TECHNOLOGICAL PROGRESS,[1] INVESTMENT AND DIFFUSION

Paul Stoneman

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1. Introduction

The thrust of this paper is to argue that technological advance is a neglected but important influence on the level of investment expenditure.[2] The importance of changes in technology in the investment decision has recently merited the attention of Hicks (1977) and is of course very much in the tradition of Schumpeter (1934), but the majority of the recent theoretical and empirical literature in the field ignores it.[3] We show that new technology is a quantitatively important factor in the investment decision, and thus ought to be incorporated into studies of investment. It is also shown that by turning to the literature on the microeconomics of technical change, one can gain a number of insights into this and other aspects of the investment decision.

As a first step consider how the literature on investment has treated technological change to date. Schramm (1972) has built a Jorgenson (1963) type investment model in which Harrod neutral[4] disembodied technical progress is included by the use of an exponential term in a Cobb Douglas production function, but this is hardly satisfactory. Feldstein and Rothschild (1974) following Feldstein and Foot (1971) have directed some attention to the currently relevant failings of such studies by investigating the role of technological progress in influencing "the other half of gross investment",

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1 By technological progress we mean the appearance of a new immediately usable technology. One may think therefore of the technology existing only once innovation (i.e. first use) has occurred.

2 I would like to thank members of the University of Warwick Industrial Economics Workshop, especially Paul Geroski, for comments on an earlier draft of this paper, and John Patient for his efforts on the exercise reported in the Appendix.

3 Although the role of investment as a carrier of new technology has merited much attention e.g. Solow (1969), Phelps (1962).

4 Which of course minimises the effect of changes in technology on capital requirements.

generating their results using a vintage model of capital. They show that depreciation (and thus the user cost of capital and net investment) and gross investment are not independent of the rate of technical progress. However a number of vintage model studies now exist which look at the whole of gross investment (King (1972), Malcolmson (1976), Mizon (1974)) so one can turn here for fuller detail. Salter (1969 p.55) adequately summarises how a new technology affects investment in these models - "each period brings forth a new set of best practice unit requirements for labour, investment and materials ... If the prices ... do not change the improvement in best practice techniques allows the possibility of super normal profits. These will induce entrepreneurs to build such plants ... until output is expanded sufficiently in relation to demand conditions (so that) super normal profits are eliminated". There are a number of objections to this the most satisfactory of the approaches.

(a) The first and most noticeable is that the empirical work does not follow the theory. For example, King (1972), derives using production function (1), investment equation (2)

$$y_v = A_v \, I_v^{\,b} \, N_v^{\,c} \qquad (1)$$

$$\log I_v = k + \frac{c}{b + c} \log \left(\frac{w}{rq}\right) + \frac{1}{b + c} \log y_v \qquad (2)$$

where $k = \left(\frac{1}{b + c}\right) \left(c \log \frac{b}{c} - \log A_v\right)$

y_v = output on vintage v machines

I_v = investment in vintage v machines

N_v = employment on vintage v machines

r = rate of interest

q = price of capital goods

w = wage rate

To follow Salter, y_v in (2) ought to be related to the extent of the improvement of the current vintage over the previous vintage. In fact King represents y_v by "a linear function of past output".

(b) Salter himself accepts that his scheme is too simple, stating that there are innumerable complications that could be introduced: gestation periods, inertia, changes in confidence and the supply of finance. Associated with this, the evidence seems to be that in contrast to the sentiments of the vintage model, new factories do not always embody the latest technology (Gregory and James (1973), (1975), Haig (1975)).

(c) The vintage and standard neoclassical models can only cater for process innovation. Product innovation and new sources of supply[1] are to be considered as just as, if not more, important than changes in process technology.

