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The Impact of Technical Change and Profit on Investment in Australian Manufacturing

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ABSTRACT *This paper combines W.E.G. Salter's analysis of capital-embodied technical change with Kalecki's analysis of financing investment from retained profits to provide a Post Keynesian model of investment with process innovation, which is applied to data from Australian manufacturing industries. The approach to process innovation taken in this study is to identify new capital stock introduced through physical investment, which results in the older vintage stock being decommissioned as technologically obsolete. In the estimated model, the profit factor is used as a measure of the ability to invest, and the rate of labour productivity growth factor reveals the inducement to invest as this rate acts as a proxy for technical change in the Kaleckian investment-ordering model. The two factors combine to explain the accumulation process, both level and variability, and its link to technical change. In conclusion, this paper demonstrates that investment, incorporating technical change, enables industries to become sustainable into the uncertain future with varying states of investment instability.*

...technical progress cannot be regarded as automatic and independent of accumulation. (Salter, 1966, p. 72)

1. Background

Investment in capital stock that embodies best practice technology represents the diffusion of innovation into the production process of the firm making the investment. This diffusion may expand the firm's productive capacity or may replace some current plant and equipment that has become technologically obsolete. W.E.G. Salter (1966) provided a seminal analysis of how technical progress

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comes about through capital accumulation by focusing on the reverse side of process innovation, that is, on obsolescence. This analysis begins by identifying that at any time, with new and established knowledge, there is a spectrum of techniques used in production from 'best practice' to 'outmoded' and on to 'obsolete'. In this context, Salter (1966, p. 54) defines obsolescence as 'plants which are sufficiently outmoded to be profitably replaced.'

Salter's analysis formalises the contribution of investment to rising productivity, which has been recognised as important in economics at least as far back as Ricardo's ([1821] 1951) famous chapter, 'On machinery'. It also provides a framework for understanding the impact on investment spending on technical change, in the form of the improved technology that is embodied in new vintage capital equipment. This improved technology is the inducement for firms to invest in new equipment even when they have ample capacity. This is Salter's concept of technological obsolescence.

There is no inevitability that firms will immediately make investment decisions to order technologically superior capital stock. This is due to many factors including financial constraints, wage costs, industry competitiveness, and level of technological flexibility (or inertia). Thus, it is important to consider the Salter process within a model of investment that incorporates these other factors. The particular investment model applied in this paper is developed from Kalecki's (1968) theory of investment ordering, implying that profitability and technical change are both factors influencing the level and the variability of investment spending, thus impacting on the business cycle and its trend.

This paper develops a theoretical model that extends Kalecki's investment ordering model to incorporate Salter's analysis of obsolescence due to technical change. The theoretical model is then applied to an empirical analysis of investment spending in a cross-section of Australian manufacturing industries. Investment spending behaviour is related to profitability and the change in profitability. These are suggested by Kalecki's analysis as the ability to invest (the financial ability term) and the inducement to invest (the effective demand term), respectively. With technical change reflected in the growth rate of labour productivity, measures of labour productivity growth, as suggested by Salter's analysis of obsolescence, are also included to capture the technological inducement to invest.

The theoretical model and empirical analysis presented merges and extends the work done in Post Keynesian economics on investment and innovation from a few fronts. Included is the analysis of the financial influences on investment at the macroeconomic level by Minsky (1980) and Davidson (1994), which leads naturally to empirical work, such as Iyoda (2005) that utilises time-series data to capture changes in financial conditions. In our model, the profit share is the basis for the financial wherewithal for investment in technical change. Then there is Kaleckian analysis of innovation and technical change on investment based around the microeconomic issues of pricing (Harcourt & Kenyon, 1976) and market coordination (Shapiro, 1991). This paper extends such analysis to capital accumulation. The balanced growth approach of Gomulka *et al.* (1990) and Steindl's ([1952] 1976) maturity and stagnation thesis, which are in the Kaleckian tradition, do not provide an opportunity to understand how technical change impacts on investment growth. Our analysis is closer to the Kaleckian

models of growth and distribution pioneered by Rowthorn (1988) and Lavoie (1992, pp. 316–322), and surveyed in Blecker (2002). In these models, technical change is incorporated by the sensitivity of the investment function to induced innovation, the profit share, and the rate of technological obsolescence of the existing capital stock. The role of these different impacts of technological innovation are examined in the current study by utilising cross-sectional industry data, along with industry-specific profitability, to specify the essential role of technical change in the accumulation process.

Salter's model of technical change is outlined in the following section, while the adaptation of Salter's analysis to the Kaleckian model of investment is developed in Section 3. In Section 4 investment, profit and productivity data are used to estimate regression equations for investment spending and the variance of investment spending. After outlining limitations of this study and presenting a way forward to overcome them in Section 5, a conclusion with discussion of the implications for Post Keynesian economics is provided in the final section.

