A NOTE ON AGGREGATE INVESTMENT IN AUSTRALIA

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ABSTRACT

Investment plays an important role in influencing short-term aggregate demand and in determining the long-run growth potential of the economy. Despite the current debate concerning the potential problem of low investment, there have been few recent empirical studies of aggregate investment in Australia. The purpose of this paper is to explore the relevance of Tobin's "q theory" of investment in explaining aggregate investment in Australia, over the period from December 1966 to December 1986.

The first part of the paper derives a q theory of investment behavior based on a model of an optimising firm facing costs to adjusting its capital stock. The second part of the paper explores the empirical relevance of the theory. In testing the q theory we relax the implicit assumption that firms have unlimited access to capital markets, allowing a proportion of aggregate investment to be determined by current profits. Using standard capital stock data, the q theory performs poorly. However, the cost of adjustment model implies that the conventional capital stock data needs to be revised to allow for these adjustment costs. Once this is done, it is found that the q theory is empirically supported. For plausible values of the cost of adjustment, the results indicate that a lower bound of 10 percent of aggregate investment is explained by q theory and 90 per cent by current profits.

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1. Introduction

Investment is a fundamental determinant of long-run growth as well as an important component of short-run aggregate demand. However, as pointed out in Carmichael and Dews (1987), it is perhaps the least well explained macroeconomic aggregate. A recent theoretical contribution was made in an important paper by Fumio Hayashi (1982) who derived a theory of the investment decision of an optimising firm facing costs to adjusting its capital stock. His resulting model was very similar to Tobin's (1969) "q theory" of investment. The purpose of the current paper is to use an approach similar to Hayashi's to derive and estimate an aggregate investment equation for Australia with the aim of incorporating the equation into the McKibbin-Sachs Global (MSG) model of the Australian economy[1].

The paper proceeds as follows. A brief overview of approaches to modelling aggregate investment is given in Section 2. Section 3 summarises previous Australian studies. A model of the investment decision of an optimising firm is derived in Section 4. In testing this theory we recognise that some firms in the economy are unable to borrow and lend as assumed by the theory and, therefore, face a binding liquidity constraint. We also recognise that there are lags between the decision to invest and the appearance of productive capital. Both these phenomena are taken into account in deriving an aggregate investment function. This aggregated model is then estimated for quarterly Australian data over the period December 1966 to December 1986 and the results are presented in Section 5. A conclusion is presented in Section 6.

We find that the q theory performs poorly when conventional capital stock data are used because the assumptions implicit in the calculation of the capital

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1. See McKibbin (1987) for the derivation of the MSG model and McKibbin and Siegloff (1987) for the Australian extension.

stock data are not consistent with the assumptions of the cost of adjustment model used to derive the q theory. Once the capital stock data is adjusted to be consistent with the theory being tested, we find that the q theory performs quite well. This suggests that standard tests of q theory are biased against the theory. For plausible values of the cost of adjustment we find that a lower bound of 10 per cent of investent is determined by q.

2. Explaining Aggregate Investment

In modelling investment demand at the macroeconomic level, researchers typically adopt one of two distinct approaches - the stock-oriented approach or the flow-oriented approach. The stock-oriented approach derives the desired demand for capital stock and then posits some adjustment path for investment spending to move the actual capital stock to the desired level. On the other hand, the flow-oriented approach seeks to explain the rate of investment spending.[2] An example of the stock approach is Jorgenson's (1963) neoclassical investment theory in which the desired capital stock is determined by the firm's production function, the demand for output, and the rental cost of capital, relying on an ad-hoc stock adjustment mechanism to explain the rate of investment. One example of the flow approach is the Keynesian accelerator model, in which the rate of investment spending is determined by the rate of change of output. Another example is Tobin's q theory.

