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ASIA-PACIFIC TELECOMMUNICATIONS LIBERALISATION AND PRODUCTIVITY PERFORMANCE

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This study examines the growth in total factor productivity (TFP) of 12 Asia-Pacific telecommunications carriers for the period 1987 through 1990. Carriers are chosen to represent the stages of telecommunications liberalisation identified by the International Telecommunication Union (1995a). A model relating TFP growth to output growth, changes in output mix, technology change and market competition and private ownership is estimated on a unique data set obtained from telecommunications carrier annual reports. Empirical results show competition, private ownership, technology change and scale economies improve carrier TFP growth.

I. Introduction

In an emerging global economy, characterised by greater trade liberalisation and increasing information needs, the telecommunications sector provides a basis for competitive advantage. The efficient delivery of telecommunication services generates direct benefits through lower input costs and indirect benefits due to accelerated information diffusion. Until recently, most Asia-Pacific telecommunications services have been provided by public monopoly. Mandated supply was typically justified by natural monopoly arguments and often tied to an obligation to provide universal service. This obligation was commonly interpreted as the promise to supply basic telephony to customers even if not economically viable to do so.[1] In an environment of rapid technology change, recent public utility reform has recognised both competition and privatisation are better able to provide benefits such as operating efficiency and lower prices (Megginson *et al.* 1994, Ramamurti 1996, Boyland and Nicoletti 2000). Accordingly, the opening of telecommunication markets to entry and transfer of telecommunications infrastructure from public to private ownership became important policy objectives from the mid-1980s.

Several papers use within-country data to study the relationship between telecommunications sector market structure and productivity. Kwoka (1993) finds economies of scale an important

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[1] By providing access to users who otherwise could not afford services, universal service obligations (USOs) may increase network value to existing subscribers through a network externality. In this case, the economic viability of providing service needs to be evaluated on a system-wide basis.

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source of productivity growth in United States (US) and United Kingdom (UK) international PSTS markets. Further, the introduction of competition in the US market and the privatisation of British Telecom are responsible for efficiency gains. Oum and Zhang (1995) investigate the behaviour of rate-of-return regulated domestic telecommunication carriers in the US following the 1984 introduction of competition. They suggest competition improves incumbent telecommunications carrier allocative efficiency. Gort and Sung (1999) also consider the effect of competition on the efficiency of the US domestic telephone industry. They find efficiency is improved faster in competitive markets and telephone company production exhibits constant returns to scale. Gort and Sung also show that technology change, measured by change in the capital vintage, contributes to productivity growth and cost reduction.

Received cross-county analysis shows competition and private ownership impact on carrier performance. Using a panel of 10 OECD Member Country international carriers from 1984 to 1987, Staranczak *et al.* (1994) relate TFP growth to output growth, technology change (share of mainlines served by digital central offices), competition, private ownership and output mix (ratio of main lines to telecommunications output to capture any cross-subsidisation of local by long-distance call prices). Results indicate output growth and privatisation are positively associated TFP growth, whilst output-mix is inversely related.[2] Ros (1999) estimates the effect of privatisation and competition on telecommunications efficiency for 74 countries from 1986 to 1995, and shows that privatisation and competition are positively associated with efficiency. Boyland and Nicoletti (2000) investigate the effects of entry liberalisation and privatisation on productivity, prices and quality of service in long-distance and mobile cellular telephony services in 23 OECD countries from 1991 to 1997. Controlling for technology and market structure model estimates show prospective and effective competition improve productivity. Madden and Savage (2001), employ a Malmquist index to calculate telecommunications TFP growth for 74 countries for 1991 through 1995. They estimate a model relating TFP growth to output growth, network digitisation, telecommunications development, output mix, business cycle and market structure. Model estimates show developing countries may increase their TFP growth through technology catch-up, and privatisation and competition are conducive to telecommunications productivity growth.

