
JLAG	0.0	0.30	0.35	0.25	0.10							
Polynomial NRC	0.03	0.05	0.08	0.10	0.11	0.13	0.13	0.13	0.11	0.09	0.05	
Polynomial M&E	0.15	0.21	0.23	0.19	0.14	0.07	0.02	- .01				

* Page 78

ness of the technique, at least for the machinery and equipment equations. By making the seasonal dummies multiplicative with the accelerator term, we have an equation with four separate accelerators, one for each quarter. The polynomial technique uses as regressors linear combinations of the independent variable whose effect is hypothesized to be lagged, and the number of such regressors depends on both the degree of the estimating polynomial and the constraints placed on it. A third- or fourth-degree polynomial would require two or three regressors respectively, which with the seasonal pattern would be eight or twelve. Since there are other terms in the equation besides the accelerator, the number of variables begins to press against the available degrees of freedom.

Polynomial lags were fitted to seasonally adjusted data, using an equation containing only lagged capital stock and the accelerator, to serve as a check on the pre-set lag patterns. The length of lags was set at eight quarters for M&E and eleven for NRC, and the polynomial used was of third degree, equal to zero in periods t+1 and t-n. The resulting patterns are shown in Table 2, after dividing through by the sum of the polynomial weights to break out the lag pattern alone. As can be seen, the NRC pattern is very close to PLLAG; in fact, an equivalent equation fitted to seasonally adjusted data using the PLLAG pattern was identical with the polynomial equation to the third significant digit. In the case of M&E the polynomial pattern differs somewhat from the predetermined lags and yields a better fit in a simple seasonally adjusted equation — as of course it should. It was therefore carried forward for testing in more complex equation formulations, while the NRC polynomial lag was not. In these later experiments, however, the polynomial lag lost its superiority over the predetermined patterns.

C. Estimation — First Phase

The model embodied in equations (1), (2), and (3) was the initial test vehicle from which information was derived concerning the depreciation rate, the lag structure, and the relevant output measure. The dependent variables throughout this phase were gross investment in non-residential construction (DB 146)[29] and in machinery and equipment in constant 1957 dollars (DB 147), unadjusted for seasonal variation, as reported in the National

Accounts.[8] Because we were working with raw data, our equations had to embody a seasonal adjustment pattern; and it was found after some experimentation that modifications (1') and (1") were most successful for non-residential construction and for machinery and equipment respectively.

$$I_{NRC} = a_1Q_1 + a_2Q_2 + a_3Q_3 + a_4Q_4 + b(KGAP)_t + cK_{t-1} \quad (1')$$

$$I_{M\&E} = a_1Q_1 + a_2Q_2 + a_3Q_3 + a_4Q_4 + b_1Q_1(KGAP)_t + b_2Q_2(KGAP)_t$$

$$+ b_3Q_3(KGAP)_t + b_4Q_4(KGAP)_t + cK_{t-1} \quad (1'')$$

All reported equations are fitted in these forms.

The independent variables at this stage were capital stock series constructed on various depreciation assumptions and output variables in seasonally unadjusted constant dollar terms. For output, two variables were used, Gross National Expenditure (DB 157) and Real Domestic Product less Agriculture. The former is simply the National Accounts series, while the latter was constructed from the index of Real Domestic Product less Agriculture (DB 2565, 1949=100) computed by the D.B.S. Industrial Output Section. By obtaining a single 1957 dollar quarterly output figure from D.B.S. and dividing this by the same quarter index value we were able to derive an expansion factor 43.9472 which when multiplied by the output index yields a constant dollar output series. The RDP series is superior to GNE conceptually in that by excluding the agricultural component it eliminates both a strong and irrele-

[8]The 1965 figures for both NRC and M&E were revised by D.B.S. after being put on Databank. First phase testing as reported in Tables 3 and 4 is with unrevised data, second phase is revised data. The revisions are:

1965	1Q	2Q	3Q	4Q
		NRC		
Old	553	710	951	925
New	576	725	971	924
		M&E		
Old	757	964	861	982
New	783	1,003	905	1,003

vant seasonal and a pronounced year-to-year fluctuation in crop value that is probably not closely related to investment behaviour. Also the Domestic rather than the National basis is clearly superior for an accelerator variable. On the other hand, GNE has as usual the virtue of simplicity and is easy to link with the other equations of a small model. Using RDP commits one to explaining the difference between national and domestic output even if agriculture is simply added as exogenous. We decided to work with both variables as long as possible, as the comparison between the two would be both interesting and useful.

A considerable number of equations were fitted at this stage, and presentation of the significant equations, let alone of all results, would take up more space than it would be worth. Rather than giving the actual equations, Tables 3 and 4 present the important features of each to show the patterns emerging. Thus Table 3 gives the results from fitting (1'), (2), (3), for NRC to three different depreciation rates and a variety of lag patterns, using as output both GNE and RDP less Agriculture. The statistic $\rho - \hat{\rho}$ is the assumed value of the depreciation rate shown at the side of the table, less the calculated value $\hat{\rho}$ or c, the coefficient of K_{t-1}. b is simply the coefficient of the accelerator variable. t-test values are not given; but all variables at this stage were strongly significant with the exception of some of the seasonal constants in the NRC equations. All equations are fitted 1953-1965 using Ordinary Least Squares (OLS).

Table 3 supplies partial answers to three questions. Convergence of ρ and $\hat{\rho}$ for NRC is clearly focused on .01, although the GNE results suggest a rate slightly higher than .01 and the RDP results a rate slightly lower. Examination of the rates of convergence shows that the implied range is between .0090 and .0105 in all cases; given the uncertainty attaching to all such measures the choice of $\rho = .01$ seemed the most reasonable. It is clearly superior to any of the others. Moreover, although three of the RDP results suggest that .01 is somewhat high, the PLLAG result is right on target. By the other criteria in Table 3, RDP is the superior output variable and PLLAG is the superior lag pattern for RDP. Consequently, its performance on the convergence test should carry some extra weight. In addition, similar equations, fitted to seasonally adjusted data using the GNE output measure, gave back calculated values of c within .0005 of .01

All Equations 1953-1965 — Table 3 First Tests of NRC $\left(K^* = \sum_{i=1}^{12} (K/Y)_{t-i}/12\right)$

Assumed Value of ρ	GNE MLAG	GNE LLAG	GNE PMLAG	GNE PLLAG	RDP ex AG MLAG	RDP ex AG LLAG	RDP ex AG PMLAG	RDP ex AG PLLAG
				$\rho - \hat{\rho}$				
.0075	-.0011	-.0013	-.0013	-.0017	-.0005	-.0007	-.0007	-.0011
.0100	.0000	-.0002	-.0002	-.0006	+.0007	+.0004	+.0005	.0000
.0125	+.0008	+.0005	+.0006	+.0001	+.0015	+.0012	+.0013	+.0007
				$\bar{R}^2$				
.0075	.697	.702	.705	.703	.716	.729	.731	.735
.0100	.697	.702	.705	.703	.715	.728	.730	.733
.0125	.696	.701	.704	.702	.715	.727	.729	.732
				b				
.0075	.023	.027	.027	.028	.034	.042	.040	.045
.0100	.024	.028	.027	.028	.035	.044	.041	.047
.0125	.024	.029	.028	.029	.036	.045	.042	.048
				D/W				
.0075	.292	.292	.289	.289	.300	.309	.306	.312
.0100	.293	.292	.290	.290	.299	.309	.306	.312
.0125	.294	.293	.291	.290	.299	.308	.306	.312

All Equations 1953-1965

Table 4 First Tests of M&E $\left(K^* = \sum_{i=1}^{12} (K/Y)_{t-i}/12\right)$

Assumed Value of ρ	GNE SLAG	GNE MLAG	GNE PSLAG	GNE POLY-NOMIAL	RDP SLAG	RDP MLAG	RDP PSLAG	RDP POLY-NOMIAL
				$\rho - \hat{\rho}$				
.045	+.007	+.013	+.009	+.013	+.014	+.020	+.017	+.018
.047	+.003	+.009	+.005	+.009	+.010	+.016	+.013	+.014
.050	-.001	+.001	-.003	+.001	+.002	+.008	+.006	+.005
				$\bar{R}^2$				
.045	.628	.644	.655	.637	.630	.661	.662	.645
.047	.631	.646	.659	.640	.633	.662	.665	.646
.050	.641	.653	.667	.649	.642	.668	.672	.655
				b				
.045	.105	.124	.113	.126	.122	.146	.133	.142
.047	.106	.126	.114	.128	.124	.148	.135	.144
.050	.109	.129	.116	.132	.128	.151	.138	.148
				D/W				
.045	.407	.361	.361	.326	.372	.373	.377	.340
.047	.414	.362	.366	.328	.370	.372	.375	.340
.050	.432	.370	.379	.336	.374	.376	.378	.346

in all cases, being right on .01 several times.

None of the other derived statistics in Table 3 cast much light on the question of the appropriate value of ρ. Clearly, higher values of $\bar{R}^2$ and D/W represent superior equations; in addition higher values of b generally were more significant and were taken as indicative of better performance. This choice reflects a bias on our part in believing that our accelerator tends to underrepresent the reaction coefficient when it is misspecified; but given our small estimates of b, this is probably happening. These three criteria are relatively insensitive to the choice of ρ, and such sensitivity as they do exhibit is conflicting. But the convergence evidence seems sufficiently strong as to justify choosing $\rho = .01$ per quarter as the appropriate rate of depreciation for non-residential construction. This works out to 3.99% per year, or about 80% of the 5% declining balance rate, the maximum rate at which Class 3 buildings may be depreciated for taxation purposes.

The other criteria do give some evidence on the choice of output variable, in that RDP is marginally superior to GNE by every measure for all combinations of ρ and lag patterns. The superiority is not great, but it is gratifyingly consistent. Because of the potential usefulness of GNE in a small aggregate model, and because the margin of superiority is small, it was decided to carry the GNE-based equations forward to the next testing phase as well; but RDP is clearly the preferred output variable.

As for the lag pattern, here the evidence is not quite so clear. The shorter MLAG pattern is slightly inferior by almost all tests; this was confirmed by a number of other experiments which also rejected PSLAG and SLAG quite conclusively. As among the other three, the RDP equations show PLLAG as superior on all tests with PMLAG second when ranked by $\bar{R}^2$, but LLAG second if b or D/W is used. The margin of preference is very very small. With the GNE output variable, the $\bar{R}^2$ test ranks them PMLAG, PLLAG, LLAG, but the other two tests are inconclusive. Other tests, including the seasonally adjusted data using GNE, confirmed this general pattern and the differences are all very small. The polynomial lag calculated from seasonally adjusted data is very close to PLLAG, sufficiently so that no further testing on the polynomial pattern appeared justified. On the basis of this information

PLLAG was accepted as the superior lag, but further tests were done with PMLAG, as well, to provide a check on the results.

We emerge from this phase of experimentation with information on the choice of depreciation rate, lags, and output variables, all more or less in accord with our a priori expectations and with a satisfactory structure on which to build. But our equation fits are not spectacular, and it is clear that much of the $\bar{R}^2$ at this stage comes from picking up the seasonal. Our parallel seasonally adjusted equations gave fits of about 40%. And our pitifully low Durbin/Watson statistics make it clear that a great deal of systematic unexplained variance remains; this is as it should be. We certainly do not expect to explain all the systematic behaviour of investment with a simple output accelerator and would be very suspicious if we did.

The M&E results reported in Table 4 follow much the same pattern as Table 3. The only difference in equation form is that the seasonals now enter multiplicatively with the accelerator variable; an equivalent pattern tested in NRC led to no improvement or even slight deterioration due to loss of degrees of freedom. Thus b for M&E must be calculated as the average of the accelerator coefficients. The convergence test points to a ρ of .050 with the GNE results suggesting a very slightly lower rate and the RDP perhaps a little higher. Again, seasonally adjusted equations confirmed the results derived at this stage. In addition, $\rho = .050$ exhibits slight but consistent superiority on all other tests of the equation, a feature that was not present in the NRC results. Consequently $\rho = .05$ seemed the appropriate choice, leading to an annual rate of 18.65%. This is slightly below the maximum permitted depreciation rate of 20% per year for Class 8 assets.

On the choice of output variables, again RDP is superior. With the exception of the marginally higher D/W for GNE-SLAG, all tests point to RDP over GNE. In general, the margins of superiority are even smaller than for NRC, but they remain consistent. As for the lag pattern, SLAG seems generally inferior. Tests were also run on LLAG, PMLAG, and PLLAG, but they produced significantly worse results. The polynomial pattern is better than SLAG in most respects, but behind PSLAG and MLAG. These results are confirmed in the seasonally adjusted data, except that there, of course, the polynomial lag is better. This is as it should be; after all, the polynomial lag was derived from seasonally adjusted data. On this basis we decided to use PSLAG and MLAG as our primary experimental pattern but to keep the polynomial pattern on the shelf and to test it out at later stages to see whether it might dominate a more sophisticated equation.

As for the overall quality of these equations, the same general comments apply as to NRC. Here the fit is not quite so good, but it is also less dominated by seasonal factors. The seasonally adjusted equations pick up about 55% to 60% of the variance in this form. It is possible that the seasonal adjustment procedure is removing some systematic components of the error variance.

