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Investment in an Uncertain World

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Abstract: The aim of this paper is to analyse divergent approaches to the analysis of fixed asset investment. In recent years, the basic predictions of orthodox and Keynesian theory have converged despite divergent policy implications. So in this analysis a range of empirical specifications of investment models is assessed in order illuminate the appropriate policy approaches for boosting investment.

JEL Classification: E2, E12

Key words: accelerator models, Knightian uncertainty, financial markets, *q* theory

Introduction

The theoretical analysis of investment concentrates on four investment models: Jorgenson's model, accelerator theory, *q* theory and option costs approaches. In Jorgenson's influential neo-classical model, investment is described as a process of optimal capital stock adjustment, with the user cost of capital (essentially the relative cost of capital inputs) and output as determinants of investment. However, in his original model, Jorgenson assumes static expectations and neglects uncertainty, although *ad hoc* lags are super-imposed in later specifications to capture expectations. Empirical modelling of Jorgenson's theory was unsuccessful in the sense that there was little agreement about the impact on investment of the user cost of capital. Also, the estimated lag parameters were difficult to interpret because the influence of expectations cannot be separated from the other factors captured by the lag structure, e.g. delivery, adjustment and installation lags. The key 'Keynesian' alternative to Jorgensonian theory was accelerator theory, which focuses on the role of output growth, ignoring relative factor costs. However, whilst a large volume of evidence suggests that accelerator theories do out-perform neo-classical theory empirically,

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accelerator models do suffer from similar problems to those seen in neo-classical theory, particularly in terms of the specification of expectations and lags.

The next step in orthodox theory was the development of adjustment cost models, in which investment is described as a process of rational dynamic optimisation. When investors maximise their stream of future profits, then investment will be determined by (marginal) *q*, defined as the shadow price of capital (the expected future marginal revenue products). A problem for *q* theory lies in the behavioural assumptions of rational maximisation. Also, *q* theory neglects the independent role of uncertainty: implicitly, *q* theorists assume that impact of uncertainty is addressed by the formation of expectations. Generally, *q* models do not perform well empirically and are generally characterised by serial correlation.

The latter problem was addressed with the evolution of real options theories. These theories centre on the insight that in times of uncertainty, given irreversible investments with large sunk costs, additional information will be valuable. So it may be optimal to delay investments given uncertainty. The options costs theorists have tended to analyse the independent effect of uncertainty within *q* models of investment and a number of studies has confirmed a negative relationship.

This paper begins with a discussion of Keynes's key insights and the development of the most influential 'Keynesian' approach to investment, i.e. accelerator theory. Then the paper traces the evolution of orthodox theory from Jorgenson's neo-classical model to options costs investment models. Econometric evidence on UK manufacturing investment between 1972 and 2001 is then presented, comparing the relative explanatory power of accelerator theory versus *q* theory once variables to capture uncertainty have been introduced. The evidence presented shows that both *q* theories and accelerator theories have some empirical merit but neither explanation stands alone in an empirical sense.

Theoretical Approaches[1]

The Influence of Keynes

Keynes's analysis of investment activity focuses on two sets of factors. In Chapter 11 of *The General Theory of Employment, Interest and Money*, Keynes discusses the objective determinants of investment and focuses on the relationship between the marginal efficiency of capital, interest rates and risk. The subjective determinants of investment are discussed in Chapter 12 of *The General Theory* and in Keynes (1937). Here Keynes discusses the relationship between the marginal efficiency of capital and 'psychological' motivations, i.e. subjective influences propelled by forces such as unquantifiable uncertainty, the state of business confidence, animal spirits, conventions and herd behaviour. Keynes analysis of investment is complex and esoteric and it is not possible to do full justice to his ideas here.[2] But just in terms of the development of the investment theories described here, four sets of ideas have been particularly influential[3]:

1. Investment activity is a crucial dynamic link between past, present and future because investment decisions made today determine productive capacity tomorrow. For this reason, expectations are crucial to investment decisions.

2.Uncertainty is endemic and means that investors can only rarely quantify their expectations of future profits. This means that investor behaviour cannot be described as a process of rational maximisation.

3.The existence of Knightian (i.e. unquantifiable) uncertainty means that entrepreneurs are often propelled by 'animal spirits', i.e. spontaneous urges to act. Animal spirits, being based on very limited information, are easily swayed when the state of business confidence is weak and so investment activity will falter with rising uncertainty.

4.Given limited information about the future, investors will tend to look to the stock market when judging the worth of potential new investments.

Whilst these insights have always been recognised within the Post Keynesian literature, as will be seen below, their importance has only gradually been accepted within the orthodox and accelerator literature.