The Asia-Pacific region experienced rapid growth through the 1980s and 1990s in network expansion and traffic flows. Average annual growth in main telephone lines from 1984 through 1994 of 7.8%, compares well to the 3.3% per annum (p.a.) of OECD Member Countries (ITU 1995a). Low-income Asia-Pacific countries, such as Indonesia and Thailand, have made substantial infrastructure investment sustaining growth rates in main lines of 15% p.a. for the period. The growth of intra–Asia-Pacific PSTS capacity and traffic suggest telecommunications is important to regional business expansion and trade links. In particular, between 1992 and 1994, international telephone circuits increased 64% in China, 69% in Thailand and 52% in Singapore.[3] Further, outgoing Australia–Asia-Pacific telephone traffic increased from 131.6 million minutes in 1987 to 274.4 million minutes in 1992 (an average increase of 16% p.a.), and Thailand–Asia-Pacific traffic increased from 22.8 to 104.2 million minutes (an average increase of 36% p.a.).

Asia-Pacific telecommunication market structure varies from state-owned monopoly to unregulated competition. The ITU (1995a) describe Asia-Pacific telecommunications liberalisation

[2] Staranczak *et al.* (1994) suggest the impact of technology change can be neutral as productivity gains are offset in the short term by capital expenditure required for digitisation.
[3] International telephone circuits refer to the number of links (voice channel equivalents) with other countries for establishing telephone communications.

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in three stages. Stage One began in the mid-1980s and was led by the more developed regional economies. The 1984 divestre of AT&T in the US marks the beginning. Japan followed soon after with part privatisation of the state-owned carrier, Nippon Telegraph and Telephone Corporation (NTT), and introducing competition into long-distance markets in 1985. The Second Wave commenced in ASEAN countries from the early-1990s with the partial privatisation of Indonesian state-owned long-distance carrier PT Indosat, Korea Telecom, Singapore Telecom and Telecom Malaysia. More recently, Stage Three began in the less developed regional countries of PR China, India, Pakistan and Vietnam. For example, in 1993, the regulatory and operating arms of the Chinese Ministry of Posts were separated and China UNICOM contracted to build a competitor long-distance telephone network (ITU 1995a, Ure 1996). There is also increased competition in the early-liberalised exchange and cellular markets. For instance, both Hong Kong and Australia have moved toward open competition in domestic fixed-line telephone service, while Australia, Korea (Rep.), New Zealand and the US have issued additional cellular licenses.[4]

This study examines TFP growth in 12 Asia-Pacific telecommunication carriers during 1987 to 1990. Carriers are chosen to represent particular stages of telecommunications liberalisation as identified by the ITU (1995a). An econometric model is developed from neoclassical production theory to relate TFP growth to output growth, technology change, output mix, and competition and ownership (public or private). Model estimates are used to see whether market structure is associated with productivity increase during Stage One of Asia-Pacific telecommunications liberalisation. By examining Stage One liberalisation, empirical findings can provide a basis to suggest the extent of potential benefits from pursuing regional deregulation in telecommunications and public utility markets.

The paper is organised as follows. Section II describes the structure of Asia-Pacific telecommunications markets and provides an overview of their performance. In Section III an econometric model is derived to explain TFP growth by its determinants. Estimation results are reported and discussed in Section IV, while conclusions are provided in Section V.

II. Asia-Pacific Telecommunication Market Indicators

Table I lists dominant national telecommunications carrier characteristics for 12 Asia-Pacific countries. Data are obtained from the ITU (1995a, 1995b) and carrier annual reports. All countries are APEC Members, while Australia, Canada, Japan, New Zealand and the US are also OECD Member Countries. Country carriers are sole or dominant providers of local exchange and long-distance services. Market structure is described by carrier ownership and market competition. A market is described competitive when more than a single carrier is authorised to operate in the domestic local exchange and long-distance public switched telephone market. Four sampled countries allow competition during 1987 through 1990, viz., Japan, Korea (Rep.), New Zealand and the US. Ownership is classified 100% public, 100% private or partial private ownership. At 1990, five carriers are public, five private and two partial private in ownership. Two of four carriers operating in competitive markets, NZ Telecom and AT&T, are 100% privately owned.

