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The Australian telecommunications sector is being improved and extended through substantial recent investment in intelligent technology such as digital switching, fibre optics, satellite and cellular transmission, and the Internet. These technologies are being progressively integrated with technology from the broadcasting, computer and electronics industries, providing a unified information infrastructure for information transmission and processing. Technological progress embodied in new equipment has the effect of increasing the efficiency of the factors of production. Such efficiency increases can be biased towards a particular factor. For instance, the impact of labour-augmenting technical change is a decline in the cost of labour per unit of production. When such biases are apparent the relativity between the costs of labour and capital per unit of production is changed. In the longer term, technical change can impact on the rate of employment growth and also on the rate of capital accumulation. In this study the Australian telecommunications cost structure is examined for the period 1919 to 1988. To measure labour saving and capital saving technical change a translog cost model is estimated. Multiproduct telecommunications cost studies typically employ the translog cost model (Evans and Heckman, 1984; Röller, 1990a; 1990b; Shin and Ying, 1992; McKenzie and Small, 1997). The translog model places no a priori restrictions on substitution possibilities among the factors of production, and allows scale economies to vary with the level of output.

I. INTRODUCTION

Since the 1970s, communication technology has made great advances, with the bandwidth of new transmission technology virtually unlimited, providing the capability to carry large volumes of voice data and video signals. New electronic switching systems are reliable and small in size when compared with earlier electromechanical systems (Noll, 1992). In Australia the telecommunications sector has recently been improved and extended through substantial investment (both private and public) in intelligent technology such as digital switching, fibre optics, satellite and cellular transmission, and the Internet. This technology is being progressively integrated with technology from the broadcasting, computer and electronics industries, providing a unified infrastructure for information transmission and processing. Such technological improvement increases the efficiency of factors of production, resulting in reduced costs. Cost reductions can be biased towards a particular factor of production. For instance, labour–augmenting technical change leads to a decline in the cost of labour per unit of production. When such biases are apparent the relativity between the costs of labour and capital per unit of production is changed. In the longer term, technical

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change can impact on the rates of employment growth and capital accumulation.

The 'disembodied' view of technological change sees investment goods of different generations (or vintages) differing by some fixed factor associated with wear, tear and retirement. Accordingly, when the loss of productive efficiency occurs at a constant rate δ, the amount of capital at any time t is the weighted sum of surviving vintages, *viz.*,

$$K(t) = I(t) + (1-\delta)I(t-1) + \cdots + (1-\delta)^t I(0) \quad (1)$$

Vintage investment $I(t)$ is measured in number of machines, and the δ weights convert earlier vintages of investment into new-machine equivalents.[1] Thus the resultant stock $K(t)$ is interpreted as the number of new machine equivalents implied by the stream of past investment (Hulten, 1992). This approach does not allow for the direct identification of any factor bias in cost diminution.

In contrast, the 'embodied' view of technical change assumes successive vintages of investment embody differences in technical design. That is, new machinery is more efficient in producing output, *ceteris paribus*, even when earlier vintage machinery has not lost any of its physical capacity. In this case Equation 1 understates the true productive potential of capital, and the appropriate measurement of capital in terms of efficiency units $H(t)$ is,

$$H(t) = \Phi(t)I(t) \quad (2)$$

where $\Phi(t)$ is interpreted as the best-practice level of technology in year t. A change in $\Phi(t)$ is the quality differential between successive vintages, and is unrelated to physical depreciation (Fisher, 1965). The embodied approach allows the growth in efficiency of conventional inputs to be non-neutral. Further, the marginal cost of inputs need not decrease at a constant rate through time.

The question addressed by this study is the extent that telecommunications investment has produced changes in the cost structure of Australian telecommunications. Specifically, the intention is to disentangle and measure (separately) cost diminution due to both disembodied and embodied (labour and capital augmenting) technical change. The estimates contained herein are derived from an econometric model of the Australian telecommunications system cost structure. Estimation is on a unique data set constructed from Postmaster-General's (PMG) Department and Telecom Australia annual reports from 1919 to 1988.