The Development of 'Keynesian' Investment Theory

Accelerator Theory

Accelerator models focus on output growth as the key determinant of investment decisions and are usually seen as 'Keynesian' given their focus on quantity (rather than price) adjustments. In fact, Clark (1917) was the first person to describe the relationship between investment and accelerating output, i.e. output growth, whilst the Post Keynesians have always emphasised the key role of profits and financial factors in determining investment decisions. How does accelerator theory link these approaches together? Matthews (1959) explains accelerator theory's emphasis on simple quantity factors by describing the connection between profits and output growth: in an uncertain world, lags on output growth are assumed to signal growth in future profitability. In deciding about their desired capital stock, investors will proxy future profit expectations by looking at current and past levels of output and demand. In addition, investors will invest to replace depreciated capital stock and to augment capital stock according to expectations of future output. This process of capital stock adjustment can be shown as follows:

$$K^*=vY^e_{t+1}$$

$$\therefore I_{gt}=K^*_t-K_{t-1}+{}^*K_{t-1}$$

where K^* is the desired capital stock, Y^e_{t+1} are expectations of output in period $t+1$, v is the capital-output ratio, I_g is gross investment, K_{t-1} is the capital stock in the preceding period and d is the depreciation rate.

Assuming Y^e_{t+1} is formed according to past output performance gives:

$$I_{gt}=vY_t+(\delta-1)K_{t-1}$$

In this model, the level of output rather than output growth is included as an explanatory variable because this allows that the capital stock is not necessarily at its desired level in the preceding periods. If the capital stock were at its desired level in the previous period, the specification would become:

$$I_{gt}=v\Delta Y_t+\beta K_{t-1}$$

Simple accelerator models include only one output growth term within their specifications and imply that the capital stock reaches its desired level in each period of time and so long-term expectations are ignored, despite Keynes's emphasis on the state of long-term expectation in Chapter 12 of *The General Theory*. In addition, the independent influence of uncertainty is ignored in simple accelerator models so these models neglect Keynes's essential insights about the relationships between expectations, uncertainty and investment.

In response to some of the empirical shortcomings of simple accelerator models, Goodwin and Chenery formulated 'flexible accelerator' models. Goodwin (1948) outlined a rudimentary flexible accelerator model that showed entrepreneurs adjusting their desired capital stock over number of years. Chenery (1952) developed Goodwin's insight by introducing 'reaction lags' into the simple accelerator model. These reaction lags reflect the interval between changes in demand and the response in terms of new investment activity and so will capture the delays between investment decisions and investment expenditures. In flexible accelerator models, adjustment to the desired capital stock is assumed to take place over many periods. Expected future output is included as a weighted distributed lag function of past output, allowing partial, delayed adjustment within the investment decision-making process. In this way, the effects of past output growth that are spread over time, reflecting decision, financing, ordering, delivery, installation and adjustment lags.

The incorporation of a distributed lag structure into accelerator models is also consistent with models of investment incorporating adaptive, extrapolative or regressive expectations. The process of forming expectations will create relationships between current and lagged variables, if current expectations are based upon past events. For example, firms may look at a series of lags on past output in forming expectations of future profitability. For all these reasons investment will respond sluggishly to current conditions.

Orthodox Models of Investment

Jorgenson's Model

In Jorgenson's (1963) early neo-classical model, fixed asset investment is described as a process of optimal capital stock adjustment. Jorgenson assumes that capital-labour ratios adapt to relative factor price changes, where the relative factor price of capital is measured as the 'user' or 'rental' cost of capital.[4] In this neo-classical approach, policy prescriptions centre around allowing the market to operate freely and efficiently by promoting the flexibility of prices. Jorgenson assumed that capital stock adjustment is instantaneous, adjustment costs are zero and investment decisions are completely reversible. This means that investors do not have to look to the future in Jorgenson's world because they can respond so quickly and effectively when the time comes and so their expectations are essentially static. This approach was subject to widespread criticism not only from the Keynesian camp but also from orthodox theorists. Accordingly, *ad hoc* lags were introduced into Jorgensonian models to capture past expectations. A large range of empirical testing of Jorgenson's model was undertaken but most models did not perform well empirically for a wide range of reasons. One of the most fundamental problems came in specifying the lag structure: it is difficult to separate the impacts on lag structure of expectations about the future versus other factors, such as delivery, adjustment, installation lags. In addition, the rate of investment over time is undefined in Jorgenson's model given instantaneous capital stock adjustment and no adjustment costs (Junankar, 1972).

q and Adjustment Costs Theories of Investment

The theoretical and empirical problems with Jorgenson's model led to attempts by the orthodox theorists to capture the future more effectively via a more rigorous approach to specifying expectations. Ironically, this implied a recognition of a key insight from

Keynes: that expectations are essential to investment decision-making because investment decisions are a crucial dynamic link and link the past, present and the future via the capital stock. The q theorists begin by incorporating positive adjustment costs into their models. For example Abel (1983) defines internal adjustment costs as the output losses that arise within a firm as a result of adapting to flows of new investment. The value of a firm's investment and employment activities is described in much the same way as in Jorgenson's model but an additional adjustment cost term is incorporated to capture output losses that result from the adjustment. Adjustment costs are increasing in investment but decreasing as the capital stock increases. Adjustment cost models describe firms maximising the value of their production and investment activities and, for each unit of capital, the net benefits from maintaining the existing capital stock come via three sources, also described in Jorgenson's user cost of capital:

1. the change in the marginal value of capital goods, i.e. capital gains and losses;
2. the opportunity cost of lost earnings from alternative, i.e. financial, investments;
3. depreciation of capital goods.

