CHAPTER 6

EMPIRICAL FINDINGS

This chapter reports the research findings based on the techniques outlined in chapter four. The first section analyzes the trend of input and output growth for Malaysian mobile telecommunications industry. Next, comparative analysis of technical efficiency and total factor productivity growth of the five mobile operators are presented along with the productivity performance for the overall industry.

6.1 GROWTH OF OUTPUT AND INPUTS

The findings begin with a summary of average annual growth rates of output, capital and labor.

Table 6.1: Average Annual Growth of Output and Inputs by Operators, 1996-2001 (%)

Operator	Output (%)	Input (%)	
	No. of subscribers	No. of labor	Total no. of capital
Maxis	77.24	11.18	49.25
Celcom	97.92	3.99	20.04
TM Cellular	185.79	35.44	52.89
DiGi	68.59	16.26	19.58
TimeCel	69.81	8.85	17.44
Mean	99.87	15.14	31.84

As seen in Table 6.1, growth in total subscribers averaged 99.87 percent per year over the entire 1996 to 2001 sample periods. TM Cellular had the highest average annual growth in total subscribers (185.79 percent) and DiGi had the lowest (68.59 percent). Moreover, TM Cellular also had the highest average annual growth in total labor (35.44 percent) and capital input (52.89 percent). On the other hand, Celcom and TimeCel recorded the lowest average annual growth for total labor (3.99 percent) and capital input (17.44 percent) respectively.

To see the changes in Malaysian mobile telecommunication production during the 1996 to 2001 period, Table 6.2 summarizes the average annual growth rates of output and inputs for the whole industry.

Table 6.2: Average Annual Growth of Output and Inputs by Year, 1996-2001 (%)

Year	Output (%)	Input (%)	
	No. of subscribers	No. of labor	Total no. of capital
1996-1997	165.2	29.4	61.03
1997-1998	45.8	-5.6	21.55
1998-1999	50.1	0.98	12.95
1999-2000	99.7	18.8	14.3
2000-2001	52.1	7.7	7.03
Mean	82.58	10.26	38.95

As can be seen from Table 6.2, output and inputs have shown a rise over the sample periods except for labor input in year 1998 (-5.6 percent). This negative rate growth may be due to the impact of financial turmoil (1997-1998) which had affected not only

telecommunication companies but other companies in other industries as well. Year 1996-1997 recorded rapid growth for output and all inputs compared to other periods. This period marked the rapid development of backbone infrastructures such as mobile switching centers (MSC), radio base stations (RBS) and wire facilities all over the countries. Growth of capital stock slowed continuously after 1997-1998 from 21 percent in 1998-1999 to below 10 percent in 2000-2001. However output growth has grown steadily above 50 percent over these periods. Since output growth showed no tendency to decline over the whole period of the study, it can be inferred that sharp decline in growth of inputs implies impressive productivity growth.

6.2 PRODUCTION FRONTIER AND TECHNICAL EFFICIENCY

Since the basic component of the Malmquist productivity index is related to measures of technical efficiency, the paper first reports technical efficiency for the five operators from 1996 to 2001 in Table 6.3 and 6.4 under constant returns to scale (CRS) and variable returns to scale (VRS)[17]. Values of unity imply that the firm is on the industry frontier in the associated year. Values less than unity imply that the firm is below the frontier or technically inefficient. Thus, the lower the values from unity the more inefficient it is compared to the values closer to one[18].

[17] Following Fare et al. (1994a), technical efficiency dealing with VRS is called pure efficiency.
[18] DEAP ver. 2.1 reports the values from 0 to 1 where 1 indicates fully efficient. Fare et al. (1994a), Mao and Koo (1996) and Fischer (1997) on the other hand reports values greater than unity denotes technically inefficient production.