As mentioned above, the pattern of residuals from testing the accelerator model with K^* defined by equation (3) suggested that the averaging-period was too short. The 'equilibrium' capital/output ratio was shifting with the cycle, reducing the impact of the accelerator at the end of each cyclical phase. Consequently new K^* were defined according to equation (3') based on a trended value of the capital/output ratio. Fitting a linear or log trend was not an adequate method of handling this problem, as it tended to be thrown off by the strong upswing at the end of the data period and by the abnormal conditions prevailing in the early postwar period. For RDP as the output variable a trend-through-peaks method was used in which relative minimum K/Y ratios were identified in 3Q56 and 4Q65. On the assumption that this represented full capacity output, and that desired output was 95% of full capacity, a linear desired K/Y ratio could be fitted through these two points. The ratio of desired output to full capacity output, 95%, is a bit high relative to similar U.S. work — the McGraw-Hill surveys suggest 90% to 92%. (See Phillips [22].) But examination of the series of actual K/Y suggested that 95% was a more reasonable value, and use of a slightly high value covers the possibility that our base quarters do not represent 100% utilization of capacity. Even in those quarters more could have been squeezed out; using a 95% ratio if the actual ratio is 90% implies that in the peak quarters output was only .90/.95 = 94.7% of the absolute maximum possible. The resulting trended K/Y series of course depends on the value of ρ used in constructing the capital stock, but for NRC with $\rho = .01$ the value of K/Y in 4Q49 was 3.214 and the quarterly increments were +.009271. For M&E with $\rho = .05$, the base value was 1.786, and the quarterly increments were

Table 5 NRC and M&E Tested With $K_t^* = (K/Y)^T \ (Y_t)$

	NRC					M&E			
	GNE		RDP ex AG			GNE		RDP ex AG	
ρ	PMLAG	PLLAG	PMLAG	PLLAG	ρ	PSLAG	MLAG	PSLAG	MLAG
		$\rho - \hat{\rho}$					$\rho - \hat{\rho}$		
.009	-.009	-.011	-.010	-.012	.047	-.002	-.002	+.007	+.007
.010	-.009	-.011	-.010	-.012	.050	-.022	-.023	-.003	-.003
		$\bar{R}^2$					$\bar{R}^2$		
.009	.793	.795	.839	.845	.047	.811	.800	.834	.829
.010	.796	.798	.842	.848	.050	.818	.807	.831	.824
		b					b		
.009	.050	.058	.066	.078	.047	.142	.139	.169	.179
.010	.052	.060	.068	.080	.050	.148	.158	.187	.197
		D/W					D/W		
.009	.380	.388	.468	.501	.047	.555	.506	.593	.576
.010	.387	.394	.477	.511	.050	.638	.537	.589	.576

iments, the margin of superiority is probably enough to justify choosing PLLAG as the optimal structure. It would be nice to be more certain. On M&E, however, we changed our ground somewhat. Observation of the statistics shows PSLAG superior to MLAG on almost all counts, with the strongest superiority in the GNE form. Yet PSLAG has always been a bit worrisome, because it peaks three quarters back. Fifty per cent of the lag weight is concentrated in one quarter. Given the seasonal tendency for M&E investment to peak in the second quarter and output (particularly GNE), to peak in the third, it was possible that PSLAG was picking up points for its seasonal pattern. This led us to choose MLAG over PSLAG. The PSLAG pattern was never a very convincing one a priori in any case. At this point, therefore, a priori prejudice and seasonal misgivings won the day over experimental results — but we tried not to let it happen again.

This experimental phase completes work on the basic model. We now have a structure for both NRC and M&E that can be used for further analysis. Our depreciation rate assumption for NRC may be somewhat low, and that for M&E somewhat high. Our net NRC total stock rises faster than Rymes' NRC stock in manufacturing [24], but then manufacturing makes up a smaller proportion of NRC than of M&E in any case. Also our M&E total stock rises more slowly than Rymes' manufacturing figures [24], but this can be explained by the rising share of manufacturing in total M&E stock as the importance of the railways, for example, declines, and by the fact that our depreciation rate contains an embodied technical progress factor.

The lag patterns chosen, PLLAG for NRC and MLAG for M&E, are comfortably in accord with a priori expectation. The longer NRC construction period means that new plant cannot be provided to meet unexpected short-term changes in demand. Thus we would expect to find a longer, flatter distribution of NRC expenditures behind changes in current output. The relative success of the PLLAG distribution and the low estimated value of b in the NRC equation support these expectations.

On other counts, however, our model is clearly still incomplete. The fits of about 80% of total variance are not bad for investment equations lacking lagged investment; but they are far from spectacular. The gross autocorrelation of the residuals suggests, first, that our parameter estimates are a lot less significant than our t-tests (all over 2.0) would indicate, and second, that there is plenty of systematic variance left to explain. And finally our equation provides no scope whatever for financial factors, policy variables, or any of the 'interesting' determinants of investment. We have an investment sector that can be influenced only through current output, and then only with long lags.

D. Estimation — Second Phase

The next phase of our work requires the development of more interesting variables of a financial nature and the specification of ways in which they enter the model. Here we would like to capture the impact on investment of interest rates, credit conditions, cash flow, tax provisions, relative goods prices, and all the factors that influence the discounted present value of a stream of future returns. Since the depreciation rates for each class of investment have been selected, explanatory equations are now fitted to net investment calculated by the scheme:

$$I^n_t = I^g_t - \rho K_{t-1} \qquad (5)$$

where ρ is .01 for NRC and .05 for M&E. In this way we restrict the coefficient of K_{t-1} to its hypothesized correct value, preventing it from influencing our decisions about other variables. We also reduce the proportion of total variance explained by our basic model, thus giving our new variables more scope in which to play their roles.

There are several specifications possible for a model with new variables added. If we denote F_t as a general financial variable, we could have any of the following forms:

$$(KGAP)_t = \sum_{i=0}^{n} W_i (F_{t-i} K^*_{t-i} - K_{t-i-1}) \qquad (6)$$

$$(KGAP)_t = \sum_{i=0}^{n} W_i F_{t-i} (K^*_{t-i} - K_{t-i-1}) \qquad (7)$$

$$I^n_t = a + bF_t(KGAP)_t \qquad (8)$$

$$I^n_t = a + b(KGAP_t) + d \sum_{j=0}^{m} V_j F_{t-j} \qquad (9)$$

where V_j are weights summing up to one that may correspond to the W_i. Clearly (9) includes the case $V_0 = 1$, $V_j = 0$, $(j \neq 0)$, in which F_t enters currently and linearly. Specification (6) implies that the variable affects the desired level of capital services, thus entering directly into the choice of inputs to the implicit production function. In a static, neoclassical world this is the appropriate specification since the level of investment cannot be influenced at any other point. Specifications (7) and (8) imply, on the other hand, that the speed of reaction of investors is sensitive to financial conditions, that their acceptance of a given capital shortage may be faster if 'other conditions' are favourable (specification 7), or that previously initiated projects may be put in place faster (specification 8). Both formulations have the difficulty that $(K^*_t - K_{t-1})$ will frequently be negative, and even KGAP will sometimes be so. In this case, mechanical application of (7) or (8) leads to the sign of $\frac{\partial I^n}{\partial F}$ changing with that of KGAP; this is, of course, wrong. To avoid this problem form (7) and (8) can be fitted with F_t multiplied only by the positive values, in the form:

$$I^n_t = a + b_1(KGAP)_t + b_2F_t(KGAP)^+_t \qquad (8')$$

The idea that investors only react to financial conditions when desired net investment is positive is a plausible sort of formulation.

Forms (6), (7), and (8) strongly suggest also that variables be used in some sort of index form based around one; this is necessary in (6) and desirable in (7) and (8) to avoid changing the value of b. If the reaction coefficient changes over the cycle, its long run value should not be influenced by F_t. This will only be true of our equations if the long run value of F_t is one, and if F_t and KGAP are uncorrelated. Finally form (9) implies that a variable is influential in the investment process, either at the stage of initiation or at the stage of completion of projects, or somewhere in between (depending on the time-shape of the V_j), but its impact could not be captured in a theoretically satisfactory manner. Its correct specification has not been found, and the linear form gives a reasonable approximation. This is obviously preferable to excluding the variable. Several different specifications were used for V_j. Both NRC and M&E were tested with linear variables entering currently, then with lags equal to those used on the accelerator term — PLLAG and MLAG respectively. In addition, an intermediate J-lag was used, with weights 0.0, 0.30, 0.35, 0.25, 0.10, for both classes of investment. Finally some M&E specifications were also tested with the M&E polynomial lag shown in Table 2.

The general variable F_t was given content in several different forms, both singly and in combination. In each case, efforts were made to assess the role a given variable played in the equation, since it was recognized that each variable could have several meanings. The variables used were: cash flow ratio (CFR), the industrial bond yield (IBY), the industrial bond index (IBI), which is simply a ratio of moving average to current values of the form:

$$IBI = \sum_{i=1}^{12} IBY_{t-i}/12IBY_t \qquad (10)$$

the average yield on government securities (10BY) of over 10 years to maturity, the government bond index (10BI), the yield on a group of selected equities (EY), the equity index (EI) calculated as in (10), the bond/equity variable (BEY), which is a weighted average of IBY and EY, the bond/equity index (BEI), the stock price index (SI), and the current and future policy variables (CPV, FPV).

CFR is calculated from the sum of corporate retained earnings and depreciation allowances (DB 1393, DB 3711), deflated by the ratio of current dollar to constant dollar business spending on plant and equipment. The current dollar series are (DB 215 and DB 216). This cash flow series is fitted to a linear trend from 1950 to 1965, and the CFR is the ratio of current to trend value.

CFR is intended to represent an availability constraint on investment, based on the commonplace that internal funds have a lower marginal cost to the firm than external funds. Its influence is not clear-cut, however, because cash flow and profits are highly correlated, and CFR could play a strong expectational role. The roles of IBY, IBI, 10BY, and 10BI are fairly clear-cut. They are intended to represent the marginal cost of external debt finance. But both IBY (which is the McLeod, Young, Weir index of ten industrial bonds (DB 268)), and 10BY, (the average yield on government bonds of over ten years to maturity (DB 2764)), have substantial trend components. The latter series is clearly a less adequate representation of the marginal cost of external debt finance to the private sector (both of course are inadequate in that they represent average rather than marginal costs), but it has the advantage of being the long rate generated elsewhere in the simultaneous econometric model. 10BY should enter our equations in a manner parallel to IBY, but less significantly. IBI and 10BI both eliminate any trend in interest rates, but they are relative rather than absolute cost factors. This may be appropriate since $(K/Y)^T$ should reflect trends in finance costs. The present cost of finance relative to its recent values might influence the speed of business reaction; presumably it should not influence K_t^* directly in the form of (6). An interest index that was picking up cyclical expectation factors might enter as in specification (6); but in this case favourable expectations would be associated with high current interest rates and low values of the interest index, and would have a lower value of K_t^* after multiplication by the index. Thus there is no danger of expectations effects masquerading as cost effects in this specification; the two would have the opposite effect in the equation, and a strongly expectational interest index, used as in specification (6), would wreck the accelerator term.

Variables EY, EI, and SI are meant to represent compounds of cost and expectation factors. EY is the Moss, Lawson ratio of latest declared dividend at annual rates to current stock price for 114 stocks (DB 2765); SI is the D.B.S. Index of Industrial Common Stocks (DB 2597), fitted to a log trend from 1946 to 1965 and then taken as ratio to trend. SI should represent purely expectational factors. This variable compared with EY or EI can suggest whether the equity yield is playing an expectational or a cost-of-funds role, which is useful because IBY and EY jointly may represent a closer approximation to the marginal cost of funds than does either one alone. On the other hand, an equity yield stronger than the bond yield suggests an expectational role that can be confirmed by SI. This type of combination is embodied in BEY, which is a quarterly series combining EY and IBY with weights equal to their proportionate shares in gross corporate new issues. This variable should play a cost role, but separate examination of IBY and EY is necessary to ensure that it is not dominated by an expectational equity yield. Finally, CPV and FPV were calculated to show the influence of the government's changes in depreciation provisions and in the sales tax on construction materials and machinery and equipment. CPV calculates the present value of depreciation provisions relative to 1Q51, adjusting for percentage changes in the price of capital goods due to the sales tax. The index is intended to parallel price effects, rising as the value of depreciation provisions falls. FPV is the expected value of CPV eighteen months hence on the naive assumption that investors believe what the government tells them. It is expected to enter the determination of b in ratio to CPV, while CPV should enter the determination of K^*. The derivation of the two variables is described in Appendix A.

At this stage the empirical results for NRC and M&E begin to diverge, as it becomes clear that different variables and different specifications are relevant to the two classes of investment. Consequently, reporting of the experimental results has been split, and NRC and M&E have been dealt with separately.

1. Non-Residential Construction

In this section we shall discuss the outcome of the NRC experiments, some of which are presented in Tables 6 to 9.