2. Salter's Model of Technical Change

Technical change has not been easily incorporated into the theory of investment analysis.¹ The standard neoclassical approach is to treat technical change as exogenous. Even new growth theory (which attempts to take account of new knowledge acquired through skill improvement) generally assumes that new knowledge is applied to existing capital equipment, obviating the need for further accumulation of capital equipment. The vintage-capital model developed by Salter (1966) distinguishes between endogenous technical change, as measured by improvements in average productivity, and exogenous technical change, as measured by the technological innovations embodied in new equipment. Improvements in average productivity (called 'technical progress') depend on investment in new equipment as well as on technical change, leading to the link between technical progress and accumulation identified by Salter in the opening quotation.

Investment in Salter's vintage-capital model is driven by both capacity expansion and technological obsolescence. Rather than treat replacement investment as determined by physical deterioration, Salter recognises the role that embodied technical change has in making older equipment outmoded (having relatively high operating costs) and, eventually, obsolete. The condition for older equipment becoming obsolete is that the operating cost, in terms of variable inputs for the older equipment, exceeds the full unit cost for all inputs (including the cost of the capital equipment) using the current best-practice equipment.

With labour as the only variable input to production, the operating cost of the oldest vintage in use is equated with that of the newest equipment when

$$w_t \lambda_{\tau-m} = w_t \lambda_{\tau} + r_{\tau,t} K_{\tau} \quad (1)$$

¹For a detailed treatment of technological innovation and the difficulties of handling it as an economic concept, see Courvisanos (2005). See also Perelman (2006, p. 247) on the difficulties of modelling capital stock scrapping and its replacement by new technology.

where w_t is the wage rate at time t , λ_τ is the labour required per unit of output for vintage τ capital, $r_{\tau,t}$ is the rental price of a unit of vintage τ at time t and κ_τ is the capital required per unit of output for vintage τ capital.² The current vintage, $t = \tau$, is assumed to be best practice and m is the age of replacement (assuming that all earlier vintages have higher labour cost).³

The effect of technical change on obsolescence is illustrated in Figure 1, which is adapted from Salter (1966, p. 59, Figure 6). Assuming as above that labour is the only variable input to production, the firm whose costs are shown in Figure 1 can produce up to q_τ units at an operating cost of c_τ . $c_\tau = w_t \lambda_\tau$ and $q_\tau = K_\tau / \kappa_\tau$, where K_τ is the quantity of capital equipment of vintage τ and κ_τ is the amount of equipment required per unit of output for that vintage. In line with Salter's assumptions, output produced with vintage τ has the lowest operating cost due to labour saving that occurs with technical change, and this operating cost is constant up to the capacity of equipment of that vintage.

If the firm increases output beyond q_τ , it must use older equipment. Costs are minimised by using the newest possible vintage as this requires the lowest possible labour input. In Figure 1, the amount of output that can be produced using equipment of vintage $\tau - 1$ along with that of vintage τ is shown by $q_{\tau-1}$ and the cost of using this equipment is shown by $c_{\tau-1}$. Further output is produced using vintage $\tau - 2$ and so on.

In the short run, a price-taking firm will find it profitable to expand production as long as price exceeds the unit operating cost. All vintages of equipment with cost exceeding this level are left idle. In the long run, the firm has the option of purchasing new vintage equipment and will do so as long as output price exceeds the unit total cost of this equipment. In equilibrium, this means output of the industry expands until price is equal to the unit total cost of best-practice equipment of the newest vintage. All equipment with operating cost exceeding this level of unit total cost is obsolete, as indicated in equation (1). For example, if in Figure 1 the unit total cost for best-practice equipment of the newest vintage is equal to $c_{\tau-2}$ then equipment of vintage $\tau - 2$ is at the border of obsolescence and equipment of vintage $\tau - 3$ is obsolete.

The drivers of obsolescence can be formalised by rewriting equation (1) as:

$$\lambda_{\tau-m} - \lambda_\tau = \frac{r_{\tau,t} K_\tau}{w_t} \quad (2)$$

which indicates that labour requirements of the oldest equipment in use exceed those of new equipment by an amount that rises with the capital cost of new

²The rental cost of capital equipment may vary with vintage as well as with time. Different vintages may have different economic lifetimes and hence different rates of depreciation due to either changes in physical deterioration or, most likely, the speed of obsolescence due to technical change.

³Under these assumptions, all vintages between $\tau-m$ and τ will have operating costs less than the full unit cost of the best-practice equipment of the current vintage. Equipment of all these intermediate vintages will continue to be fully utilised.

Figure 1. Determining the margin of obsolescence

equipment, but falls with the level of the wage rate.⁴ Further, the difference in labour requirements on the left-hand side of equation (2) depends on the extent of labour-saving technical change, which for ease of exposition is assumed to occur at a constant rate, Θ , so that

$$\lambda_{\tau} = \lambda_{\tau-m} e^{-\Theta m}, \quad \Theta \geq 0. \quad (3)$$

Substituting from equation (3) into equation (2) yields:

$$e^{-\Theta m} = \frac{-[1 + r_{\tau,t} \kappa_{\tau}]}{w_t \lambda_{\tau-m}}. \quad (4)$$

Taking the logarithms of both sides of equation (4) and rearranging terms then implies:

$$m = (1/\Theta)(\ln[1 + r_{\tau,t} \kappa_{\tau}] - \ln[w_t \lambda_{\tau-m}]) \quad (5)$$

which shows that m , the length of time before capital equipment becomes obsolete, depends on requirements for inputs in both new and old equipment as well as on the current prices of the inputs.