Although Helliwell's (1976) statement that "investment equations typically ignore technical change" is not quite the complete picture, it seems, however, reasonably well founded to argue that technological change has not received adequate and appropriate treatment in the theory of investment. However it also seems reasonable to argue from the above that the sentiments of the vintage model indicate the way ahead. To explain gross investment in the Jorgenson manner of generating net investment and then adding depreciation is not appropriate, the two cannot really be separated. The vintage approach whereby capital goods are purchased first and then depreciation and obsolescence results as a response to the performance characteristics of these goods seems

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1 See below.

the preferable method.[1] This is the line we follow in section 3. First however we look at the role of different stimulants of gross investment in section 2.

2. Why do firms invest?

In their submission to the Wilson Committee, Unilever (1977) state (to quote at length):-

> "Our objectives in deciding to invest are normally one or more of the following:-
>
> (a) to increase productive capacity in line with the expansion of demand for our products;
> (b) to replace obsolete equipment;
> (c) to raise the efficiency of our operations by improved quality or lower costs;
> (d) to meet improved safety and environmental requirements;
> (e) to produce new products in product areas in which we already operate;
> (f) to enter new product areas.

We may classify, therefore, that investment results from demand presaure ((a) above), substitution effects (part of (c)), process innovation (part of (c)), product innovation ((e) and (f)), institutional factors (d) and obsolescence (b). In what follows we will abstract from institutional changes, and for simplicity sake we generally assume that machines are scrapped on account of economic rather than technical obsolescence (although technical obsolescence is discussed in sections 3 and 4 below). This leaves as the prime motives for investment, demand pressure, substitution effects, new processes and

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1 This is not to deny that the resultant obsolescence will not be treated as a cost in the investment decision.

new products. In the Appendix below we report on an exercise designed to illustrate these motives further and to show that the latter two are quantitatively significant. We alo isolate another influence on investment expenditure which we label new sources of supply. The argument is that the discovery of a new resource will stimulate investment expenditures to exploit it.

With these above motives we can move on to an approach to the technological progress/investment nexus, but one final comment is appropriate prior to doing so. Unilever (op.cit.) state that all investment proposals are evaluated, prior to installation. This is a factor also noted in the Appendix. Thus although new products and processes etc. stimulate investment the actual decision to invest still involves the consideration of economic factors.

3. An approach to investment and technological progress

We have argued above that the appropriate framework is one in which we attempt to explain gross investment and then depreciation becomes endogenous (and so net investment is also determined). In the second section we have detailed five factors affecting investment:- demand and substitution effects, product and process innovation and new sources of supply. To stress our point that the last three are important we might just ask the question - can one really explain investment in the U.K. without some discussion of the discovery of North Sea Oil? The historians have already taken this point to heart, to explain 19C U.K. investment without discussing the spread of railways is inconceivable.

The final point we wish to make before proceeding is that the neo-classical approach to investment starts from an analysis of the firm and then aggregates over firms. We will proceed by looking at the demand for specific capital goods and then consider summation over capital goods. This is in fact a return to the Keynes' approach,[1] and is the link to the literature on technological change.

Consider first the question of process innovation and investment. The demand for process innovations has received considerable emphasis in the literature on diffusion theory (see for example Mansfield (1968)). The theoretical models themselves vary from the behavioural (Davies (1976)) to the overtly mathematical (Mansfield (1968)) but the result that is common to all these models and is the centrepiece of diffusion studies is the existence of the S shaped diffusion curve. Although the curve may be logistic, log normal or Gompertz we can illustrate using the logistic. As expressed by Pyatt (1964) this is represented as that investment (I) in the new process is related to the stock of new type capital goods installed (S) and the equilibrium (or satiation) stock of the capital goods (S^*) by the relationship (3)

$$I_t = g(t) \cdot \frac{S_t}{S^*_t} \cdot (S^*_t - S_t) \quad \text{for} \quad S^*_t \geqslant S_t \qquad (3)$$

$$I_t \equiv S_t - S_{t-1}$$

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1 In the textbooks the Keynesian approach has been discussed with a technological change influence (e.g. Brunhild and Burton (1974) pp.287-8). But the model never has had much empirical following, and differs considerably from our approach here.