[4] A telecommunications trade liberalisation agreement reached at the WTO in February 1997 sees traditional monopoly and closed markets replaced by markets open to foreign ownership, competition and privatisation.

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Table I Asia-Pacific telecommunication carriers at 1990

Country and Dominant Carrier	*Competition*	*Ownership*	*Main Lines (000s)*	*Teledensity (%)*	*Digitisation (%)*
Australia Telecom Australia	No	Public	7,787	46	20
Canada Bell Canada	No	Private	15,296	51	57
Hong Kong HK Telecom	No	Private	2,305	48	60
Japan NTT	Yes (1985)	Partial (35%)	52,000	40	33
Korea (Rep.) Korea Telecom Authority (KTA)	Yes (1990)	Public	15,293	31	19
Malaysia Telekom Malaysia (TM)	No	Partial (25%)	1,817	10	78
New Zealand NZ Telecom	Yes (1990)	Private	1,473	43	92
Philippines Philippines Long Distance Telephone Company (PLDT)	No	Private	1,047	2	4
Singapore Singapore Telecom	No	Public	982	38	49
Taiwan Directorate General of Telecommunications (DGT)	No	Public	7,874	40	2
Thailand Telephone Organisation of Thailand (TOT)	No	Public	1,325	2	57
United States AT&T	Yes (1984)	Private	100,062	54	47

Note: Parentheses in the competition column show when competition was introduced. Parentheses in the ownership column show the private ownership share.
Source: ITU (1995a, 1995b), Carrier annual reports and FCC (1987–1990).

Main telephone lines provide a measure of telecommunications infrastructure investment and network size. Sample data show main lines range from just below one million for Singapore Telecom to 15 million for KTA. ITU (1995a) data indicate clear disparities between rural and urban telecommunications infrastructure investment. 71% of the developing Asia-Pacific national populations reside in rural areas but only 17% of telephone networks cover these areas. Teledensity (main lines per 100 persons) is an ITU preferred measure of network roll out and range from 2 (TOT and PLDT) to 54 (AT&T). NTT's teledensity is 40 but still lags behind that of HK Telecom, the largest carrier of the Dragon economies, Hong Kong, Korea (Rep.), Singapore and Taiwan.[5] Based on current growth rates, teledensity among high-income Dragon carriers is projected to surpass that of Asia-Pacific OECD Member Country carriers by the early-21st century (ITU 1995a). While OECD countries have taken from 10 to 15 years to achieve teledensity of 10 to 30, Dragon carriers have attained this penetration in 6 to 10 years. Carriers from Thailand and Malaysia are set to achieve this penetration more quickly.

[5] The high level of teledensity in Hong Kong is due to its population density.

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Table II TFP growth 1987 to 1990

Carrier	*1987*	*1988*	*1989*	*1990*	*Mean*	*Std. Dev.*
Telecom Australia	2.14	−0.98	−0.02	7.69	2.21	3.88
Bell Canada	1.62	3.24	2.81	2.08	2.44	0.73
HK Telecom	5.50	8.49	3.46	4.40	5.46	2.18
NTT	−0.63	−0.38	3.18	2.39	1.14	1.93
KTA	1.91	−1.89	1.74	1.83	0.90	1.86
TM	0.78	5.60	−4.11	−2.86	−0.15	4.36
NZ Telecom	−3.34	−0.72	−0.07	0.99	−0.79	1.84
PLDT	4.27	−0.97	0.06	6.12	2.37	3.37
Singapore Telecom	1.12	3.33	−0.54	−1.47	0.61	2.11
DGT	1.20	1.00	0.69	2.58	1.37	0.84
TOT	6.23	4.54	7.42	10.29	7.12	2.42
AT&T	−1.29	−7.11	−8.78	5.82	−2.84	6.61
Mean	1.63	1.18	0.49	3.32	1.65	–
Std. Dev.	2.75	4.12	4.04	3.75	2.65	–
Mean (excl. OECD)	3.00	2.87	1.25	2.98	2.53	–