Assuming that obsolescence occurs before physical deterioration of old capital equipment, the economic life of capital equipment, as given by m in equation (5), is inversely proportional to the rate of labour saving, Θ , embodied in new versus old equipment. For example, a doubling of the rate of labour saving cuts the economic life of the equipment in half.

With obsolescence as the determinant of the scrapping of capital equipment, the amount of depreciation of capital equipment, d , is inversely related to the

⁴The capital cost of old equipment is sunk, so it does not affect the expression.

age of obsolescence, m , and directly related to the value of capital stock, K , as follows:

$$d = \frac{K}{m}. \quad (6)$$

Thus, the analysis above indicates that the amount of depreciation for capital equipment is positively and proportionally related to the rate of labour saving in technical change.⁵

In the empirical analysis below, the rate of reduction in labour requirements is measured by the average rate of growth in labour productivity over a long period. The rate of reduction in the labour requirements for best-practice technology enters into the determination of the age of obsolescence, m , equation (5), and thereby influences the charge for depreciation, equation (6). Over long periods of time this rate can be approximated by the average reduction in labour requirements over all production processes.⁶ Further, the average rate of reduction in labour requirements is equal to the average increase in labour productivity, as the former is the inverse of the latter.

3. Kalecki's Model of Investment Adapted for Technical Change

Kalecki (1971, p. viii) notes in his writings, that 'there is a continuous search for new solutions in the theory of investment decisions, where even the last paper represents—for better or for worse—a novel approach.' The 'last paper' referred to in the quote is Kalecki (1968), which integrates the treatment of technical progress into his approach of moving equilibrium in order to analyse long-run growth together with the business cycle. The analysis below emphasises this approach.⁷

Kalecki (1968) links technical change to investment decisions through the gain in profits captured by new plants. He equates this gain to the saving in labour cost from taking old equipment out of production. Using equation (1),

⁵In this formulation, the reciprocal of the age of obsolescence corresponds to Kalecki's (1968) concept of the 'pay off period', the period over which the capital invested is recovered. White (1999, fn. 3) notes that obsolescence is the preferred treatment for depreciation in Kalecki (1968). In terms of accounting concepts, d may be thought of as an allowance for amortisation of the declining economic value of old equipment (due to its low productivity relative to new equipment) rather than depreciation as an allowance for physical deterioration.

⁶In a short period, the rate of growth of labour productivity depends on the speed with which new equipment is added to the production process, as average labour productivity depends on the relative importance of equipment of different vintages. Over time, fluctuations in the additions to capital equipment average out, leaving only a small residual effect of the trend growth in capacity on the vintage composition of the capital stock.

⁷In the earlier treatments, such as given in Kalecki (1954), depreciation is noted as being due to wear and tear or obsolescence. However, there is no discussion of obsolescence as due to technical change.

this saving per unit of output is equal to the capital cost of new equipment:

$$w_t \lambda_{\tau-m} - w_t \lambda_{\tau} = r_{\tau,t} K_{\tau}. \quad (7)$$

The saving of labour cost from equation (7) for the amount of output shifted from old to new equipment is equal to the capital cost of the new equipment. This capital cost consists of a depreciation charge and a return to capital. When scrapping of equipment is determined by technological obsolescence, the depreciation charge for old equipment is given by equation (6). However, this is the same as the depreciation charge for new equipment as long as technical change occurs at a constant rate and the price of capital equipment is constant. Thus, the factor identified as affecting the depreciation charge in equation (6), namely the rate of labour saving, in turn drives investment decisions in Kalecki's model, as long as a constant rate of technical change and constant capital price are assumed.

Laramie & Mair (2003) identify two sources of technological obsolescence that emerge from Kalecki's (1968) investment model. One is the rising cost of operating the capital stock due to the ageing process. Even with no innovation occurring, new replacement investment would be relatively more productive than the existing capital stock.⁸ This would result in a rising increment of profits from the new investment compared with the old capital stock. Kalecki's technical change coefficient would be positive even if all the replacement investment had no embodied technical improvements. However, Kalecki considered this aspect of technological obsolescence as minor since most replacement investment has embodied in it at least some element of technical change.

The other source is directly related to technical change, and is the source emphasised by Kalecki. In this case, obsolescence of existing capital occurs even if the productivity of the existing capital stock remains constant. Obsolescence occurs here because the new technically superior investment reduces the relative productivity of the existing capital stock.⁹ Thus, the new investment is not merely replacing ageing capital stock, but adding a new element to the capital stock. Depending on the nature of the innovation introduced, the power of the technical change coefficient in this case is stronger than that of the first (no innovation) case. The power of this coefficient would be based on the productivity and value creation gains that emerge directly from embodied technical improvements.

White (1999), in his re-examination of Kalecki (1968), implicitly supports the Salter mechanism described above. White identifies process innovation in

⁸Perelman (2006) criticises Keynesian economists (of all descriptions) for ignoring the productivity power of replacement investment, despite it being almost two-and-half times as large as net additions to the capital stock.

