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in Australian Manufacturing”*

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# **Investment in Process Innovation: Technological Obsolescence in Australian Manufacturing\***

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## **Abstract**

This is an empirical study of investment in process innovation for manufacturing industry. In examining the extent of technological innovation embodied in capital investment, this study identifies the nature technological obsolescence that is implied in this investment process. The empirics are from Australian manufacturing, but the model and the implications are applicable to any advanced capitalist economy. The research begins by identifying technological obsolescence from an approach devised by Wilfred Salter in his analysis of technical change. By defining obsolescence in terms of cost minimisation, Salter provides a method of identifying how and when firms find it profitable to invest in technological innovation embodied in the newest vintage capital equipment. Thus, technological innovation becomes endogenous to the investment process. Technical change in this paper is modelled as affecting the use of each input differently rather than reducing use of all inputs by a uniform proportion. Input-saving estimates calculated for different industries show obsolescence to be identified with the introduction of new equipment that is labour saving. This result enables the inclusion of labour saving as a proxy for technological innovation into an investment model based on the work of Michał Kalecki. With profits as the ability to invest factor, innovation as the inducement, the two factors combine for an explanation of the capitalist accumulation process.

**Keywords:** embodied technical change, Salter, Kaleckian economics, vintage capital

**JEL:** E22, L16, O31

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

## **Background**

Investment in capital stock that embodies best practice technology is a specific form of innovation. When firms make a decision to invest in plant and equipment that embodies new technological knowledge, this is referred to as process innovation and, at the same time, some current plant and equipment become technologically obsolete. For the purposes of this study, technological innovation (TI) is the investment in plant and equipment that enables *new* products, processes or services to be introduced. Salter (1966) provides a seminal analysis of how technical progress comes about through capital accumulation by focusing on the reverse side of process innovation, that is, on technological obsolescence (TO). Salter (1966, p. 54) defines TO as “...plants which are sufficiently outmoded to be profitably replaced.”<sup>1</sup> At any time, with the new and established knowledge, there is a spectrum of techniques used in production from ‘up-to-date’ to ‘outmoded’ and on to ‘obsolete’. There are significant factors that determine investment decisions in addition to the Salter process. Thus, there is no inevitability that firms will automatically make investment decisions to immediately order the technologically superior capital stock. This is due to many factors including financial constraints, wage costs, industry competitiveness, and level of technological flexibility (or inertia).

Technological innovation (TI) has not been easily incorporated into the theory of investment analysis.<sup>2</sup> Most studies see technical progress as exogenous. Even new growth theory (which attempts to add new knowledge through improved skill) assumes as exogenous the acquisition of this new knowledge. By defining TO in terms of cost minimisation, Salter provides a method of identifying how and when firms find it profitable to invest in TI embodied in the newest vintage equipment. Thus, technological innovation becomes endogenous to the investment process.

Salter bases the calculation of TO on the comparison of the labour cost of operating existing capital equipment to the total cost (labour plus capital) of operating best-practice equipment. Bloch and Madden (1995) use this comparison to express the age of TO in terms of the rate of labour saving in a model with factor-augmenting technical change. Recent empirical work by Bloch (2007) provides estimates of the rate of labour saving in Australian manufacturing industries at the three-digit level of ANZSIC (Australia – New Zealand Standard Industrial Classification) scheme. This paper uses these estimates as proxies for TO within an empirical investment model to identify the impact of TI on investment expenditure in Australian manufacturing. The investment model is developed from Kalecki’s (1968) theory of investment ordering, implying a role for profitability as well as TI as factors influencing both the level and variability of investment spending.

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<sup>1</sup> Salter goes on to say: “Plants embodying techniques which are not up to current best-practice, but not yet obsolete, are termed ‘outmoded’.” From this definition it is clear that this study has nothing to do with planned obsolescence of products, which is related to marketing issues and not technical progress.

<sup>2</sup> For 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.

### **Investment Model with Obsolescence and Process Innovation**

In a review of investment models, Courvisanos (1996) argues that the Kaleckian approach to investment produces the best econometric results. Kalecki (1968) introduces, in his third and final version of his business cycle model, a complex interaction between the change in total profits and the marginal change (or increment) in profits arising from new investment orders. The former term, Kalecki identifies as the inducement to invest, while the latter term acts as a guide to future investment. All new investment in this model is process innovation as it incorporates technical change to at least some extent, and this would be reflected through the positive technical change coefficient in the profit increment term.

Laramie and Mair (2003) identify two sources of TO that emerge from the Kalecki (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. This would result in a rising increment of profits from the new investment compared to the old capital stock. Perelman (2006) has criticised 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. Kalecki's technical change coefficient would be positive even if all the replacement investment had no embodied TI. However, Kalecki considered this aspect of TO as minor since most replacement investment does have some element of TI.