For the years reported in Table 6.3 and 6.4, Maxis is consistently technically efficient, under constant returns to scale (CRS) and variable returns to scale (VRS). In fact, Maxis is the only operator determining the frontier in CRS version of technology. On the contrary, TM Cellular and Celcom are the least technically efficient firms in the sample firms with the average value of 0.834 and 0.884 for CRS and VRS versions respectively. The estimates also indicate that Celcom and DiGi have successfully keep pace with technically feasible production possibilities and increased their distance to the industrial production frontier for both versions of technology. DiGi also was efficient in most years, except in 1997 and 1998. TimeCel on the other hand, was efficient in 1996 and 1997, but became inefficient in the last four years of the sample periods under CRS version. However, under the VRS version, TimeCel has recorded full efficiency together with Maxis for the period of 1996-2001.

Table 6.3: Technical efficiency of operators, 1996-2001 (Constant Return to Scale)

Operator	1996	1997	1998	1999	2000	2001	1996-2001
Maxis	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Celcom	0.569	0.779	0.739	1.000	1.000	1.000	0.848
TM Cellular	0.997	1.000	0.615	0.706	0.926	0.758	0.834
DiGi	1.000	0.762	0.876	1.000	1.000	1.000	0.940
TimeCel	1.000	1.000	0.755	0.623	0.845	0.965	0.865
Mean	0.913	0.908	0.797	0.866	0.954	0.954	0.897

Table 6.4: Technical efficiency of operators, 1996-2001 (Variable Return to Scale)

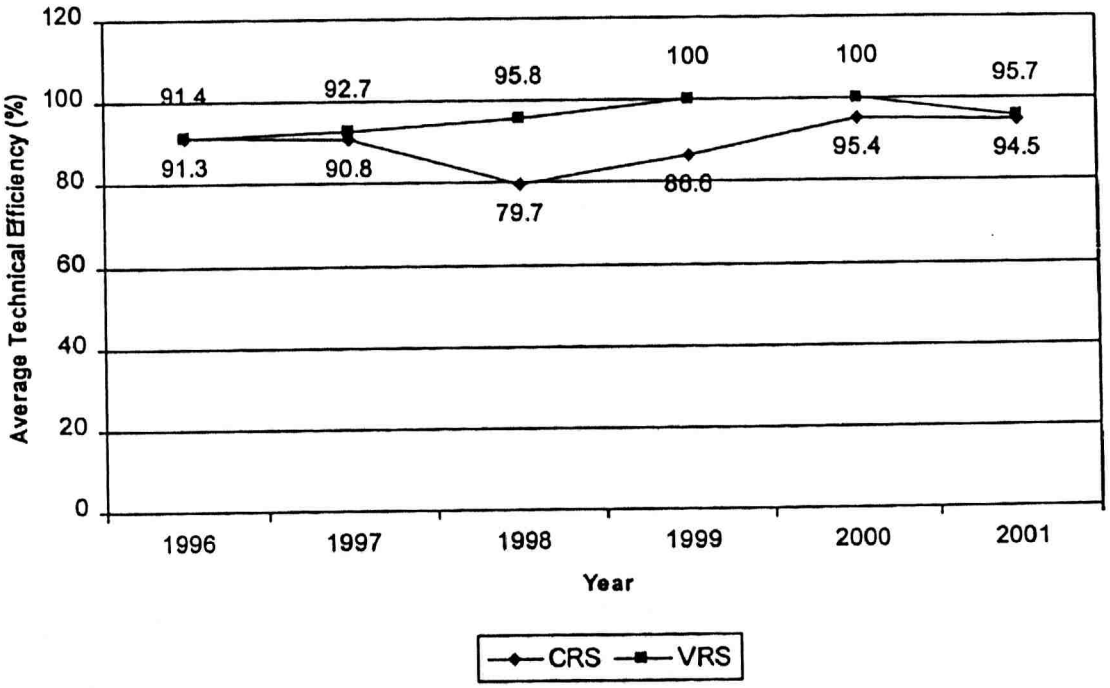
Operator	1996	1997	1998	1999	2000	2001	1996-2001
Maxis	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Celcom	0.569	0.873	0.862	1.000	1.000	1.000	0.884
TM Cellular	1.000	1.000	1.000	1.000	1.000	0.786	0.964
DiGi	1.000	0.762	0.930	1.000	1.000	1.000	0.949
TimeCel	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Mean	0.914	0.927	0.958	1.000	1.000	0.957	0.959

