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"Technological Change in Australian Manufacturing"
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ABSTRACT

In the modern era, the extent and character of technical change features prominently in discussions of productivity growth and movements in the competitiveness of manufacturing. While technical change is pervasive in modern manufacturing, it occurs unevenly. In this study, technical change is estimated by fitting dual cost functions for each of 38 sectors of Australian manufacturing over the 32-year period, 1968/69 to 1999/2000. The estimates show that technical change is heavily labour saving in all industries, but that the rate of change and the degree of bias towards saving labour, rather than capital or material, varies substantially across industries.

Key words: technical change, manufacturing, cost functions
JEL codes: D24, M41, O33

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1. Introduction

Two key characteristics of modern manufacturing technology are the speed of change and an emphasis on displacement of labour. Yet, the pace of change and the degree of labour-saving bias are not uniformly distributed over the economy. This has clear consequences for structural change in the economy arising from altering the competitiveness and employment growth of individual industries.

In the present paper, estimates of the rate of technical change and degree of bias towards labour are provided by fitting the dual cost functions to data for each of 38 manufacturing sectors at the three-digit level of the ANZSIC classification scheme. The dual cost functions allow for rates of factor augmentation that vary across capital, labour and materials inputs. The estimates universally lead to rejection of the hypothesis that technical change is neutral. Instead a labour-saving bias is found in all industries, albeit to a degree that varies substantially across industries.

The finding of a labour-saving bias to technical change in Australian manufacturing supports an earlier finding by Whiteman (1991), even though our findings are based on a different specification of technology. Instead of the translog functional form for the dual cost function with factor-augmenting technical change for labour and capital used by Whiteman, we utilise the Leontief functional form of the dual cost function with separate rates of augmentation for capital, labour and materials. Thus, our specification is less flexible by not allowing for input substitution, but considers a larger number of inputs.

Hall (1988) argues that when there is imperfect competition, the difference between price and marginal cost can lead to bias in the measurement of technical change from production data. A related bias can occur with our estimates, as we use industry revenue as a proxy for industry total cost due to the difficulty of accurately measuring capital costs. To avoid bias, we estimate an integrated system of equations following Appelbaum (1982), in which the gap between price and marginal cost depends on firm conjectures about the reactions and the industry price elasticity of demand.

The method for estimating technical change is discussed in Section 2 below. In Section 3, the method is applied to time-series data for each of 38 3-digit manufacturing sectors over the 32-year period, 1968/69 to 1999/2000. These estimates are used to test whether technical change is neutral in its impact on the usage of all inputs. We also test for evidence of imperfect competition. We conclude the paper with observations on the implications of our findings.

2. Estimating the cost functions with factor-augmenting technical change

A standard method for estimating bias in technical progress is to fit regressions to dual cost functions that incorporate factor-augmenting technical change.[1] This approach is used by the Bureau of Industry Economics (BIE) in a study of technical progress in Australian manufacturing industries (see BIE, 1985; Harris, 1986 and Whiteman, 1991). Our approach is similar, except that we use a different specification of technology and we consider the impact of the price of materials input along with capital and labour prices. We also allow for the possibility that competition is imperfect, with price exceeding marginal cost.

[1] As discussed in Berndt (1991) to avoid simultaneous equations bias, the right hand side variables of the function should be exogenous. Further, when using disaggregated data within markets that are relatively competitive, input prices, rather than input quantities, are generally considered exogenous. If this is the case, then estimation should be undertaken within a cost, rather than production, framework.

We utilise a Leontief specification of production technology which, for efficient production, imposes a fixed ratio of input to output for each input at any point in time. The generalised Leontief is more flexible and allows for input substitution. However, estimation of a generalised Leontief with three inputs to production involves a substantial number of explanatory variables (one for each input price and for each cross product of input prices). We choose to rely on the simple specification of Leontief technology as a first-order approximation to the generalised function.