The paper is organized as follows. A multi-product translog cost function is specified in Section II, and measures of factor-augmenting cost diminution are developed. Section III presents procedures to measure capital stock and its quality. An index of average labour quality, due to Gort *et al.* (1993), is also presented. Finally, data used for the construction of these indices and cost function estimation are described. Section IV describes model estimation procedures and reports the results of this estimation. The properness of the estimated cost function is assessed in Section V. Estimates of technical change are reported in Section VI. Concluding remarks and policy implications are provided in Section VII.

II. ISOLATING THE SOURCES OF TECHNICAL CHANGE

Telecommunications technology can be studied empirically using either production or cost functions. The cost function of a telecommunications firm identifies its minimum cost of providing services, given prices and the state of technology.[2] Here Australian telecommunications technology is described by the long run cost function:

$$\ln C_t = g(\ln P_{Lt}, \ln P_{Kt}, \ln Q_{1t}, \ln Q_{2t}, \ln \omega_t, \ln k_t, \ln \Omega_t) \quad (3)$$

where ln is the natural logarithm operator, C is the long run total cost of producing telephone services, P_L is the quality unadjusted wage rate, P_K is the user cost of capital stock, Q_1 is the number of local calls, Q_2 is the number of toll calls, ω is the labour quality index, k is the capital quality index and Ω the firm's stock of knowledge (organizational capital).

To isolate the underlying sources of change in long-run cost, and extract estimates of embodied and disembodied technical change, requires that the cost function is totally differentiated:

$$\begin{aligned}\dot{C}_t &= g_L \dot{P}_{Lt} + g_K \dot{P}_{Kt} + g_{Q1}\dot{Q}_{1t} + g_{Q2}\dot{Q}_{2t} \\ &\quad + g_\omega \dot{\omega}_t + g_k \dot{k}_t + g_\Omega \dot{\Omega}_t \quad (4)\end{aligned}$$

where $\dot{C}$ is the overall rate of cost diminution, g_L is the derivative cost function with respect to labour (the cost elasticity of labour), $\dot{P}_L$ the rate of growth of quality unadjusted wage, g_K is the derivative the cost function with respect to capital, $\dot{P}_K$ is the rate of growth of the user cost of capital stock, g_{Q1} is the derivative the cost function with respect to local output, $\dot{Q}_1$ is the rate of growth of local output, g_{Q2} is the derivative cost function with respect to toll output, $\dot{Q}_2$ is the rate of growth of toll output, $g_\omega \dot{\omega}$ measures the annual percentage shift in the cost function due to improved labour quality, $g_k \dot{k}$ measures the annual

[1] So that one unit of seven year old capital is equivalent in production to $(1-\delta)^7$ units of new capital.

[2] Cost function specification implies the output level is exogenous. Australian telecommunications services were provided by a public monopoly until 1991. The monopoly was not allowed to choose its own production level to maximize profits, but had to supply services at regulated prices, subject to meeting universal service obligation requirements. Since decisions were made with regard to the determination of the optimal levels of inputs, the specification that input levels are endogenous and output is exogenous seems reasonable.

percentage shift in the cost function due to improved capital quality, and $g_\Omega \dot{\Omega}$ measures the rate of time-dependent disembodied technical change.

To obtain estimates for the above measures requires the specification of an empirically estimable cost function. The following translog model is specified for this purpose:

$$\begin{aligned}
\ln C_t = {} & \beta_0 + \beta_1 \ln Q_{1t} + \beta_2 \ln Q_{2t} + \beta_L \ln P_{Lt} \\
& + \beta_K \ln P_{Kt} + \beta_\omega \ln \omega_t + \beta_k \ln k_t + \beta_\Omega \ln \Omega_t \\
& + \frac{1}{2} \sum_{i=1,2} \sum_{j=1,2} \beta_{ij} \ln Q_{it} \ln Q_{jt} \\
& + \frac{1}{2} \sum_{k=K,L} \sum_{1=K,L} \beta_{k1} \ln P_{kt} \ln P_{1t} \\
& + \sum_{m=1,2} \sum_{n=K,L} \beta_{mn} \ln Q_{mt} \ln P_{nt} \\
& + \sum_{p=1,2} \beta_{p\omega} \ln Q_{pt} \ln \omega_t + \sum_{q=1,2} \beta_{qk} \ln Q_{qt} \ln k_t \\
& + \sum_{r=1,2} \beta_{r\Omega} \ln Q_{rt} \ln Q_t + \sum_{s=K,L} \beta_{s\omega} \ln P_{st} \ln \omega_t \\
& + \sum_{w=K,L} \beta_{wk} \ln P_{wt} \ln k_t + \sum_{x=K,L} \beta_{x\Omega} \ln P_{xt} \ln \Omega_t \\
& + \beta_{\omega k} \ln \omega_t \ln k_t + \beta_{\omega\Omega} \ln \omega_t \ln \Omega_t \\
& + \beta_{k\Omega} \ln k_t \ln \Omega_t + \beta_{\omega\omega} \ln \omega_t \ln \omega_t + \beta_{kk} \ln k_t \ln k_t \\
& + \beta_{\Omega\Omega} \ln \Omega_t \ln \Omega_t + \varepsilon_t
\end{aligned} \tag{5}$$

By Shepard's lemma the corresponding cost share equations are:

$$\begin{aligned}
S_{Lt} = \frac{\partial \ln V_t}{\partial \ln P_{Lt}} = {} & \beta_L + \beta_{1L} \ln Q_{1t} + \beta_{2L} \ln Q_{2t} \\
& + \beta_{LL} \ln P_{Lt} + \beta_{LK} \ln P_{Kt} + \beta_{L\omega} \ln \omega_t \\
& + \beta_{Lk} \ln k_t + \beta_{L\Omega} \ln \Omega_t
\end{aligned} \tag{6}$$

$$\begin{aligned}
S_{Kt} = \frac{\partial \ln C_t}{\partial \ln P_{Kt}} = {} & \beta_K + \beta_{1K} \ln Q_{1t} + \beta_{2K} \ln Q_{2t} \\
& + \beta_{LK} \ln P_{Lt} + \beta_{KK} \ln P_{Kt} + \beta_{K\omega} \ln \omega_t \\
& + \beta_{Kk} \ln k_t + \beta_{K\Omega} \ln \Omega_t
\end{aligned} \tag{7}$$

Symmetry restrictions imply that $\beta_{12} = \beta_{21}$ and $\beta_{KL} = \beta_{LK}$. Homogeneity requires $\beta_L + \beta_K = 1$, $\beta_{KK} + \beta_{KL} = 0$, $\beta_{LL} + \beta_{LK} = 0$, $\beta_{1K} + \beta_{1L} = 0$, $\beta_{2K} + \beta_{2L} = 0$, $\beta_{L\omega} + \beta_{K\omega} = 0$, $\beta_{LK} + \beta_{Kk} = 0$, and $\beta_{K\Omega} + \beta_{L\Omega} = 0$. The measures of labour and capital embodied, and disembodied technical change, respectively, obtained from the cost function (Equation 5) are:

$$\begin{aligned}
g_\omega \dot{\omega}_t = {} & [\beta_\omega + \beta_{\omega\omega} \ln \omega_t + \beta_{1\omega} \ln Q_{1t} + \beta_{2\omega} \ln Q_{2t} + \beta_{L\omega} \ln P_{Lt} \\
& + \beta_{K\omega} \ln P_{Kt} + \beta_{k\omega} \ln k_t + \beta_{\Omega\omega} \ln \Omega_t] \dot{\omega}_t \\
g_k \dot{k}_t = {} & [\beta_k + \beta_{kk} \ln k_t + \beta_{1k} \ln Q_{1t} + \beta_{2k} \ln Q_{2t} + \beta_{Lk} \ln P_{Lt} \\
& + \beta_{Kk} \ln P_{Kt} + \beta_{\omega k} \ln \omega_t + \beta_{\Omega k} \ln \Omega_t] \dot{k}_t \\
g_\Omega \dot{\Omega}_t = {} & [\beta_\Omega + \beta_{\Omega\Omega} \ln \Omega_t + \beta_{1\Omega} \ln Q_{1t} + \beta_{2\Omega} \ln Q_{2t} \\
& + \beta_{L\Omega} \ln P_{Lt} + \beta_{K\Omega} \ln P_{Kt} + \beta_{\omega\Omega} \ln \omega_t + \beta_{k\Omega} \ln k_t] \dot{\Omega}_t
\end{aligned} \tag{8}$$