In contrast to Jorgenson's theory, in q theories, new investments impose additional adjustment and installation costs and the firm will only be maximising its value when all these marginal benefits and marginal costs of production and investment are equalised. The optimal investment rate will be reached when:

1. The marginal productivity of capital and net marginal capital costs outlined above are equalised.
2. For new investments, the marginal benefits (in terms of expected future output) and marginal costs (i.e. capital goods prices and marginal installation costs) are equalised.
3. The marginal productivity of labour is equal to the wage rate.

This gives a model of investment in which the investment rate is a function of marginal q (q_M), the shadow price of capital, i.e. the discounted stream of expected future 'spot' marginal revenue products from an investment.

The optimisation rule seen in q theories is the dynamic equivalent of Jorgenson's decision-rule of equating the marginal benefits and costs of investing. When these marginal benefits and marginal costs are in balance, the firm is maximising profits over an infinite time horizon. In other words, an increase in the optimal capital stock as a result of investment will lead to an increase in future output but this will be balanced by an increase in the marginal adjustment cost. The rate of investment will rise until the higher marginal return on investment is exactly counter-balanced by the higher marginal adjustment costs. Delivery, adjustment, expectational, technological and other lags drop out of the optimisation rule. Therefore, many of the problems associated with specifying the lag structure in capital stock adjustment models are resolved. In addition, the dynamics of expectations and technology are recognised explicitly and isolated within this specification and the error term can be directly interpreted as capturing technology shocks.

Even if the rational expectations assumption is accepted without question, a key problem remains for the empirical specifications of q theory: how can expectations be captured? Brainard & Tobin (1968) provide the bones of the most influential resolution of this problem.[5] Given a range of assumptions, described by Hayashi (1982), q_M can be captured by average q (q_A) the ratio of market capitalisation to the current replacement cost of the capital stock. This empirical device is based upon an efficient markets assumption: that asset prices fully reflect all available information, respond completely and instantaneously to news and therefore provide an indicator of rational agents' assessments of the fundamental value of firms. It follows that the true market value of a firm will be captured by its stock market capitalisation of the firm. In other words, Tobin's q theorists argue that stock market valuations will give an unbiased estimate of the future value of a firm's production and investment activities. So the incentive to invest can be captured by comparing this estimate of future value with current costs. The result can be explained intuitively. If additional capital leads to a marginal increase in the market value of a firm and this is greater than the cost of acquiring that capital (i.e. when q_M is greater than 1), then the marginal benefits of investment exceed its costs and investment will take place. Thus q_M captures the incentive to invest and, when q_A *is* equal to q_M, q_A will therefore give a quantifiable measure of this incentive to invest. The role of q_A can also be explained as follows: if the market capitalisation of a firm exceeds the current replacement cost for the firm's capital stock, q_A will be greater than one and net investment will take place. The actual capital stock will increase until its current replacement cost equals the market capitalisation. At this point the capital stock will be at its optimal level, q_A will equal q_M and both will be equal to unity. The q theorists assume that this relationship can be aggregated but econometric models tend to be characterised by serial correlation (possibly reflecting model misspecification). Also, the efficient markets hypothesis, essential to q theory, is widely criticised.

Uncertainty in Options Cost Models

In response to the theoretical and empirical shortcomings of q theories, orthodox theory adapted again - with the introduction of uncertainty into options costs models of investment. Uncertainty dampens investment activity if investments are irreversible. Investment involves sunk costs. These arise not only because de-installation is costly but also because capital goods have a very limited resale value. A large proportion of investment purchases involve sunk costs because many investment assets are industry or firm specific. If demand conditions change, then other firms within a given industry will be unwilling to buy second-hand capital goods because they face the same demand conditions as the seller of the capital goods. In non-competitive markets, highly specific capital goods have no re-sale value because they are of no use to other businesses. Given these sunk costs, net disinvestment is impossible and without the sale of assets gross disinvestment is constrained to be equal to the amount of depreciation.

The inability to reverse investment decisions imposes additional costs on investors if there is an adverse change in circumstances and investors will accordingly be more cautious in the face of down-side uncertainty. Once irreversible investment is introduced, a negative correlation between investment and uncertainty seems likely. Cukierman (1980) argues that risk-averse investors facing irreversible investment decisions and increased uncertainty will require and acquire more information about future demand conditions before they decide to invest. Whilst they delay investment decisions, they will not necessarily cancel investment plans altogether. The length of time devoted to collecting information, the 'optimal waiting period', will increase as the variance of expected rates of return increases. Cuikerman relates this result to the precision of information. A decrease in the precision of information about the future potential of investments will have ambiguous effects. The overall value of information will decrease and therefore there will be less incentive to wait for information before investing. However, it takes more time to accumulate enough relevant information and therefore the optimal waiting period will increase.