Tables 6 and 7 are largely unsatisfactory efforts to use a linear form for NRC. All the variables tested are strongly significant, but they are, in general, wrongly signed. The cash flow ratio has the correct sign and is significant throughout, but tends to weaken the accelerator coefficient substantially. In current form, CFR does not lead to a strong fit, though it does have the desirable property of small and mostly insignificant seasonals. Shifting CFR to a PLLAG structure strongly increases

Table 6 Net NRC with Financial Variables Linear and Current

KGAP is PLLAG

Q1	Q2	Q3	Q4	KGAP	CFR	IBY	BEY	EY	SEE	$\bar{R}^2$	D/W
- 66.73	6.26	163.53	106.89	.028	326.81				73.6	.729	0.35
(0.61)	(0.05)	(1.20)	(0.86)	(2.75)	(2.71)						
-271.47	-118.27	26.16	- 72.44	.070		104.43			56.0	.843	0.63
(3.63)	(1.58)	(0.34)	(0.94)	(8.04)		(6.77)					
-282.62	-126.89	20.97	- 81.09	.052			106.10		65.6	.784	0.49
(2.53)	(1.14)	(0.19)	(0.71)	(5.72)			(4.59)				
- 0.27	149.00	288.75	197.83	.086		107.48		-58.13	52.0	.864	0.72
(0.00)	(1.29)	(2.52)	(1.69)	(8.80)		(7.49)		(2.90)			
-608.80	-546.19	-395.29	-455.46	.061	363.62	107.91			46.1	.894	0.90
(6.52)	(5.04)	(3.67)	(4.47)	(8.24)	(4.80)	(8.50)					
-746.80	-698.73	-543.45	-601.17	.042	433.21		123.33		53.9	.854	0.84
(5.60)	(4.66)	(3.64)	(4.19)	(5.46)	(4.81)		(6.38)				
-474.33	-402.22	-253.73	-315.84	.068	320.03	108.55		-20.15	46.1	.893	0.87
(2.85)	(2.20)	(1.41)	(1.80)	(6.75)	(3.64)	(8.53)		(0.98)			

Table 7 Net NRC With Financial Variables Linear and PLLAG

KGAP is PLLAG

Q1	Q2	Q3	Q4	KGAP	CFR	IBY	EY	BEY	SI	SEE	$\bar{R}^2$	D/W
-649.91	-498.38	-347.10	-440.57	.011	849.42					49.7	.876	0.69
(6.21)	(4.75)	(3.31)	(4.19)	(1.60)	(8.42)							
-108.00	42.32	192.52	97.91	.070		73.54				74.2	.724	0.37
(.81)	(.32)	(1.43)	(.72)	(4.30)		(2.52)						
252.44	406.97	558.26	466.99	.035				- 6.62		79.2	.686	0.31
(1.09)	(1.75)	(2.40)	(2.00)	(2.30)				(.13)				
1,039.92	1,187.95	1,336.89	1,241.20	.084		14.02	-175.45			46.3	.892	0.91
(6.60)	(7.53)	(8.47)	(7.85)	(8.18)		(.72)	(8.57)					
-693.00	-542.28	-391.25	-485.37	.020	818.48	16.69				49.9	.875	0.70
(5.86)	(4.56)	(3.28)	(4.05)	(1.54)	(7.54)	(.79)						
-590.46	-438.60	-287.25	-380.47	.008	850.46			-13.03		50.1	.874	0.69
(3.32)	(2.46)	(1.61)	(2.12)	(.81)	(8.35)			(.42)				
335.14	484.16	633.98	538.92	.052	444.61	3.21	-116.30			40.6	.917	1.13
(1.45)	(2.10)	(2.75)	(2.34)	(4.22)	(3.81)	(.19)	(4.90)					
-256.26	- 99.51	51.83	- 37.51	.013					440.02	72.8	.735	0.37
(1.55)	(.60)	(.31)	(.23)	(1.09)					(2.91)			
-617.79	-466.70	-315.43	-409.26	.014	882.39				-60.72	50.1	.874	0.69
(4.96)	(3.75)	(2.54)	(3.30)	(1.60)	(7.21)				(.49)			
-671.83	-521.25	-370.20	-464.44	.020	838.81	14.94			-31.46	50.4	.873	0.70
(4.50)	(3.48)	(2.47)	(3.10)	(1.54)	(6.01)	(.66)			(.24)			

its significance and picks up over fifty per cent of the residual variance. On the other hand, KGAP is nearly wiped out and the seasonals rise sharply. The cash flow ratio clearly plays a strong role, although in this form it weakens our model. The great improvement achieved with CFR PLLAG suggests that non-residential construction programmes tend to be relatively inflexible once initiated and that the financial climate when the capital shortage occurs is much more influential on the investment later put in place than are subsequent conditions. This holds whether CFR plays an expectations or a cash flow restraint role and is in line with a priori expectation.

As for the financial variables tested, IBY is wrongly signed in all equations. In current form it adds strongly to the power of the equation, though with the wrong sign. It is not clear how this should be interpreted, whether it is acting as an activity proxy or whether the causal sequence is reversed — high levels of building driving up interest rates. Yet if CFR is a cash flow variable and operates with a lag, this implies that projects are financed when initiated, not on a pay-as-you-go basis. This is much more plausible, but then why are current rates so strongly correlated and lagged rates generally less so? In any case it is clear that the appropriate interest cost variable has not been found. The current bond/equity variable BEY is off as badly as IBY wherever it is used and the same pattern recurs. For EY, however, the sign is correct in current form and strongly correct in lagged form. Since it diverges from the behaviour of IBY, EY is probably exhibiting its expectations variable aspect. When EY is combined with CFR and IBY, all PLLAG, the latter drops out entirely and CFR loses much of its weight. Also the accelerator coefficient recovers substantially. This combination (with IBY excluded) is probably the optimal linear equation for NRC. All equations were run with linear variables in a JLAG format as well;[10] this gave results part way between current and PLLAG, as expected. JLAG CFR was better than current, but worse than PLLAG, and the interest and equity variables were also intermediate.

An interesting aspect of the expectations problem is brought out by the use of the stock index PLLAG in Table 7. By itself,

[10]See Table 2.

this variable is correctly signed, but it adds little to the value of the equation and knocks out the accelerator term. In conjunction with CFR, however, it is, in turn, knocked out. The equity yield EY does not drop out in this way; on the contrary it adds greatly to the power of the equation. When EY is added to IBY, $\overline{R}^2$ rises from .724 to .892 and, even when CFR is included, $\overline{R}^2$ rises from .875 to .917. Thus it appears that EY is superior to SI as an expectations index. Perhaps this is so partly because SI is a stock price index, while EY is a ratio of dividends to stock prices. EY thus abstracts from the variance of stock prices the amount related to the variance of current dividends, leaving perhaps a purer measure of optimism or pessimism about the future.

Thus we strongly suspect that CFR is behaving like an expectations variable rather than a cash flow constraint variable. This is interesting when compared with the statement by Michael Evans ([7] p. 152) that: "Profit-type variables are more important as flow-of-funds variables rather than as expectations variables. Thus lagged rather than present values are more relevant in explaining investment...." With the second half of the statement, we obviously concur. But does it really follow from the first half? Our results show CFR and EY competing for explanatory power. If CFR is not expectational, what is EY? Do we hypothesize that most new construction is financed by equity issue, hence the irrelevance of IBY? We would rather not.

Since CFR appears to exhibit its main impact at the point of initiation of investment projects, and so to be most influential with a long lag, it was tested directly on K_t^* as in formulation (6). This implies that desired capital stock is a function of the long run factors embodied in the trend capital/output ratio, the present level of output, and expectations about future output embodied in the CFR. As can be seen in Table 8, the equation in this form is greatly superior to current CFR and only somewhat inferior to the lagged linear CFR. The coefficient on KGAP gains greatly in significance, but decreases in size, reflecting a substantial increase in the fluctuations of the KGAP variable. When further linear variables were added, this accelerator coefficient displayed remarkable stability, moving within a range of one standard error.

The bond yield, when added lagged to this format, is insig-

Table 8 Net NRC $K^{*} = (CFR)\ (K/Y)^{T}(Y)$, Financial Variables Linear and PLLAG. KGAP is PLLAG

Q1	Q2	Q3	Q4	KGAP	IBI	IBY	EY	EI	10BI	t	SI	SEE	$\bar{R}^2$	D/W
217.56	369.15	521.08	427.90	.026								56.7	.839	0.53
(13.40)	(22.91)	(32.24)	(26.61)	(8.26)										
-308.97	-158.42	- 7.12	-101.58	.029	548.90							44.4	.901	0.84
(3.23)	(1.65)	(.07)	(1.06)	(11.30)	(5.55)									
772.40	922.30	1,072.74	978.56	.027		-14.95	-100.27					42.4	.910	0.99
(5.03)	(5.99)	(6.98)	(6.35)	(9.38)		(.96)	(5.21)							
-138.22	14.54	167.39	72.46	.026					376.08			49.6	.879	0.69
(1.56)	(.16)	(1.88)	(.81)	(9.11)					(4.09)					
-244.52	- 94.92	56.45	- 41.11	.033	393.72					1.97		36.4	.935	1.28
(3.07)	(1.19)	(.71)	(.51)	(14.78)	(4.45)					(4.97)				
-325.02	-172.85	- 20.05	-115.44	.029	560.41						11.94	45.3	.899	0.83
(2.01)	(1.07)	(.12)	(.72)	(7.17)	(5.47)						(.11)			
208.43	359.45	511.45	415.58	.030	319.25		- 60.54					39.8	.922	1.11
(1.25)	(2.16)	(3.08)	(2.50)	(13.00)	(2.87)		(3.65)							
- 92.11	58.78	210.91	113.85	.031	707.67			-339.37				42.0	.913	0.94
(.76)	(.48)	(1.74)	(.94)	(12.29)	(6.47)			(2.71)						
TQ1	TQ2	TQ3	TQ4											
- 1.21	1.71	4.55	2.78	.0322	303.61							36.2	.936	1.33
(2.80)	(4.04)	(10.89)	(6.81)	(14.58)	(15.06)									
- .90	2.02	4.86	3.09	.0307					290.13	Final Equation		36.4	.935	1.31
(2.15)	(4.96)	(12.06)	(7.83)	(13.70)					(14.94)	OLS				

nificant; while the equity yield has a strong negative sign and helps the equation considerably. Most notably, however, the bond index PLLAG has the correct sign and is strongly significant. The significance of the bond index PLLAG is unaffected by the addition of the stock index and only partially reduced by the equity yield. It is possible that a genuine cost-of-funds impact has been isolated. The performance of 10BI relative to that of IBI provides further evidence of a cost-of-funds role. A cost-of-funds argument would require 10BI to behave similarly to IBI but not so well, because presumably 10BI is a less appropriate measure of the true cost of finance to the firm. If instead IBI picks up expectational factors, nothing much can be said about the reaction of IBI and 10BI. In fact we find that 10BI is similar to IBI but raises the $\bar{R}^2$ less, has a lower coefficient, and is slightly less significant. These results are far from 'proof' of the cost-of-funds hypothesis, but at least they fail to contradict it.

One further suggestive feature of the linear results is the strong performance of the trend term, a factor whose importance was clear from the residuals. By itself, the existence of such a trend is a rather puzzling feature. In conjunction with the seasonals, however, the trend performs even better, and the significance of the other variables is greatly increased. That the size of the seasonal dummies should grow over time with the growth in NRC investment is a much more plausible feature. The trend is fitted from 1947 to 1965; this means that the rate of increase over the regression period (1953-65) is lower than it would be if the trend began in 1953.

This procedure yields our final equation and enables us to finish with a very reasonable result. The fit is better than any previous results, and all coefficients are strongly significant. The cash flow variable enters directly into the determination of the desired capital stock, suggesting an expectational role; but the bond index appears to be playing a cost or constraint role, and this is what we should want it to do. Both variables enter only with the same lag as the accelerator variable, suggesting that, once initiated, construction projects are not very flexible and do not respond much to more current conditions. Another encouraging note is that the Durbin/Watson statistic is up sharply over all previous experiments. It is even possible at this level that autocorrelation is not present, though a look at the residuals makes this a bit doubtful. In any case autocorrelation is not nearly so severe a problem as it has been throughout our earlier experiments.

Breaking out the relationship between the interest rate and the quarterly investment level requires one to pass through two lag structures. The level of investment follows the bond index with a PLLAG pattern, and the index depends on the current and past twelve quarters' interest rates. The mean values of I^n_{NRC} and I^g_{NRC} are \$357 million and \$626 million over the period 1953-65. IBI and 10BI have means of .9661 and .9506. Their respective coefficients are 303.61 and 290.13, leading to long run elasticities of net investment of .82 and .77, and gross investment of .46 and .44. These elasticities are with respect to changes in the bond indices and take eleven quarters to work through. The instantaneous elasticity of a change in the index is, of course, 0, while the maximum response in any one quarter of I^n_{NRC} to a maintained change of 1% in the IBI is .14%.

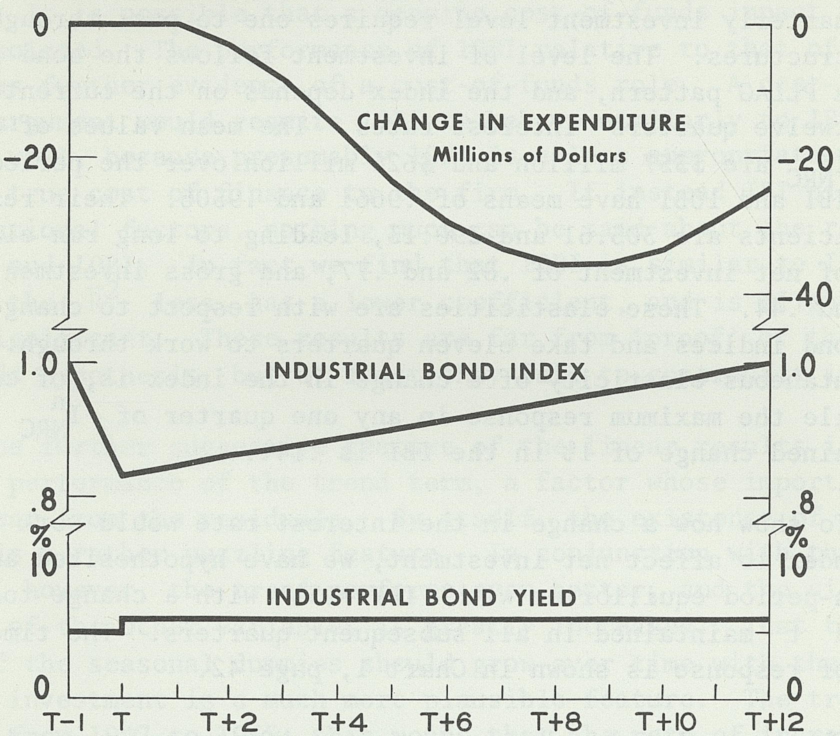
To show how a change in the interest rate would work through the index to affect net investment, we have hypothesized an initial n-period equilibrium with IBY = 5% with a change to 6% in period t maintained in all subsequent quarters. The time pattern of response is shown in Chart 1, page 42.