In Tobin's q theory, investment spending is determined by equating the marginal (stock market) value of capital assets with the marginal cost of those assets. This approach is forward looking in the sense that expectations are incorporated into the market's valuation of capital assets. The theory is based on the premise that managers, in seeking to maximise the benefits to existing stockholders and hence the market value of their corporations, are induced towards investment in reproducible new or existing capital assets whenever they value those capital assets at prices which are greater than their replacement cost.[3]

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2. For further discussion see Abel (1980).
3. See Kopcke (1985) for further discussion.

In short, Tobin argues that aggregate investment spending on additional capital assets will vary positively with q - the ratio of the market value of business capital assets to the replacement value of those assets. Accordingly, Tobin asserts that q can be used as a quantitative measure of the market's incentive to invest. If q is greater than unity, a favourable investment climate is indicated and investment spending is encouraged; conversely, a q well below unity discourages investment spending.

Although the relevant q is strictly a marginal q (the ratio of an additional unit of capital to its replacement cost) which is not observable, we can observe average q (the ratio of the market value of existing capital to its replacement cost). In testing the q theory, researchers use average q as a proxy for marginal q, implying equality between average and marginal q. Such equality holds only in the special case where each firm is a price-taker with constant returns to scale in both production and installation; if each firm is viewed as a price-maker, average q will exceed marginal q by an amount termed monopoly rent.[4] As Tobin's q uses current stock market data about corporate enterprises in its derivation, it directly captures financial market expectations concerning future profitability and risk to corporate enterprises; it is, therefore, intuitively more appealing than alternative theories which rely on past experience only.[5] However, in empirical work, q theory has performed rather poorly in explaining investment behaviour at the macro level.[6]

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4. See Tobin and Brainard (1977), pp243. Note that average q can also differ from marginal q due to tax distortions.

5. For example the accelerator model, which proposes that firm's demands for investment goods depends upon lagged values of output and capital stock.

6. See von Furstenberg (1977) and Hayashi (1982) for overseas evidence.

3. Australian Studies

In the early 1970s, empirical work on investment behaviour in Australia was strongly influenced by standard neo-classical theory.[7] Although this approach was theoretically more appealing than the popular accelerator models of the 1960s, it proved to be a poor explanation of investment behaviour in Australia. A broader study by Higgins et.al. (1976) sought to improve empirical understanding of investment by employing a more refined neo-classical model as well as a variety of different models. As in the earlier studies, Higgins et.al. found that the neo-classical model performed poorly; furthermore, they found that it was noticeably inferior to simpler investment functions based on the accelerator and securities value models[8]. Subsequent development of the neo-classical model has been taken up by Australian macro-econometric models such as the RBII[9] model, while the AMPS[10] and NIF88[11] models claim to use a variant of Tobin's q theory to determine business fixed investment. In a recent study, Rider (1987) tests the q theory using a tax-adjusted q series. However, the results do not support the q theory.

4. Cost of Adjustment Model

The cost of adjustment model which is used here to explicitly derive a q theory, is similar to that used in Hayashi (1982). We assume that price-taking firms choose factors of production to maximise the value of the firm subject to the constraint that capital is costly to adjust. The value of the firm is defined as the present discounted value of the stream of future after tax net income:

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7. See Mackrell et.al. (1971) and McLaren (1971) for example.

8. For a useful survey article of the econometric contributions of the 1970s see Hawkins (1979). See also Stegman (1982) for a novel approach to estimating an accelerator-type investment function, and Kohli and Ryan (1986) for a more refined neo-classical model.

9. See Edey et.al. (1987).

10. See Murphy et.al. (1986).

11. See Simes (1987).

$$V_t = \int_t^\infty [(1-\tau)\pi_s - P_s^I I_s]e^{-rs}ds \quad (4.1)$$

where

$$\pi_s = Y_s - w_s L_s \quad (4.2)$$

$$Y_s = F(K_s, L_s) \quad (4.3)$$

and

τ = effective corporate tax rate

π_s = real profits in period s

P_s^I = relative price of investment goods which we assume equal to unity in period s

I_s = gross investment expenditure at period s

r = real interest rate

Y_s = aggregate production in period s

W_s = real wage in period s

K_s = beginning-of-period stock of capital

L_s = labour input

Note that investment expenditure is defined outside the definition of real profits.