Chow (1967) argues that the S shaped diffusion curve[1] results from the fact that as time proceeds and S_t increases the size of the potential market $(S_t^* - S_t)$ reduces but the probability of purchase increases. This probability is measured by S_t/S_t^*, the argument being that as the new process spreads, information about it also spreads leading to a greater number of purchases. We will come to the determinants of $g(t)$ and S_t^* below. Thus a new process will lead to a burst of investment following some such curve as (3), finally investment returning to some base level when the diffusion is complete.

Relationship (3) can however take us much further. Consider S_t^*, the equilibrium or satiation stock of the capital good. In the literature (e.g. Chow (1967), Stoneman (1976)) S_t^* has been taken to be a function of a number of variables, two of which interest us here:-

a) real output of or demand for products produced using the capital good;

b) the relative price of the capital good.

Let it be that the diffusion of the capital good is complete so that $(S_t/S_t^*) = 1$ and that any change in S_t^* will not influence this to any great extent. Then we can see that for any value of $g(t)$ an increase in demand can lead to an increase in S_t^* and thus positive investment, and a change in relative prices can have similar effects, i.e. we can have demand and substitution induced investment within the same general framework. If $S_t/S_t^* < 1$, then we can have these effects within a diffusion environment.

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1 In fact I_t/S_t^* has the S shape, I_t in (3) has the bell shape of a normal curve for a given S_t^* and $g(t)$.

One can also argue that physical obsolesence by reducing S_t will lead to positive gross investment.

Turn now to product innovation. Ironmonger (1972) argues that new products also have an S shaped diffusion curve (this is only as it should be as one industry's new product is another's new process). If we concentrate initially on new consumer durables this implies that the demand for new products can be plotted as a bell shape against time. Given a fixed coefficient of capital to output this imposes a definite time profile on S_t^*. Thus a new product launch requires extra capital goods the actual investment occurring depending on the existing stock of this capital good and g(t). In the absence of any existing stock of the required capital good the bell shape of S_t^* would imply a similar time profile for investment (assuming fixed inputs of a machine per unit of output). If the new good is a non durable, one would not expect the downturn in demand observed with durables and thus S_t^* (with fixed coefficients) would trace out an S shape against time. One point of relevance here is that it may be argued that the S shaped diffusion curves result from capacity constraints rather than the capacity decisions being based on the time profile of demand. Although this is possible it is usually argued in the discussion of consumer good diffusion that the factors generating the S shaped curves are demand rather than supply forces.

The method of dealing with new sources of supply is not essentially different from the above. We may think of exploiting a new resource as similar to the diffusion of a new process. Thus for example the discovery of North Sea oil is like the installation of a new process, but instead of installing new capital to produce an existing product we install capital to produce from the new source.

If for the moment we think then of an economy with just one capital good A, and a new product appears,[1] a new resource is discovered, or an autonomous change in demand or prices occur, then for a given value of g(t) one would expect positive gross investment following some relationship such as (3). If then a new capital good B appears, superior to A, one would expect a boost of gross investment until all output is produced on B rather than A, when investment will return to some base level. As a scenario this is much richer than approaches discussed in section 1, but those approaches are also special cases of this suggested framework.

We have left until now the discussion of g(t). This component of (3) is essentially the speed factor in the diffusion process. It is within g(t) that the actual decision making process is encapsulated. The determinants of g(t) will reflect the objectives and restraints upon the firm. Thus, for example, the return to any given project, the availability of finance or expectations with regard to market conditions would be considered as determinants of g(t). The importance of such factors is really the topic on which investment theorists have concentrated. However the technological change literature contains many studies of the demand for specific capital goods, and the prime objective of such studies was to detail the determinants of g(t). By turning to this literature we have a fertile field of unexploited results on the determinants of investment expenditure. Details can be found in Rogers (1962) or Norris and Vaizey (1973), but the following have been isolated as well supported arguments:-[2]

(a) In comparing firms, the firm which expects to generate high profitability from a new technology uses it earlier than one expecting low profit.

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1 At present assuming no decline in the output of existing products.