Developing these ideas, Dixit and Pindyck (1994) develop a 'real options' theory of investment under uncertainty. Dixit and Pindyck (1994) argue that leeway over the timing of investment has profound effect on the investment process when investment is irreversible and involves sunk costs. Uncertainty has counter-balancing effects on investment: irreversibility will lead to decreased investment under uncertainty but the desire for increased flexibility to deal with buoyant conditions will promote increased investment under uncertainty. The net outcome depends on which effect predominates. Dixit and Pindyck argue that the benefits of delaying investments include the ability to acquire more information about the investment and, if demand falls, avoid problems of excess capacity. Costs of delaying investment include forgone cash flows and risk of new entrants. Investors will incorporate these benefits and costs into their optimisation problem.

Dixit and Pindyck compare investment decisions to financial call options. The option to invest has a value that includes the value of future investment opportunities that can exploit a firm's existing capacity, skills, technology and market position. Increased uncertainty increases the value of the option to invest and therefore whilst the firm will hold less capital as uncertainty increases, the market value of existing capital will be greater, reflecting the value of future options to invest. The exercise of the option to invest involves an opportunity cost not only of the sunk costs of irreversible investment but also of the costs implicit in not being able to invest at some, possibly more favourable, future point. There are also costs involved in abandoning the opportunity to collect more information. This is because the alternatives are not to invest now or never. In fact, once postponement of investment decisions is recognised as a possibility, the standard net present value (NPV) rules do not apply unless the opportunity cost of exercising the option to invest is recognised. Dixit and Pindyck (1994) argue that the use of NPV investment appraisal techniques without recognising the opportunity cost of exercising options to invest will encourage over-investment. Optimal investment rules should be modified to advocate investment only when the value of exercising the investment option is greater than the purchase and installation cost plus the value of retaining the option. The existence of opportunity costs of exercising investment options may explain why real-world firms use hurdle rates of return generally 3-4 times the cost of capital; even allowing for differences in the risk-adjusted cost of capital, hurdle rates are generally high.

In the options cost literature, orthodox economists have adopted another key insight from Keynes: that uncertainty is negatively correlated with investment. In times of uncertainty, given irreversible investments with large sunk costs, additional information will be valuable. This implies that exercising an option to invest has a certain opportunity cost. There may be other times in the future that are better times to invest and so perhaps it is preferable to delay investments when faced with rising uncertainty. The options costs theorists have tended to analyse the independent effect of uncertainty within *q* models of investment and a large volume of studies have confirmed a negative relationship between investment and uncertainty, recognising an insight always emphasised by Keynes and the Post Keynesians.

Similarly, accelerator theories have a number of parallels with Jorgenson's neo-classical theory. Both approaches focus on capital stock adjustment to some desired or optimal level. Whilst a large volume of evidence suggests that accelerator theories do out-perform neo-classical theory empirically, they suffer from similar problems to those seen in neo-classical theory, for example problems of uncertainty and the nature of expectations formation are not dealt with satisfactorily. Also, the lag structures seen in accelerator models are justified on similar grounds to the lag structures in Jorgensonian models and the independent influences of the various sources of lags are not separated.

So empirical problems with the specifications of orthodox models has led to the gradual recognition of insights from Keynes, always emphasised in the Post Keynesian literature, namely that uncertainty and expectations are crucial to investment decision making. However, the problem remains that whilst a range of economists from orthodox and Keynesian perspectives can explain a negative relationship between uncertainty and investment, the explanations must be separated because the policy implications are so radically different. This is why an empirical assessment of the competing theories is so important.

So, overall, it may appear that there has been a degree of theoretical convergence in the investment literature. However, whilst it is heartening to observe such convergence (even if it is unwitting), it does not necessarily help our understanding of economic processes or inform policy approaches. Economists representing a wide range of viewpoints can explain a negative relationship between uncertainty and fixed asset investment and/or an explanation for the link between stock markets and fixed asset investment. However, these economists recommendations would be radically different with the orthodox theorists recommending policies to promote the efficient operation of markets and the price mechanism whereas Keynesian economists would recommend government intervention to moderate forces of instability and uncertainty. So it is important to separate and test the theories, for example by an empirical assessment of the theoretical models.

The Empirical Evidence

Previous empirical analyses

A large number of accelerator models have been estimated since Clark first introduced the approach in 1917. Once the problems with simple accelerator models had been resolved, subsequent empirical evidence verified that output growth was an important determinant of fixed asset investment activity (Chenery, 1952; Diamond, 1962 amongst many others). Survey evidence supported the assertion that quantity variables such as demand, output, sales and capacity-utilisation were more important than price factors such as the cost of funds and interest rates (Hall & Hitch, 1939; Rockley, 1973; Morris, 1974; Neild, 1964). These survey findings were confirmed in econometric analyses that favoured flexible accelerator theories of investment over interest-rate models (e.g. Modigliani and Weingartner, 1958; Eisner, 1965; Kuh, 1971).[6]

Empirically, Chenery found that the flexible accelerator coefficients in his model were less than the upwardly biased average capital-output ratio estimated for simple accelerator models and so his flexible accelerator solved some of the empirical difficulties with the simple accelerator specifications outlined above. However, a key practical problem for flexible accelerator models (and other models incorporating many lagged variables, including Jorgenson's neo-classical theory lies in empirically specifying the lag structure. Often there is no clear *a priori* information about how many lags on output growth to include empirical specifications. It is difficult to get reliable quantitative information about lag structures although survey data and econometric evidence does reveal some information about lag length.