The other source is directly related to TI, and is the source emphasised by Kalecki (1968). In this case, TO of the existing capital occurs even if the productivity of the existing capital stock remains constant. Obsolescence occurs here because the new technically superior new investment reduces the relative productivity of the existing capital stock.<sup>3</sup> 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 TI case is stronger than in the first (no innovation) case. The power of this coefficient would be based on the productivity and value creation gains that emerge from the TI.

The Kalecki investment orders function, with its technical change coefficient, is appealing in a theoretical form, but obtaining data on increments of profit associated with new investment - both replacement and innovation investment - is unfeasible. There are no available statistics collected in Australia that can distinguish the technically efficient nature of investment being introduced into each industry (and the Australia Bureau of Statistics [ABS] is a leader in collecting industrial statistics). There is a need for an alternative approach to specifying the investment function that is faithful to Kalecki's theory but that allows data to be applied.

A Kaleckian empirical study linking innovation and investment by Courvisanos (2007) relates Australian private new capital expenditure (investment) to profits and research and development (R&D) expenditure. In the total sample, both lagged profits and lagged R&D influence investment with nearly equal significance. Panel data analysis shows that in mature industries, profits are much more influential, while

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<sup>3</sup> Laramie and Mair (2003) illustrate this situation with the example of a new energy-efficient light bulb producing more light relative to wattage power, compared to the standard light bulb which is still in actual terms just as efficient as prior to the introduction of the new light bulb.

growth industries show marked diversity with some reflecting high R&D impact and others very low. 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 (2007) study that provide a basis for investigation using the Salter approach are (i) the diverse nature of TI stemming out of more than just R&D, and (ii) labour costs and their influence on TI. The Salter approach allows the investigation directly of investment with process innovation, without needing to trace back to sources of TO. This provides a more direct method of understanding the roles of profits (inducement to invest) and TI (incentive to invest) in the investment ordering process.

Laramie *et. al* (2007) derive strong econometric results when using U.K. data on manufacturing and construction to estimate an investment orders function that incorporates Kalecki's (1968) function with Keynes's susceptibility for long-term expectations to change. The susceptibility model of investment specified is

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

where  $D_t$  is aggregate investment orders in the current period  $t$ ;  $P_{t-1}$ , is previous period ( $t-1$ ) level of profits;  $\Delta P$  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.<sup>4</sup> 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 identifies 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  $\Delta P$  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.<sup>5</sup>

From a theoretical perspective, TI should be incorporated into investment theory as innovation alters the incentive 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

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<sup>4</sup> For details, see Courvisanos (1996, pp. 114-62).

<sup>5</sup> Indirectly, this study ascertains technological obsolescence when it estimates the average optimal life of U.K. capital stock (the inverse of capital-output ratio) as approximately 6.57 years.

invest to TI by utilising a vintage capital model in which innovation is embodied in capital equipment.

Specifically, Salter (1966, pp. 74-5) 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. Labour hiring and materials are the operating costs in this calculation. On this margin, a particular capital stock in a particular industry will be such that TO and TI 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 outmoded existing capacity. Thus, when the former becomes less than the latter, then existing marginal capacity becomes TO. If labour and other input 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.

Salter goes on to identify mature industries where excess capacity is so high that there is no TO since the cost of replacement of existing plant is not profitable.<sup>6</sup> In such industries, given existing new knowledge, TI will not happen until the labour costs increase enough to make new capital stock profitable. 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. Such a characterisation of investment with process innovation brings the analysis directly back to the Kalecki (1968) investment orders formulation that began this section, with profits and profit increment as the investment variables. What Salter brings to the analysis is a clear decision-based convention or rule for when new TI should be introduced into the investment ordering 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.

### **Technological Innovation and Obsolescence in Australian Manufacturing**

Bloch (2007) fits a system of equations including a cost function and derived input demand functions to time-series data Over the financial years, 1968-69 to 1999-2000, for each of 38 Australian manufacturing industries. Technical change is modelled as affecting the use of each input differently rather than reducing use of all inputs by a uniform proportion. The estimated coefficients provide separate estimates for the impact of technical change on use of labour, material and capital inputs in each industry. The coefficients and their t-ratios (in brackets) are shown in Table 1, where RKS, RLS and RMS are rates of capital saving, labour saving and materials saving, respectively.

A positive coefficient in Table 1 indicates that technical change in the industry is associated with saving that input in the production process, while a negative coefficient indicates that technical change is associated with more intensive use of the input. An outstanding feature of the table is that there is evidence of labour saving in each industry, as all RLS coefficients are positive and statistically significant at the 5

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<sup>6</sup> Industry maturity is of course at least partly a reflection of the lack of TI, at least in a model of capital-embodied technical change. If TI 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.

per cent level or better. The estimated rates of labour saving range from .007 in Bakery Products, to .051 in Sheet Metal Products.<sup>7</sup> Further, in every industry the rate of labour saving is greater than the rate of materials or capital saving, indicating a labour saving bias to technical change in Australian manufacturing. Rates of materials saving are mostly positive but small and often not statistically significant, while the RKS coefficients suggest that technical change is mostly capital using (negative coefficients) but not necessarily statistically significant.