The accumulated reduction in gross NRC expenditures is \$272 million by the end of twelve quarters. Of course, one would expect multiplier effects on Y to change this pattern of response, but this would require a simultaneous model. The impact on quarterly investment is falling, though still substantial. Thus the long bond rate operates with substantial lags and with no particular force in any one quarter.

Table 9 represents the outcome of experimentation with our policy variables, as well as with a slightly different model that did not work out. The first two equations represent the final equation from Table 8 with K^* multiplied by 100/CPV, and in the second case, with FPV/CPV multiplied by the positive values of $(K^*_t - K_{t-1})$ before the weighting pattern is applied. As can be seen, the use of CPV alone has almost no effect on the equation; use of FPV and CPV together weakens the other coefficients, although adding to both $\overline{R}^2$ and D/W. Unfortunately, not much

Chart 1

REDUCTION IN GROSS NON-RESIDENTIAL CONSTRUCTION EXPENDITURE IN RESPONSE TO A 1% INCREASE IN THE INDUSTRIAL BOND YIELD



significance can be read into this result since the raw correlation between KGAP and KGAP$^+$ FPV is .9474. There has not really been enough variation in tax policy for our CPV and FPV variables to show themselves over the relevant data period.

The last two equations are run on a model designed to evade the problem of the negative KGAP. Here the dependent variable is gross investment, and the initial model is broken up thus:

$$KGAP = \sum_{i=0}^{n} W_i (K^*_{t-i} - K_{t-i-1} + \rho K_{t-i-1})$$

This implies that depreciation investment is not an automatic factor entering currently and equal to the amount of capital

Table 9 NRC PLLAG Other Specifications

Dependent Variable is Net NRC

TQ1	TQ2	TQ3	TQ4	KGAP with $\frac{100}{CPV} K^*$	IBI	$KGAP^+$ with $\frac{FPV}{CPV} (K^* - K_{t-1})$	SEE	$\bar{R}^2$	D/W
- 1.36 (3.06)	1.58 (3.66)	4.44 (10.39)	2.69 (6.42)	.032 (14.08)	316.32 (15.22)		37.3	.932	1.28
- 1.85 (3.77)	1.15 (2.46)	3.99 (8.56)	2.25 (4.95)	.016 (1.91)	285.50 (11.41)	.0003 (2.06)	36.0	.936	1.37

Dependent Variable is Gross NRC

Q1	Q2	Q3	Q4	KGAP1	KGAP2	KGAP1 with CFR	KGAP2 with CFR	SEE	$\bar{R}^2$	D/W
-20.04 (.37)	127.87 (2.32)	278.04 (5.00)	181.23 (3.20)	.084 (6.98)	.063 (5.88)			64.9	.830	0.45
- 7.01 (.21)	144.79 (4.22)	295.18 (8.52)	196.28 (5.55)			.064 (8.72)	.043 (6.41)	45.9	.915	0.86

stock worn out; but rather is to be treated symmetrically with capacity-expanding investment. It will be subject to the same lag structure and the same elasticity of expectations considerations. Breaking up the equation:

$$KGAP = \sum_{i=0}^{n} W_i K^{*}_{t-i} + \sum_{i=0}^{n} W_i (\rho - 1) K_{t-i-1}$$

$$\equiv KGAP1 + KGAP2$$

Clearly the coefficient of KGAP2 should be $(\rho - 1)$ times that of KGAP1 and both can be multiplied by any term whose influence is to be exerted on the speed of reaction. Unfortunately, as can be seen from the table, this model is most inadequate. The coefficient on KGAP2 is wrongly signed and is too small relative to KGAP1. Moreover, the raw correlation between the two is -.9874, which may go some distance toward explaining the unsatisfactory structure. It appears that, while work in this direction might be interesting and useful, some way around the collinearity problem would have to be found. And that is another paper.

2. *Machinery and Equipment*

The results for machinery and equipment are somewhat mixed, as shown in Table 10. The first seven equations in the table represent efforts to include current linear variables, and of these only CFR produces the correct sign with both significance and explanatory power. The IBY and the BEY have no significance, and IBY has the wrong sign; in conjunction with EY, IBY becomes correctly signed but is still insignificant. The substantially stronger performance of EY strongly suggests that this variable is expectational and is unconnected with the cost of funds. Both these indications are confirmed when the CFR is included in the equations; IBY becomes slightly larger and positive, and EY loses significance. None of these variables add anything to CFR in the current form.

When some variables were tested with the JLAG (0.0, 0.30, 0.35, 0.25, 0.10), the interest rate variables gained in sign and significance. Results are reported only for CFR and BEY, but, in

Table 10 Net M&E. Financial Variables are Linear, Current Equations 1 to 7 and JLAG Equations 8 to 10. KGAP is MLAG

Q1	Q2	Q3	Q4	Q1KGAP	Q2KGAP	Q3KGAP	Q4KGAP	CFR	IBY	BEY	EY	b	SEE	$\bar{R}^2$	D/W
-283.51	-221.31	-358.44	-319.08	.142	.136	.124	.174	385.0	(final phase two equation OLS)			.144	44.0	.840	0.73
(4.65)	(2.83)	(4.68)	(4.58)	(4.78)	(4.62)	(4.47)	(6.38)	(5.52)							
156.23	317.67	148.16	188.98	.187	.201	.154	.213		1.36			.188	50.8	.764	0.58
(2.33)	(4.70)	(2.16)	(2.68)	(4.68)	(5.05)	(3.95)	(5.58)		(.12)						
203.41	365.69	196.39	239.40	.188	.204	.157	.217			- 8.06		.191	50.7	.765	0.58
(2.21)	(3.92)	(2.12)	(2.46)	(4.72)	(5.09)	(4.02)	(5.61)			(.47)					
426.11	579.67	400.04	458.41	.214	.221	.164	.237		- 9.50		-42.16	.209	47.9	.790	0.60
(3.42)	(4.75)	(3.36)	(3.64)	(5.47)	(5.76)	(4.43)	(6.36)		(.80)		(2.51)				
-240.18	-171.30	-330.66	-258.18	.174	.175	.143	.195	367.38	16.27			.172	42.1	.853	0.79
(2.52)	(1.53)	(3.03)	(2.45)	(5.20)	(5.18)	(4.40)	(6.08)	(5.21)	(1.61)						
-271.15	-204.72	-360.57	-291.72	.171	.171	.143	.191	373.70		21.63		.169	42.5	.851	0.82
(2.21)	(1.46)	(2.65)	(2.17)	(5.05)	(4.92)	(4.34)	(5.74)	(5.07)		(1.38)					
-127.51	- 53.55	-217.42	-141.75	.184	.184	.147	.205	340.12	11.85		-12.91	.180	42.3	.852	0.76
(.74)	(.78)	(1.20)	(.78)	(5.11)	(5.14)	(4.45)	(5.95)	(4.31)	(1.02)		(.78)				
-113.29	60.93	-111.32	- 83.55	.165	.179	.128	.187	255.80				.164	46.1	.806	0.69
(1.19)	(.67)	(1.22)	(.87)	(4.48)	(4.85)	(3.55)	(5.29)	(3.04)							
396.63	559.26	391.16	433.20	.187	.202	.156	.216			-47.91		.190	46.7	.800	0.65
(4.48)	(6.30)	(4.42)	(4.84)	(5.08)	(5.50)	(4.38)	(6.19)			(2.79)					
115.84	287.79	117.07	148.75	.170	.184	.136	.196	194.88		-33.51		.171	44.7	.817	0.73
(.76)	(1.93)	(.78)	(.97)	(4.73)	(5.13)	(3.84)	(5.64)	(2.22)		(1.89)					

general, equations on IBY and IBY plus EY were similar. Both variables had correct signs, roughly equal coefficients with IBY slightly larger, and coefficients summing to a value a little larger (absolutely) than the coefficient of BEY. For the most part, the significance of the individual coefficients was slightly lower than the significance of BEY.

This generally good picture is marred by a problem made apparent if CFR JLAG is compared with CFR current, the latter being obviously much superior. The coefficient is larger, the t value is greater, and the $\bar{R}^2$ is up. Thus IBY and EY have produced their good results only when included with a less satisfactory CFR variable. Since it is clear that current CFR is the correct variable, we have to move to estimation of our linear variables with various lags in conjunction with the current CFR. Some results from this procedure are shown in Table 11.

The variables employed in this test were IBY, EY, BEY, IBI, EI, and BEI, all entering both currently and with MLAG, while CFR was entered currently. In addition, a trend term was entered to parallel the NRC results. From these regressions, all but the four reported in Table 11 produced wrong a priori signs and/or insignificant coefficients on the financial variables. The trend variable was completely insignificant. Of the current variables, only the expectational impact of EY, EI, and SI was picked up, and, as can be seen, the inferiority of SI as an expectational index was confirmed. EY had the correct sign; EI was even better and greatly strengthened the accelerator coefficients. But the impact of EI grows at the expense of the CFR, confirming the expectational role of the latter. Best fit of all and a marked reduction in autocorrelation were achieved by using both EI and IBI currently; but unfortunately the strong negative coefficient of the latter makes this unacceptable.

Efforts to include the financial variables with a MLAG pattern were uniformly unsuccessful. All were insignificant, even the strong EI whose coefficient went almost to zero and took on the wrong sign. This seems a clear indication that financial variables at the point of project initiation are much less important to M&E investment. Presumably such investment programmes are much more flexible and thus respond strongly to current expectations as embodied in CFR or EI. Financial constraints do not

Table 11 Net M&E on CFR Current and Other Current Linear Variables. KGAP is MLAG.

Q1	Q2	Q3	Q4	Q1KGAP	Q2KGAP	Q3KGAP	Q4KGAP	Current Financial Variables: CFR	Current Financial Variables: EY		b	SEE	$\bar{R}^2$	D/W
6.06	88.79	- 77.32	- .34	.192	.193	.154	.215	304.99	-21.13		.179	42.4	.852	0.72
(0.05)	(0.70)	(0.65)	(0.00)	(5.46)	(5.55)	(4.74)	(6.53)	(4.29)	(1.46)					
									SI					
-133.89	- 45.78	-204.19	-135.10	.178	.182	.151	.206	293.06	42.04		.181	43.3	.845	0.73
(1.95)	(0.53)	(2.52)	(1.78)	(5.17)	(5.25)	(4.55)	(6.22)	(2.61)	(0.48)					
									EI					
-247.28	-149.23	-327.67	-241.93	.228	.226	.175	.250	231.82	235.48		.220	40.5	.865	0.77
(3.13)	(1.68)	(3.67)	(2.94)	(5.99)	(6.11)	(5.38)	(7.00)	(3.01)	(2.51)					
										IBI				
- 45.84	73.95	-126.84	- 32.00	.254	.245	.172	.267	129.70	424.25	-301.43	.235	35.2	.898	1.16
(0.53)	(0.76)	(1.35)	(0.35)	(7.51)	(7.53)	(6.07)	(8.52)	(1.80)	(4.45)	(3.82)				
										BEY MLAG				
-207.25	-137.22	-294.12	-220.32	.177	.180	.150	.203	366.73		10.67	.178	43.3	.845	0.76
(1.09)	(0.64)	(1.39)	(1.08)	(5.15)	(5.19)	(4.54)	(6.20)	(3.69)		(0.44)				
										BEY JLAG				
-169.34	- 95.02	-252.41	-179.98	.176	.179	.149	.202	351.53		5.36	.177	43.4	.845	0.75
(0.94)	(0.46)	(1.26)	(0.93)	(5.08)	(5.10)	(4.48)	(6.09)	(3.64)		(0.24)				

seem to be significant at either end of the process. Tests were also run with the JLAG pattern on the financial variables; but these were also of no help. Table 11 gives two of the equations, both with KGAP in MLAG, CFR in currently, and BEY in as MLAG and as JLAG. As can be seen BEY has the wrong sign and contributes nothing to the equation. This behaviour was general for the financial variables with either lag pattern.

Efforts were also made to include the financial variables multiplicatively, but this was not successful. Carrying the CFR into K^*, as had been done for NRC, was a complete failure; the average b coefficient was reduced by one-third, the $\bar{R}^2$ dropped below .60, and the Durbin/Watson was halved. Even so, the accelerator remained significant; but it was clear that this form could not be used. This is at least a consistent result; our linear experiments have shown the strong superiority of current over lagged CFR. Efforts to bring in the CFR multiplicatively with KGAP or with $(K^*_{t-i} - K_{t-i-1})$ were thwarted by the prevalence of negative terms, to be expected in total M&E, since the stock of such capital is growing less rapidly than NRC. Here the implications of our required assumptions about embodied technical progress may be returning to trouble us. A possible solution to this problem, unfortunately not considered until the experimentation was completed, would be to use the reciprocal of CFR multiplicatively with KGAP. It is possible that such a manoeuvre would set up the type of breakthrough achieved in NRC with CFR multiplied by K^*, but it is not necessarily so. The strong positive associations between present financial conditions and M&E investment, combined with their complete impotence in lagged form, would be quite hard to reverse. The only helpful linear variable is the current equity yield, which apparently captures some aspect of expectations formation that the CFR does not. But this variable is hardly useful as a predictive tool. Thus the best equation appears to be simply the accelerator model with the current CFR, explicitly admitting that M&E investment is pretty responsive to current conditions but insensitive to most financial considerations.