Following the development of Jorgenson's model, a large empirical literature emerged comparing accelerator theories with Jorgenson's model. Most analyses indicated that aggregate investment is not responsive to changes in the user cost of capital and so accelerator theory is often credited with having superior explanatory power in comparison with Jorgenson's neo-classical accelerator theory. However, there are a number of empirical problems with the estimation of accelerator theory and the apparently superior explanatory power of accelerator theory is not necessarily convincing as a complete explanation for investment behaviour. In accelerator theory, expectations are essentially static, the direction of causality is not established and lags are often introduced in an *ad hoc* way.

The empirical evidence on *q* theory is mixed. Generally, Tobin's *q* models (and other rational expectations based *q* models) did not perform well empirically, perhaps because of the range of assumptions adopted. One of the fundamental problems with the approach lies in the efficient markets assumption that financial markets will capture the fundamental value of assets and will respond fully, instantaneously and accurately to any relevant news. However, the literature on speculative bubbles shows that financial markets are not efficient processors of information so share prices do not necessarily reflect the long-term prospects of firms' profitability. Also, if the efficient markets hypothesis holds, then the rate of investment will be solely determined by contemporaneous *q* because all current, relevant information will be reflected in market valuations of a firm's assets. However, most empirical specifications of *q* incorporate other variables and lags on *q*. Incorporating lags on *q* is more defensible than incorporating other variables because investment decisions may take some time to materialise. The inclusion of other variables is also justified in the *q* literature but this does mean that elements of 'ad hockery' creep into empirical specifications of *q*. In addition, the *q* theorists neglect the independent influence of uncertainty on investment outcomes; Tobin's *q* theory does not explain how individual expectations are affected by Knightian (unquantifiable) uncertainty because *q* models are built in an ergodic world, in which rational expectations of future outcomes can be quantified. Following the development of the real options costs models, a number of orthodox economists have confirmed the existence of a negative relationship between investment and uncertainty when uncertainty variables are super-imposed upon *q* models. However, this result does not allow the separation of theoretical explanations because a post Keynesian economist would predict a negative relationship between investment and uncertainty too. One of the aims of the econometric analysis presented in this paper is to separate these approaches after controlling for uncertainty.

An Econometric Assessment of Competing Models

The Models

In this paper, two theoretical models were estimated: a flexible accelerator model and a q model. The accelerator model was estimated in the form outlined below, assuming that the capital stock was not at its desired level in the preceding period. This essentially a flexible accelerator model, i.e. a distributed lag form of the simple accelerator model outlined in the section on accelerator theory. It has also been augmented with a capacity utilisation terms:

$$i_{gt} = \alpha + \sum_{n=0}^{4} \beta_n y_{t-n} + \gamma \sum_{n=0}^{4} \varphi_n CU_{t-1} + (\beta - 1)K_{t-1} + \varepsilon_t$$

where y is the natural log of output, i_{gt} is the natural log of gross investment, k_{t-1} is the natural log of the capital stock, CU is the index of capacity utilisation and, t is a stochastic error term.

The q model is estimated in the following form:

$$i_{gt} = \theta + \sum_{n=0}^{4} \psi_n q_{t-n} + (\beta - 1)K_{t-1} + \xi_t$$

where q is the ratio of market capitalisation to the current replacement cost of the capital stock. The inclusion of lagged qs is justified on the basis that investment is subject to decision and delivery lags and so not all current investment will be determined by current expectations as captured within q.

Uncertainty and cyclical factors were also included in both models. Uncertainty was captured by stock market volatility (measured as the standard deviation per quarter in monthly averages of the FT all ordinaries share index). Cyclical factors were captured via the inclusion of a capacity utilisation variable. Hendry's 'top-down' approach to econometric modelling was adopted, with both the accelerator and q models estimated in unrestricted form, incorporating a full set of lags, and then in restricted form, after excluding the insignificant variables.

The Empirical Results

The empirical models were estimated using quarterly data on UK manufacturing investment between 1972 and 2001. The empirical results are outlined in Tables 1-5 and the data sources are outlined in Table 6.

For the accelerator model, the diagnostic tests for serially correlated residuals, incorrect functional form and heteroscedasticity were insignificant at 10%

significance levels, although there was significant evidence of non-normality in the residuals and the result on the serial correlation test is borderline. The explanatory power of the model was good with an R^2 suggesting that about 95% of the variability in investment explained by the model. The estimate of the long-run elasticity of investment with respect to output was insignificantly different from +1, which is consistent with the predictions of accelerator theory. However, it should be acknowledged that the actual point estimate of 0.15595 seems far from +1, the insignificant result could reflect inaccurate estimation, e.g. stemming from multicollinearity or micronumerosity.