With factor-augmenting technological change, the 'effective' quantities of input change over time in relation to the actual quantity. When we assume a constant rate of factor augmentation, the effective quantities of labour, L'_{it}, capital, K'_{it}, and materials, M'_{it} can be written as:

$$
\begin{aligned}
L'_{it} &= L_{it}\, e^{\Theta t} \\
K'_{it} &= K_{it}\, e^{\Phi t} \\
M'_{it} &= M_{it}\, e^{\psi t}
\end{aligned}
\qquad (1)
$$

L_{it} in (1) is the actual quantity of labour employed by the ith firm at time t, K_{it} is the corresponding actual quantity of capital and M_{it} is the actual quantity of materials. Further, Θ is the rate of labour saving in technical change, Φ is the rate of capital saving and ψ is the rate of material saving. We envision the possibility that technical change is labour saving and capital using in modern manufacturing, in which case Θ is positive and Φ is negative, whereas changes in material usage are usually small unless there have been dramatic alterations in an industry's products or processes.[2]

Taking account of the impact of factor augmentation on the amount of work done by a unit of input yields adjusted prices for 'effective' units of input. We assume each firm faces the same market price for actual units of input and, as above, treat the rate of augmentation as identical across firms. This means that the prices of 'effective' units of labour, w'_t, capital, r'_t, and materials m'_t are given by:

$$
\begin{aligned}
w'_t &= w_t\, e^{-\Theta t} \\
r'_t &= r_t\, e^{-\Phi t} \\
m'_t &= m_t\, e^{-\Psi t}
\end{aligned}
\qquad (2)
$$

w_t in (2) is the price of an actual unit of labour at time t, r_t is the rental price of an actual unit of capital, and m_t is the price of an actual unit of material.

As the rate of labour, capital and material augmentation are not known *a priori*, we estimate the cost function using the actual wage rate, rental price of capital and material price by substitution from (2). The rates of labour, capital and material augmentation are then given by estimated coefficients. In order to ensure consistency with cost-minimising behaviour, we impose homogeneity of degree one with respect to nominal magnitudes. We also assume constant returns to scale and constant rates of technical change over time for simplicity. The resulting Leontief cost function for unit costs for the ith firm at time t, c_{it}, in terms of the rental price of capital, r_t, the market wage rate, w_t, and material input price, m_t, is then given by:

[2] The process of capital accumulation under modern capitalism creates the expectation that the cost of capital decreases relative to the cost of labour over time. This provides a ready market for capital equipment that requires less labour to operate per unit of output, even if this comes at a cost in terms of a higher price for the service of equipment per unit of output.

$$c_{it} = \gamma_{ik} r_t e^{-\Phi t} + \gamma_{il} w_t e^{-\Theta t} + \gamma_{im} m_t e^{-\Psi t} \quad (3)$$

In the absence of firm-level data on input prices and costs, we use industry-level data in estimating dual cost functions for each of 38 Australian manufacturing industries. Aggregating equations in the form of (3) over all producers in an industry yields the following industry-level equation:

$$c_t = \gamma_k r_t e^{-\Phi t} + \gamma_l w_t e^{-\Theta t} + \gamma_m m_t e^{-\Psi t} \quad (4)$$

If the unit cost variable in (4) is calculated by weighting each firm's unit cost by its share of industry output, the corresponding γ_k , γ_l and γ_m parameters are each correspondingly weighted averages of the corresponding firm-level values, as the term multiplying each parameter is the same for each firm.