An effort was also made to insert variables that would indicate international influences on Canadian investment. A terms of trade variable (ratio of prices of goods exports to goods imports) and a ratio of 'world activity' to Canadian real domestic product were used for this purpose. Both were tested linearly and, after dividing each series by its mean, multiplicatively with K^*. In the linear form neither variable was significant, while multiplicatively the terms of trade variable badly weakened the accelerator. The activity ratio had little effect. In addition, the long rate differential between Canada and the U.S. was included linearly. Unfortunately the rates themselves are highly collinear (.97 simple correlation), and even in index form the U.S. and Canadian government long-term bond interest index variables have a simple correlation of .896. If both interest rate indices are put in the NRC equation, neither is significant, and the U.S. index has a negative sign. If the U.S. index is put in without the Canadian variable, it has a coefficient of 280 with a t value of 11.7. The Canadian rate thus appears to be a slightly more important variable than the U.S. rate, but the strong collinearity between them does not allow us to say with any certainty what would be the effect of a change in the Canadian rate with the U.S. rate unchanged. Unilateral changes have happened to such a small extent in the past that econometric analysis cannot tell us what would be the result if it did happen. We are only able to say that our estimate of the effects on investment of a change in the Canadian rate are conditional upon the maintenance of the 'usual' interest rate differential between Canada and the U.S.

E. Putting the Phase Two Equations to Work

The experimentation thus far has simply involved the use of an OLS format to choose the optimum equation structure. We have attempted with some limited success to develop a theoretically justifiable structure that would perform adequately when fitted to our data period. For non-residential construction we now have an accelerator model embodying both expectations and cost-of-capital variables. Fitting the model produces the equation:

1Q53 - 4Q65 (OLS)

$$I^n_{NRC} = \underset{(2.15)}{-.90}\, TQ_1 + \underset{(4.96)}{2.02}\, TQ_2 + \underset{(12.06)}{4.86}\, TQ_3 + \underset{(7.83)}{3.09}\, TQ_4$$

$$+ .0307\,(KGAP)_t + 290.13 \sum_{i=0}^{10} W_i (10BI)_{t-i}$$
$$(13.70) \qquad (14.94)$$

SEE = 36.4 $\bar{R}^2 = .935$ D/W = 1.31

I^n_{NRC} is quarterly net investment in non-residential construction in 1957 dollars, calculated by subtracting from gross investment 1% of the capital stock at the end of the last quarter. T is a trend term, running from 1 in 1Q47 to 76 in 4Q65, and the Q_i are seasonal dummies. KGAP is equal to $\sum_{i=0}^{10} W_i (K^*_{t-i} - K_{t-i-1})$, with W_i the same weighting pattern as used with 10BI. This is the pattern labelled PLLAG with $W_0 = W_1 = 0$, $W_2 = .06$, $W_3 = .11$, $W_4 = .16$, $W_5 = .17$, $W_6 = .16$, $W_7 = .13$, $W_8 = .11$, $W_9 = .07$, $W_{10} = .04$, and with all other $W_i = 0$. The K_t are values for quarterly net capital stock, construction-type, derived with an assumed 1% quarterly depreciation rate. K^*_t is the desired level of capacity, equal to $(Y_t) * (K/Y)^T_t * (CFR)_t$. The component variables are as follows: Real Domestic Product less Agriculture in constant 1957 dollars (Y_t); the trended capital/output ratio $(K/Y)^T_t$, which is the 'desired' ratio assumed to embody the various price, tax, discount rate, and other factors affecting the user cost of capital whose influence could not be measured directly; and $(CFR)_t$, which is the ratio of cash flow to its trend value, indicating both expectations about future sales and availability of internal finance. On the basis of experiments described above, we believe the expectations role to be dominant.

10BI is the ten-year bond index, calculated by dividing the current value of the yield on government bonds of ten years and over to maturity into the average value of this yield over the past twelve quarters. It is intended to represent the marginal cost of external debt finance, although it is recognized that it measures the average relative cost of debt finance rather than the marginal absolute cost. An experimentation with the index form was clearly superior to the rate form, which was wrongly signed. The ten-year government rate was used because it is endogenous to the overall simultaneous model; but it is theoretically preferable to use the industrial bond rate, which is the relevant cost to private borrowers. Using this in index form yields:

1Q53 - 4Q65 (OLS)

$$I^{n}_{NRC} = \underset{(2.80)}{-1.21}\ TQ_1 + \underset{(4.04)}{1.71}\ TQ_2 + \underset{(10.89)}{4.55}\ TQ_3 + \underset{(6.81)}{2.78}\ TQ_4$$

$$+ \underset{(14.58)}{.0322}\ (KGAP)_t + \underset{(15.06)}{303.61} \sum_{i=0}^{10} W_i\ (IBI)_{t-i}$$

$$SEE = 36.2 \qquad \bar{R}^2 = .936 \qquad D/W = 1.33$$

As one would expect, this equation is slightly better on all counts, but as one would hope, it is very little different. Thus the use of the 10BI variable made necessary by the simultaneous model is an adequate approximation.

The Durbin/Watson statistic, however, suggests strongly that the residuals from both these equations are autocorrelated. Consequently, though the coefficients are unbiased, their standard errors are underestimated. To see how serious this problem was, we performed a first-order autoregressive transformation on all our variables using a value of $\rho = .35$, derived from the Durbin/Watson statistic, and then refitted the equation. This produced:

1Q53 - 4Q65 (AUTO, $\rho = .35$)

$$I^{n}_{NRC} = \underset{(1.64)}{-0.91}\ TQ_1 + \underset{(3.66)}{2.01}\ TQ_2 + \underset{(8.91)}{4.84}\ TQ_3 + \underset{(5.75)}{3.06}\ TQ_4$$

$$+ \underset{(9.85)}{.0307}\ (KGAP)_t + \underset{(10.40)}{291.43} \sum_{i=0}^{10} W_i\ (10BI)_{t-i}$$

$$SEE = 34.1 \qquad \bar{R}^2 = .935 \qquad D/W = 1.71$$

All standard errors have risen slightly, but in no case is the rise sufficient to cast serious doubts on the significance of a variable. The coefficients on the independent variables are effectively unchanged. The new Durbin/Watson statistic suggests that some second-order autocorrelation may be present, but the problem does not seem severe enough to warrant attention.

The machinery and equipment investment equation is inferior to the NRC both in structure and in terms of goodness of fit. The CFR variable as an expectation indicator turns out to be unusable as a component of K^*, because the accelerator drops out of the equation when CFR is used multiplicatively with Y_t and $(K/Y)^T_t$. CFR does however enter very strongly in a linear current form, and knocks out all other financial variables. Efforts made to include other cost-of-capital variables, as described above, led to insignificant coefficients and/or wrong signs. Nor was there any observable trend in the seasonals, although it did appear that the strength of the accelerator varied over the year. Consequently the final equation form from the second stage experiments is:

1Q53 - 4Q65 (OLS)

$$I^n_{ME} = \underset{(4.65)}{-283.51}\,Q_1 - \underset{(2.83)}{221.31}\,Q_2 - \underset{(4.68)}{358.44}\,Q_3 - \underset{(4.58)}{319.08}\,Q_4$$

$$+ \underset{(4.78)}{.142}\,Q_1\,\text{KGAP} + \underset{(4.62)}{.136}\,Q_2\,\text{KGAP} + \underset{(4.47)}{.124}\,Q_3\,\text{KGAP}$$

$$+ \underset{(6.38)}{.174}\,Q_4\,\text{KGAP} + \underset{(5.52)}{385.0}\,\text{CFR}_t$$

$$\text{SEE} = 44.0 \qquad \bar{R}^2 = .840 \qquad \text{D/W} = 0.73$$

In this equation I^n_{ME} is net investment in machinery and equipment, found by subtracting 5% of end-of-last-quarter stock from this quarter's gross investment. $(\text{KGAP})_t$ is defined as above except that: (a), K now refers to the stock of machinery rather than of buildings; (b), CFR is not included in K^*, and (c), the weighting pattern of W_i is now MLAG with $W_0 = 0$, $W_1 = .10$, $W_2 = .15$, $W_3 = .30$, $W_4 = .25$, $W_5 = .15$, $W_6 = .05$, and with all other $W_i = 0$. In this form also CFR appears to play an expectational role; although its behaviour in the presence of stock market variables suggested a possible internal funds constraint as well. It is interesting that the behaviour of CFR differs in the two equations — the current form being superior for M&E while the lag is best for NRC.

In this equation, autocorrelation is an even more severe problem than in NRC, which probably reflects the less adequate specification. It was also refitted after a first-order autoregressive transformation which used $\rho = .65$, as indicated by the Durbin/Watson statistic in the OLS equation. The results from this were:

1Q53 - 4Q65 (AUTO, ρ = .65)

$$I^n_{ME} = \underset{(2.98)}{-218.59}\, Q_1 - \underset{(1.51)}{141.02}\, Q_2 - \underset{(3.07)}{281.25}\, Q_3 - \underset{(3.00)}{249.22}\, Q_4$$

$$+ \underset{(5.86)}{.176}\, Q_1\, KGAP + \underset{(5.19)}{.159}\, Q_2\, KGAP + \underset{(4.52)}{.133}\, Q_3\, KGAP$$

$$+ \underset{(6.24)}{.181}\, Q_4\, KGAP + \underset{(3.79)}{314.88}\, CFR_t$$

SEE = 33.5 $\bar{R}^2 = .892$ D/W = 1.78

The seasonal pattern is somewhat changed, and the average accelerator coefficient has risen from .144 to .162. The significance of the accelerator, however, is unchanged, and only the CFR falls slightly. The equation fit is improved, and the standard error of estimate falls sharply. Again, some second-order autocorrelation may be present but is no cause for concern.

The values of I^n derived from the AUTO equations are then added to ρK_{t-1} to derive gross investment series for NRC and M&E. In Chart 2 the actual series are graphed against estimated values from equations fitted 1953-1965. In addition the equations were run forwards into 1966 and 1967 and compared with actual values of those years.

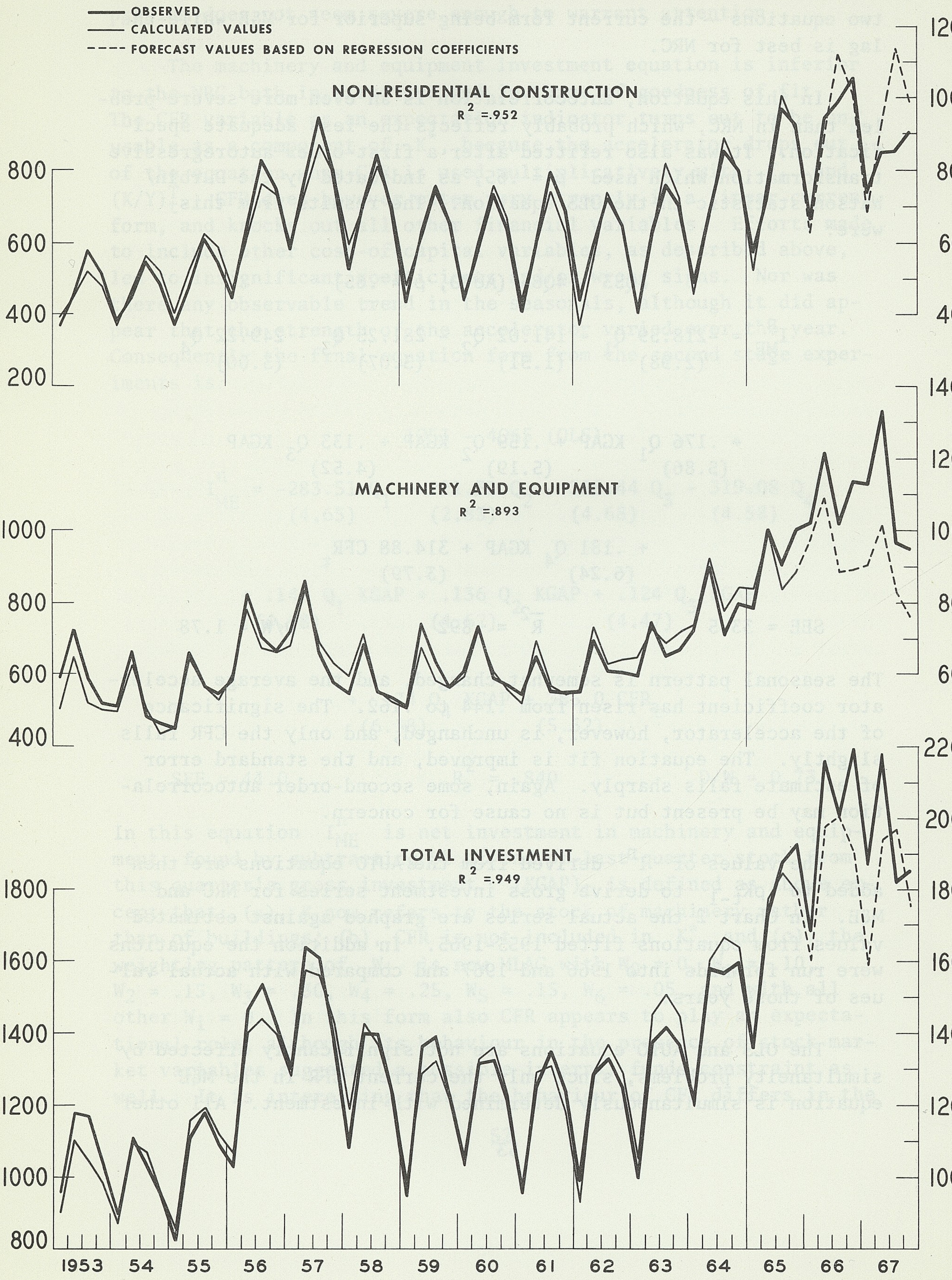
The OLS and AUTO equations are not significantly affected by simultaneity problems, since only the current CFR in the M&E equation is simultaneously determined with investment. All other

Chart 2

GROSS FIXED INVESTMENT FROM EQUATIONS FITTED 1953-65 AND USED TO FORECAST 1966-67

Quarterly - Millions of 1957 Dollars

R^2 measures the fit of the calculated gross investment series over the 1953-65 estimation period.



variables are either exogenous or predetermined. Since the errors in the M&E equations are fairly strongly autocorrelated (ρ = .65), the forecast values from the equation are considerably influenced by the choice of the forecast horizon. The forecasts shown in Chart 2 are started in 1Q66. Although they include knowledge of the forecasting error in 4Q65, they assume that forecasts are not revised on the basis of subsequent forecasting experience. This aspect of the choice of a starting date for a forecasting test affects only the M&E equation, as there is little autocorrelation of the NRC residuals; in any case the NRC equation fits better.