III. DATA AND VARIABLES

To estimate the translog cost function for the Australian telecommunications sector requires the calculation of capital stock series from investment data. The perpetual inventory method is used for this purpose. Aggregate capital stock is calculated by applying the rule:

$$K_{it} = \sum_{s=t-T}^{t} (1 - \delta_i)^{t-s} I_{is} = I_{it} + (1 - \delta_i) K_{i,t-1} \tag{9}$$

where K_{it} is the net capital stock of the ith equipment at time t, I_{is} is gross investment in the ith equipment in year s, δ_i is the rate of depreciation, T is the service life of the ith equipment and s is the age of the capital stock i.

While the perpetual inventory method provides a measure of the quantity of capital it does not accurately reflect its quality. Many capital inputs used by telecommunications carriers change through time. The productivity of a unit of new capital brought on line is usually greater than that of a unit of capital already in operation. Where there is a productivity differential a change in quality has occurred (Triplett, 1996). The average vintage of capital for a particular year is the weighted average of vintages of gross investment:

$$k_{it} = \sum_{s=t-T}^{t} \frac{(1 - \delta_i)^{t-s} I_{is}}{K_{it}} s \tag{10}$$

where the weights are the ratio of annually depreciated gross investment to the capital stock. Accordingly, k_{it} represents capital quality (average vintage) of equipment category i at time t. Thus, the age of the capital stock is a distribution of discrete incremental investments. To obtain the average vintage of aggregate capital stock the average vintage of capital stock categories are weighted by their capital expense shares and summed:

$$k_t = \sum_{i=1}^{n} c_{it} k_{it} \tag{11}$$

Table 1. *Summary statistics*

Variable		Mean	Std. dev.	Max	Min
Cost ($m)	C	31.7	34.6	132.1	1.9
Local calls (m)	Q_1	1964.1	2037.3	8074.7	220.6
Toll calls (m)	Q_2	219.2	330.6	1488.5	11.0
Labour price ($)	P_L	395.0	156.0	648.0	145.0
Capital price ($)	P_K	9.9	3.5	17.2	2.6
Labour quality	ω	1.1	0.2	1.4	0.7
Capital quality (m)	k	244.7	273.9	943.3	8.0
Capital share	S_K	0.5	0.1	0.6	0.2
Labour share	S_L	0.5	0.1	0.8	0.4

where c_{it} is the capital expenditure share of the ith equipment and n is the number of types of equipment.

Labour inputs can also vary in its quality in a manner which impacts on its productiveness. Here a quality index is calculated based on the average wage rate of occupational groups (senior management, management and workers). Differences in wage rates are assumed to reflect differences in labour quality. Types of labour input considered are the sum of working hours by occupational group and the weighted sum of working hours of occupational groups. Weights are the ratio of an occupational group's hourly earning to average wage in the private sector. The maintained hypothesis is that relative wage rates reflect differences in marginal product. The labour quality index is,

$$\omega = \frac{\sum \frac{\omega_j}{\omega_L} L_j}{\sum L_j} \tag{12}$$

where ω_i ($j = 1, 2, 3$) is the wage rate for the jth occupational group, L_j is the number of working hours for the jth occupational group and ω_L is the average wage rate in the economy.

Table 1 presents summary statistics of the variables. The inflation series used to deflate all dollar amounts (cost, labour price and capital price) is the Reserve Bank of Australia inflation series (1901 = 1000). Cost is the sum of annual total labour and capital expenditures reported in PMG Annual Profit and Loss statements. Local and toll calls are the numbers of calls made annually. The price of labour is calculated by dividing the real total labour cost by total staff numbers. Capital price is obtained by dividing the accumulated net capital stock by total mainlines. Capital and labour quality are calculated using the methods described above. The 4% rate applied to depreciate capital stocks is the average of the rates adopted by the PMG over the sample period. For the purpose of estimation all series are divided by their sample means.