The relationship between TI and investment can be twofold. Disembodied TI can encourage investment by expanding product markets either through lowering production costs and prices (process innovation) or through improving product characteristics (product innovation). TI also encourages investment when new technology is embodied in capital equipment so that the reduction in production cost requires the acquisition of new equipment through investment. Salter (1966) applies a vintage capital model in which technical change is embodied in capital equipment. Specifically in this case, newer vintages of equipment require less labour per unit of output without requiring more capital or material input, so the deployment of new vintage equipment implies TI. This contrasts to the case where the TI is disembodied and can be deployed without any further investment in capital equipment.

In Salter's vintage capital model, new capital equipment is always acquired to supply any incremental output, as the total cost of an extra unit of production is always lower with the newest vintage than with any older vintage. Likewise, new vintage equipment is acquired if it is necessary to replace equipment that has physically worn out. In addition, firms may abandon older vintage equipment if the unit operating cost of this equipment (in terms of only labour and materials) exceeds the total unit cost of new equipment (including capital cost as well as labour and materials). This defines TO, as operation of older vintage equipment that is unprofitable, even though it is physically capable of continuing production. TO provides a further link between TI and investment in that TO is induced by TI, but for this to become a reality, investment is required to replace production from the obsolete equipment.

The manufacturing sector data in Table 1 is for 3-digit ANZSIC categories identified as 38 separate industry groupings. There are no available investment data for two industries (*viz.* 218 Beverage and Malt, 219 Tobacco Product), so that leaves 36 industries for which there are investment data to correspond to the estimates of labour, capital and material saving rates. The three input-saving rate estimates are applied to the four-year average Australian investment manufacturing data for each industry group over the financial (July-June) years 2001-02 through 2004-05. These four years are a complete trough-to-peak expansion in the Australian manufacturing investment cycle (see Figure 1), following decline of manufacturing investment until mid-2001 as a result of a minor recession in the Australian economy in 1999-2001.<sup>8</sup> This enables an examination of the investment ordering process at the time when there is relatively low susceptibility to over-investment and firms would be keen to introduce new efficient capital stock to meet rising aggregate demand in the economy.

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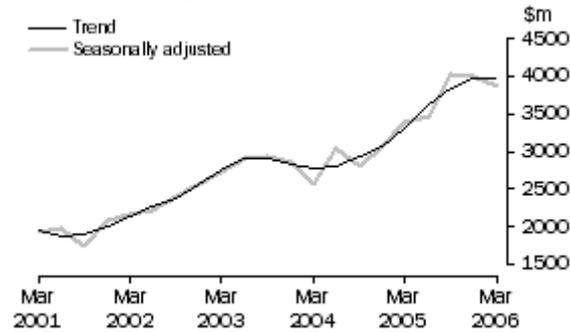
<sup>7</sup> Estimates of input-saving rates assume constant rate of factor augmentation.

<sup>8</sup> This expansion ended as at December 2005, as reported in the release of the capital expenditure for manufacturing in September 2006 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."