Note that the M&E equation fails to catch adequately the strong burst of spending in 1966 and early 1967. The NRC equation generally fits well, but misses the surprising weakness in construction in 3Q67. Could that many people have finished their Centennial projects by midyear? The forecast for total investment, being the sum of the forecasts for M&E and NRC, also fits fairly well, but has a mean absolute error of 8% of gross investment.

In order to obtain a longer forecasting period and an estimation period comparable to that used by Wilson [28] in his careful analysis of total quarterly capital expenditures, we reestimated the equations using 1953-63 data and used them for some additional forecasting tests.

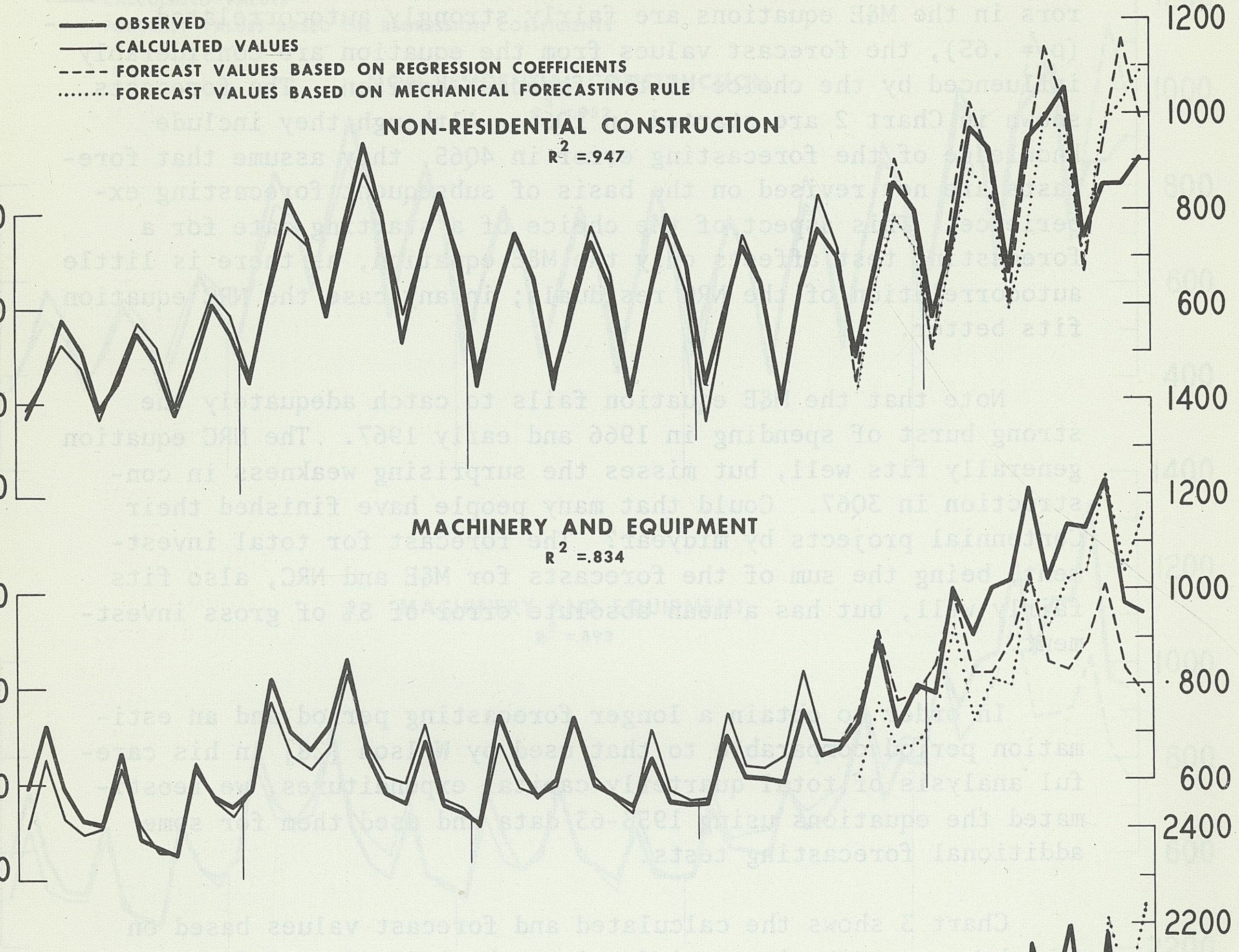
Chart 3 shows the calculated and forecast values based on the shorter estimation period. Over the 1953-63 period, our equation for total investment (obtained by summing the equations for NRC and M&E) has an R^2 of .926 and a standard error of estimate of $53.5 million. This is quite comparable with the seasonally unadjusted data version of Wilson's preferred equation ([28] Table 5, equation 3) which has an R^2 of .923 and a standard error of estimate of $52.6 million. With respect to forecasting ability, it is not possible to compare the two models on a quarterly basis, as Wilson conducts all his forecasting experiments using an equation fitted to seasonally adjusted data. As an alternative forecasting test, we set up what seemed to us the most appropriate mechanical forecasting rule. Under this rule, the forecast for any quarter is equal to the actual expenditures in the same quarter of the previous year, multiplied by the

Chart 3

GROSS FIXED INVESTMENT FROM EQUATIONS FITTED 1953-63 AND USED TO FORECAST 1964-67

Quarterly - Millions of 1957 Dollars

R^2 measures the fit of the calculated gross capital expenditures series over the 1953-63 estimation period.



(arithmetic) average (1953-63) of actual expenditures divided by expenditures in the corresponding quarter of the previous year. We applied the rule separately for NRC and M&E, and obtained an estimate of the total by summing. We obtained forecasts from our model by starting in 4Q63, and by using the actual 1964-67 values of the predetermined variables.[11] The results of both sets of forecasts are shown in Chart 3. In forecasting total gross business capital expenditures, the average absolute forecasting error from our equations for the sixteen quarter forecast period, 1Q63 - 4Q67, is $130 million, while the corresponding error for the mechanical rule is $205 million. This marked superiority of the equations over the forecasting rule is substantially reduced if one looks only at the forecasts for NRC and M&E separately. Much of the assistance provided by the equations at the aggregate level is due to a general absence of errors of the same sign for NRC and M&E. For the NRC forecasts taken by themselves, the equation forecasts gross investment with an average absolute error of $72 million compared to an average absolute error of $90 million for the mechanical rule. For M&E the mechanical rule forecasts slightly better than our equation, with an average absolute error of $127 million compared to $133 million for our equation. In the aggregate, however, the mechanical rule loses out due to its propensity to be wrong on both M&E and NRC in the same direction at the same time.

If the equations are used in a way that takes account of the autocorrelation of the forecasting errors, their performance is further improved relative to the mechanical rule. The mechanical rule already takes account of the autocorrelation of errors by being based on the actual investment in the same quarter of the preceding year. If the M&E and NRC equations are restarted every quarter, taking account of the error in the previous quarter, the average absolute error of our M&E forecast drops from $130 million

[11]The test is not on all fours, as the mechanical model is favoured by being based on actual values of investment drawn from within the forecast period, while our model uses (lagged values of) endogenous variables generated during the forecast period. Given the autoregressive structure of M&E forecasting errors, the test probably favours the mechanical model. Note that the forecast and the mechanical model both run behind from 3Q65 to 1Q66, but the mechanical model then 'learns' from its errors and catches up — Chart 3. Our model, like a real-life forecaster in 1963, cannot do this.

to $72 million. The average absolute error of the NRC forecast rises by $1 million while the average absolute error of the aggregate forecast drops by 20 per cent, from $128 million to $105 million. Unfortunately, forecasting performance achieved in this way is of little cheer to the man who has to forecast two or three years into the future.

Looking over our brief range of tests of the phase two equations, we concluded that they provide some support for our earlier judgment that the NRC equation is fairly sound, while suggesting that further work on the M&E equation might permit better specification of the structure underlying M&E expenditures. The next and final section of the paper reports on our further experiments and presents the latest pair of equations.

F. Further Tests and the Final Equations

In our phase one and two experiments we defined the desired capital output ratio by a trend-through-peaks method, where the dating of the peaks was determined by the relation between capacity and output for the capital stock as a whole. In our latest experiments we have permitted M&E and NRC to have their trends-through-peaks determined separately. The peaks are unchanged for NRC, but for M&E there are now three peaks: 3Q56 and 4Q65, as before, and also 4Q63. The new K/Y equation is:

$$(K/Y)_{ME} = 1.8217 - .00676\, T_1 - .000646\, T_2$$

where T_1 is a time trend starting with the value 1 in 1Q50 and ending in 4Q63, and T_2 is a time trend starting with the value of 1 in 1Q64.

After defining a new K/Y equation for M&E, we had to go back to our phase two experiments and search again for convergence between the assumed rate of depreciation ρ and c — the estimated rate of replacement investment. This also gave us a chance to test the significance of our earlier misgivings about the assumption that ρ should equal c. If the rate of 'automatic' replacement c is chosen by investors so as to maintain the physical productivity of their capital stock (there is no very obvious reason why the rate should be so chosen), then ρ will be greater than c if there is a positive rate of embodied technical progress. Since the data on the prices of secondhand capital goods are presently not adequate to permit estimation of the rate of embodied technical progress,[12] we tested the consequences of various discrepancies between ρ and c in terms of the structure and predictive power of our investment equations.

Table 12 shows that in the second phase gross investment

Table 12 Results of Gross M&E Regressions*

Assumed rate of depreciation ρ	Estimated coefficient on K_{t-1} c	ρ - c	$\bar{R}^2$	SEE
.040	.04489	-.00489	.8411	50.76
:				
.045	.04851	-.00351	.8489	49.49
.046	.04900	-.00300	.8501	49.28
.047	.04941	-.00241	.8513	49.10
.048	.04973	-.00173	.8522	48.94
.049	.04996	-.00096	.8531	48.80
.050	.05007	-.00007	.8538	48.69
.051	.05010	.00090	.8543	48.60
.052	.05004	.00196	.8547	48.54
.053	.04989	.00311	.8549	48.50
.054	.04965	.00435	.8549	48.50
.055	.04933	.00567	.8547	48.53
:				
.060	.04704	.01296	.8507	49.19

* The equation form estimated was:

$$I^g_{ME} = a_1Q_1 + a_2Q_2 + a_3Q_3 + a_4Q_4 + b_1Q_1\ KGAP + b_2Q_2\ KGAP$$

$$+ b_3Q_3\ KGAP + b_4Q_4\ KGAP + cK_{t-1}$$

[12] The problems of identifying the rate are considered in some detail by Hall [10].

model, using the new K/Y equation for M&E, convergence between ρ and c was once again obtained with a ρ of .05 per quarter. Positive rates of embodied technical progress appear to require an assumed rate of depreciation greater than .050. Although the differences are tiny, the value of $\bar{R}^2$ reaches a maximum at $\rho = .053$ and .054, suggesting a .003 or .004 quarterly rate of embodied technical progress. The model with $\rho = .053$, $c = .050$ was then converted into a net investment equation; the current CFR variable was added, parameters estimated with and without autoregressive transformation, and the final results compared to those from the model with $\rho = c = .05$. The standard error of estimate, $\bar{R}^2$, and the forecasting properties of the model with $\rho = c$ were marginally better than those of the models with $\rho > c$.[13] Thus we decided to continue using a model with $\rho = c$. The new K/Y relationship produced a considerable increase in the goodness of fit of the net M&E equation and a less marked, but still worthwhile, increase in forecasting ability.

As a final set of experiments, we tried adjusting all our interest rate variables to allow for changes in expected rates of change of prices. Our 'real' 10BY, for example, was defined as

$$10BY - 100\left[\frac{PGNE - PGNE_{t-4}}{PGNE_{t-4}}\right],$$ where PGNE is the implicit private gross national expenditures price deflator generated in RDX1. These real interest rate variables worsened the fit of our equations, whether in level or index form. Perhaps alternative assumptions about the formation of price expectations would allow price-adjusted interest rates to play a role in our model, but for the time being raw rates will have to do.

We proceed now to outline our final equations, as used in

[13]This would be a puzzling result if CFR really were uncorrelated with the KGAP variables. However, CFR in the 1953-65 sample period has simple correlations with the KGAP variables of .30, -.01, -.01, and .13. This shifts the peak $\bar{R}^2$, if CFR is included in the gross investment model, to a point where $\rho = .043$ and $\rho - c = -.0075$. On a priori grounds we resisted the assumptions about the rate of embodied technical progress and/or replacement behaviour required to justify values of c greater than ρ. In any event, there was next to nothing to be gained, either in goodness of fit or forecasting ability, by altering our earlier procedure of running the gross investment equations without financial variables.

the RDX1 aggregate model. Our coefficients differ slightly from those in the aggregate model because in RDX1 PGNE has to be used as a proxy for the investment goods price index used in calculating CFR.