The firm is assumed to maximise (4.1) subject to an accumulation equation for the capital stock

$$\dot{K} = J_t - \delta K_t \quad (4.4)$$

where

J = gross capital accumulation in period t

δ = (constant) rate of depreciation on capital in period t

and an equation which posits that capital is costly to adjust

$$I = J(1 + 0.5\phi(J/K)) \quad (4.5)$$

where

ϕ = cost of adjustment parameter

$0.5\phi(J^2/K)$ = cost of installing an additional unit of capital

Equations (4.4) and (4.5) assume that gross investment expenditure (I) increments the capital stock by gross capital accumulation (J), where the difference is the cost of converting goods into capital stock. This cost is assumed to be quadratic in the level of gross capital accumulation.

To assist in understanding the cost of adjustment model, equation (4.5) can be rewritten:

$$(I-J)/J = .5\phi JK \tag{4.5a}$$

This clearly shows that the difference between gross capital expenditure (I) and gross capital formation (J), expressed as a proportion of J (that is, the cost of adjustment in terms of J) is a linear function of the level of J scaled by the existing capital stock. For example if ϕ=10 and I/K=.03, then from (4.5) we find J/K=.026. This implies the cost of adjustment is 13 per cent of J or 11.3 per cent of I. In other words, every $1 of I yields 88.7 cents of physical capital.

To solve this intertemporal optimisation problem we first define the Hamiltonian:

$$H = [(1-\tau)(Y-WL) - J(1+0.5\phi(J/K))]e^{-rt} + \Lambda(J - \delta K) \tag{4.6}$$

Define

$$\Lambda_t = \lambda_t e^{-(r)t}$$

Using the conditions for an optimum $(\partial H/\partial L = 0;\ \partial H/\partial J = 0;$ $\partial H/\partial K = -\partial\Lambda/\partial t)$ we find:

$$Y_L = w \tag{4.7}$$

$$(1 + \phi(J/K)) = \lambda \tag{4.8}$$

$$\dot{\lambda} = (r+\delta)\ \lambda - (1-\tau)\ Y_K - 0.5\ \phi(J/K)^2 \tag{4.9}$$

Equation (4.7) is a familiar result which states that an optimising firm will employ labour up to the point where the real wage (w) is equal to the marginal product of labour (Y_L).

Equation (4.8) can be written as:

$$J/K = (\lambda-1)/\phi \tag{4.10}$$

Clearly, gross capital formation (J) is positive if $\lambda>1$ and negative if $\lambda<1$.

The evolution of the shadow price is given in equation (4.9). Note that (4.9) can be integrated forward and solved as:

$$\lambda_t = {}_t\int^{\infty} [(1-\tau)\ Y_K + 0.5\phi\ (J/K)^2\ ]\ e^{-(r+\delta)s} ds. \tag{4.11}$$

Equation (4.11) gives the shadow value of investment as the marginal increment to firms' value arising from a unit increase in gross capital formation. The shadow price (λ) corresponds closely to the concept of Tobin's q. From this point, we assume λ=q.

Equation (4.10) can be used with (4.5) to find gross investment expenditure which is the observable variable:

$$I/K = [(q-1)/\phi]\ (1 + 0.5\ (q-1)) = (1/\phi)Q \tag{4.12}$$

where, for convenience, we assume $Q = (q-1)(1+0.5(q-1))$.

To estimate the model of aggregate investment we assume that s of investment in the economy is determined according to (4.12) and (1-s) of investment is undertaken by firms that are constrained by the amount they can borrow and lend and therefore invest out of retained earnings. These we proxy by assuming profits are a linear function of output. Specifically:

$$I = \gamma_1 + \beta Y \tag{4.13}$$

We use a superscript q to indicate optimising firms and n to indicate non-optimising firms. Aggregate desired investment expenditure is:

$$\widehat{I/K} = s(I^q/K) + (1-s)\ (I^n/K) \tag{4.14}$$

Here, optimising firms have total investment expenditure of I^q whereas non-optimising firms have total investment of I^n.