2 See, for example, Mansfield (1968), Nabseth & Ray (1974), Davies (1976), Griliches (1957) or Freeman (1974).

(b) in comparing technologies those with higher profitability diffuse faster;

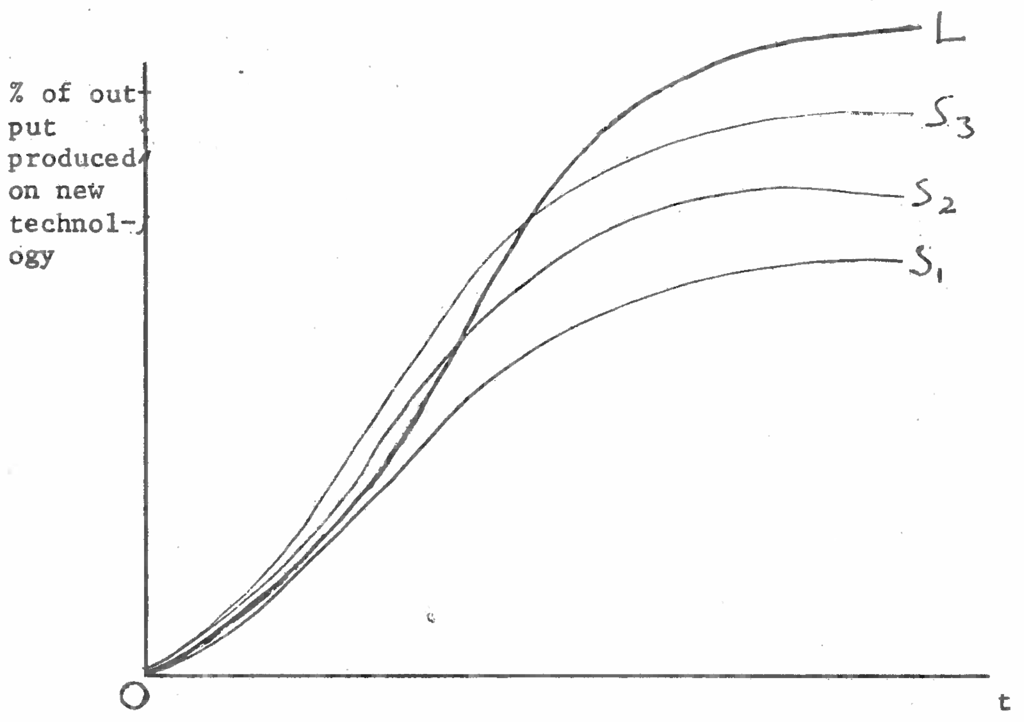
(c) technologies that are complicated and require large capital investments diffuse slower than cheap simple technologies;

(d) a number of other factors, such as liquidity, market structure, the age of the existing capital stock, management attitudes and supply difficulties have all been looked at as influences on the speed of diffusion.

Thus one prime determinant that has been isolated is profitability. If we now think of $g(t)$ as relevant in all investment decisions, for we are suggesting that some form such as (3) ought to apply to all such decisions, we have an extensive set of empirical results on the determinants of investment expenditure. Primarily it brings to the forefront of investment studies the importance of profitability - an influence generally discounted as unimportant especially in the neoclassical investment literature (Jorgenson (1971) p.1141).

At this point we ought to raise a problem that has in fact merited little attention in the diffusion theory literature, and that although not crucial to the matter on hand is worthy of discussion. We have argued that S_t^* may be a function of prices (and thus profitability of the new process or technology - in fact Griliches (1957) actually relates it to profitability) and $g(t)$ may be a function of profitability. The diffusion theory literature is really split into two factions, those who assume S_t^* fixed exogenously (as the satiation stock) and then allow profitability changes to be reflected solely in the speed coefficient $(g(t))$, and those who allow S_t^* to vary (and thus call S_t^* the equilibrium stock). The problem is illustrated in Figure 1. Let OS_i $(i = 1 \ldots n)$ be short run diffusion curves along each of which S_t^* is given but different and OL be a long run diffusion curve on which S^* equals its final or satiation value (i.e. the value when the diffusion is complete). If one estimates $g(t)$ on OL the estimate will obviously be larger than would be the estimate along each OS_i.