The OLS estimation of our final M&E equation produced the following:

1Q53 - 4Q65 (OLS)

$$I^n_{ME} = \underset{(3.82)}{-209.54}\, Q_1 - \underset{(1.83)}{128.40}\, Q_2 - \underset{(3.96)}{270.64}\, Q_3 - \underset{(3.71)}{231.31}\, Q_4$$

$$+ \underset{(5.76)}{.170}\, Q_1\, KGAP + \underset{(6.03)}{.176}\, Q_2\, KGAP + \underset{(5.36)}{.148}\, Q_3\, KGAP$$

$$+ \underset{(7.58)}{.201}\, Q_4\, KGAP + \underset{(5.08)}{315.41}\, CFR_t$$

$SEE = 38.5$ $\bar{R}^2 = .878$ $D/W = 0.88$

The equation marks an improvement in several respects. The standard error of estimate is down by about 10%, the accelerator coefficients are increased in size and significance, and the autocorrelation of residuals is reduced. Reestimation after autoregressive transformation ($\rho = .56$) produced slight further improvement and the final equation:

1Q53 - 4Q65 (AUTO, $\rho = .56$)

$$I^n_{ME} = \underset{(2.84)}{-192.68}\, Q_1 - \underset{(1.30)}{112.49}\, Q_2 - \underset{(3.06)}{257.33}\, Q_3 - \underset{(2.87)}{220.1}\, Q_4$$

$$+ \underset{(6.56)}{.195}\, Q_1\, KGAP + \underset{(6.29)}{.189}\, Q_2\, KGAP + \underset{(5.29)}{.151}\, Q_3\, KGAP$$

$$+ \underset{(7.23)}{.201}\, Q_4\, KGAP + \underset{(3.98)}{304.54}\, CFR_t$$

$$SEE = 32.4 \qquad \bar{R}^2 = .895 \qquad D/W = 1.70$$

In the aggregate model RDX1, this equation will be used in conjunction with the final NRC equation outlined in the last section:

1Q53 - 4Q65 (AUTO, ρ = .35)

$$I^n_{NRC} = \underset{(1.64)}{-.091}\, TQ_1 + \underset{(3.66)}{2.01}\, TQ_2 + \underset{(8.91)}{4.84}\, TQ_3 + \underset{(5.75)}{3.06}\, TQ_4$$

$$+ \underset{(9.85)}{.0307}\, KGAP_t + \underset{(10.40)}{291.43} \sum_{i=0}^{10} W_i (10BI)_{t-i}$$

$$SEE = 34.1 \qquad \bar{R}^2 = .935 \qquad D/W = 1.71$$

In the last section we presented the results of some quarterly forecasting tests using gross investment series derived from the final NRC equation and the best phase two M&E equation. Chart 4 repeats the NRC graph from Chart 2 and adds the M&E and Total Gross Investment series derived from our final equations. Note that the values of R^2 (which are measured over the estimation period only) are increased both for gross M&E and total investment. This is true whether the equations are fitted to the end of 1963 or the end of 1965. The increases in forecasting accuracy are not so marked. For the equations fitted to the end of 1963 and used to forecast 1964-67, the average absolute error of the quarterly M&E forecast drops from $133 million to $120 million, enough to beat the mechanical forecasting rule but still not an outstanding record. The average quarterly absolute error of forecast for total gross investment drops from $130 million to $127 million, showing that some of the improvement in the M&E equation is washed out in the aggregate.

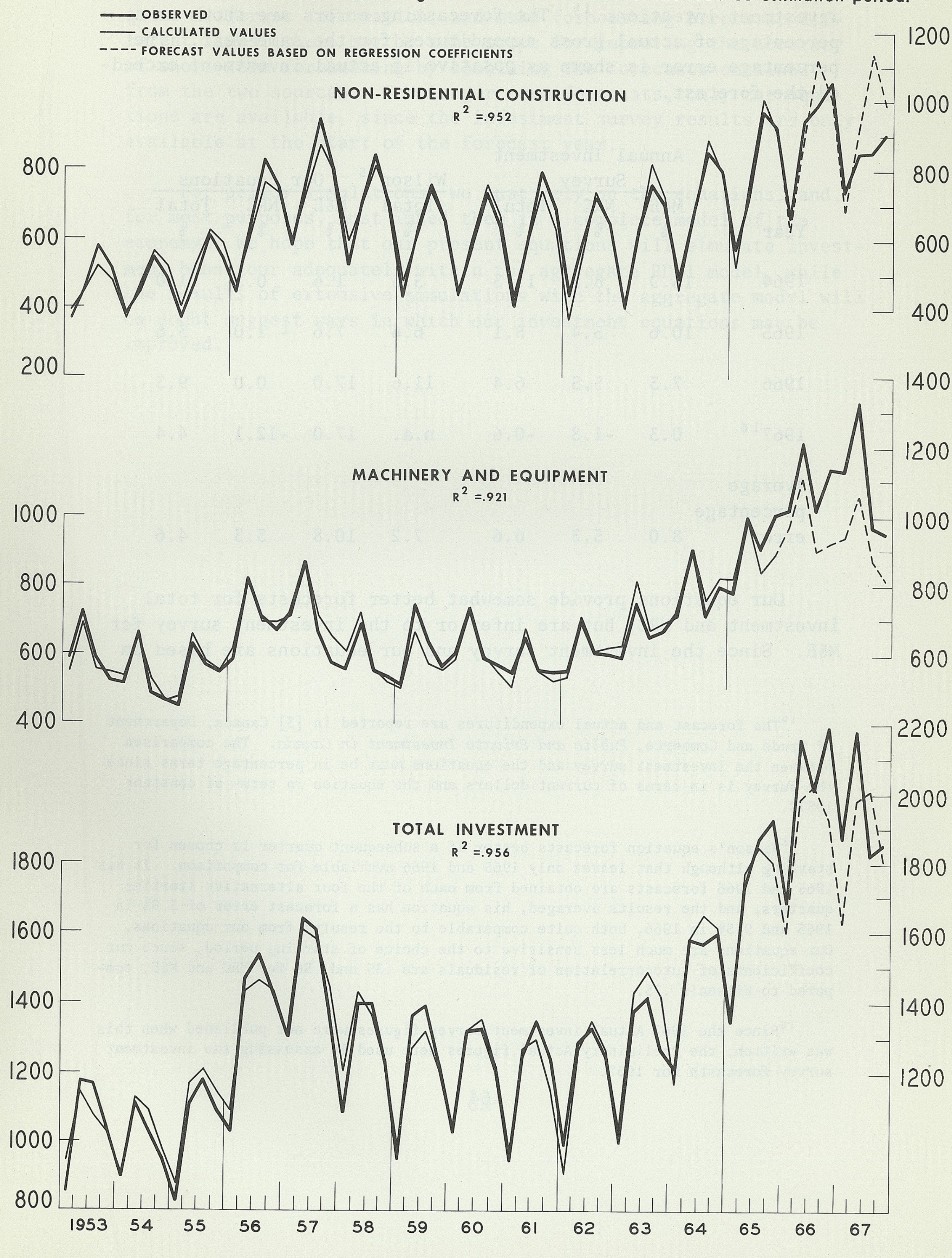
To allow our equations to be compared to other forecasting methods, we initialized the model in 4Q63 and used it to generate four annual investment forecasts. The percentage errors of these forecasts are shown below, along with the comparable forecasts from T. Wilson's model ([28] p. 73) and from the annual survey of

Chart 4

GROSS FIXED INVESTMENT FROM FINAL EQUATIONS FITTED 1953-65 AND USED TO FORECAST 1966-67

Quarterly - Millions of 1957 Dollars

R^2 measures the fit of the calculated gross investment series over the 1953-65 estimation period.



investment intentions.[14] The forecasting errors are shown as a percentage of actual gross expenditures for the same year. The percentage error is shown as positive if actual investment exceeded the forecast.

	Annual Investment Survey			Wilson[15]	Our Equations		
Year	M&E %	NRC %	Total %	Total %	M&E %	NRC %	Total %
1964	13.9	8.5	11.3	3.3	1.6	0.3	1.0
1965	10.6	5.4	8.1	6.6	7.6	- 1.0	3.6
1966	7.3	5.5	6.4	11.6	17.0	0.0	9.3
1967[16]	0.3	-1.8	-0.6	n.a.	17.0	-12.1	4.4
Average percentage error	8.0	5.3	6.6	7.2	10.8	3.3	4.6

Our equations provide somewhat better forecasts for total investment and NRC, but are inferior to the investment survey for M&E. Since the investment survey and our equations are based on

[14]The forecast and actual expenditures are reported in [3] Canada, Department of Trade and Commerce, *Public and Private Investment in Canada*. The comparison between the investment survey and the equations must be in percentage terms since the survey is in terms of current dollars and the equation in terms of constant 1957$.

[15]Wilson's equation forecasts better if a subsequent quarter is chosen for starting although that leaves only 1965 and 1966 available for comparison. If his 1965 and 1966 forecasts are obtained from each of the four alternative starting quarters, and the results averaged, his equation has a forecast error of 3.9% in 1965 and 9.3% in 1966, both quite comparable to the results from our equations. Our equations are much less sensitive to the choice of starting period, since our coefficients of autocorrelation of residuals are .35 and .56 for NRC and M&E, compared to Wilson's .75.

[16]Since the 1967 Actual investment survey figures were not published when this was written, the Preliminary Actual figures were used in assessing the investment survey forecasts for 1967.

quite different information, and make forecasting errors at different times, there may be some scope for improving the accuracy of short-term forecasting by combining the forecasts obtained from the two sources. For longer term forecasts, only the equations are available, since the investment survey results are only available at the start of the forecast year.

For policy simulations, we must rely on the equations, and, for most purposes, must imbed them in a complete model of the economy. We hope that our present equations will simulate investment behaviour adequately within the aggregate RDX1 model, while the results of extensive simulations with the aggregate model will no doubt suggest ways in which our investment equations may be improved.

APPENDIX A

Fiscal Policy Variables

The fiscal policy variables that we are trying to insert into our investment equations are of two forms. The first, CPV, is an attempt to measure current conditions, and enters into the determination of desired capital stock in the flexible accelerator/stock adjustment model. The second, FPV/CPV, is the ratio of future to present conditions, and is assumed to influence the rate of adjustment of capital stock. Thus, if policy conditions eighteen months hence are expected to be tighter than at present, one would expect a deficiency in actual, as compared with desired, capital stock to be made up more rapidly.

CPV attempts to capture the influence of accelerated and deferred depreciation schemes; and of changes in sales tax provisions, while FPV is investors' current expectations as to the value of CPV eighteen months hence, on the naive assumption that they believe what the government tells them. The present value of a policy measure is calculated as a percentage of the cost of investment under that measure, and this, adjusted for the proportion of total investment subject to the measure, yields the impact of the provision. Although taxes do not come in directly, their influence is felt early in the period since a lower tax rate lowers the present value of any depreciation scheme. Using 1Q51 as a base period the policy variables are calculated for each quarter from 1947 to 1965. The present value of depreciation provisions can be found by the calculation:

$$P.V. = I \times T \times \frac{d}{d+R}$$

where I is the level of investment, T is the corporate tax rate, d is the rate of depreciation allowed with a declining balance system, and R is the discount rate assumed to be used by investors. Assuming $R = 10\%$, $T = 50\%$, we know that for non-residential construction $d = .05$, and for machinery and equipment $d = .2$. Thus in 1Q51, P.V. for NRC is .1667I, and P.V. for M&E is .3333I. Since 1Q51 is our base period, our policy variables are set equal to 100 for these values.

Working backward, the tax rate in 4Q50 was only 43%, and the P.V. of the depreciation provisions fall to .1433I and .2866I respectively. We had the choice here of allowing our index to rise or to fall — we decided to let it move analogously to an index of capital goods prices and to rise as depreciation policy becomes less of an incentive to investment. So our current indices rise to 102.3% and 104.7%, moving by a percentage equal to the change in per cent of investment returned through the depreciation provisions.

From 1Q49 to 4Q50 the corporate tax rate was 40%, and our indices are 103.3% for NRC and 106.7% for M&E. In 1947 and 1948 the P.V. of depreciation must be calculated on a different basis, since straight-line depreciation, at rates of 2½% and 10% with a 37% tax rate, was in force. These provisions had a P.V. of .0905I and .2363I respectively, yielding indices of 107.6 and 109.7 for the period 1Q47 to 4Q48.

Moving forward again, in 2Q51 the deferred depreciation scheme was introduced. This deferred allowable depreciation for four years and reduced the value of NRC depreciation to .1138I and of M&E depreciation to .2277I. Our index rises to 105.3 and 110.6, and remains up until 4Q52, when the deferment was discontinued. Both current indices fall back to 100 and remain there until 4Q60.

In 1Q61 Regulation 1108 went into effect. This provided for depreciation of 10% in the first year and 5% in succeeding years on NRC and of 40% and 20% on M&E. Regulation 1108 applied only to investment for the production of goods of a kind new to Canada, or to investment new to a surplus manpower area. In fact, however, the influence of these provisions was quite small, and, when account is taken of the minute proportion of total investment eligible for this acceleration, the effect on our index is nil. This provision was in force from 1Q61 to 4Q63 but appears to have had little or no effect on the profitability of investment.

In 3Q61 Regulation 1109 provided for first year depreciation of 7½% and 30% on investment for reequipment and modernization. This provision had more influence on investment since it applied to all investment, even though the stimulus given to projects undertaken under the regulation was less than for Regulation 1108. Regulation 1109 shifts our indices down to 99.3 for NRC and 98.5 for M&E from 3Q61 to 2Q63. It remained in force through 1Q64, but after 2Q63 its effects are offset by other provisions.