⁹Laramie & Mair (2003) illustrate this situation with the example of a new energy-efficient light bulb producing more light relative to wattage power, compared with the standard light bulb, which continues to generate as much light as it did prior to the introduction of the new light bulb, and hence is no less efficient in absolute terms than before.

the form of technical progress in new capital equipment as the source of increased productivity, making the previous capital stock technologically obsolete. White also identifies product innovation coming from the stimulus to investment arising from entrepreneurs wanting to be the ‘first to avail themselves of the technical novelties’ and thus adding a new level of demand (Kalecki, 1968, p. 269). Together, the two forms of innovation ‘add to profit expectations over and above those generated by the movement of demand in the course of the cycle’ (White, 1999, p. 347), leading to a cumulative process of cyclical growth.¹⁰ For the model in this paper, any product innovation—when it is more than just minor marketing improvement (e.g. adding fins on to a car body)—requires process innovation that will necessarily embody technical improvements (see Utterback, 1979).

The Kalecki investment orders function, with its technical change coefficient, is appealing in a theoretical form. However, no data are collected on increments of profit associated with new investment—either replacement or innovation investment. There is a need for an alternative approach to specifying the investment function that is faithful to Kalecki’s theory but that also allows data to be applied.

A Kaleckian empirical study linking innovation and investment by Courvisanos (2007) relates Australian private new capital expenditure to profits and research and development (R&D) expenditure. In the total sample, both lagged profits and lagged R&D spending influence investment with nearly equal significance. Panel data analysis shows that in mature industries, profits are much more influential, while growth industries show marked diversity with some reflecting high R&D impact and others showing very low impact. One difficulty with this approach is that technical change in Australia generally entails the use of overseas technology and its application to Australian conditions. Much of this technology is embodied in imported capital equipment and need not be reflected in R&D expenditures of domestic firms.

Two issues arising from the Courvisanos study that provides a basis for investigation using the Salter approach are (i) the diverse nature of embodied technical change stemming out of more than just R&D, and (ii) labour costs and their influence on this technical change. The Salter approach allows investment with process innovation to be directly investigated, without needing to trace back to sources of technological obsolescence. This provides a direct method of understanding the impact of technical change (inducement to invest) and profits (ability to invest) in the investment ordering process.

As noted in Kalecki (1968), technical change affects both the level and variability of investment. Both aspects are developed by Courvisanos (1996) in a model that incorporates Kalecki’s (1968) investment function with Keynes’s susceptibility for long-term expectations to change. This susceptibility exposes the variability of investment. Freeman & Perez (1988) explain this variability from a structural view with respect to technical change, and note the mismatch of

¹⁰White (1999, p. 350) identifies a third mechanism by which innovation brings about an investment disturbance. This is the stimulus to investment ‘arising from changes in relative profit rates as a result of changes in technology.’

current investment to new available technology. They identify variations in business confidence regarding new technological innovation paradigms as the cause of this mismatch. In turn, this leads to greater investment variability.

Going back to Salter's distinction, endogenous technical change influences investment variability via the amount of new investment, but it is exogenous technical change that distinguishes periods of low variability (with established industries in monopoly control) from periods of higher variability (when a new technological paradigm is implemented). New innovation paradigm systems generate strong expansion out of deep recessions, creating the impression of stable growth. As shown in Courvisanos (2007), these are expansionary phases of investment cycles with growing susceptibility pressures for eventual strong downturns. Less successful implementations of new systems result in aborted efforts to rise out of deep recessions, but have only weak contractionary pressures. These two patterns emerged globally in the 1990s—the former in Southeast Asia and the United States, the latter in Europe and Southern Asia—showing convergence within global regions and divergence across global regions (Hollanders *et al.*, 1999).

Laramie *et al.* (2007) derive strong econometric results when using UK data on manufacturing and construction to estimate the susceptibility model of investment specified as

$$D_t = f(P_{t-1}, \Delta P, g_{t-1}, c_{t-1}) \quad (8)$$

where D_t is aggregate investment orders in the current period t ; P_{t-1} is previous period $(t - 1)$ level of profits; ΔP is actual increment in profit levels from $(t - 2)$ to $(t - 1)$; g_{t-1} is previous period gearing ratio; and c_{t-1} is previous period capacity utilisation (for details, see Courvisanos, 1996, pp. 114–162). Consistent with Kalecki, this function identifies the investment order decisions with gestation lags to when these orders are expended and in full operation. National statistics quote investment expenditure data that identify the realisation of the investment orders, including any modifications to the orders that may have occurred during the gestation period.

Laramie *et al.* (2007, p. 197) find that previous profits, lagged by one and two quarters as a set, have the greatest impact on new investment orders. They state that '[b]oth of these profit coefficients are positive, indicating that it is unlikely that ΔP plays a part in influencing new orders.' Capacity utilisation also plays a significantly large role, while gearing as a financial constraint has only a small impact on their results. Although capacity utilisation is important in the Laramie *et al.* results, its specification in that study is only as a proxy, where c_{t-1} is the difference between current output (Y) and output associated with target capacity utilisation (which is a fixed proportion of capital stock). In their results they identify that when Y falls below approximately two-thirteenths of the existing capital stock, then capacity utilisation has a negative influence on new orders.¹¹

¹¹Indirectly, this study ascertains technological obsolescence when it estimates the average optimal life of UK capital stock (the inverse of the capital–output ratio) as approximately 6.57 years.