FIGURE 1. Short and long run diffusion curves



For present purposes however, both studies of OL type curves and studies of the short run type curves have shown profitability to be an important determinant of the speed of diffusion. The choice between the two approaches is really a matter of the appropriate definition of the diffusion concept.

However it would seem more fertile to consider the value of S_t^* at a moment in time as a function of prices and profitability, and thus the study of the short run curves is appropriate. This is the method we prefer. It is for this reason that we consider that this framework can also be used to look at demand induced and substitution generated investment.

All of the above, as summarised in equation 3, refers to the demand for a specific capital good. To obtain an investment function we need to aggregate over all capital goods and moreover we need either as a consequence of this aggregation, or in addition to it, to generate a value of investment demand as opposed to the numbers concept used so far. Capital valuation and aggregation are two areas where wise men fear to tread (Sen (1974)). Here we indicate some of the relevant issues without any final derivation of an aggregate version of (3) which would determine the value of aggregate investment expenditures.

(a) If we are thinking of a given set of capital goods in existence and product innovation or a demand change occurs then gross investment will only be positive if the sum of the effects do not cancel out. The sort of problem to face can be illustrated by the new product example. If a new product as well as being successful takes the market from an old then one would expect positive gross investment if a) the new product is produced by a different firm, b) produced on different capital goods or c) a higher level of demand will be reached on the new rather than the old product. These do not seem unreasonable conditions. Moreover if the new product is produced using an existing process requiring similar inputs of capital to the old product and the total market for the new product is greater than the market lost by the old product there will be positive net investment as well as gross. Gross investment under these conditions will also exceed counter-factual gross investment and net investment will also be positive. Given only positive capital good prices, there will also be a positive value of gross investment above the counter factual and a net increase in the value of the capital stock.

With substitution the problem is more involved. If prices change such that for the production of a particular set of commodities a new type of capital good is preferred, there would be a positive number of capital goods being installed. Whether finally the capital stock will have a higher or lower value is the argument of the Cambridge capital controversy. It should thus be clear that we can say little about the value of investment in response to such substitution pressures, although the capital stock will be changing composition in response to them and thus gross investment required.

(b) To install a new process must mean positive gross investment. The problem arises as to whether the value of this investment will be greater than on the counter-factual path.[1] As the new process is an improvement on the old, it must use less inputs per unit of output. For a given "price of a unit of capital" this could mean that an absolutely capital saving innovation could imply a lesser value of investment than would have occurred along the counter factual path. However the extent of the capital saving bias would have to be very large to generate this effect. If one considers an industry with a capital stock that along the counter factual path will be

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1 I'd like to thank PaulGeroski for pointing me in this direction.

replaced by new old type capital goods then the bias has to be such that it will offset the diffusion of the new capital goods as well as the replacement of the worn out new type capital goods. Although this means that process innovation may mean lower investment, casual empiricism suggests that modern process innovations are not absolutely capital saving, in fact quite the reverse would seen a reasonable assumption. Thus gross investment above the counter factual is a plausible result.

(c) A factor related to (b) above is that the evidence seems to suggest (e.g. Stoneman (1976)) that the price of new type capital goods embodied in a new process tends to fall due to further technological advance. Thus when we study the bell shaped investment curve which has been defined on the number of machines installed, a falling price could well provide a flattened curve defined on the value of machines installed. Thus one may not observe in a value series the normal curve of gross investment against time. This is relevant to the empirical testing of economic hypotheses on investment, but for the output and performance of the economy it is really the change in the physical quantity of inputs that matters, and that is what our analysis centres upon, not the value of the inputs.