Digitisation refers to the number of main lines connected to digital switches and provides an indicator of network sophistication. Switches connect telephone subscribers by selecting paths (circuits) through the network. Digital switching lower costs, increase transmission speed and quality, and allow transmission of a greater range of voice grade and data services than analogue systems. The shift to digital technology facilitates the development of network capacity and improves the quality and efficiency of service provision. In Hong Kong and Malaysia exchange line digitisation is over 60%, while in Australia, despite the high level of teledensity, only 20% of local lines are digitised. In 1990, New Zealand has the highest level of local digitisation (92%), with Wellington among first cities globally to be completely digitised.

Table II reports TFP growth summary statistics for 1987 through 1990. TFP estimates are calculated by using the Tornqvist approximation of the Divisia index to aggregate outputs and inputs.[6] Average TFP growth for sampled carriers is 1.65% p.a. When OECD Member carriers are excluded this average rises to 2.53%. TOT achieved above the average TFP growth (7.12%), while TM, NZ Telecom and AT&T registered negative average growth for the period. The productivity decline for AT&T was greatest from 1988 through 1990. This outcome reflects substantial costs incurred in converting existing long-distance network to full digitisation. All carriers with the exception of Bell Canada, Hong Kong Telecom, DGT and TOT experienced at least a year of negative TFP growth.

III. Econometric Model and Data

Recent empirical work on telecommunications TFP is based on Fuss and Waverman (1977). They describe carrier production technology by a cost function

$$C = f(q_l, q_d, q_{int}, w_l, w_m, w_k, t), \tag{1}$$

where C is the total cost of production, q_l is local exchange output, q_d is long-distance output, q_{int} is international output, w_l, w_m, w_k are input price for labour, material and capital, respectively.

[6] Calculations, data source and transformations are provided in the Appendix.

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t is a time trend to proxy improvement in technology. Totally differentiating (1) with respect to time for outputs q_j and input prices w_i and t, respectively, gives

$$\frac{dC}{dt} = \sum_j \frac{\partial C}{\partial q_j}\frac{dq_j}{dt} + \sum_i \frac{\partial C}{\partial w_i}\frac{dw_i}{dt} + \frac{\partial C}{\partial t}. \tag{2}$$

Dividing (2) by C and applying Shephard's lemma provides

$$\frac{1}{C}\frac{dC}{dt} = \sum_j \frac{1}{C}\frac{\partial C}{\partial q_j}\frac{dq_j}{dt} + \sum_i \frac{1}{C}x_i\frac{dw_i}{dt} + \frac{1}{C}\frac{\partial C}{\partial t}, \tag{3}$$

where $x_i = \frac{\partial C}{\partial w_i}$ is the derived carrier demand for input i. Substitution of $\dot{C} = \frac{1}{C}\frac{dC}{dt}$, $\varepsilon_{CQ_j} = \frac{q_j}{C}\frac{\partial C}{\partial q_j}$, $\dot{Q}_j = \frac{dq_j}{dt}\frac{1}{q_j}$, $\dot{w}_i = \frac{dw_i}{dt}\frac{1}{w_i}$ and $\dot{T} = \frac{1}{C}\frac{\partial C}{\partial t}$ into (3) and rearranging gives

$$\dot{T} = \dot{C} - \sum_j \varepsilon_{CQ_j}\dot{Q}_j - \sum_i \frac{w_i x_i}{C}\dot{w}_i, \tag{4}$$

that shows the proportionate shift in the cost function equals the change in costs, less the sum of cost elasticity (equal to the reciprocal scale elasticity) weighted j output changes, less the sum of weighted input price changes.