**Table 1 – Rates of Input Saving Technical Change for Australian Manufacturing Industries**

| Industry                                       | RKS                    | RLS                  | RMS                   | Industry                                             | RKS                   | RLS                  | RMS                   |
|------------------------------------------------|------------------------|----------------------|-----------------------|------------------------------------------------------|-----------------------|----------------------|-----------------------|
| Fruit and Vegetable Processing (213)           | -0.034834<br>(-9.258)  | 0.033606<br>(43.090) | 0.011700<br>(8.417)   | Petroleum and Coal Product mfg (252)                 | -0.067760<br>(-1.443) | 0.034241<br>(10.904) | -0.040206<br>(-5.146) |
| Oil and Fat mfg (214)                          | -0.196727<br>(-3.083)  | 0.024863<br>(7.740)  | 0.013885<br>(4.354)   | Basic Chemical mfg (253)                             | -0.004438<br>(-1.143) | 0.041990<br>(39.248) | 0.014013<br>(7.941)   |
| Flour Mill and Cereal Food mfg (215)           | -0.080765<br>(-10.428) | 0.025489<br>(23.045) | 0.015846<br>(9.042)   | Other Chemical Product mfg (254)                     | -0.023211<br>(-7.782) | 0.044141<br>(53.868) | 0.005091<br>(3.609)   |
| Bakery Product mfg (216)                       | -0.155674<br>(-4.584)  | 0.007257<br>(8.286)  | -0.001115<br>(-0.549) | Rubber Product mfg (255)                             | -0.005447<br>(-1.304) | 0.031587<br>(22.726) | 0.006490<br>(3.053)   |
| Other Food mfg (217)                           | -0.023896<br>(-5.982)  | 0.018184<br>(15.928) | 0.007805<br>(3.073)   | Plastic Product mfg (256)                            | -0.040165<br>(-8.168) | 0.019409<br>(9.664)  | 0.003111<br>(1.963)   |
| Beverage and Malt mfg (218)                    | -0.046756<br>(-11.560) | 0.040804<br>(45.910) | 0.010823<br>(6.555)   | Glass and Glass Product mfg (261)                    | 0.019025<br>(5.093)   | 0.050656<br>(28.709) | 0.001042<br>(0.234)   |
| Tobacco Product mfg (219)                      | -0.051184<br>(-6.932)  | 0.030440<br>(6.549)  | 0.006237<br>(1.950)   | Ceramic mfg (262)                                    | -0.013040<br>(-2.107) | 0.024512<br>(17.714) | -0.014306<br>(-3.256) |
| Textile Fibre, Yarn and Woven Fabric mfg (221) | -0.001797<br>(-0.335)  | 0.049555<br>(67.830) | 0.029568<br>(13.546)  | Cement, Lime, Plaster and Concrete Product mfg (263) | -0.003384<br>(-0.643) | 0.021226<br>(24.831) | -0.008399<br>(-2.643) |
| Textile Product mfg (222)                      | -0.010536<br>(-1.188)  | 0.019035<br>(8.754)  | 0.007450<br>(3.689)   | Non-metallic Mineral Product mfg (264)               | -0.076319<br>(-6.568) | 0.027043<br>(12.905) | 0.006070<br>(1.053)   |
| Knitting Mills (223)                           | 0.034669<br>(4.170)    | 0.038722<br>(11.123) | -0.001186<br>(-0.146) | Iron and Steel mfg (271)                             | -0.017527<br>(-3.136) | 0.045306<br>(20.873) | 0.011248<br>(4.207)   |
| Clothing mfg (224)                             | -0.018784<br>(-4.082)  | 0.033184<br>(34.387) | 0.021779<br>(8.597)   | Basic Non-ferrous Metal mfg (272)                    | -0.092582<br>(-8.083) | 0.028687<br>(13.213) | 0.021785<br>(5.359)   |
| Footwear mfg (225)                             | 0.001116<br>(0.178)    | 0.022398<br>(21.809) | 0.005848<br>(2.033)   | Non-ferrous Basic Metal Product mfg (273)            | -0.413201<br>(-1.454) | 0.031892<br>(17.422) | 0.015756<br>(4.925)   |
| Leather and Leather Product mfg (226)          | 0.000868<br>(0.048)    | 0.036513<br>(10.553) | -0.025721<br>(-8.019) | Structural Metal Product (274)                       | -0.001393<br>(-0.181) | 0.014198<br>(12.052) | 0.004648<br>(2.321)   |
| Log Sawmilling and Timber Dressing (231)       | -0.119612<br>(-5.144)  | 0.014141<br>(11.313) | 0.017490<br>(3.039)   | Sheet Metal Product (275)                            | 0.011025<br>(1.985)   | 0.051632<br>(19.927) | -0.014149<br>(-2.815) |
| Other Wood Product mfg (232)                   | -0.056365<br>(-3.695)  | 0.015008<br>(14.461) | 0.011938<br>(3.672)   | Fabricated Metal Product mfg (276)                   | -0.045021<br>(-7.063) | 0.009325<br>(13.080) | 0.012804<br>(4.620)   |
| Paper and Paper Product mfg (233)              | -0.022863<br>(-7.666)  | 0.041618<br>(49.407) | 0.007333<br>(4.791)   | Motor Vehicle and Part mfg (281)                     | -0.033991<br>(-4.866) | 0.022341<br>(18.096) | 0.002144<br>(1.181)   |
| Printing and Services to Printing (241)        | -0.059040<br>(-7.231)  | 0.029880<br>(30.584) | 0.018161<br>(5.365)   | Other Transport Equipment mfg (282)                  | 0.006536<br>(0.339)   | 0.032215<br>(13.693) | -0.021155<br>(-6.601) |
| Publishing (242)                               | -0.065041<br>(-7.067)  | 0.016849<br>(11.736) | 0.020181<br>(4.941)   | Industrial Machinery and Equipment mfg (286)         | -0.016997<br>(-3.421) | 0.019485<br>(16.971) | -0.000914<br>(-0.579) |
| Petroleum Refining (251)                       | 0.018377<br>(1.559)    | 0.039978<br>(5.950)  | -0.055069<br>(-9.145) | Furniture mfg (292)                                  | -0.001975<br>(-0.391) | 0.008410<br>(7.836)  | -0.007864<br>(-4.703) |

**Figure 1 - Manufacturing Investment March 2001 to March 2006**



*Source:* Private New Capital Expenditure and Expected Expenditure, Australia, March 2006, Australian Bureau of Statistics (ABS), Catalogue No. 5625.0