As we have said the aggregation and valuation of capital is a thorny problem. We have presented a demand curve for a specific capital good, and have argued that after aggregation over all capital goods, the conditions required for the value of gross investment to increase (and to also exceed the counter factual) in response to product and process innovation (and thus also new sources of supply) and demand increases, are not over stringent. In the case of substitution responses however, although a change in prices should change the optimal mix of capital goods in the total capital stock and new capital goods will be required, we are not willing to draw any conclusions on what is really a much disputed topic - the effect on the value of investment.

Finally we have argued that, in response to a technological change, we may expect to see a bell shaped time profile of gross investment measured in numbers of machines. This profile may well not be noticeable in a value series. This may present problems when estimating functions to explain the value of investment, but it is the physical concept of investment that is really relevant to the discussion of the performance of an economy, and it is with regard to this concept that our results carry most weight.

Conclusion and Implications

With the seeming absence of an adequate treatment of technological change in the study of investment we have suggested a framework based on diffusion studies that will allow for the introduction of new products and processes as well as cater for the existing approaches to investment. The core of this approach is some relationship such as equation (3).

Using (3) one can explain why not all new factories embody the latest technology. It is due to the information problem or the factors affecting the diffusion speed. Moreover discussing the determinants of this speed we have good empirical grounds for reintroducing profitability of investment into investment studies. A basic question however is - have we anything here very different from what already exists. In terms of factors considered the answer is yes, but in terms of the appearance of (3) the answer would seem to be no, but appearances are deceptive. In terms of the factors we are isolating as determinants of the speed of diffusion we are getting close to the Neo-Keynesians' approaches to investment (Junankar (1972)) with their internally determinated adjustment speeds, but our aggregation structure is different. Most importantly, technological change is considered as the rule rather than the exception and is built in from the beginning. With this view of the world we open up a rich store of empirical results that can be used to advance our knowledge on the determinants of investment expenditure.

Finally a comment on omission. We have tended to treat demand and technology as exogenous. This is a useful simplification but not realistic. If however one can introduce technical change into investment theories (as a Schumpeterian would wish) these simplifications can be removed later. We have also ignored "the other half of gross investment" - depreciation and obsolescence. Feldstein and Rothschild (1974) have a significant contribution to make here. Our major concern has been to discuss gross investment, but turning to their work one can then move from the performance of the new capital good to the scrapping of old, and thus net investment.

P.Stoneman
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Appendix

In this Appendix our intention is to look at the firm's investment decisions at a very disaggregated level in an attempt to find further evidence on the above detailed motives behind the purchase of new capital goods. Our method is essentially to look at Company Reports, or their equivalent for nationalised industries, to see what the company itself tells the public about its investment decisions.[1]

The sample was derived from Census of Production Reports of 1968 and 1970-1975. These detail investment by industry at MLH level. From this list we selected all manageable industries with investment in 1972 in excess of £30m. To this we have added industries for which investment data is available as a long time series.[2] Further inspection of the data indicated that no industry with particularly high investment in the years 1968-1975 was excluded. In Table Al we list the industries. The total investment in plant and machinery, land and existing buildings and new building covered by the sample was £1957.6m. in 1972, current prices, which represents 65%[3] of all investment in 1972 covered by the Census in these categories. In Table A.1 we also set out the major companies operating in those industries. As one can see company diversification in some cases prevents one seeing a one to one picture, but we feel that by going to the reports of the major companies one should get a reasonable idea of what is influencing investment in their constituent industries.

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1 As an exercise it gives wide coverage without the extensive resources required for a questionnaire survey.

2 This sample was collected for other purposes, but there is no harm introduced by its inclusion.

3 Total £2992.9m.

The search of the company reports[1] yielded a mass of information, to present all of which would take up too much space here. What we have done therefore is to present the results in terms of the motivations isolated, although this inevitably means discarding much interesting corroborative evidence and at times much fascinating detail. In sifting this information a certain amount of interpretation of statements takes place, but in general the sentiments of the reports are clear. Where possible we will quote the reports.