For the *q* model, there were signs of serial correlation and non-normality in the residuals, significant at 10%. In addition, the estimate of long-run elasticity of investment with respect to *q* is negative, which is contrary to the predictions of *q* theory. It is possible that this result is explained by a complicated lag structure. The presence of serial correlation is consistent with previous empirical evidence but given the high R^2 of about 95%, this serial correlation may be explained by non-stationarity in the *q* variable.

For both sets of models, the uncertainty and capacity utilisation variables were insignificant, although a negative relationship between investment and uncertainty was detected, which is consistent with previous empirical evidence. The sign on the capacity utilisation was negative but this could reflect reverse causality, i.e. a high capacity utiliisation rate will imply that capacity scrapping has taken place because of low investment rates in previous periods and may be a capturing times of recession.

Model Comparison Tests

The *q* and accelerator models are compared using non-nested hypothesis testing techniques. These tests are constructed by testing the insight that a good model should contribute explanatory power independently of alternative models. The non-nested tests reveal that both *q* and accelerator theories add independent explanatory power, suggesting that the development of some sort of hybrid model may be appropriate. Neither *q* theory nor accelerator theory seem to capture all that is important to investment activity.

Summary of Empirical Results

Whilst the results from the accelerator model are somewhat encouraging, the limitations of these econometric models should be recognised. Further econometric analysis is required to resolve possible simultaneity problems, for example between investment and capacity utilisation. In addition, the possible non-stationarity in the q variable and the absence of a cointegrating relationship between investment and q suggests that further econometric work is needed to illuminate the relationships between q and investment activity. Further theoretical work is also needed because it seems clear that neither q theory nor accelerator theory provides a complete explanation for investment activity because it seems that some combination of output and financial variables determine investment activity.

Conclusions and Policy Implications

In the theoretical section the development of orthodox models of investment was described. Overall, there has been a gradual recognition in this literature that expectations and uncertainty will have crucial effects on investment decisions. In this sense has been theoretical convergence in divergent approaches. However, these parallels are not as heartening as they may seem at first glance. Whilst a range of approaches can explain a negative correlation between investment and uncertainty, the associated policy implications are radically different. The orthodox theorists recommend policies to enhance the operation of markets in order to help rational, optimising investors to assess investment opportunities effectively. Accelerator theorists recommend policies to boost output and demand, e.g. government fiscal policies. However, the empirical evidence presented here suggests that neither theory provides a complete and coherent explanation for aggregate investment behaviour. This could be because both sets of theories leave something out, either financial variables or demand factors. The key policy implication of an approach that recognises the importance of financial variables as well as demand factors would be that, rather than concentrating on enhancing the flexibility of markets, governments should concentrate on reducing uncertainty and moderating destabilising speculation.

NOTES

[1] For a more comprehensive analysis of the details underlying these models see Baddeley (2002).

[2] For a fuller discussion of Keynes's analysis, see Baddeley (1996, 1999, 2002).

[3] Another crucial element of Keynes's theory, developed by Post Keynesians, is the importance of the money and finance in a world of uncertainty. For example, the analysis of the 'finance motive' to invest is addressed in Davidson (1978), Baddeley (1996, 2002).

[4] Not to be confused with Keynes's user cost of capital.

[5] Other solutions are outlined in Chirinko (1993).

[6] See Baddeley (1996, 2002), Nickell (1978) and Junankar (1972) for surveys of the empirical evidence.

REFERENCES

Abel, A.B., (1983), 'Optimal Investment under Uncertainty', American Economic Review, 73(1): 228-33.

Baddeley, M., (1999), 'Keynes on Rationality, Expectations and Investment', in C. Sardoni (ed.), Keynes, Post Keynesianism and Political Economy: Essays in Honour of Geoff Harcourt - Volume 3 (London: Routledge).

Baddeley, M.C., (1996), Rationality, Expectations and Investment: the Theory of Keynes vs. Neo-Classical Theory, PhD dissertation, Faculty of Economics and Politics, Cambridge University

Baddeley, M.C., (forthcoming 2002), Real Investment: Theories and Analysis, (London:Macmillan).

Brainard, W.C. and Tobin, J., (1968), 'Pitfalls in Financial Model Building', American Economic Review, 58(2): 99-122.

Chenery, H.B. (1952), 'Overcapacity and the Acceleration Principle', Econometrica, 20(1):1-28.

Chirinko, R.S., (1993), 'Business Fixed Investment Spending: Modelling Strategies, Empirical Results and Policy Implications', Journal of Economic Literature, XXXI:1875-1911.

Clark, J.M., (1917), 'Business Acceleration and the Law of Demand: A Technical Factor in Economic Cycles', Journal of Political Economy, 25(1):217-35.

Cukierman, A., (1980), 'The effects of uncertainty on investment under risk neutrality with endogenous information', Journal of Political Economy, 88(3):462-75.

Davidson, P., (1978), Money and the Real World (2nd Edition), Macmillan, London.

Dixit, A.K. and Pindyck, R.S., (1994), Investment Under Uncertainty, (Princeton: Princeton University Press).