The three input-saving rate estimates are used to determine the impact of TI on the investment data. 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 rate” variable that is comparable across industries of radically different size. Two regression exercises are conducted to investigate the significance of various profit variables and Salter-based technical change inputs (RLS, RKS, RMS) have on the investment rate so identified. The first regression exercise (called R1) investigates the three technical change input rates individually with two profit rate variables: (i) the average profits in each industry as a ratio of average IVA for same four-year period, and (ii) the change in profits as a ratio of average IVA for the four years. The average profit rate is a measure of the inducement to invest, while the change in profits is a measure of the incentive to invest in terms of the Kaleckian investment model described in the previous section. The same two profit variables, together with RLS, are also regressed against the investment rate variance measured across the 36 industry groups to examine whether the stability of investment is sensitive to the profit or TI measures.

A separate regression exercise (called R2) is conducted by taking average profits as a ratio of IVA for the four-year block immediately preceding the 2001/02 to 2004/05 investment period as the lagged profit variable, together with RLS, and regressing both against the same four-year investment rate. This is a different version of the Kaleckian lagged profit variable. The data for this lagged period does not include data for industry 214 Oil and Fat manufacturing. Thus, the number of industry groups reduces to 35 for regression R2.

### **Investment with Innovation Results for Australian Manufacturing**

The results from the regression exercises in R1 and R2, relating the various rates of input-saving and profit measures to investment rates in Australian manufacturing are shown in Tables 2 and 3. R1 exercise results in Table 2 show that among the input-saving variables, only labour saving has a statistically significant coefficient. It is positive and indicates that each rise of .01 in the rate of labour saving is associated with a 0.0126 rise in the investment rate. The positive and significant coefficient of the labour-saving variable combined with the absence of significance for any of the other input-saving variables is consistent with technical change being capital embodied with a labour-saving bias and TI affecting investment through TO.

Among the profit measures included in the R1 regressions reported in Table 2, only the average profit rate approaches statistical significance. 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, there is a larger role for business conditions as reflected in average profitability and change in profitability to affect investment rates over the length of the business cycle than with other factors, such as TI, which change only slowly.

**Table 2 - Average Investment Rate in Australian Manufacturing 2001/02 to 2004/05 – R1 Regression Results**

|                                                                                                                                                             | Estimated coefficient |                     |                    |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|---------------------|--------------------|
|                                                                                                                                                             | RLS                   | RKS                 | RMS                |
| Intercept                                                                                                                                                   | 0.0289<br>(0.0317)    | 0.0683<br>(0.0252)  | 0.0679<br>(0.0254) |
| Avg Operating Profit/Avg IVA                                                                                                                                | 0.16276*<br>(0.0947)  | 0.1453<br>(0.1003)  | 0.1444<br>(0.0993) |
| Change in Operating Profit/Avg IVA                                                                                                                          | 0.0679<br>(0.0471)    | 0.0768<br>(0.0507)  | 0.0791<br>(0.0558) |
| RLS                                                                                                                                                         | 1.2590*<br>(0.6729)   |                     |                    |
| RKS                                                                                                                                                         |                       | 0.00603<br>(0.1112) |                    |
| RMS                                                                                                                                                         |                       |                     | 0.0350<br>(0.5582) |
| R-squared                                                                                                                                                   | 0.2312                | 0.1472              | 0.1472             |
| F-statistic                                                                                                                                                 | 3.208**               | 1.841               | 1.842              |
| <b>Notes:</b> Standard errors in parentheses<br>Observations = 36<br>** indicates significance at the 5% level<br>* indicates significance at the 10% level |                       |                     |                    |

The R1 regression results in Table 2 identify the significance of RLS and average operating profit to the four-year (2001-02 to 2004-05) investment block in the specified manufacturing industries, but the regression model lacks any lagged profits variable as identified in the Kaleckian investment theory. Thus, in the spirit of the cross-section analysis being conducted, the R2 regression exercise is introduced. Each industry's four-year average operating profit for the period 1997-98 to 2000-01 (as a ratio of each industry's average IVA) is regressed, with their respective RLS ratios against the four-year investment block for 2001-2 to 2004-5. 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 testing Kalecki's lagged profit variable.

The R2 results reported in Table 3 show a strong (F-statistic) regression result with a very significant four-year block profit variable. Note that RLS is still mildly

significant so that the TI relationship is still relevant. The change in operating profit variable is not included in the block lag test because it lacks significance in the prior test. 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 tested in R1 (Table 2).