From a theoretical perspective, technical change should be incorporated into investment theory because innovation alters the inducement to invest by changing the cost of production or altering product demand. Kalecki (1968) and Laramie *et al.* (2007) both imply technical progress in their investment function specifications but only indirectly; the former by theory and the latter by empirical estimation. Salter (1966) links the inducement to invest to technical change by utilising a vintage capital model in which innovation is embodied in capital equipment.

Specifically, Salter (1966, pp. 74–75) determines that the ‘margin of obsolescence’ appears in a particular industry where the unit total cost of production using best-practice capital stock equals the unit operating cost of the oldest vintage plant. On this margin, a particular capital stock in a particular industry will be such that technological obsolescence and technical change are mirror images. This can be linked to the above Kaleckian investment function through capacity utilisation on the basis that the ‘margin of obsolescence’ can be alternatively identified as where the total cost of new capacity equals the operating costs of out-moded existing capacity. Thus, when the former becomes less than the latter, then existing marginal capacity becomes technologically obsolete. This formulation provides an indirect way of incorporating capacity utilisation into the empirical investigation. Using company figures that include old vintage excess capacity and do not take account of the impact of process innovation is unreliable. This unreliability becomes obvious if, despite official company figures of excess capacity, labour costs rise such that operating existing capital becomes costlier than introducing new capital stock. Then the existing capital stock will be replaced with new labour-saving best-practice capital stock. Thus, in this study, ‘margin of obsolescence’ is the reference used for replacing obsolete capital stock.

Salter goes on to identify mature industries where excess capacity is at such a high level that there is no technological obsolescence, since cost of replacing existing plant is so excessive that it is not profitable to build in new capital stock.¹² In such industries, given existing new knowledge, technical change will not happen until labour costs increase sufficiently to make investment in new capital stock profitable, or firms are forced to invest to remain competitive against low wage cost countries. In industries that have internationally dominant firms, strong profits induce obsolescence of existing capacity relatively promptly. Such a characterisation of investment with process innovation brings the analysis directly back to the Kalecki investment orders formulation that began this section, with profits and profit increments as the investment variables. What Salter brings to the analysis is a clear decision-based convention or rule governing when new embodied technical change should be introduced into the investment ordering

¹²Industry maturity is of course at least partly a reflection of the lack of technical change, at least in a model of capital-embodied technical change. If technical change is substantial and embodied in capital, the total cost of production using new equipment falls below the operating cost of older equipment and, in this sense, excess capacity is removed. In new growth innovation-bound industries there is no existing capital stock, so there is no issue of existing operating costs and no excess capacity.

process, subject to demand growth. In fact, it is new best-practice capital stock that can be used most effectively to meet any projected demand growth.

4. Investment and Technical Change: Results for Australian Manufacturing

The Australian manufacturing data used in our empirical application are for three-digit ANZSIC categories identified as 36 separate industry groupings.¹³ Different industries experience different rates of technical change as measured by the rate of growth of labour productivity. It is this rate of growth of labour productivity or, inversely, the rate of decline in unit labour requirements that, according to Salter's analysis, influences the margin of obsolescence and the amount of replacement of obsolete equipment in equation (7) above. We use the average rate of growth of labour productivity over the longest period for which data are available prior to our sample period, which is 1968 to 2000.¹⁴

We use the rate of labour productivity growth in a regression analysis to explain the differences in gross investment spending in the cross-section of the 36 manufacturing industries.¹⁵ A four-year average of gross investment expenditure is used for each Australian manufacturing industry group over the financial (July–June) years 2001–02 to 2004–05. These four years are a complete trough-to-peak expansion in the Australian manufacturing investment cycle (see Figure 2), following a decline of manufacturing investment until mid-2001 as a result of a minor recession in the Australian economy in 1999–2001.¹⁶ This period of investment expenditure enables an examination of the *a priori* investment ordering process at the time when there was relatively low susceptibility

¹³The datum available for this study at the lowest level of specificity is the three-digit industry level. There are no available investment data for two manufacturing industries (namely 218 Beverage and Malt, 219 Tobacco Product).

¹⁴Use of an average over a long period captures the relevant rate of labour productivity growth in even those industries with slow productivity growth, while still treating all industries equally. By using labour productivity growth for the period prior to the sample period, we avoid the possibility that investment in new equipment increases our measure of labour productivity growth, which would render the labour productivity growth rate endogenous in the regression analysis.

¹⁵A cross-section of industries is used rather than a panel as there is only one measure of labour productivity growth for each industry. Correspondingly, the investment expenditure variable is averaged over several years to reduce variation due to short-term influences. As the sample is a pure cross-section, variables are excluded that vary over time but have similar effects across industries. Such variables include unemployment, aggregate demand and interest rates.

¹⁶This expansion ended as at December 2005, as reported in the Australian Bureau of Statistics, Catalogue No. 5625.0, September 2006 release of the capital expenditure for manufacturing data in the following terms: 'The trend estimate for Manufacturing has decreased 4.3% this [September] quarter, the third consecutive fall [since the peak in December 2005]. In seasonally adjusted terms, the estimate has decreased 2.5% which is the fourth consecutive fall.'