Eisner, R. (1965), 'Realisation of Investment Anticipations', in Duesenberry, J.S., Fromm, G., Klein,L.R. and Kuh, E. (eds)(1965), The Brookings Quarterly Model of the United States, North-Holland, Amsterdam.

Goodwin, R.M. (1948) 'Secular and Cyclical Aspects of the Multiplier and Accelerator', in Income, Employment and Public Policy (Essays in Honor of Alvin H. Hansen), New York: W.W. Norton & Co.

Hall, R.L. and Hitch, C.J. (1939), 'Price theory and business behaviour', Oxford Economic Papers, no. 2, pp. 12-45.

Hall, R.L. and Hitch, C.J. (1939), 'Price theory and business behaviour', Oxford Economic Papers.

Hayashi, F., (1982), 'Tobin's Marginal q and Average q: A Neoclassical Interpretation', Econometrica, 50:213-224.

J.J. Diamond (1962) 'Further Development of a Distributed Lag Investment Function', Econometrica, 30(4):788-800.

Jorgenson, D.W., (1963), 'Capital Theory and Investment Behaviour', American Economic Review, 53:247-59.

Jorgenson, D.W., (1971), 'Econometric Studies of Investment Behaviour: A Survey', Journal of Economic Literature, 9(4):1111-1147.

Junankar, P.N., (1972), Investment: Theories and Evidence, (London: Macmillan).

Keynes, J.M., (1936), The General Theory of Employment, Interest and Money, (London: Macmillan).
Keynes, J.M., (1937), 'The general theory of employment', Quarterly Journal of Economics, 51:209-23.
Matthews, R.C.O., (1959), The Trade Cycle, (Cambridge: Cambridge University Press).
L.E. Rockley (1973), Investment for Profitability, London: Business Books.
Matthews, R.C.O. (1959), The Trade Cycle, Nisbet & Co and Cambridge University Press, Cambridge.
Modigliani, F. and Weingartner, H.M. (1958), 'Forecasting Uses of Anticipatory Data on Investment and Sales', Quarterly Journal of Economics, LXXII(1):23-54.
Morris. D.J. (1974), The Structure of Investment Decisions, D.Phil thesis, Oxford University.
Neild, R.R. (1964), 'Replacement Policy', National Institute Economic Review, National Institute of Economics, London.
Nickell, S.J., (1978), The Investment Decision of Firms, (Cambridge: Cambridge University Press).

Table 1.: Unrestricted OLS Regression of Accelerator Theory

Dependent variable: Natural log of UK manufacturing investment
Estimation period: 1972Q1 to 2001Q2

Manufacturing investment (logged)$_{t-1}$	.88796	21.6166 [.000]
Manufacturing output (logged)$_t$	.22762	1.1635 [.247]
Manufacturing output (logged)$_{t-1}$	-.26706	-.90701 [.366]
Manufacturing output (logged)$_{t-2}$	.61558	2.1482 [.034]
Manufacturing output (logged)$_{t-3}$	-.41271	-1.4371 [.154]
Manufacturing output (logged)$_{t-4}$	-.15112	-.70601 [.482]
Stock market volatility$_{t-4}$	-.1141E-3	-.83178 [.407]
Capacity Utilisation$_{t-1}$	-.0013203	-2.8018 [.006]
Capital stock, manufacturing (logged)$_{t-1}$	.070174	1.5673 [.120]
Intercept	.16368	.36276 [.717]
R^2 (adjusted)	.95734	
Akaike Information Criterion	214.5198	
Schwarz Bayesian Criterion	200.6664	
Diagnostic Tests		
Breusch-Godfrey LM test for AR(4) serial correlation	$\chi^2(4) = 7.6330$ [.106]	
Ramsey's RESET test for incorrect functional form	$F(1,107) = 1.3384$ [.250]	
Jarque-Bera test for non-normally distributed residuals	$\chi^2(2) = 13.0183$ [.001]	
LM test for dependent variable heteroscedasticity	$\chi^2(1) = 0.57534$ [.448]	

[Probability values in square brackets]
Estimate of long-run elasticity with respect to output = 0.15595
t test of H_0: long-run elasticity of unity:
t = -1.4185 ? do not reject H_0 at 5% significance level

Table 2.: Restricted OLS Regression of Accelerator Theory

Dependent variable: Natural log of UK manufacturing investment

Estimation period: 1972Q1 to 2001Q2

Regressor	Coefficient	T-Ratio[Prob]
Manufacturing investment $(\text{logged})_{t-1}$	.89300	23.2600 [.000]
Manufacturing output $(\text{logged})_{t-2}$	.61177	2.8847 [.005]
Manufacturing output $(\text{logged})_{t-3}$	-.55369	-2.6483 [.009]
Stock market volatility$_{t-4}$	-.4054E-4	-.31699 [.752]
Capacity Utilisation$_{t-1}$	-.0013793	-3.4055 [.001]
Intercept	.68016	2.1083 [.037]
R^2 (adjusted) .95713 Akaike Information Criterion 216.0804 Schwarz Bayesian Criterion 207.7683		
Diagnostic Tests		
Breusch-Godfrey LM test for AR(4) serial correlation	$\chi^2(4) = 6.7335$ [.151]	
Ramsey's RESET test for incorrect functional form	$F(1,107) = 3.4902$ [.064]	
Jarque-Bera test for non-normally distributed residuals	$\chi^2(2) = 14.2654$ [.001]	
LM test for dependent variable heteroscedasticity	$\chi^2(1) = .87622$ [.349]	