Data on the cost of all inputs into production are not readily available for Australian manufacturing industries. There are data for labour and material costs, but the cost of capital is not reported. If competition is perfect and firms are maximising profits, price is equal to marginal cost (and unit cost under our assumption of constant returns to scale). Price can then be substituted for unit cost in (3) to yield

$$p_t = \gamma_l w_t e^{-\Theta t} + \gamma_m m_t e^{-\Psi t} + \gamma_k r_t e^{-\Phi t} \quad (5)$$

Appelbaum (1982) shows that even under conditions of imperfect competition it is possible to estimate a dual cost function using average revenue data in place of a direct measure of unit cost. In particular, he assumes that firms behave as non-collusive oligopolists who have conjectures about the influence of changes in their own outputs on the total quantity of output supplied to the market. Assuming that industry output is homogenous across firms, the first-order condition for profit maximisation for each firm implies that:

$$p_{it} = c_{it} / [1 - \lambda_i / \eta_t] \quad (6)$$

where λ_i is defined by

$$\lambda_i = \left[\frac{\partial q}{\partial q_i} \frac{q_i}{q} \right] \quad (7)$$

is the conjectural elasticity of total industry output with respect to the output of the ith firm, and η_t is the market demand elasticity at time t.

The conjectural elasticity, λ_i, in (7) consists of the ith firm's output share in the industry, q_i / q , and a conjectural variation term, $\partial q / \partial q_i$. In the special case of Cournot behaviour, the conjectural variation term is equal to one, $\partial q / \partial q_i = 1$, thereby reducing the conjectural elasticity, λ_i to the output share of the ith firm. Furthermore, under perfect competition, λ_i for the ith firm is zero since $\partial q / \partial q_i = 0$ and under perfect implicit collusion, λ_i for the ith firm is one since $\partial q / \partial q_i = q / q_i$. Thus, the conjectural elasticity, λ_i reflects the underlying market competitiveness. Appelbaum (1982) refers to the combined term, λ_i / η_t , as a measure of the degree of oligopoly.

Following Cowling and Waterson (1976), the optimality condition for the ith firm in (6) can be applied to an industry consisting of identical firms, in which $\lambda_i = \lambda$ for all *i*. Clarke and Davies (1982) extend this approach to allow for differences in conjectures, perceived marginal revenue and marginal cost across firms, demonstrating that equality of marginal cost and marginal revenue can still occur for each firm. In this case, the industry conjecture variable must be an appropriate aggregation of the corresponding firm-level measure.[3] Assuming this aggregation holds, substituting from (4) into (6), after aggregating to an industry relation without the I subscripts, then yields the following pricing relation for an industry;

$$p_t = \gamma_l w_t e^{-\Theta t} + \gamma_m m_t e^{-\Psi t} + \gamma_k r_t e^{-\Phi t} / \left[1 - \lambda / \eta_t\right] \qquad (8)$$

The double logarithmic market demand function, as employed by Appelbaum (1982), has the form

$$\ln Y_t = \alpha + \eta \ln\left(\frac{p_t}{W_t}\right) + \rho \ln\left(\frac{Q_t}{W_t}\right) \qquad (9)$$

where W is the implicit GNP price index and Q is GNP in current dollars. In this case the elasticity of market demand that enters into determination of the profit-maximising price in (8) is constant over time, with η replacing η_t.

3. Results for Australian manufacturing

Regression results from estimating a dual cost function for each of the three-digit level sectors within manufacturing are shown in Table 1. RKS, RLS and RMS represent rates of saving of capital, labour and materials respectively. In each case, the seemingly unrelated regression (SUR) estimation method is used to estimate the pricing equation in (8) together with the corresponding market demand equation in (9). The efficiency of estimation is increased by including the demand equations for labour and materials in the system of estimated equations.[4] The data used in the estimates are annual data for the period 1968/69 to 1999/2000. Data sources are explained in the Data Appendix.

In all but four industries the results indicate an absence of market power in that the restriction that $\lambda=0$ can't be rejected using a log-likelihood test. The four industries with evidence of market power are Oil and Fat (214), Bakery Product (216), Non-ferrous Basic Metal Product (273) and Other Transport Equipment (282).[5] The results reported for rates of factor augmentation and cost diminution below for these four industries are for a pricing equation in the form of (8), while for all other industries the results are for a pricing equation in the form of (5).