Figure 2. Manufacturing investment March 2001 to March 2006. Source: Private new capital expenditure and expected expenditure, Australia, March 2006, Australian Bureau of Statistics, Catalogue No. 5625.0

to over-investment and when firms were keen to introduce new, efficient capital stock to meet rising aggregate demand in the economy. The available investment expenditure data are used as a proxy for the investment ordering process, which is based on examining industry behaviour related to introducing technical change when investment decisions are made.

The investment data for each industry group are divided by the average industry value added (IVA) over the same four-year period to create an 'investment share' variable that is comparable across industries of radically different size. Regressions are used to investigate the significance that various profit variables and the Salter-based technical change measure, average labour productivity growth, have on the investment share so identified. The two profit variables are: (i) the profit share as measured by the average profits in each industry as a ratio of average IVA for the same four-year period, and (ii) the change in profit share as measured by the change in profits as a ratio of average IVA for the four years. The average profit share is a measure of the ability to invest, while the change in profit share is a measure of the inducement to invest in terms of the Kaleckian investment model described in the previous section. The investment share, rate of growth of labour productivity, profit share and change in profit share for the 36 industry groupings in our sample are shown in Table 1.

The results from the regressions relating labour productivity growth and profit measures to investment shares in Australian manufacturing are presented in Table 2. These results show that labour productivity growth has a positive and statistically significant coefficient. It indicates that each rise of 0.01 in the rate of labour productivity growth is associated with a 0.01448 rise in the investment share. The positive and significant coefficient of the labour variable is consistent with technical change being capital embodied and labour saving, thus affecting investment through technological obsolescence as explained in the analysis in Section 3.

Among the profit measures included in the regressions reported in column (1) of Table 2, only the average profit share approaches statistical significance. If the change in profit is omitted from the regression, the level of profit becomes significant at the 10% level and the coefficient for labour productivity growth is not much

Table 1. Manufacturing data for 3-Digit ANZSIC industries, 2001/02 to 2004/05

3-Digit ANZSIC industry	Investment share	Labour productivity growth rate	Average operating profit/ Average IVA 4 yrs	Change in operating profit/ IVA
213 Fruit and vegetable processing	0.454443195	0.03520322	0.235095613	0.098987627
214 Oil and fat mfg	0.36101083	0.03962632	0.39133574	-0.112635379
215 Flour mill and cereal food mfg	0.391125719	0.02741984	0.289235826	0.033963298
216 Bakery product mfg	0.388841927	0.01060844	0.17920541	0.071005917
217 Other food mfg	0.674793444	0.01565738	0.241771638	-0.038466748
221 Textile fibre, yarn and woven fabric mfg	0.380626781	0.05393496	0.077492877	-0.034188034
222 Textile product mfg	0.348459384	0.01657906	0.159103641	0.070588235
223 Knitting mills	0.255591054	0.03541146	0.083067093	0.191693291
224 Clothing mfg	0.226151495	0.03876238	0.267408863	0.075092775
225 Footwear mfg	0.293785311	0.02900052	0.223163842	0.084745763
226 Leather and leather product mfg	0.301234568	0.03875234	0.201234568	-0.049382716
231 Log sawmilling and timber dressing	0.475083585	0.01502306	0.248527305	0.084699889
232 Other wood product mfg	0.285567803	0.01100944	0.228531146	0.082542938
233 Paper and paper product mfg	0.469406732	0.04240919	0.275897341	-0.028640506
241 Printing and services to printing	0.434232434	0.03123401	0.149250749	0.075924076
242 Publishing	0.142240534	0.01425917	0.413086129	0.198940553
251 Petroleum refining	0.707317073	0.04429529	0.288802661	1.000739098

(Continued)

Table 1. Continued

3-Digit ANZSIC industry	Investment share	Labour productivity growth rate	Average operating profit/ Average IVA 4 yrs	Change in operating profit/ IVA
252 Petroleum and coal product mfg n.e.c.	0.444444444	0.03067563	0.363315697	0.077601411
253 Basic chemical mfg	0.9817467	0.04732820	0.277637368	0.111204718
254 Other chemical product mfg	0.41690286	0.04661817	0.250064416	-0.064158722
255 Rubber product mfg	0.356997972	0.03294475	0.140365112	0.055172414
256 Plastic product mfg	0.533756653	0.02261100	0.199831917	0.109440657
261 Glass and glass product mfg	0.834871142	0.05097163	0.212535794	-0.001272669
262 Ceramic mfg	0.361885105	0.02949112	0.372893017	0.089439284
263 Cement, lime, plaster and concrete product mfg	0.75994814	0.02180673	0.316146405	0.111698414
264 Non-metallic mineral product mfg n.e.c.	0.342105263	0.02629146	0.196898496	0.171052632
271 Iron and steel mfg	0.420905569	0.04115398	0.252810059	0.317520798
272 Basic non-ferrous metal mfg	0.960255603	0.03835306	0.498233044	0.246308757
273 Non-ferrous basic metal product mfg	0.428321678	0.04116538	0.152972028	0.006993007
274 Structural metal product mfg	0.212743549	0.01487189	0.219062665	0.182411796
275 Sheet metal product mfg	0.345670267	0.04785883	0.253231804	0.133876395