In the third quarter of 1963 an accelerated provision was brought in which allowed 20% straight-line depreciation for NRC and 50% straight-line for M&E. This raised the value of depreciation provision to .3791I and .4339I respectively. But the provision was restricted to investment in manufacturing and processing in surplus manpower areas. Firms meeting certain Canadian ownership requirements could also claim accelerated depreciation for machinery and equipment investment outside surplus manpower areas. This provision was to last from 3Q63 to 2Q65. In 1964 it was extended to 1Q67, a feature that influences the future index, not the current one. The value of depreciation for investment made under the provision increased by 21.3% for NRC and 10.1% for M&E. When allowance is made for its limited coverage, however, it moves our indices by 0.3% and 2.4%.

During the same budget, the sales tax was applied to hitherto exempt building materials and production machinery, in stages of 4% (3Q63 to 1Q64), 8% (2Q64 to 4Q64), and 11% thereafter. This raises our index by 4%, 8%, and 11% for M&E for these periods. Consultation with D.B.S. indicated that for NRC about 42% of investment consisted of taxable materials; therefore the rate of sales tax was reduced by this percentage to yield the change in index.

Thus from 3Q63 to 1Q64, Regulation 1109 is tending to reduce our indices by 0.7% and 1.5%, the depressed area and other production machinery provisions to reduce them by 0.3% and 2.4%, but the sales tax works to increase them by 1.7% and 4%. The net effect is to raise the indices to 100.7 and 100.1. During the first two of these three quarters, Regulation 1108 was reaching the end of its ineffectual life. In 2Q64, Regulation 1109 ran out, and from then till 4Q64 the sales tax was at 8%. Our indices stand at 103.1 and 105.6. From 1Q65 to 1Q66 the sales tax was up to 11%, and the depressed area and other provisions were still in force. The indices are 104.3 and 108.6. In 2Q66, the new depreciation deferment raises these to 108.4 and 116.9; and there the matter rests.

For the index of expected future conditions, we employ the naive assumption that investors believe everything the government tells them. Thus from 1Q47 to 1Q52 the future indices are equal to the current. This is because, when the 1951 deferment was initially announced, it was to be in force for several years. By 2Q52, however, government statements made it clear that the deferment would terminate by the end of the year. In that quarter our indices return to 100.

The future indices do not move again until 3Q61 when Regulation 1109 pushes them down to 99.3 and 98.5. But since this regulation was to expire on April 1, 1964, its influence disappears from the future series in 4Q62. In 3Q63 the sales tax exemptions were withdrawn, and the depressed area provision was introduced. Both were expected to be in force eighteen months hence; the sales tax being at its full 11% rate. Thus for 3Q63 and 4Q63 the net effects on the indices are sales tax, up 4.6% and 11%, depressed area provisions, down 0.3% and 2.4%. So the future indices are 104.3 and 108.6. In 1Q64 the depreciation acceleration was expected to run out in 3Q65; hence the indices go up to 104.6 and 111.0. But on March 16, 1964 the depressed area provisions were extended to April 1, 1967; therefore the NRC future index falls to 104.3 until 4Q65. Henceforth it returns to 104.6.

For machinery and equipment the picture is a little more complicated. Of the movement in the index due to the 1963 depreciation provisions, about 0.3% is attributed to the depressed area aspect. So the index from 2Q64 to 2Q65 stands at 110.7. On April 26, 1965 the whole machinery and equipment acceleration was extended until December 1966; therefore in 2Q65 the index stands at 108.6. In 3Q65 it returns to 110.7, and in 4Q65 and 1Q66 (looking ahead to 2Q67 and 3Q67) it returns to 111.0. In 2Q66, looking ahead to 4Q67, the new deferment provisions will no longer be in force and the sales tax on production machinery will be down to 6%. The index thus stands at 106.0.

Tables 13 and 16 on the following four pages give the calculated values of the policy index from 1947 to mid-1966. The resulting index could undoubtedly be improved, particularly by a more sophisticated measure of expectations.

Table 13

CPV — Non-Residential Construction — Current

	1Q	2Q	3Q	4Q
1947	107.6	107.6	107.6	107.6
1948	107.6	107.6	107.6	107.6
1949	103.3	103.3	103.3	103.3
1950	103.3	103.3	103.3	102.3
1951	100.0	105.3	105.3	105.3
1952	105.3	105.3	105.3	105.3
1953	100.0	100.0	100.0	100.0
1954	100.0	100.0	100.0	100.0
1955	100.0	100.0	100.0	100.0
1956	100.0	100.0	100.0	100.0
1957	100.0	100.0	100.0	100.0
1958	100.0	100.0	100.0	100.0
1959	100.0	100.0	100.0	100.0
1960	100.0	100.0	100.0	100.0
1961	100.0	100.0	99.3	99.3
1962	99.3	99.3	99.3	99.3
1963	99.3	99.3	100.7	100.7
1964	100.7	103.1	103.1	103.1
1965	104.3	104.3	104.3	104.3
1966	104.3	108.4		

Table 14

CPV — Machinery and Equipment — Current

	1Q	2Q	3Q	4Q
1947	109.7	109.7	109.7	109.7
1948	109.7	109.7	109.7	109.7
1949	106.7	106.7	106.7	106.7
1950	106.7	106.7	106.7	104.7
1951	100.0	110.6	110.6	110.6
1952	110.6	110.6	110.6	110.6
1953	100.0	100.0	100.0	100.0
1954	100.0	100.0	100.0	100.0
1955	100.0	100.0	100.0	100.0
1956	100.0	100.0	100.0	100.0
1957	100.0	100.0	100.0	100.0
1958	100.0	100.0	100.0	100.0
1959	100.0	100.0	100.0	100.0
1960	100.0	100.0	100.0	100.0
1961	100.0	100.0	98.5	98.5
1962	98.5	98.5	98.5	98.5
1963	98.5	98.5	100.1	100.1
1964	100.1	105.6	105.6	105.6
1965	108.6	108.6	108.6	108.6
1966	108.6	116.9		

Table 15

FPV — Non-Residential Construction — 18 Months Forward

	1Q	2Q	3Q	4Q
1947	107.6	107.6	107.6	107.6
1948	107.6	107.6	107.6	107.6
1949	103.3	103.3	103.3	103.3
1950	103.3	103.3	103.3	102.3
1951	100.0	105.3	105.3	105.3
1952	105.3	100.0	100.0	100.0
1953	100.0	100.0	100.0	100.0
1954	100.0	100.0	100.0	100.0
1955	100.0	100.0	100.0	100.0
1956	100.0	100.0	100.0	100.0
1957	100.0	100.0	100.0	100.0
1958	100.0	100.0	100.0	100.0
1959	100.0	100.0	100.0	100.0
1960	100.0	100.0	100.0	100.0
1961	100.0	100.0	99.3	99.3
1962	99.3	99.3	99.3	100.0
1963	100.0	100.0	104.3	104.3
1964	104.6	104.3	104.3	104.3
1965	104.3	104.3	104.3	104.3
1966	104.6	104.6		

APPENDIX B

Key to the Variables

DB — Numbers in brackets with the prefix DB refer to the index numbers of these series on the Databank Master Tape at the Bank of Canada. It is intended to make publicly available a master tape containing all series referred to in the Bank of Canada Staff Research Studies.

Dependent Variables

I_{NRC} — (or I^g_{NRC}) Gross investment in non-residential construction, quarterly, constant 1957 dollars unadjusted, National Accounts basis, (DB 146).

$I_{M\&E}$ — (or $I^g_{M\&E}$) Gross investment in machinery and equipment, quarterly, constant 1957 dollars unadjusted, National Accounts basis, (DB 147).

I^n_{NRC} — Net investment in non-residential construction, equals I_{NRC} less assumed depreciation equal to a constant proportion of NRC capital stock at end of previous quarter. [constant = ρ]

$I^n_{M\&E}$ — Net investment in machinery and equipment, equals $I_{M\&E}$ less assumed depreciation equal to a constant proportion of M&E capital stock at end of previous quarter. [constant = ρ]

Independent Variables — First Stage

K_{t-1} — Net constant dollar capital stock at end of quarter t-1 found by cumulating net investment onto a mid-1949 base value. Separate series calculated for NRC and M&E using various assumed constant proportional depreciation rates.

and equipment. This is fitted to a linear trend from 1950 to 1965. The CFR is the ratio of actual deflated cash flow in quarter t to its trend value.

IBY_t The Industrial Bond Yield in quarter t, the McLeod, Young, Weir index of ten industrial bonds (DB 268).

IBI_t The Industrial Bond Index in quarter t,

$$IBI_t = \sum_{i=1}^{12} IBY_{t-i}/12IBY_t.$$

$10BY_t$ The average yield on government securities of over ten years to maturity in quarter t (DB 2764).

$10BI_t$ The ten-year Bond Index, $10BI_t = \sum_{i=1}^{12} 10BY_{t-i}/12(10BY_t)$.

EY_t Equity Yield in period t, Moss, Lawson ratio of latest declared dividend to current average price of 114 stocks (DB 2765).

EI_t Equity Index in quarter t, $EI_t = \sum_{i=1}^{12} EY_{t-i}/12EY_t$.

BEY_t The Bond/Equity Yield, a combination of IBY_t and EY_t weighted by their respective shares in gross corporate new issues in quarter t.

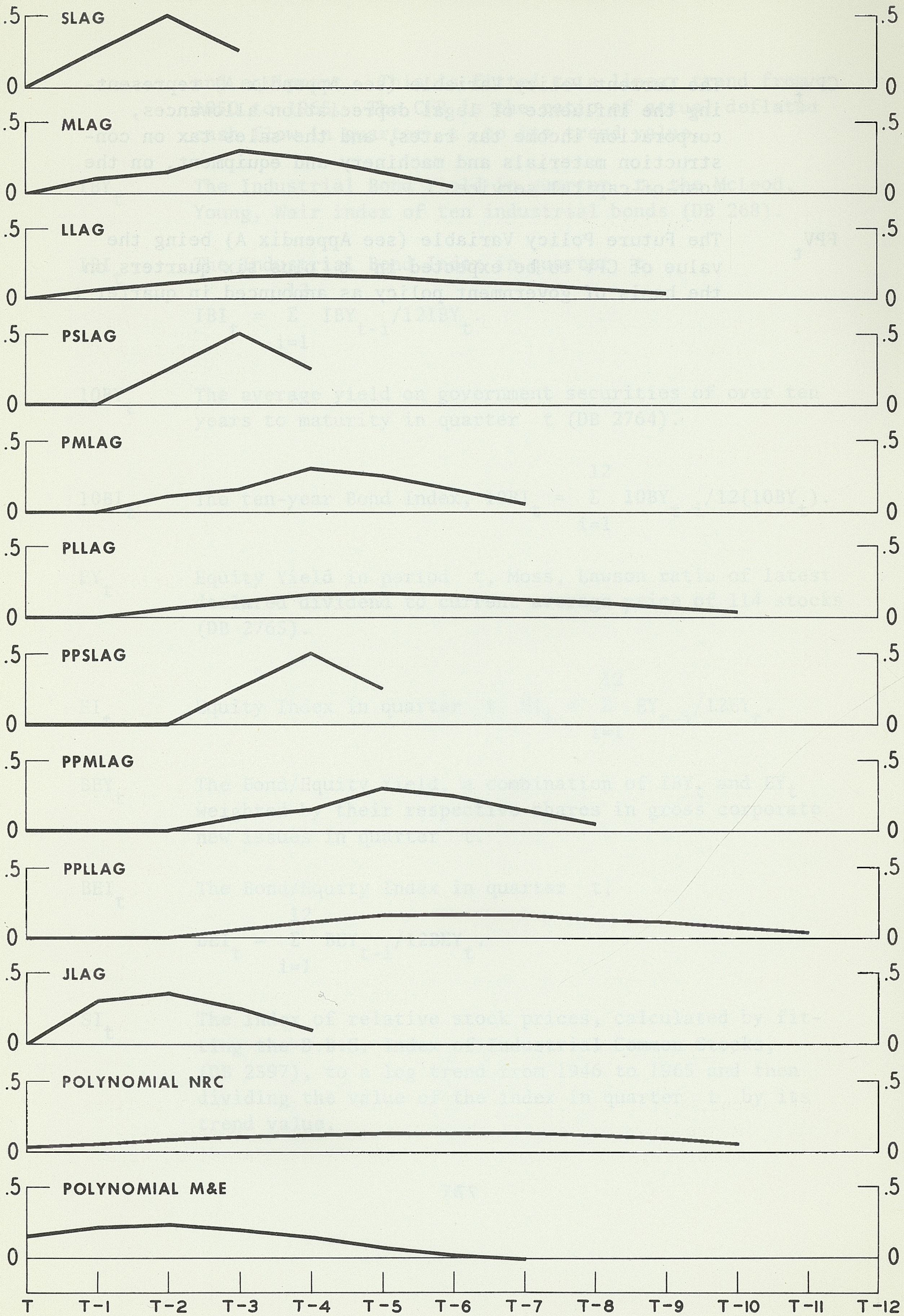
BEI_t The Bond/Equity Index in quarter t,

$$BEI_t = \sum_{i=1}^{12} BEY_{t-i}/12BEY_t.$$

SI_t The index of relative stock prices, calculated by fitting the D.B.S. Index of Industrial Common Stocks, (DB 2597), to a log trend from 1946 to 1965 and then dividing the value of the index in quarter t by its trend value.

Chart 5

PRE-SPECIFIED LAG PATTERNS



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[29] Numbers in brackets with the prefix DB refer to the index numbers of these series on the Databank Master Tape at the Bank of Canada. It is intended to make publicly available a master tape containing all series referred to in the Bank of Canada Staff Research Studies.