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[3] The linearity of the cost function in (3) means that exact aggregation of individual firm costs is guaranteed for any arbitrary weighting of the individual firm cost equations. This is a condition that is particularly important, and often violated, in studies, such as the current study, that use data aggregated to the industry level.

[4] A demand equation for each input is derived using Shepard's Lemma, taking the first derivative of the cost function with respect to the relevant input price, where the cost function is given by multiplying the unit cost function in (4) by the level of output. This yields $L_t = Q_t e^{-\Theta t}$ and $M_t = Q_t e^{-\psi t}$ as demand functions for labour and materials, respectively. We omit the demand equation for capital due to lack of data on the volume of capital services used.

[5] The estimated ratio of price to unit cost in these industries ranges from 1.1 in Other Transport Equipment to 1.6 in Bakery Product. Detailed results are available on request from the author.

The estimates in Table 1 show that the rate of labour saving in every industry is statistically greater than zero at the one percent significance level using Student's t test. The rate of materials saving is also generally greater than zero and often at the one or five percent significance level. However, technical change is shown to be generally capital using with negative rates of factor augmentation for capital, often by amounts that are statistically significant at the one or five percent level. Even in those few industries with capital-saving technical change the rate of labour saving is always greater, so each Australian manufacturing industry in this study is found to have a labour-saving bias to technical change.[6]

The rate of labour saving in technical change, while always positive, varies substantially across industries. Rates of labour saving range from less than one percent a year, in Bakery Products as well as Furniture and Fabricated Metal Products, to over five percent a year, in Sheet Metal Products as well as Glass and Glass Products. The average rate of labour saving is 0.028837, with a standard deviation across industries of 0.01208.

Variation across industries is also observed in the rate of materials and, especially, in the rate of capital saving. The rate of materials saving ranges from below negative two percent per year, in Other Transport Equipment as well as Leather and Leather Products, to more than positive two percent, in Basic Non-ferrous Metal and Textile Fibre, Yarn and Woven Fabric. The average rate of materials saving is 0.003162 and the standard deviation is 0.017042. The rate of capital saving varies from almost negative twenty percent per year, in Oil and Fat, to more than positive three percent, in Knitting Mills. The average rate of capital saving is -0.044966 and the standard deviation is 0.077697.

In Table 2 the estimates from Table 1 are used to calculate a rate of cost diminution due to factor augmenting technical change for each industry. Each rate of input saving from Table 1 is multiplied by that input's average share of industry cost over the sample period, 1968 through 1999, to give an estimate of the contribution to cost saving of technical change in the use of that input. The sum of these individual elements then gives the total cost diminution for the industry.

The total rate of cost diminution varies substantially across industries in Table 2, ranging from an annual cost saving of over 5% a year in non-metallic Mineral Products to an annual cost increase of over 5% a year in Bakery Products. The average cost saving is about .47% per annum and the standard deviation is 1.8%. Decomposing the total cost saving into the impact of augmentation for individual factors shows that saving labour reduces costs on average by about .59% per annum. Saving materials reduces costs by about .25% per annum and using increased capital usage raises costs by approximately .38% per annum.

[6] Whiteman (1991) also finds a labour-saving bias in each of the industries in his study.