To begin the classification we can start with demand pressure as a stimulant to investment in the best tradition of the accelerator theorists. The prime example of the influence of demand pressures is in the electricity industry. Thus to quote from the C.E.G.B. 1969/70 report:

> "The capacity of new generating plant depends on the estimated maximum demand, assessments of generating plant availability and the old generating plants expected to become unavailable".

i.e. demand is the driving force although plant installed may be of the latest type. Similar demand influences can be identified in the tobacco industry,

> "production facilities are being expanded and modernised to meet increased demands" (British American Tobacco)

and in the water industry. Other examples can be found but these are sufficient to illustrate the point.

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1 A task well performed by John Patient.

Table A1 - Industries and Companies   The Sample

INVST £m 1972	INDUSTRY	MAJOR COMPANIES
78.2	Brewing & Malting (231)	Courage, Watneys, Whitbread, Scottish & Newcastle, Bass Charrington, Allied Breweries
205.8	Iron & Steel (311)	British Steel Corporation, G.K.N.
508.3	Electricity (602)	Central Electricity Generating Board
69.0	Coal Mining (101)	National Coal Board
98.0	Motor Vehicle Manufacturing (381)	British Leyland, Ford, Chrysler U.K., Vauxhall
22.1	Tobacco (240)	B.A.T., Imperial Tobacco, Rothmans International, Gallagher
45.8	Rubber (491)	Dunlop, Avon Rubber Co.
116.6	Gas (601)	British Gas
112.4	Water (603)	Water Resources Board
28.5	Shipbuilding (370)	Harland & Wolff, Swan Hunter, Vickers, Furness Withey
23.0	Aerospace (383)	British Aircraft Corporation
22.0	Paper & Board (481)	Reed International, Wiggins Teape
41.0	General Printing & Publishing	Reed International, Thomson Organisation
210.0	Petroleum & Natural Gas (104)	B.P., Shell, Esso, Burmah, Texaco, Mobil
108.6	Mineral Oil Refining (262)	
72.2	Organic Chemicals (271(2))	B.P., Shell, I.C.I., Rio-Tinto Zinc, Courtaulds, Unilever, G.E.C.
32.8	Inorganic Chemicals (271(1)	
50.2	Synthetic Resins (276)	
34.3	Pharmaceutical Chemicals (272)	
36.1	Plastics Products (496)	Turner & Newall
414.0	Wool (414)	I.C.I., Courtaulds, Coats Patons, Tootal

The second influence we isolate is the substitution effect. This effect can arise either (a) through a change in final output prices leading to a change in demand for output and thus inputs (but we classify this as a demand effect) or (b) a change in input prices leading to a desired change in technology. A problem of classification arises here in that changes in prices may lead to shifts along and shifts of a production function (see Rymes (1971)). We really only wish to isolate the former in this category. Examples are not easy to find, although capital expenditure to reduce fuel costs can be seen in the Paper and Board Industry.

These two above motives are well documented however. Let us turn then to the major concerns of this paper - technological change. First consider process innovation as an investment motive.

> "Quality improvement is a key feature of the investment programme particularly in the light of ever greater technical demands being made on the corporation by its customers. Modernisation and expansion backed by corresponding closures are thus essential to achieve improved competitiveness both on quality and costs. The U.K. makes the lowest proportion of its output in high productivity oxygen steelmaking plants and the highest proportion in the relatively small open-hearth plants. The Corporation envisages the concentration of all its steelmaking capacity into oxygen steel-making and electrical arc plants by 1980 with open-hearth works ... phased out" (British Steel Corporation, Report 1973/4, p.29).

One could not ask for a better indication of technological changes as a promotor of investment. This move to oxygen steel-making is a well studied diffusion example (Nabseth and Ray (1974)).

In Printing and Publishing a similar picture emerges. For example The Thomson Organisation discusses the installation of computerised photo composition and the new printing technologies available. In Chemicals, I.C.I., talk in their 1976 report of a £40m. plant built to use a new process to grow micro-organisms by continuous fermentation of alcohol.