**Table 3 - Average Investment Rate in Australian Manufacturing 2001/02 to 2004/05 – R2 Regression Results with RLS and Block Lag Data**

|                                                                                                                                                                                                    | Estimated Coefficient |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| Intercept                                                                                                                                                                                          | 0.0360<br>(0.0229)    |
| Lag 4-year block of Avg Operating Profit/Avg IVA                                                                                                                                                   | 0.2526***<br>(0.0754) |
| RLS                                                                                                                                                                                                | 1.0602*<br>(0.6280)   |
| R-squared                                                                                                                                                                                          | 0.3210                |
| F-statistic                                                                                                                                                                                        | 7.5630***             |
| Notes: Standard errors in parentheses<br>Observations = 35<br>*** indicates significance at the 1% level<br>** indicates significance at the 5% level<br>* indicates significance at the 10% level |                       |

Innovation can impact on the variability of investment as well as on its level. Our estimates give the rate of input-saving on average over a 32-year sample period, but it is unlikely that the course of TI is smooth. Instead, it is expected that there will be periods of rapid advance interspersed with lesser developments. To this extent, industries with more rapid average input saving might also exhibit more uneven induced TO 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 4 presents R1 results from regressions for two measures of the variability of the investment rate, the variance of the investment rate and the standard error given by the square root of the variance. The explanatory variables are the rate of labour saving, which is the only statistically significant measure of TI from Table 2, and the average profit rate and change in profit rate are as used in the Table 2 regressions.

The explanatory power of the regressions in Table 4 greatly exceeds those of the regressions in Table 2. However, the only consistently significant coefficient in the regression is the change in profit variable, which is positive and highly significant. This indicates that industries which experience a more positive change in their profit rate also exhibit greater investment instability. Consistent with Kalecki, the investment instability is related to profit changes. Salter helps to support the Kaleckian investment model through linking the investment rate to each industry's TI and TO as well as their respective overall profits.

**Table 4 - Variation in Investment Rate in Australian Manufacturing 2001/02 to 2004/05 – Regression Results**

| <b>Coefficient / Dependent Variable</b>                                                                                                                                                            | <b>Variance of Investment Rate</b> | <b>Standard Error of Investment Rate</b> |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------|------------------------------------------|
| Intercept                                                                                                                                                                                          | -0.0028<br>(0.0023)                | -0.0092<br>(0.0167)                      |
| Avg Operating Profit/Avg IVA                                                                                                                                                                       | 0.0035<br>(0.0067)                 | 0.0411<br>(0.0500)                       |
| Change in Operating Profit/Avg IVA                                                                                                                                                                 | 0.0169***<br>(0.0033)              | 0.0950***<br>(0.0248)                    |
| RLS                                                                                                                                                                                                | 0.0738<br>(0.0477)                 | 0.7185**<br>(0.3548)                     |
| R-squared                                                                                                                                                                                          | 0.4965                             | 0.4120                                   |
| F-statistic                                                                                                                                                                                        | 10.5192***                         | 7.473***                                 |
| Notes: Standard errors in parentheses<br>Observations = 36<br>*** indicates significance at the 1% level<br>** indicates significance at the 5% level<br>* indicates significance at the 10% level |                                    |                                          |

Table 5 lists the 36 manufacturing industries with available investment data, ranked from highest to lowest RLS. The first column on the right shows industry average IVA for the period 2001-02 to 2004-05. The next two columns show total investment rate and its variance for this four-year period. The final two columns provide the four-year average profit and change in profit (as ratios of IVA) for each industry group. For this period, the top five largest RLS-based industry groups shows relatively low average profit rate, and mid-range investment (except for 261 Glass and Glass Product, which is third highest in total investment over the four years). The variances of the investment rate for these same industries are also relatively low. Three industry groups with high profit rates and high variance in investment rates, that also exhibit high labour saving rates, are 253 Basic Chemicals, 233 Paper and Paper Products, and 251 Petroleum Refining (sixth, seventh, eighth respectively). These three are also significant capital goods spenders over this period, coming in at first, tenth and sixth (respectively) in total investment spending (as a ratio of IVA).

The picture that emerges from Table 5 is of two mechanisms operating with TI in the high RLS industries. One is by the smaller IVA, lower profit industries that are forced for survival to invest in new process technology in order to remain price and quality competitive in mature industries that are dominated by low wage cost manufacturers overseas. This is indicative of the second and third highest RLS industries (Glass and Textile) which have negative change in profit rate over the four-year study period.<sup>9</sup> The other contemporaneous mechanism is the large investment from strong profits that induce new technologies to replace old vintage stock in order for these local industries to remain dominant. This is indicative of four top-eight RLS industries with very strong rise in profit rate over the four-year study period: Petroleum, Basic

<sup>9</sup> The Knitting Mills industry is smallest IVA industry and has the lowest average profit rate of all the 36 industries in Table 5, but has the fifth-highest change in profit rate for this four-year period. If this pattern continues then this industry has potential to join the investment group described in the text.

Chemical, Iron & Steel, and Sheet Metal. Also, Table 5 shows that these four large investment industries have relatively unstable investment compared to the other top RLS industries that have much lower variance in investment rates. The remaining two top-eight RLS industries (Paper and Other Chemical) also have strong investment rates on the back of healthy average profit rates, but with large negative profit changes in the four-year study period.