IV. MODEL ESTIMATION

The translog cost function (Equation 5) and capital share (Equation 6) are estimated by Zeilner's (1962) seemingly unrelated regression equations (SURE) technique using annual data from 1919 to 1988 (Table 2). A Durbin-Watson statistic indicates autocorrelation is present among the residuals. Accordingly, the SURE estimation procedure

Table 2. *Restricted sure estimation results*

Variable	Parameter	t-ratio
Constant	0.92	1.66
Local	1.09	4.50
Toll	−0.10	−0.90
Local × Local	−3.29	−2.98
Toll × Toll	−1.62	−4.41
Local × Toll	5.34	9.15
Technology × Local	1.32	3.17
Technology × Toll	−1.95	−4.50
Technology	0.08	0.38
Technology × Technology	−0.78	−7.09
Local × Capital price	0.77	0.78
Toll × Capital price	0.05	1.03
Capital price	0.36	14.63
Capital price × Capital price	0.07	2.36
Capital price × Labour quality	0.25	1.72
Capital price × Capital quality	−0.14	−1.70
Technology × Capital price	0.05	0.12
Local × Labour quality	9.60	12.44
Toll × Labour quality	−1.51	−3.05
Labour quality	−2.48	−11.30
Labour quality × Labour quality	−1.44	−2.13
Labour quality × Capital quality	−6.80	−12.15
Technology × Labour quality	1.01	4.62
Local × Capital quality	−2.67	−3.60
Toll × Capital quality	−1.96	−4.71
Capital quality	−0.55	−3.18
Capital quality × Capital quality	2.74	3.87
Technology × Capital quality	1.51	5.86
	Cost function	Capital share
Adjusted R^2	0.99	0.74
Autocorrelation	0.18	0.51

is modified to follow the treatment developed by Park (1967). The cost function and the capital share equation are first estimated by ordinary least squares (OLS). OLS residuals are then used to obtain estimates of the autocorrelation coefficients for the cost function and the capital share equation. Data are transformed by the Prais-Winsten method to remove the autocorrelation. Using these transformed data, OLS is again used to estimate Σ. Feasible generalized least squares is then used based on the estimated Σ and the transformed data.

Twenty of the 28 estimated coefficients are significant at the 5% level. With the exception of Toll and Technology all first-order terms are significant. All the significant estimated coefficients have their expected signs. The second-order output coefficients are of plausible magnitudes. The coefficient on labour quality implies a percentage increase in capital quality results in a 0.5% downward shift in the cost function, while the coefficient on labour quality implies a 2.5% downward shift. The coefficient for the disembodied technology variable is effectively zero. The interactive terms Toll $\times$ Capital quality and Local $\times$ Capital quality both have negative coefficients indicating no apparent bias in technical change between local and toll calls. By contrast, the interaction terms Technology $\times$ Local, Technology $\times$ Toll, Toll $\times$ Labour quality and Local $\times$ Labour quality indicate a bias towards toll output cost diminution.

Finally, Table 3 compares the estimated input shares with the sample and sub-sample means. Whilst individual observations are sensitive to annual investment flows, the sub-samples indicate stable and distinct regimes.

V. PROPERNESS

When cost function estimation is undertaken the regularity conditions for a proper cost function need to be considered. Linear homogeneity in input prices and symmetry are imposed a priori, whilst continuity follows from the functional form. The marginal cost with respect to outputs are non-negative when:

$$\partial \ln C/\partial \ln Q_i = \beta_i + \beta_{ii} \ln Q_i + \beta_{ij} \ln Q_j + \Sigma_n \beta_{in} \ln P_n + \beta_{i\omega} \ln \omega + \beta_{ik} \ln k + \beta_{i\Omega} \ln \Omega \geq 0 \quad (13)$$

for all $i \neq j$ where $i, j = 1, 2$ and $n = K, L$. Substitution of the estimated coefficients into Equation 13 reveals that 35 of the 70 observations have positive marginal costs for local and toll output. Mean and final observation values are reported in Table 4.