Further, we assume that investment decisions take time to come on line as investment expenditure, independently of the cost of adjustment. We posit a Koyck lag:

$$(I/K)_t - (I/K)_{t-1} = \gamma_2 + (1-\alpha)\ [(\widehat{I/K})_t - (I/K)_{t-1}] \tag{4.15}$$

Substituting (4.12), (4.13) and (4.14) into (4.15) we find:

$$(I/K)_t = \gamma_3 + (1-\alpha)\ [s(Q_t/\phi) + (1-s)\ \beta(Y/K)_t] + \alpha\ (I/K)_{t-1} \tag{4.16}$$

where $\gamma_3 = \gamma_1 + \gamma_2$

Equation (4.16) is the equation to be estimated below.

5. Estimation

Before discussing the results, several comments should be made about the data.

(a) Data Assumptions

Equation (4.16) is estimated using quarterly Australian data for the period December 1966 to December 1986[12]. As it stands, (4.16) is over-identified because we want to estimate α, s, β, and ϕ, yet we only have three variables on the right hand side. We therefore impose ϕ in the following analysis. One reason for this choice is based on data construction. The estimates of capital stock given in national statistics are based on the assumption of no cost of adjustment in investment and an accumulation equation which holds that every dollar of investment expenditure leads to an increment in the capital stock of one dollar.[13] That is, I=J and therefore:

$$\dot{K} = I_t - \delta K_t \tag{5.1}$$

We have posited a theory that $I \neq J$ because of costs of adjustment and therefore must be careful to use this assumption when constructing the data for capital stock to test the theory. We take two approaches here. The first uses the available series for K[14] and the second constructs a series for K using available data and an assumption about depreciation (δ) and adjustment costs (ϕ). In the second approach we incorporate equation (4.5) (which gives the relationship between the observed I and unobserved J) directly into the estimation of K, yielding a series for K which is based on the assumption that capital adjustment is costly. Here, each dollar of investment spending increases the capital stock by less than a dollar because of installation costs associated with it. The equation used for the generation of the K series is:

$$K_{t+1} = K_t(1-\delta) + J_t \tag{5.2}$$

where J_t = investment expenditure less the adjustment cost of capital.

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12. The sources for (I) gross business fixed investment expenditure (non-dwelling construction plus plant and equipment) and (Y) gross domestic product - [constant 1979-80 prices/seasonally-unadjusted] - were ABS Cat#5206.0, Quarterly Estimates of National Income and Expenditure, Australia, March quarter, 1987 and ABS Cat#5207.0, Historical Series of Estimates of National Income and Expenditure, Australia, September quarter, 1959 to March quarter, 1980.

13. ABS Cat#5221.0, Australian National Accounts, Estimates of Capital Stock 1985-86.

14. Quarterly estimates of capital stock based on the annual estimates given in ABS Cat#5221.0 (constant 1979-80 prices).

As J is not directly observable, it, like K, must be estimated. From (4.5) we see that a value for J_t can be inferred given knowledge of an initial value for K_t and I_t. We assume the value for J_t to be the positive root associated with the quadratic form of (4.5), given by:

$$(1/2.\phi.J_t^2)/K_t + J_t - I_t = 0 \tag{5.3}$$

Now K_t and I_t are known at t=0, but ϕ is not; hence, a series for J which evolves from (5.3) is dependent upon the value given to ϕ. A cost-adjusted K series can thus be generated for various levels of ϕ by using (5.2). In constructing the series for J and K, we assume a quarterly rate of depreciation on capital of 6 per cent per annum, and value capital stock in September 1966 at \$56,032 million[15]. We also choose a range of values for ϕ to test the sensitivity of results to this assumption. The values chosen are ϕ=10, 20 and 30. These translate into a cost of 11 per cent, 21 per cent and 31 per cent of investment expenditure, respectively. The q series used are the updated estimates for Tobin's q in Australia produced by Dews (1986).