A major exception to the Table 5 patterns identified above is Publishing, the third largest IVA industry (and rising). This industry has a very low investment rate, but the second strongest average profit rate (after Basic Non-ferrous) and the fourth highest change in profit rate. This is an outlier industry with very little investment despite strong profits. It deserves a research case study to understand its situation.

### **Limitations**

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 the use of various inputs. 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 and Hopp, 1992; Whelan, 2006) it is clear that the speed of obsolescence is complex and depends on the rates of TI 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 TI.

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

A third limitation is the lack of in-depth understanding of what is actually happening at the specific industry level in relation to TO and RLS. The decision making in each industry would be peculiar to its own environment, but would emerge from in-depth case studies as patterns of behaviour that could lend support to the mechanisms described in the previous section.<sup>10</sup>

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 development of in-depth case studies to address the final limitation. The results presented in this paper encourage further investigations along this track.

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<sup>10</sup> For an explanation of the relevance of case studies to investigations in investment decision making, see Courvisanos (1996, pp 190-216).

**Table 5 – Australian Manufacturing Industries Ranked by Rates of Labour Saving and Related to Investment and Profits**

| <b>RLS</b>  | <b>Industry</b>                                    | <b>Av IVA<br/>4 yrs (\$)</b> | <b>Total Investment/<br/>Avg IVA 4 yrs</b> | <b>Variance<br/>Investment Rate</b> | <b>Avg Op.Prof/<br/>Avg IVA 4 yrs</b> | <b>Change in<br/>Op.Prof/IVA</b> |
|-------------|----------------------------------------------------|------------------------------|--------------------------------------------|-------------------------------------|---------------------------------------|----------------------------------|
| 0.05163227  | 275 Sheet metal product mfg                        | 1412                         | 0.345670267                                | 0.00018998                          | 0.253231804                           | 0.133876395                      |
| 0.05065626  | 261 Glass and glass product mfg                    | 786                          | 0.834871142                                | 0.00068998                          | 0.212535794                           | -0.001272669                     |
| 0.04955518  | 221 Textile fibre, yarn and woven fabric mfg       | 439                          | 0.380626781                                | 0.00035862                          | 0.077492877                           | -0.034188034                     |
| 0.04530621  | 271 Iron and steel mfg                             | 3937                         | 0.420905569                                | 0.00117259                          | 0.252810059                           | 0.317520798                      |
| 0.04414072  | 254 Other chemical product mfg                     | 3881                         | 0.41690286                                 | 0.0005112                           | 0.250064416                           | -0.064158722                     |
| 0.04199034  | 253 Basic chemical mfg                             | 2671                         | 0.9817467                                  | 0.01698189                          | 0.277637368                           | 0.111204718                      |
| 0.04161829  | 233 Paper and paper product mfg                    | 2689                         | 0.469406732                                | 0.00256748                          | 0.275897341                           | -0.028640506                     |
| 0.03997761  | 251 Petroleum refining                             | 1353                         | 0.707317073                                | 0.02261395                          | 0.288802661                           | 1.000739098                      |
| 0.03872225  | 223 Knitting mills                                 | 157                          | 0.255591054                                | 0.00121968                          | 0.083067093                           | 0.191693291                      |
| 0.03651328  | 226 Leather and leather product mfg                | 203                          | 0.301234568                                | 0.0002521                           | 0.201234568                           | -0.049382716                     |
| 0.03424144  | 252 Petroleum and coal product mfg n.e.c.          | 142                          | 0.444444444                                | 0.0021169                           | 0.363315697                           | 0.077601411                      |
| 0.03360561  | 213 Fruit and vegetable processing                 | 1111                         | 0.454443195                                | 0.0007033                           | 0.235095613                           | 0.098987627                      |
| 0.03318356  | 224 Clothing mfg                                   | 1145                         | 0.226151495                                | 0.00010741                          | 0.267408863                           | 0.075092775                      |
| 0.03221492  | 282 Other transport equipment mfg                  | 2327                         | 0.349451966                                | 0.00090202                          | 0.17311412                            | 0.096281969                      |
| 0.03189221  | 273 Non-ferrous basic metal product mfg            | 572                          | 0.428321678                                | 9.4155E-05                          | 0.152972028                           | 0.006993007                      |
| 0.03158654  | 255 Rubber product mfg                             | 616                          | 0.356997972                                | 0.00144256                          | 0.140365112                           | 0.055172414                      |
| 0.02987982  | 241 Printing and services to printing              | 3754                         | 0.434232434                                | 0.00032357                          | 0.149250749                           | 0.075924076                      |
| 0.02868714  | 272 Basic non-ferrous metal mfg                    | 5164                         | 0.960255603                                | 0.00287493                          | 0.498233044                           | 0.246308757                      |
| 0.02704294  | 264 Non-metallic mineral product mfg n.e.c.        | 532                          | 0.342105263                                | 0.00099003                          | 0.196898496                           | 0.171052632                      |
| 0.02548913  | 215 Flour mill and cereal food mfg                 | 913                          | 0.391125719                                | 0.00044939                          | 0.289235826                           | 0.033963298                      |
| 0.02486342  | 214 Oil and fat mfg                                | 346                          | 0.36101083                                 | 0.0001737                           | 0.39133574                            | -0.112635379                     |
| 0.02451222  | 262 Ceramic mfg                                    | 727                          | 0.361885105                                | 0.00041779                          | 0.372893017                           | 0.089439284                      |
| 0.02239817  | 225 Footwear mfg                                   | 177                          | 0.293785311                                | 0.00020978                          | 0.223163842                           | 0.084745763                      |
| 0.02234082  | 281 Motor vehicle and part mfg                     | 5455                         | 0.725572869                                | 0.00218093                          | 0.189184235                           | 0.047662695                      |
| 0.02122631  | 263 Cement, lime, plaster and concrete product mfg | 2507                         | 0.75994814                                 | 0.00138975                          | 0.316146405                           | 0.111698414                      |
| 0.01948491  | 286 Industrial machinery and equipment mfg         | 4065                         | 0.269372694                                | 3.9273E-05                          | 0.223800738                           | 0.104305043                      |
| 0.01940928  | 256 Plastic product mfg                            | 2677                         | 0.533756653                                | 0.00164418                          | 0.199831917                           | 0.109440657                      |
| 0.01903462  | 222 Textile product mfg                            | 893                          | 0.348459384                                | 7.3088E-05                          | 0.159103641                           | 0.070588235                      |
| 0.01818377  | 217 Other food mfg                                 | 3692                         | 0.674793444                                | 0.00666665                          | 0.241771638                           | -0.038466748                     |
| 0.01684944  | 242 Publishing                                     | 5097                         | 0.142240534                                | 3.5431E-05                          | 0.413086129                           | 0.198940553                      |
| 0.01500783  | 232 Other wood product mfg                         | 1951                         | 0.285567803                                | 0.00021293                          | 0.228531146                           | 0.082542938                      |
| 0.01419791  | 274 Structural metal product mfg                   | 2374                         | 0.212743549                                | 2.278E-05                           | 0.219062665                           | 0.182411796                      |
| 0.01414096  | 231 Log sawmilling and timber dressing             | 1570                         | 0.475083585                                | 0.00012085                          | 0.248527305                           | 0.084699889                      |
| 0.009325357 | 276 Fabricated metal product mfg                   | 3146                         | 0.289938007                                | 0.00012588                          | 0.234620887                           | 0.120489588                      |
| 0.008410041 | 292 Furniture mfg                                  | 2389                         | 0.227267971                                | 0.00012879                          | 0.19200586                            | 0.04227268                       |
| 0.007257105 | 216 Bakery product mfg                             | 1479                         | 0.388841927                                | 7.2544E-05                          | 0.17920541                            | 0.071005917                      |