Another requirement for the cost function to be proper is that the costs of production are non-decreasing in input prices, *viz*,

$$\partial \ln C/\partial \ln P_n = \beta_n + \beta_{nn} \ln P_n + \beta_{1n} \ln P_1 + \Sigma_i \beta_{in} \ln Q_i + \beta_{n\omega} \ln \omega + \beta_{nk} \ln k + \beta_{n\Omega} \ln \Omega \geq 0 \quad (14)$$

for all $1 \neq n$ where $1, n = K, L$ and $i = 1, 2$. Mean and final observation values are reported in Table 5. The final condition required for properness is that the cost function be concave in input prices.

Following Diewert and Wales (1987), the cost function is concave in input prices since the matrix:

$$\Gamma(q) \equiv \begin{bmatrix} \beta_{LL} - S^*_L(1 - S^*_L) & \beta_{LK} + S^*_L S^*_K \\ \beta_{KL} + S^*_K S^*_L & \beta_{KK} - S^*_K(1 - S^*_K) \end{bmatrix} \quad (15)$$

is negative definite (where * indicates the estimated cost shares). All 70 observation satisfy Equations 14 and 15. Mean and final observation values are reported in Table 6.

Table 4. *Marginal costs of output*

	Local calls	Toll calls
Average	0.10	0.67
Final observation (1988)	0.60	0.88

Table 5. *Cost function response to factor price changes*

	Capital price	Labour price
Average	0.63	0.37
Final observation (1988)	0.60	0.40

Table 6. *Cost function concavity*

	$\lvert H_1 \rvert$	$\lvert H_2 \rvert$
Average	−0.16	0.08
Final observation (1988)	−0.17	0.08

Table 3. *Input shares*

	Share estimates	Sample means	1919–1932	1933–1946	1947–1960	1961–1974	1975–1988
Capital	0.36	0.47	0.44	0.62	0.55	0.38	0.35
Labour	0.64	0.53	0.56	0.38	0.45	0.62	0.65

VI. ESTIMATES OF TECHNICAL CHANGE

Figures 1 and 2 show the paths of labour and capital embodied technical change, respectively, for the period 1919 to 1988. The growth rates of both labour and capital embodied technical change display considerable volatility. For labour quality the absolute magnitudes of the annual percentage changes appear relatively large for 1920 (95%), 1922 (60%), 1924 (110%) and 1931, 1965 and 1988 (60%). Casual inspection suggests that labour quality was mostly cost reducing from 1925 through 1931, cost increasing until 1952 and broadly cost reducing thereafter. By contrast, the magnitude of capital quality changes (Fig. 2), aside from the large initial spikes in 1923 and 1925,