Table 1 – Estimates of Rates of Factor Augmentation

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

Notes: Figures in parentheses are t-ratios

Table 2 - Contributions to Cost Diminution

Industry	Capital	Labour	Materials	Total	Industry	Capital	Labour	Materials	Total
Fruit and Vegetable Processing (213)	0.00105	0.00694	0.00964	0.01762	**Petroleum and Coal Product (252)**	0.02066	0.00767	-0.04345	-0.01512
Oil and Fat (214)	-0.04494	0.00237	0.00939	-0.03318	**Basic Chemical (253)**	-0.00157	0.00434	0.00761	0.01039
Flour Mill and Cereal Food (215)	-0.02229	0.00263	0.00984	-0.00983	**Other Chemical Product (254)**	-0.00648	0.00714	0.00285	0.00351
Bakery Product (216)	-0.05275	0.00162	-0.00049	-0.05161	**Rubber Product (255)**	-0.00143	0.00723	0.00330	0.00910
Other Food (217)	-0.00470	0.00250	0.00520	0.00300	**Plastic Product (256)**	-0.00717	0.00425	0.00187	-0.00104
Beverage and Malt (218)	-0.01278	0.00560	0.00638	-0.00080	**Glass and Glass Product (261)**	0.00821	0.01126	0.00036	0.01983
Tobacco Product (219)	-0.01869	0.00437	0.00306	-0.01126	**Ceramic (262)**	-0.00494	0.00621	-0.00527	-0.00400
Textile Fibre, Yarn and Woven Fabric (221)	-0.00048	0.00983	0.01588	0.02523	**Cement, Lime, Plaster and Concrete Product (263)**	-0.00144	0.00249	-0.00383	-0.00278
Textile Product (222)	-0.00103	0.00443	0.00499	0.00838	**Non-metallic Mineral Product (264)**	0.03698	0.01071	0.00661	0.05429
Knitting Mills (223)	0.01308	0.01087	-0.00041	0.02354	**Iron and Steel (271)**	-0.00382	0.00817	0.00677	0.01111
Clothing (224)	-0.00426	0.00819	0.01146	0.01539	**Basic Non-ferrous Metal (272)**	-0.02116	0.00289	0.01461	-0.00366
Footwear (225)	0.00019	0.00675	0.00307	0.01001	**Non-ferrous Basic Metal Product (273)**	-0.02793	0.00509	0.01218	-0.01067
Leather and Leather Product (226)	0.00015	0.00652	-0.01669	-0.01001	**Structural Metal Product (274)**	-0.00017	0.00321	0.00301	0.00605
Log Sawmilling and Timber Dressing (231)	0.00743	0.00229	0.01574	0.02547	**Sheet Metal Product (275)**	0.00446	0.01399	-0.00459	0.01386
Other Wood Product (232)	0.00609	0.00371	0.01028	0.02008	**Fabricated Metal Product (276)**	0.00198	0.00286	0.00944	0.01428
Paper and Paper Product (233)	-0.00681	0.00700	0.00391	0.00410	**Motor Vehicle and Part (281)**	-0.00756	0.00360	0.00132	-0.00263
Printing and Services to Printing (241)	0.00415	0.00950	0.01366	0.02731	**Other Transport Equipment (282)**	-0.00017	0.01547	-0.01156	0.00374
Publishing (242)	-0.00369	0.00451	0.01363	0.01445	**Industrial Machinery and Equipment (286)**	-0.00265	0.00574	-0.00050	0.00260
Petroleum Refining (251)	0.01162	0.00104	-0.01882	-0.00616	**Furniture (292)**	-0.00031	0.00237	-0.00440	-0.00234

Cost diminution is the dual reflection of technical change. Saving inputs means less input is required to produce a given quantity of output, hence the reduction in unit cost. The data in Table 2 indicate that on average there is a rate of technical progress in Australian manufacturing of about half a percentage point per annum over the sample period. Further, differences in the rate of cost diminution across industries are the reflection on the cost side of differences in the rate of technological progress. Thus, the magnitude of the differences in cost diminution shown in Table 2 indicates that technological progress has variable impact on cost competitiveness across Australian manufacturing industries.[7]

4. Conclusions

A key finding of the current study is that technological change in Australian manufacturing has a clear bias toward saving labour and using capital. This is not surprising given that the history of manufacturing at least since the Industrial Revolution has been one of increased mechanisation and enhanced labour productivity. Whiteman (1991) also finds a labour-saving (and capital-using) bias to technological change in Australian manufacturing. However, in the current study all changes in input usage are ascribed to technological change, whereas Whiteman splits changes in labour and capital usage between input substitution and factor-augmenting technological change.