Totally differentiating the cost, $C = \sum_i w_i x_i$, with respect to time and substituting into (4) gives an expression for technological change

$$\dot{T} = -\sum_j \varepsilon_{CQ_j}\dot{Q}_j + \sum_i \frac{w_i x_i}{C}\dot{x}_i. \tag{5}$$

Since the Divisia index for aggregate input Z is $\dot{Z} = \sum_i \frac{w_i x_i}{C}\dot{x}_i$, and $T\dot{F}P = \dot{Q} - \dot{Z}$, (5) is rearranged as

$$T\dot{F}P = \sum_j (1 - \varepsilon_{CQ})\dot{Q} - \dot{T}. \tag{6}$$

Equation (6) decomposes TFP growth into scale economies ($\dot{Q}$) and technology change ($\dot{T}$). When no economies of scale are present $\sum \varepsilon_{CQ} = 1$ and TFP growth is solely attributable to the effects of technological change, measured by shifts in the cost function through time. To make the model suitable for estimation an intercept and error term are added to (6) such that

$$T\dot{F}P_{it} = \alpha_0 + \alpha_1\dot{Q} + \alpha_2\dot{T}_{it} + u_{it} \tag{7}$$

for all $i = 1, \ldots, n$ and $t = 1, \ldots, T$. The α's are parameters to be estimated, $\alpha_1 = \sum_j (1 - \varepsilon_{CQ})$ and u_{it} is an error term. Equation (7) is further augmented to allow TFP growth to vary with independent country factors, such as output mix (*MIX*), competition (*COMP*) and privatisation (*PRIV*), and the initial level of TFP at 1986 (*PROD86*), viz.,

$$T\dot{F}P_{it} = \delta_0 + \delta_1\dot{Q}_{it} + \delta_2\dot{T}_{it} + \delta_3 MIX_{it} + \delta_4 COMP_{it} + \delta_5 PRIV_{it} + e_{it} \tag{8}$$

where the δ's are parameters to be estimated and e_{it} is a white noise error term.

Output growth $\dot{Q}$ is defined as the log difference of aggregate telecommunications output, where total telecommunications output is measured by minutes of local exchange, long-distance and outgoing international traffic. Whilst, the telecommunications sector is characterised by relatively high capital intensity, recent empirical analyses do not demonstrate conclusively that scale economies exist (Productivity Commission 1997). Since δ_1 is one minus the respective

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cost elasticities, $0 < \delta_1 < 1$ imply economies of scale. Technology change $\dot{T}$ is the log change of the telecommunications technology index and the proxy for technology change is based on a network-switching indicator of most recent vintage. Following Oum and Zhang (1995), the index is defined annually as the log of one plus the percentage of main lines served by digital switches. δ_2 is expected positive and so imply increased productivity growth.

Telecommunications pricing by state-owned (or regulated) carriers typically focuses on achieving USOs rather than efficient pricing. A cost premium is often charged for long-distance and IMTS services, whilst local-exchange services are charged below cost. Denny *et al.* (1981) show that such cross-subsidisation can influence the measurement of productivity change. In particular, higher growth rates for subsidised services relative to total service can lead to cost inefficiency and lower productivity gains. Output mix (*MIX*), the log change in domestic output divided by the log change in aggregate output, captures cross-country output mix differences and accounts for cross-subsidisation effects (log per cent change in national mainlines is a proxy for local call output growth). δ_3 is expected negative.