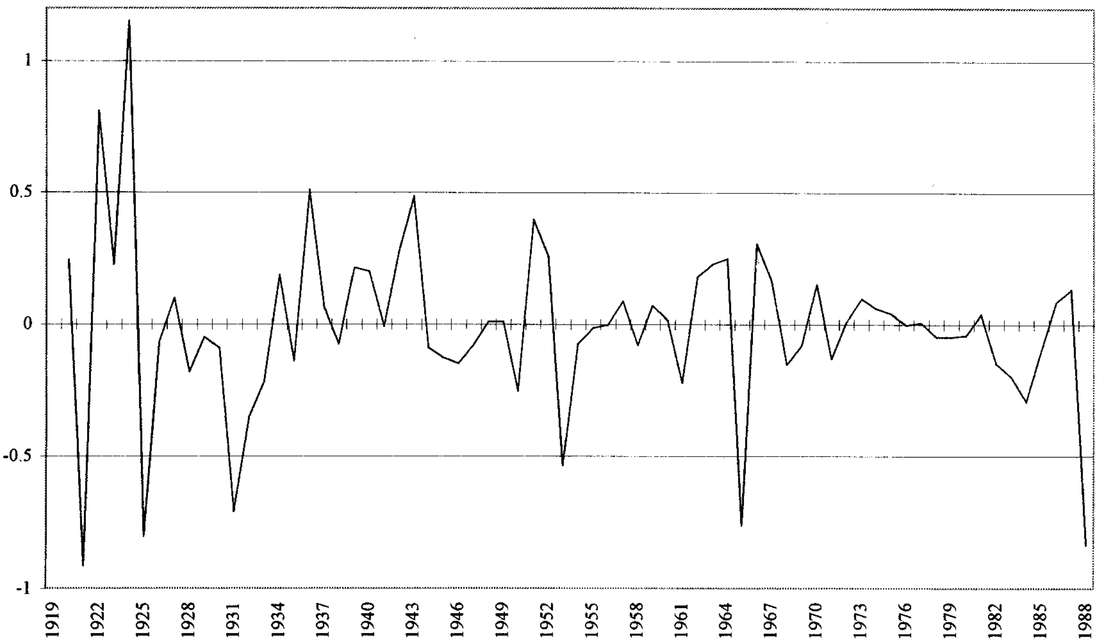

Fig. 1. *Labour augmenting technical progress*

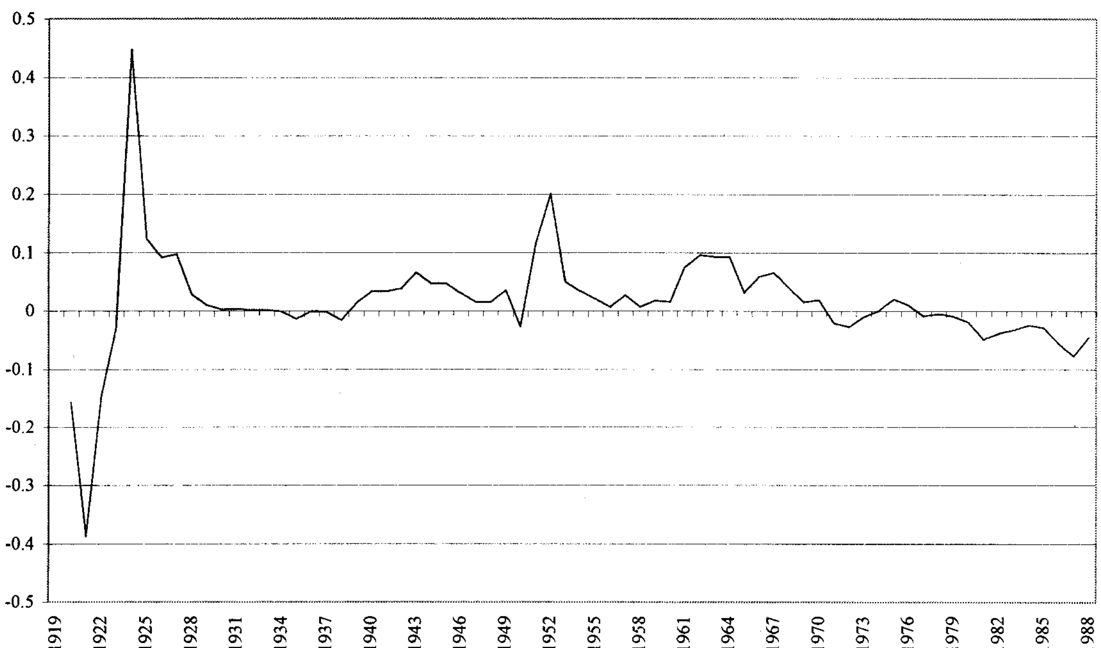

Fig. 2. *Capital augmenting technical change*

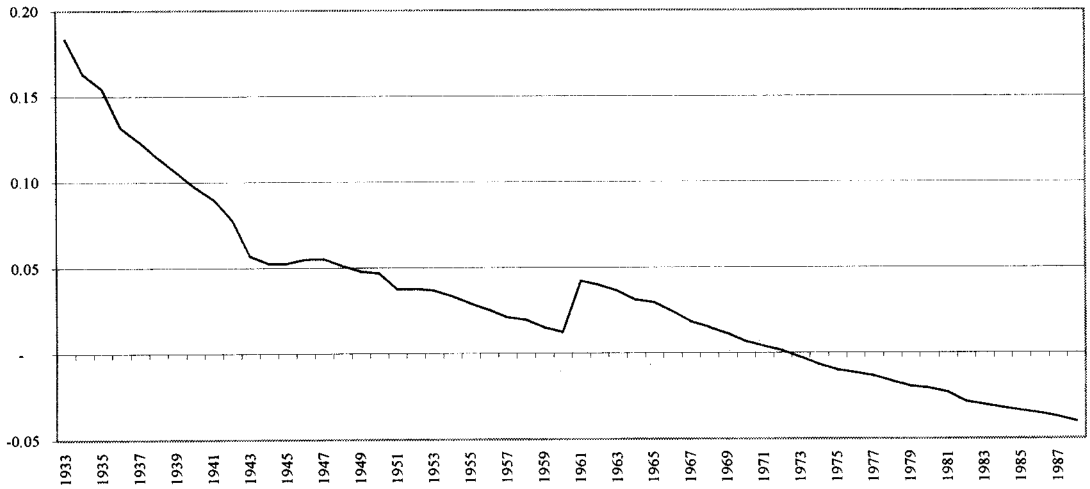

Fig. 3. *Disembodied technical change*

reveals a distinct downward trend. Changes in capital quality are cost reducing after 1975. This period corresponds with the separation of postal and telecommunications services. Figure 3 plots annual changes in disembodied technical change for the period 1933 to 1988. A downward drift is apparent with annual changes cost reducing from the early 1960s onwards.

Table 7 reports measures of cost diminution (both elasticity and shifts) for labour quality (labour embodied technical change), capital quality (capital embodied technical change), and technology (disembodied technical change). Observations are divided into five sub-periods. For capital embodied technical change, the early stages of network development (1919–1932) contributed to cost diminution of approximately −0.17%. This trend is reversed for the sub-periods 1933–1946 and 1947–1960. During the former period the rate of investment was sharply reduced to 25% of that for the 1919–1932 period. Sustained improvements in capital augmenting technical did not recur until the post-1975 period. The period coincides with the separation of postal and telecommunications services and the aggressive replacement of analogue technology with computer and the introduction of digital systems. Labour embodied technical change is cost reducing for all but the 1975–1988 sub-period. This period is coincides with the Accord. The Accord was a scheme administered by the Federal government to limit wage rises, it had the effect of compressing wage relativities. Disembodied technical change is cost diminishing only for the period 1975–1988. Telecommunications and postal services were provided by a mandated monopoly for the entire period 1919–1974. The latter period coincided with the separation of postal and telecommunications services, and a move towards corporatization.

VI. CONCLUSIONS