[Probability values in square brackets]

Table 3.: Unrestricted OLS Regression of *q* Theory

Dependent variable: Natural log of UK manufacturing investment
Estimation period: 1972Q1 to 2001Q2

Regressor	Coefficient	T-Ratio[Prob]
Manufacturing investment (logged)$_{t-1}$	.83749	21.4077 [.000]
Logged q_t	-.12555	-1.9775 [.051]
Logged q_{t-1}	.13632	1.1449 [.255]
Logged q_{t-2}	-.019851	-.15881 [.874]
Logged q_{t-3}	.061265	.51479 [.608]
Logged q_{t-4}	-.070022	-1.0943 [.276]
Stock market volatility$_{t-4}$	-.4880E-4	-.35071 [.726]
Capacity Utilisation$_{t-1}$	-.0022259	-4.9276 [.000]
Capital stock, manufacturing (logged)$_{t-1}$	.11974	2.2198 [.029]
Intercept	.13101	.26538 [.791]
R^2 (adjusted)	.95602	
Akaike Information Criterion	212.7189	
Schwarz Bayesian Criterion	198.8655	
Diagnostic Tests		
Breusch-Godfrey LM test for AR(4) serial correlation	$\chi^2(4) = 9.2443$ [.055]	
Ramsey's RESET test for incorrect functional form	$F(1,107) = 1.4358$ [.233]	
Jarque-Bera test for non-normally distributed residuals	$\chi^2(2) = 13.0607$ [.001]	
LM test for dependent variable heteroscedasticity	$\chi^2(1) = .72346$ [.395]	

[Probability values in square brackets]
Estimate of long-run elasticity with respect to q = -.10977
t test of H_0: long-run elasticity of unity:
t =-15.128 ? reject H_0 at 5% significance level

Table 4.: Restricted OLS Regression of *q* Theory
Dependent variable: Natural log of UK manufacturing investment
Estimation period: 1972Q1 to 2001Q2

Manufacturing investment (logged)$_{t-1}$	.83731	21.4902 [.000]
Logged q_t	-.10002	-2.0051 [.047]
Logged q_{t-1}	.090527	1.8144 [.072]
Capacity Utilisation$_{t-1}$	-.0019886	-4.7431 [.000]
Capital stock, manufacturing (logged)$_{t-1}$	.11443	2.1343 [.035]
Stock market volatility$_{t-4}$	-.5867E-4	-.42359 [.673]
Intercept	.18086	.36828 [.713]
R^2 (adjusted)	.95626	
Akaike Information Criterion	214.4276	
Schwarz Bayesian Criterion	204.7302	
Diagnostic Tests		
Breusch-Godfrey LM test for AR(4) serial correlation	$\chi^2(4) = 11.2569$[.024]	
Ramsey's RESET test for incorrect functional form	F(1,107) = 1.9362[.167]	
Jarque-Bera test for non-normally distributed residuals	$\chi^2(2) = 14.0356$[.001]	
LM test for dependent variable heteroscedasticity	$\chi^2(1) = .38812$[.535]	

[probability values in square brackets]

Table 5.: Non-nested Model Comparison Tests of Restricted Models

	q against accelerator	Accelerator against q
Cox test	-3.9004 [.000]	-4.0614 [.000]
Cox (adjusted) test	-.38679 [.699]	-1.0317 [.302]
Wald test	-.38543 [.700]	-1.0212 [.307]
J test	2.0608 [.039]	2.3669 [.018]
JA-Test	-1.6291 [.103]	-1.4815 [.138]
Encompassing	F(2,109) =2.1041 [.127]	F(2,109) =2.9977 [.054]
Akaike's Information Criterion of q versus accelerator = .92415 favours q model Schwarz's Bayesian Criterion of q versus accelerator = .92415 favours q model		

[probability values in square brackets]

Table 6.: Data Sources

Variable	*Definition*	*Source*
Investment	UK manufacturing investment, 1995 prices	ONS Economic Trends Annual Supplement (ETAS)
Output	UK manufacturing output, 1995 prices	ONS – ETAS
q	Ratio of market capitalisation to current replacement cost of capital stock	Derived from data below
Market capitalisation	FT all ordinaries shares	London Stock Exchange web-site
Capital Stock	Manufacturing capital stock	ONS *National Accounts – The Blue Book*
Capacity Utilisation	Survey data on capacity utilisation by manufacturing firms	Confederation of British Industry (CBI)
Stock market volatility	Standard deviation per quarter of average monthly FT all ordinaries share index	London Stock Exchange website