The inverse of the values in Table 6.3 and 6.4 shows the percentage of the realized output level compared to the maximum potential output level at the given input mix. Thus for example TM Cellular produced 99.7 percent of its potential output and Celcom produced only 56.9 percent of its potential output in 1996 under CRS version. On the contrary, DiGi produced 93 percent of its potential output and Celcom produced only 86.2 percent of its potential output in 1998 under VRS version.

As indicated by the weighted geometric mean of Table 6.3, the average technical efficiency for the whole industry decreased continuously from 1996 to 1998. In 1999 and 2000, technical efficiency however has increased by 8.66 and 10.16 percent respectively but showed a decline again in 2001 by 0.06 percent. Year 1997 marked the least efficient period for the industry with only 79.7 percent output compared to its maximum potential output achievable with the observed input level. In contrast, Table 6.4 under VRS version reports a constant increase of average technical efficiency from 1996 to 2000 and a slight decline in 2001. Comparing the two tables for overall period 1996-2001, mean value of

VRS version reflects higher potential output achieved with 95.9 percent compared to only 89.7 percent under CRS version. Figure 6.1 gives a visual summary of the whole industry technical efficiency from 1996 to 2001 under the two version of technology.

Figure 6.1: Malaysian Mobile Telecommunications Industry Technical Efficiency Performance, 1996-2001



6.3 PRODUCTIVITY PERFORMANCE OF INDIVIDUAL FIRMS

Table 6.5 to 6.7 reports the performance of operators in adjacent periods from 1996 to 2001 for TFP change and its two subcomponents, efficiency change and technical change respectively. Note that a value of the Malmquist TFP productivity index and its components less than one implies decrease or deterioration. Conversely, values greater than one indicate improvements in the relevant aspect[19]. Subtracting 1 from the number reported in the table gives average increase or decrease per annum for the relevant time period and relevance performance measure[20]. Also recall that that these measures capture performance relative to the best practice in the relevant performance relative to the best practice in the sample.

Table 6.5: Operators Relative TFP Change Between Time Period t and t+1, 1996-2001

Year	Maxis	Celcom	TM Cellular	DiGi	TimeCel
1996-1997	1.002	2.421	2.132	1.274	1.829
1997-1998	1.410	1.245	0.880	1.711	0.907
1998-1999	0.971	1.619	1.556	1.571	1.274
1999-2000	1.691	1.450	2.056	1.536	2.018
2000-2001	1.349	1.344	1.108	1.242	1.407
Mean	1.280	1.570	1.470	1.455	1.416

[19] To interpret as percentage changes, take the natural logarithm of the indexes.
[20] Since the Malmquist index is multiplicative, these averages are also multiplicative (i.e., they are geometric means).

Table 6.5 displays calculated changes in the Malmquist-based Total Factor Productivity index. According to the results, Celcom and DiGi had positive productivity changes for all the two adjacent years within the study period. In contrast, TM Cellular and TimeCel recorded a deterioration in TFP for year 1997-1998 and Maxis in year 1998-1999 at the rate of 12 percent, 9.3 percent and 2.9 percent respectively. In addition, Celcom had the highest average TFP growth at an annual average rate of 57 percent, TM Cellular followed next with an annual rate of 47 percent, and then DiGi came after with an annual rate of 45.5 percent. Overall, all the operators had increased their TFP on average by at least 25 percent per year for the period of 1996-2001. The Malmquist TFP index was further decomposed into its two components, technical change and efficiency change.