COMP, *PRIV*, and (*COMP* × *PRIV*) are intended to isolate market structure impacts on carrier productivity. *COMP* is a dummy variable that equals one when there is more than a sole authorised carrier operating in local-exchange and long-distance PSTS markets at *t*, and zero otherwise. Competing hypotheses about the relationship between competition and productivity growth suggest no *a priori* sign expectation for δ_4.[7] Received empirical evidence, however, reveal a positive relationship between telecommunication productivity growth and competition (Kwoka 1993, Oum and Zhang 1995, Gort and Sung 1999, Ros 1999, Boyland and Nicoletti 2000, Madden and Savage 2001). Following Madden and Savage (2000, 2001), *PRIV* is a privatisation index defined by one plus the private ownership share of the dominant carrier. To the extent that private sector ownership provides an incentive for more efficient production, innovation and improved customer service a positive sign for δ_5 is expected (Kwoka 1993, Megginson *et al.* 1994, Wellenius and Stern 1994, Staranczak *et al.* 1994, Ramamurti 1996, Ros 1999, Madden and Savage 2001).[8] The interaction term COMP×PRIV is included to isolate the joint impact of competition and privatisation on TFP growth. δ_6 has no expected sign.[9] The initial level of telecommunications productivity (*PROD86*) is included as an explanatory variable in (8) to allow investigation of convergence in Asia-Pacific telecommunications. TFP growth is calculated by using the Divisia index to aggregate outputs and inputs, with capital expense residually derived from total revenue and costs. Whilst this approach overcomes data limitations, it calculates TFP growth by implicitly normalising TFP levels around a common base year (1987) for all countries. Hence, it is not possible to directly calculate initial TFP levels in

[7] Schumpeter (1942) argues monopoly power (or market concentration) and large firm size drive technology advance and productivity growth. By contrast, perfect competition suggests firms must exhibit cost-minimising behaviour and instantly respond to technical advance to survive. Further, North (1990), Levy and Spiller (1996) and Ros (1999) argue competition does not allow pursuit of objectives other than profit-maximisation. Competition also enables price and profit to signal information about enterprise costs and efficiency. Such information assist principals in determining input levels needed to compete effectively.

[8] Ownership may also affect firm behaviour through incentive structures (North 1990, Levy and Spiller 1996, Ros 1999). Privatisation implicitly assumes the switch from public to private ownership leads to more precise objectives and creates an improved monitoring of management. With public ownership non-commercial objectives are pursued and less effort is employed in the pursuit of efficiently (Ramamurti 1996). By contrast, the objective of private ownership is to achieve a higher level of management supervision and more commercial and timely financial decisions.

[9] The degree and timing of regulatory change is probably influenced by lagged industry performance, however, as the time from an initial government decision and to subsequent market structure changes is reasonably long it is unlikely to affect the exogeneity of COMP and PRIV to TFP growth for the short time series employed in this study (see Boyland and Nicoletti 2000, Kridel *et al.* 1996).

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Table III Summary statistics 1987 to 1990

Variable		*Mean*	*St. Dev.*	*TFP Growth Correlations*
TFP growth	$\dot{TFP}$	0.016	0.037	1.000
Output growth	$\dot{Q}$	0.090	0.067	0.187
Digitisation	$\dot{T}$	0.066	0.083	0.215
Output mix	MIX	−0.269	4.974	0.069
Privatisation	PRIV	1.387	0.469	0.012
Competition	COMP	0.250	0.438	−0.255
Interaction	PRIV×COMP	0.124	0.250	−0.290
Initial teledensity 1986	PROD86	28.008	17.051	−0.276

1986 in an absolute sense. However, recent evidence suggests possibilities for technological catch-up and substantial productivity growth in developing economies with low teledensity levels (Melody 1997, Intven and Tetrault 2000, Madden and Savage 2001). Accordingly, the level of teledensity at 1986 represents a suitable proxy for *PROD86*. By analogy with standard growth models, *PROD86* is expected to enter (8) with a negative sign ($\delta_7 < 0$), implying convergence. Annual data for 12 Asia-Pacific telecommunication carriers for 1987 through 1990 are used to construct variables to estimate (8). Means, standard deviations and correlations of variables contained in (8) are reported in Table III.

IV. Empirical Results

A fixed-effect model with country intercepts is used to estimate (8) on panel data described in Table III. The model is also estimated on sub-sets of these data. In particular, the sample excluding Hong Kong and the sample excluding Canada and the US.[10] Generalised least squares (GLS) estimates, with appropriate corrections for group-wise heteroskedasticity and within group first-order autocorrelation, are presented in Table IV. All regression equations are well specified and report Buse R^2's of 0.56 to 0.68. Model results appear robust across regressions model parameter estimates qualitatively similar.