(b) Results

Having generated a series for J and hence K for different values of ϕ, we then use non-linear least squares to estimate (4.16), rewritten for convenience as:

$$(I/K)_t = \gamma_3 + (1-\alpha)\ s(Q_t/\phi) + (1-\alpha)\ (1-s)\ \beta(Y/K)_t + \alpha(I/K)_{t-1} \tag{5.4}$$

Table 1 contains the estimation results for the standard capital stock series and the reconstructed series assuming ϕ=10, 20 and 30.[16] The results for the standard capital stock data are shown in the first column. In this case, s, which is the share of investment based on q, is insignificantly different from zero. The coefficient β is significant but has no direct economic interpretation. The coefficient α, the speed of adjustment of actual to desired investment, is also significant. An α equal to 0.75 can be

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15. Constant 1979-80 prices.

16. We experimented with ϕ from 5 to 30 and found results approximately proportional to those presented in Table 1. Note that seasonal dummies were included in the estimation, but results were not reported in the interest of brevity.

interpreted as an average lag of three quarters between the decision to investment and the appearance of half of the new productive capital.

Results for ϕ= 10, 20, and 30 are presented in the remainder of the table. The interesting feature of these results is the effect on the share of investment determined by q (the s coefficient), as ϕ is increased. In the case of ϕ=10, this coefficient is insignificant, but for ϕ =20 and 30, the coefficient is significant. We find that for any value of $\phi \geq 16$, the coefficient on q is significant. Note also that as ϕ is increased, both the significance and size of the s coefficient increases. Our priors are that the appropriate value of ϕ is at least 20, although this cannot be tested in the current model. This implies that as a lower bound, at least 10 per cent of investment is based on q while the remaining 90 per cent of investment is based on current profits.

Figure 1 plots the actual and predicted values of investment for the 1980s from the regression in the case where ϕ = 20. It can be seen that there appears to be no systematic tendency for the model to over or under predict the behaviour of investment.

In summary, we find that the model tracks investment expenditure quite well and that at least 10 per cent of investment is based on q theory while almost 90 per cent is based on current profitability.

6. Conclusion

This study has attempted to explain aggregate investment in Australia by using a combination of the q theory and profits theory of investment behaviour. It is novel in attempting to incorporate competing hypotheses directly into the specification of the problem rather than testing one hypothesis with the alternative implicit in the rejection of the null hypothesis. It also explicitly incorporates the theoretical derivation of the model into the construction of the data used to test the theory. It is found that ignoring this implication of the theoretical model biases the test of the q theory towards rejection.

We find that the model explains a large part of the variation in aggregate investment. Future work should focus on incorporating liquidity constraints explicitly into the firm's optimisation problem. It should also be based on a broader measure of the firm's incentive to invest taking into account both debt and equity sources of financing investment.

APPENDIX:

Table 1: Estimation Results

Parameters and regression statistics	Capital stock[a]	Capital stock[b] ϕ=10	ϕ=20	ϕ=30
Parameters				
γ_3	-0.002	0.0006	-0.0001	-0.0004
	(0.058)	(0.003)	(0.004)	(.005)
s	0.074	0.046	0.103*	0.171*
	(0.057)	(0.025)	(0.050)	(.070)
β	0.171*	0.128*	0.144*	0.166*
	(0.073)	(0.040)	(0.053)	(0.747)
α	0.749*	0.737*	0.750*	.760*
	(0.064)	(0.066)	(0.065)	(0.066)
Regression statistics				
R^2	0.91	0.92	0.91	0.90
h	-0.96**	-1.03**	-0.98**	-0.97**

a. the capital stock series based on annual estimates of capital stock, ABS Cat#5221.0;

b. the capital stock series generated according to cost of adjustment theory (ϕ=10,20,30);