(Continued)

Table 1. Continued

3-Digit ANZSIC industry	Investment share	Labour productivity growth rate	Average operating profit/ Average IVA 4 yrs	Change in operating profit/ IVA
276 Fabricated metal product mfg	0.289938007	0.01602901	0.234620887	0.120489588
281 Motor vehicle and part mfg	0.725572869	0.02755282	0.189184235	0.047662695
282 Other transport equipment mfg	0.349451966	0.02805804	0.17311412	0.096281969
286 Industrial machinery and equipment mfg	0.269372694	0.02161105	0.223800738	0.104305043
292 Furniture mfg	0.227267971	0.01162631	0.19200586	0.04227268

Source: Manufacturing Industry: Industry Performance by ANZSIC Class, Australia: 2001/02 to 2004/05, Australian Bureau of Statistics, Catalogue No. 8221.0.

Table 2. Average investment share in Australian manufacturing 2001/02 to 2004/05—regression results

	Estimated coefficients		
	(1)	(2)	(3)^
Intercept	0.024 (0.030)	0.024 (0.031)	0.027 (0.022)
Avg. operating profit/Avg. IVA	0.146 (0.0922)	0.170* (0.0927)	
Change in operating profit/Avg. IVA	0.071 (0.046)		
Lag 4-year block of avg. operating profit/Avg. IVA			0.244*** (0.074)
Labour productivity growth rate	1.448** (0.640)	1.507** (0.652)	1.338** (0.604)
R-squared	0.26	0.21	0.36
F-statistic	3.84	4.37	8.96***

Notes: Standard errors in parentheses.

Observations = 36.

^ Regression (3) contains 35 industries (lagged profit data unavailable for industry 214).

*** indicates significance at the 1% level.

** indicates significance at the 5% level.

* indicates significance at the 10% level.

affected. The weak relationship for average profit and the absence of a relationship for change in profit contrasts to other studies of Kaleckian investment models (especially, Courvisanos, 2007). This is perhaps not surprising given the differences in the data used in estimation. Here, we are using cross-section data for different industries within Australian manufacturing over a limited sample period, 2001–02 to 2004–05. Each industry is affected by the same general business cycle conditions. In contrast, Courvisanos (2007) uses time-series data from 1984 to 1998, covering two expansions out of significant recessions. In that study, a larger role is found for business conditions (as reflected in average profitability and change in profitability) to affect investment shares over the length of the business cycle than with other factors, such as technical change, which alter only slowly.

The regression results in columns (1) and (2) of Table 2 lack any lagged profits variable as identified in the Kaleckian investment theory. Thus, in the spirit of the cross-section analysis being conducted, a separate regression exercise is introduced. Each industry's four-year average operating profit for the period 1997–98 to 2000–2001 (as a ratio of each industry's average IVA) is regressed, with its respective labour productivity growth rate against the same four-year investment block. In effect, the four years of profits prior to this four-year investment block are a lagged profit variable. This is an alternative way of empirically implementing Kalecki's lagged profit variable. The data for this lagged period do not include data for industry 214, Oil and Fat manufacturing. Thus, the number of industry groups reduces to 35. The results with the lagged profit variable are reported in column (3) of Table 2.

Results with the lagged profit share variable in column (3) of Table 2 show a strong F-statistic regression result with a very significant lagged profit variable. Note that labour productivity growth is still mildly significant, so that the technical change relationship is still relevant. The variable showing change in operating profit is not included in the block lag test because it lacks significance in the prior regression. This variable also has no theoretical meaning within the context of regressing across two block periods, when change in profits only refers to the one (current) investment block already used in Table 2.

Pursuant to the susceptibility of investment model, profitability and technical change impact on the level and variability of investment. Our estimates give the average rate of labour productivity growth over a 32-year sample period, but it is unlikely that the course of technical change is smooth. Instead, it is expected that there will be periods of rapid advance interspersed with less technological developments. To this extent, industries strongly implementing new technological systems resulting in more rapid labour productivity growth might also exhibit more uneven (or variable) induced technological obsolescence and resulting investment. Further, in the context of Kaleckian investment theory, upswings in business conditions may increase susceptibility of investment so that investment might be unstable as profitability rises.

Table 3 presents results from regressions for two measures of variability of the investment share over the four-year study period, (i) the variance of the investment share, and (ii) the standard error given by the square root of the variance. The explanatory variables are the rate of labour productivity growth, the average profit share and change in profit.

Table 3. Variation in investment share in Australian manufacturing 2001/02 to 2004/05—regression results

Coefficient/Dependent variable	Variance of investment share	Standard error of investment share
Intercept	−0.0032 (0.0021)	−0.00913 (0.0162)
Avg. operating profit/Avg. IVA	0.0025 (0.0065)	0.0314 (0.0493)
Change in operating profit/Avg. IVA	0.1704*** (0.0032)	0.0973*** (0.0245)
Labour productivity growth rate	0.0892* (0.0454)	0.7386** (0.3422)
R-squared	0.517	0.421
F-statistic	11.4196***	7.7548***

Notes: Standard errors in parentheses.