## Conclusion

This study is another step in the long and winding road towards incorporating TI into the accumulation process as expressed by Salter in the opening quote. 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 in this way recognising when technical change augments capital accumulation. New capital stock is introduced that results in the older vintage stock being decommissioned as technologically obsolete.

Estimated rates of input saving (labour, capital and materials) obtained for the Australian manufacturing sector by industry groups show that technical change has a significant labour-saving bias. This bias is argued to be an essential element in the technological obsolescence of old vintage capital equipment. Regression results indicate that the rate of labour saving play a significant role in the investment process out of the mild Australian cyclical trough at the end of the Twentieth Century. This result enables the inclusion of labour saving as a proxy for technological innovation 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 the strength of labour saving and the strong positive profit relationship to the variance 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.<sup>11</sup> This macroeconomic feedback from investment to profits is the source of saving in the community. In his *Treatise on Money*, Keynes called it the Widow's Curse, while Kalecki's Dictum states that "capitalists earn what they spend, and workers spend what they earn" (Sawyer, 1985, p.73).<sup>12</sup> What this study does is contribute to analysing the form of this investment. Keynes referred to "fruitful investment" in the context of productive expenditure on capital stock that is not speculative investment (Keynes, 1936, p.150). We take this one step further and identify the nature of fruitful investment in terms of the extent of technical change through innovation that is embodied in the capital accumulation process. Investment that incorporates technological innovation enables industries to become sustainable into the uncertain future, but with varying states of investment instability.

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<sup>11</sup> See Harcourt (2006, and in particular pp. 160-4).

<sup>12</sup> Professor Geoffrey Harcourt suggests that Kalecki's Dictum would be better phrased as "wage-earners spend what they earn while profit-receivers receive what they spend." (Dalziel and Lavoie, 2003, p. 340 fn.4).

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