In Coal Mining the National Coal Board in the 1968/9 report talk of a policy to increase productivity

"by more intensive use of proved techniques"

and of capital investment on a modern mechanised 200 yard face with powered supports, with capital investment chiefly to increase efficiency. A similar example can be found in shipbuilding. Swan Hunter in their 1970 company report state:

> "the extent of our order book makes it possible to carry out capital expenditure improvements which will increase productivity and which have been under consideration for some time".

The point is made without further example so turn now to product innovation as an influence on investment. We have detailed above the lack of any treatment of this issue in the literature. We are arguing that the diffusion of a new product requires investment in production facilities that would not occur without this technological change. An associated effect is investment to match diversification into a different product line by an individual company, but although this is a relevant factor we wish to concentrate on the products new to the economy. The best example we have here is in the brewing industry. Here the new product is lager. In this industry

"the eagerness to invest in new breweries is explained

> by the changing product mix and especially by the rising demand for lager" (Times 28/1/77).

Thus Courage is spending £51m. at Reading, Allied Breweries spent £12m. at Burton, and Harp Lager spent £13m. in the early 70s to increase lager capacity.

In other industries we find similar examples. It is however in motor vehicles that we really find this effect strongly. In this industry nearly all investment is tied to model changes, which means new products. Thus the Economist (13/4/75) state that £20m. was required by Chrysler to tool up for a new model. The sums discussed for the British Leyland Mini project approximate £250m. the Chevette involved Vauxhalls in an investment of £25m. (Evening Standard, 22/8/75). The Central Policy Review Staff estimated that a new set of dies cost £15m. and tooling and equipment for a new engine involves sums in excess of £150m. The Ryder Report considers that British Leyland will need to invest £1,000m. in the period to 1982 for new products and improvements in old products. The moral is clear.

In aircraft assembly one expects to see a similar pattern. It can also be seen in the Tobacco industry. Imperial Tobacco invested £15m. in a plant to produce Cytrel, the tobacco substitute. To give one further example, G.E.C., talk in 1976 of their diesels division where

> "by 1978 output will consist almost entirely of machines developed since 1973 and produced in factories completely rehabilitated and re-equipped with the most modern tools and processes".

New products are thus adequately documented as a force behind investment. Finally we look at a force generating investment that we will call "new sources of supply". The principle here is that the discovery of a new source of raw materials stimulates investment expenditure to exploit it. Thus in the Coal Industry, for example, in its 1973/4 report the N.C.B . is talking of

> "investments totalling about £600m ... to generate 42m. tons of new capacity to replace the inevitable exhaustion of many of the present collieries..."

The prime examples are, however, North Sea Oil and Gas. In their 1975/6 report, British Gas state that

> "the investment made so far to exploit natural gas has been some £2,000m. over the last decade".

In physical terms the investment is in terms of transmission lines, terminals, conversions etc.

However natural gas as an investment stimulant pales into insignificicance beside North Sea Oil. We are not here discussing expenditure on exploration only expenditure on exploitation. Thus in 1972 British Petroleum considered that the Forties Field would require an investment of £400m. on their part, and Burmah estimated that to develop the Ninian & Thistle field would cost £300m. In general however exploration and development expenditures are not separated by the companies, thus Esso in 1976 spent £254m. in the North Sea, having already spent £340m. and intended to spend £1500m. by 1980. Such investments cannot be ignored.

The effect of these new sources of supply do not finish here however. Thus in the steel industry there is discussion of increased demand due to the North Sea Oil program, and there has also been investment in production platform construction facilities. The point is made.

Thus although we have not presented a great deal of the information available it is clear to see that the five factors we have isolated can all be observed at work, and the latter three which we label "technological change effects" are quantitatively significant. Finally, however, a relevant point to note is that technological change motivated investment is influenced by demand conditions. Thus Swan Hunter state

> "the extent of our order book makes it possible to carry out capital expenditure improvements ... which have been under consideration for some time"

and in the wool industry Coats Patons talk in 1974 of restricting investment because of high interest cost and an insufficient cash flow. Thus although new products, processes and sources of supply stimulate investment, the actual decision to invest still involves the consideration of economic factors.

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