Observations = 36.

*** indicates significance at the 1% level.

** indicates significance at the 5% level.

* indicates significance at the 10% level.

The explanatory power of the regressions in Table 3 greatly exceeds that of the regressions in Table 2. The change in profit variable is consistently positive, and has a significant coefficient at the 1% level in the regressions, which indicates that industries that experience a greater positive change in their profit share also exhibit greater investment variability. Consistent with Kalecki (1968), the investment variability is related to profit changes.

Salter helps to support the Kaleckian investment model by linking investment to each industry's technical change and technological obsolescence. In addition to the positive effect of labour productivity growth on the investment share shown in Table 2, there is a positive and moderately significant impact on the variability of investment in Table 3. Industries with higher average labour productivity growth are characterised by a higher, but more variable, investment share.

5. The Way Forward

Three limitations have been identified whilst undertaking this study. The first is the assumption employed using the Salter approach in deriving estimates of the impact of technical change on capital depreciation from obsolescence. For statistical tractability, it is assumed that technical change occurs at a constant rate over time. From detailed studies of technological obsolescence (see Frankel, 1955; Nair & Hopp, 1992; Whelan, 2006) it is clear that the speed of obsolescence is complex and depends on the rates of technical change in different economies. These factors are subject to uncertainty in the sense that the expected outcome of the decision to introduce new enhanced capital stock is unknown *a priori*. Thus, in practice, firms may rely on the average of past experience in forming expectations of future embodied technical change.

The second limitation is the short four-year period of investment data used in the regression analysis. This period contains a significantly strong cyclical upswing, which helps to identify positive investment decision-making and any links between

technological obsolescence and accumulation. It is difficult to go back over a longer investment period due to the lack of comparable data on profits and investment within industry groups with changing industrial classifications.

The third limitation is the lack of in-depth understanding of what is actually happening at the specific industry level in relation to technological obsolescence and labour productivity growth. The decision-making in each industry would be peculiar to its own environment, but what would emerge from in-depth case studies are patterns of behaviour that could lend support to the mechanisms described in the previous section.¹⁷

All three limitations are being addressed as part of the ongoing research in this project of linking Salter's technical change approach to the Kaleckian investment-ordering model. The research is progressing both at the econometric level to address the first two limitations, and through the development of case studies to address the final limitation. The results presented in this paper are limited by the four-year study period but encourage further investigations in these directions, especially over the length of a whole business cycle.

6. Conclusion

This study is another step in the long and winding road towards incorporating innovation embodied in new equipment (or technical change) into the accumulation process. By formalising the Salter approach into the Kaleckian investment ordering model, the rate of labour saving becomes a crucial element in identifying technological obsolescence, and hence in recognising when technical change augments capital accumulation. New capital stock is introduced that results in the older vintage stock being decommissioned as technologically obsolete.

Salter's analysis shows that labour productivity growth embodied in new vintage equipment is the dominant element in the technological obsolescence of old vintage capital equipment, suggesting the need to include the rate of labour productivity growth as a proxy for technological change into the Kaleckian investment ordering model. Regression results indicate that the rate of labour productivity growth plays a significant role in the investment process out of the mild Australian cyclical trough at the beginning of the 21st century. This result enables the inclusion of labour productivity growth as a proxy for technical change into the Kaleckian investment ordering model. Together with profits as the ability-to-invest factor, the two variables combine for an explanation of the accumulation process in a prototype advanced capitalist economy. Instability in this accumulation process is also identified by relating labour productivity growth and profit growth to the variability of investment ordering. These results show Kaleckian investment instability as being based on profit changes and innovation.

One central insight of Post Keynesian economics, in which Kalecki played a prominent role, is that investment drives saving because it generates income and additional effective demand (see Harcourt, 2006, in particular

¹⁷For an explanation of the relevance of case studies to investigations in investment decision-making, see Courvisanos (1996, pp. 190–216).

pp. 160–164). This macroeconomic feedback from investment to profits is the source of saving in the community. In his *A Treatise on Money*, Keynes (1931) called it the Widow's Cruse, while Kalecki's Dictum states that 'capitalists get what they spend and workers spend what they get'. What this study does is contribute to analysing the form of this investment. We have analysed investment in terms of the extent of technical progress through process innovation that is embodied in the capital accumulation process. The empirical results indicate that investment which incorporates technical change enables industries to become sustainable into the uncertain future, but with varying states of investment variability.

Our results also suggest the need for caution in interpreting statistics on capacity utilisation, which do not make allowance for technological obsolescence. In Salter's analysis, equipment becomes obsolete when its operating cost is greater than the total cost of new equipment, including capital cost. Existing equipment may be kept on premises even when it is obsolete, so that it can be used when all other equipment with lower operating cost is already in use. However, utilising the equipment is more costly than replacing its output with that from newly purchased equipment, so its continued use is unsustainable. Our results provide evidence of this process by showing that Australian manufacturers spend more on investment in new equipment when there is a faster rate of technical change as reflected in higher labour productivity growth. What appears to be an increase in productive capacity may simply be a replacement of obsolete equipment.

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