The distinction between movements in usage of inputs due to technological change and that due to input substitution becomes muted once it is recognised that technological change reflects expectations of differential input price movements. Much technological change in manufacturing is embodied in capital equipment. Equipment producers attract buyers by ensuring that the equipment has low expected operating costs over the full lifetime of the equipment. With wage rates having strong trend growth, in both nominal and real terms, there is a clear incentive to continually reduce the labour requirements embodied in new equipment. Thus, the overwhelming labour-saving bias observed in technological change is associated with a clear historical rise in the relative price of labour, which is built into the future expectations of equipment manufacturers and buyers.[8]

[7] The dual relation between cost diminution and technological progress means that a negative rate of cost diminution implies technological regress. As technological change is labour saving in all industries, a negative rate of cost diminution goes along with technological change that is capital using and/or materials using. This raises the question of whether there has been over commitment, particularly to capital equipment, in industries experiencing negative cost diminution. Another possible reason for estimating negative technological change is failure to fully account for changes in product quality. Interestingly, the Bakery Product industry, which shows the most negative rate of cost diminution, has experienced a fundamental change in the distribution of its products, from large centralised bakeries to on-site baking in retail shops. Arguably, this is associated with a change in the quality of the product, particularly freshness.

[8] In this circumstance it is very difficult to statistically disentangle contemporaneous input substitution from built-in technological change. In Whiteman's results the parameter that indicates the degree of input substitution in almost half the industries (16 out of 34) is not statistically different from zero at the five percent significance level. In the current study estimates of a generalized Leontief cost function, which allows for input substitution, are characterized by low statistical significance and of key parameters along with frequent violation of the restrictions required for regularity of the cost function.

Data Appendix

Price and Quantity of Output

Industry output is measured by the constant dollar value of manufacturing output for the industry from unpublished data supplied by the Australian Bureau of Statistics. A price index is calculated for each industry by dividing the constant dollar output into the value of turnover for the industry. For the period 1968/69 to 1991/92 turnover data are taken from Industry Commission (1995) and for the period 1991/92 to 1999/2000 the data are taken from ABS Catalogue 8221.0: Manufacturing Industry.

Wages and Hours Data

As is traditional in this area, wages and hours data for males, rather than persons, are used. For the period 1981 to 2000 the data are taken from, the Survey of Earnings, Employment and Hours (EEH), ABS Catalogue 6306.0: *Average Weekly Ordinary Time Earnings (AWOTE) and Average Weekly Ordinary Time Hours (AWOTH)*. Prior to 1981 the data are taken from Bureau of Industry Economics (1985). Adjustments are made to link the series. Details are available from the authors.

Price of Materials and Quantity of Materials

The price index of materials is taken from ABS Catalogue 6427.0 (Table 14 online). A simple average is used to form annual data from the quarterly data series. Where necessary, data from the two-digit classification level are attributed to component three-digit industries. The quantity of materials is the value of purchases divided by the price index above. Data for purchases from 1968/69 to 1991/92 are taken from Industry Commission (1995) in ASIC classification. A concordance is used to match ASIC industry to ANZSIC. Interpolation is used to fill in a few years with missing data. Data for 1991/92 are taken from ABS Catalogue 8221.

Rental Price of Capital

For the rental price of capital with exogenous depreciation, the data for the period 1954 through 1981 is taken from BIE (1985). For later years, 1982 to 2000, corresponding data are calculated according to the formula:

$r = (1/m + i)\ pk$

where

r = rental price of capital.

m = age of obsolescence. Set to 14.4 years, the mean asset life for manufacturing taken from ABS Catalogue 5216.0: Australian System of National Accounts Concepts, Sources and Methods, 2000.

i = interest rate, set to 7.44% as in Whiteman (1991).

pk = The price of capital used for all series is the Implicit Price Deflator for Private Corporate Trading Enterprises and Households (Unincorporated). These come as individual series and are weighted according to gross fixed capital formation within each category. The series are taken from unpublished working estimates provided by the ABS.

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