The Australian telecommunications sector has been continuously improved and extended through investment in technology. New technology can increase the efficiency of the factors of production. Such efficiency increases can be biased towards a particular factor. This study examines the Australian telecommunications cost structure for the period 1919 through 1988. A translog cost model is estimated. The estimated cost function is statistically well specified. Estimation results concerning cost diminution in the Australian telecommunications industry and its embodied

Table 7. *Measures of technical change*

Source		1919–1932	1933–1946	1947–1960	1961–1974	1975–1988
Labour embodied	Elasticity	−3.79	−2.62	−2.06	−4.74	3.86
	Shift	−0.05	0.08	−0.01	0.01	−0.10
Capital embodied	Elasticity	−0.17	0.67	0.44	0.54	−0.63
	Shift	0.01	0.02	0.04	0.04	−0.03
Disembodied	Elasticity	3.51	2.15	1.16	0.81	−1.68
	Shift	0.71	0.11	0.03	0.02	−0.03
Total shift		0.67	0.21	0.06	0.07	−0.16

and disembodied sources are complex. Labour quality improvements are the dominant source of increased efficiency in the period 1919–1974 while capital quality and disembodied change impact in the 1975–1988 period. The inability of improvements in capital, presumed to be embodied in new equipment, to contribute to increased efficiency until well into the 1970s is in large part due to the age distribution of the capital stock. Substantial early network investment resulted in cost diminution, a slowing of this investment led to a cessation in cost improvements. It should be noted that these conclusions could change significantly if the rate of depreciation used to construct the capital stock series is substantially altered. In particular, the notion of wear and tear employed here is one of accounting depreciation and it may be that such a measure is a poor proxy for the economic obsolescence of telecommunications equipment. The next step in this research programme is to use the measures of labour and capital embodied technical change to infer the optimal age of retirement for capital. This calculation will allow the rates of obsolescence of telecommunications capital to be inferred. These data will form the basis of comparisons with actual accounting rates of depreciation employed in network planning.

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