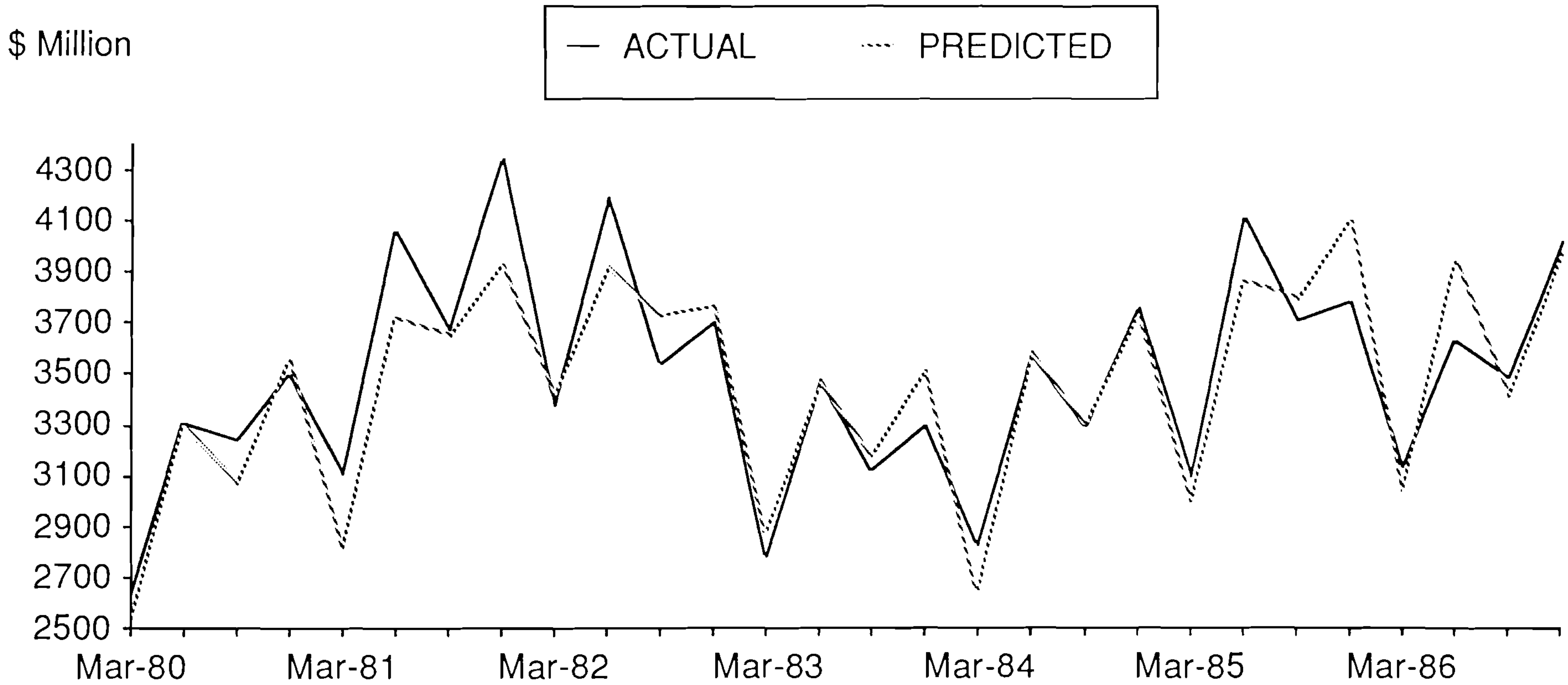
* significant at the 5 per cent level;

** comparison with the critical value at the 5 per cent and 1 per cent levels of the standard normal distribution indicates the absence of first-order autocorrelation.

13.

FIGURE 1

GROSS BUSINESS FIXED INVESTMENT EXPENDITURE
(1979/80 prices)



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