The coefficient for $\dot{Q}$ is positive (implying $\varepsilon_{CQ} < 1$). For the full sample, a per cent increase in output leads to 0.086% increase in TFP, indicating increasing returns (or declining unit costs) exist for this sample of Asia-Pacific carriers. $\dot{T}$ has an estimated positive coefficient in (i) and (iii). This finding suggests Asia-Pacific carriers can achieve immediate productivity benefits from their investment in digital technology. Estimated coefficients for *PRIV* and *COMP* are positive and suggest privatisation and competition have contributed to productivity growth in Stage One of Asia-Pacific liberalisation. Privatisation appears to have the stronger impact across regressions. This is not surprising as private ownership may, in the short run, impose a stricter operational discipline on telecommunications carrier management than the introduction of competition (Ramamurti 1996). It is worth noting that several received studies of the impact of telecommunications market performance and structure fail to identify a relationship between competition and productivity. In particular, Staranczak *et al.* (1994) argues that their sample period is too short to capture the dynamic gains of competition. Here it is suggested that carrier

[10] Hong Kong is a somewhat atypical jurisdiction as it was controlled by the UK during the sample period, and its carrier HK Telecom has always been privately owned. Both the US and Canada are also atypical due to their geographic location, *viz-a-viz*, the rest of the sample and their private ownership structure.

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Table IV TFP equation estimation results

Dependent Variable: TFP Growth	$\dot{TFP}$	*(i) Full Sample*	*(ii) Sub Sample with Hong Kong Omitted*	*(iii) Sub Sample with Canada and the US Omitted*
Output growth	$\dot{Q}$	0.0859[a]	0.0674[b]	0.0969[a]
		(2.629)	(1.788)	(2.501)
Digitisation	$\dot{T}$	0.0760[b]	0.0606	0.0724[b]
		(1.821)	(1.404)	(1.771)
Output mix	MIX	0.0006	0.0006	0.0011
		(0.486)	(0.596)	(0.902)
Privatisation	PRIV	0.0356[a]	0.0318[a]	0.0350[a]
		(4.449)	(3.415)	(2.907)
Competition	COMP	0.0767[a]	0.0682[b]	0.0759[b]
		(2.059)	(1.773)	(1.725)
Interaction	PRIV×COMP	−0.0596	−0.0531	−0.0587
		(−2.339)[a]	(−2.003)[a]	(−1.932)[a]
Initial teledensity 1986	PROD86	−0.0008[a]	−0.0008[a]	−0.0009[a]
		(−2.852)	(−2.548)	(−2.198)
Constant		−0.0151[b]	−0.0103	−0.013
		(−1.902)	(−1.034)	(−0.783)
N×T		48	44	40
Buse R^2		0.68	0.57	0.56
F		2.98[a]	2.47[a]	2.52[a]

Note: [a]denotes significant at the 5% level; [b]denotes significant at the 10% level; asymptotic t-ratio in parentheses; the F-test statistic examines the hypothesis $\delta_4 + \delta_5 + \delta_6 = 0$.

TFP performance is better in Asia-Pacific markets that have moved away from monopoly supply. While the sign of the interaction variable is negative, an F-test indicates the combined impact of competition and privatisation is different from zero in (i) through (iii). This implies that privatisation or competition, and both privatisation and competition together, improve TFP. Finally, $\delta_7 < 0$ indicates convergence of TFP levels through time. That is, low telecommunications productivity countries can improve their productivity growth through technological catch-up.

V. Conclusions

This study examines TFP growth for 12 Asia-Pacific telecommunications carriers during Stage One regional liberalisation. Empirical results show a relationship between telecommunications output and TFP growth. An important component of output growth is international telephone traffic, which increased 20% annually since the mid-1980s. Such traffic flows are influenced by trade and inter-regional investment. The positive relationship between technology change and TFP growth bodes well for carriers and consumers during the Second Stage and Third Stage of liberalisation. In particular, investment in digital technology has produced productivity gains that will ultimately flow through to lower call prices and improved service quality. Finally, the positive effect of private ownership and competition on TFP growth across regressions lends support to the ongoing reform of Asia-Pacific telecommunications markets. The positive relationship between competition and TFP growth is encouraging since the introduction of competition is often accompanied by regulation limiting carrier behaviour. Such restrictions are usually politically motivated and intended to preserve cross subsidy contained within rate structures (Ramamurti 1996).

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Appendix: Data Sources and TFP Calculation

Telecommunications carrier data are for sole or dominant providers for sampled APEC Member Country carriers. Carrier data used in TFP calculations are drawn from carrier annual reports. Reports are obtained via direct correspondence. As annual reports could not be obtained for the dominant carriers of Indonesia and PR China they are not included. Further, Brunei, Chile, Mexico and Papua New Guinea carrier data are not included in the sample as their nations are not APEC Member Countries in the sample period. In calculating TFP consistent across countries is difficult due to alternative cost definitions and accounting standards used by carriers. For example, sometimes company information is reported while for others information is provided in consolidated form. Company information is used where possible. Consolidated reports are relied on for Telecom Australia, Telecom New Zealand, Hong Kong Telecom and NTT. TFP calculations are based on either carrier output or input data depending on the format of annual reports. Further, financial information detailed in the annual reports is occasionally disaggregated, however, such data are often reported in an irregular manner.

(i) Output data

Total operating revenue (TOR) does not include interest income, disposals, capital gains/losses and dividends, and is typically comprised of international and domestic traffic revenue, leased circuit and data communication facility and sales of terminal equipment. In some countries postal service revenue is also included as a component of TOR.

Output price is used to deflate TOR into constant currency. Output price is based on national telecommunications price indexes (TPI) for a service basket (1987 = 100) where available. TPI data are available for Australia, Japan, Taiwan and the US. For the remainder domestic consumer price index (CPI) data are employed (World Bank 1994).

Output is revenue deflated by TPI or CPI.

(ii) Input data

Labour and material expense includes salary and wages, pension and benefit payments, labour-related taxes, services obtained from outside suppliers, materials, cost of installation and maintenance of customer services, and rent of premises.

Labour and material price is used to deflate combined labour and material expense. CPI data are used as carrier price deflators for labour and materials are not available (1987 = 100).

Labour and materials are CPI deflated combined labour and material expense.

Capital expense is the difference between TOR and combined labour and material expense. This treatment assumes total revenue equals cost, and revenue not spent on labour and materials is expended on capital purchases. Here capital expense includes interest, depreciation, income taxes and takes into consideration plant under construction.

Capital price is used to deflate capital expense. The average net book value of property, plant and equipment is calculated to obtain a capital investment trend. An index is constructed based on this trend with respect to the base year (1987 = 100).

Capital is the capital expense deflated by capital price.

(iii) TFP calculations

TFP growth is calculated by using the Tornqvist approximation to the Divisia index to aggregate outputs and inputs. The time change in TFP is

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$$T\dot{F}P = \ln \dot{Q} - \ln \dot{Z} \tag{A1}$$

where Q is aggregate output, Z is aggregate input, and the dot represents growth rates. The change in aggregate output and aggregate input, respectively, are

$$\dot{Q} = \exp\left(\sum 1/2(r_{it} + r_{it-1}) \ln \dot{q}_j\right) \tag{A2}$$

and

$$\dot{Z} = \exp\left(\sum 1/2(s_{it} + s_{it-1}) \ln \dot{z}_i\right) \tag{A3}$$

where r_{jt} is the revenue share of output j at time t and s_{it} is the expense share of input i at time t.

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