Table 6.6: Operators Relative Technical Change Between Time Period t and t+1, 1996-2001

Year	Maxis	Celcom	TM Cellular	DiGi	TimeCel
1996-1997	1.002	1.769	2.126	1.673	1.829
1997-1998	1.410	1.314	1.433	1.488	1.201
1998-1999	0.971	1.195	1.354	1.376	1.544
1999-2000	1.691	1.450	1.601	1.536	1.488
2000-2001	1.349	1.344	1.326	1.242	1.232
Mean	1.280	1.403	1.553	1.455	1.426

Table 6.6 presents the index values of technical progress/regress as measured by average shifts in the best-practice frontier from period *t* to *t+1*. According to the results, there was technical progress for each individual firm from year 1996 to 2001 except for Maxis which had technical regress (2.9 percent) between 1998 to 1999. TM Cellular

recorded the highest change in technical progress among the operators with 112.6 percent between 1996 to 1997 over the sample periods. This is shown as TM Cellular also had the highest average input growth with capital growth rate of 52.89 percent (refer Table 6.1).

Table 6.7: Changes in Operators Relative Efficiency Between Time Period t and t+1, 1996-2001

Year	Maxis	Celcom	TM Cellular	DiGi	TimeCel
1996-1997	1.000	1.369	1.003	0.762	1.000
1997-1998	1.000	0.948	0.615	1.150	0.755
1998-1999	1.000	1.354	1.149	1.141	0.825
1999-2000	1.000	1.000	1.310	1.000	1.357
2000-2001	1.000	1.000	0.819	1.000	1.142
Mean	1.000	1.119	0.947	1.000	0.993

Table 6.7 displays changes in relative output efficiency for each individual operators. The results indicate considerable variation across operators and across time. Only Maxis was efficient (and therefore showed no change in efficiency) in all periods from 1996 to 2001. For the other operators, there were periods with positive, negative or no changes in efficiency. Furthermore the results showed that many operators improved their efficiency between 1998 to 1999, 1999 to 2000 and 2000 to 2001. For any two periods from 1996 to 2001, our results showed that Celcom had the highest efficiency change in 1998-1999 with 35.4 percent and TM Cellular recorded the worst efficiency deterioration with -38.5 percent in 1997 - 1998. On average, Celcom was the only firm to have recorded a positive efficiency change over the period of 1996 to 2001.

In order to identify change in scale efficiency, efficiency change was further decomposed into pure efficiency change and scale efficiency change which is reported in Table 6.8.

Table 6.8: Changes in technical efficiency components by operators, 1996-2001

Year	Maxis		Celcom		TM Cellular		DiGi		TimeCel	
	PEC	SEC	PEC	SEC	PEC	SEC	PEC	SEC	PEC	SEC
1996-1997	1.000	1.000	1.533	0.893	1.000	1.003	0.762	1.000	1.000	1.000
1997-1998	1.000	1.000	0.987	0.960	1.000	0.615	1.221	0.942	1.000	0.755
1998-1999	1.000	1.000	1.161	1.167	1.000	1.149	1.075	1.062	1.000	0.825
1999-2000	1.000	1.000	1.000	1.000	1.000	1.310	1.000	1.000	1.000	1.357
2000-2001	1.000	1.000	1.000	1.000	0.786	1.042	1.000	1.000	1.000	1.142
Mean	1.000	1.000	1.119	1.000	0.953	0.993	1.000	1.000	1.000	0.993

Notes: Pure Efficiency Change (PEC).
Scale Efficiency Change (SEC)

The results showed that the scale efficiency appears to be a very unimportant source of growth to efficiency change compared to the pure efficiency change component for every firm in the sample. Average annual growth for 1996 to 2001 indicates that there are no changes for scale efficiency for 3 out of the 5 operators in the sample. TM Cellular and TimeCel on the other hand, had a deterioration of scale efficiency by 0.007 percent for the respective period. Hence, the results suggest that the size of firms does not really matter in determining the firms' productivity and efficiency level. Table 6.8 also indicates that

Celcom had the highest growth in pure efficiency with 53.3 percent in period of 1996-1997 while DiGi had the highest deterioration with -23.8 percent.

6.4 FIRMS THAT INNOVATED

Although the average results with respect to technical change which is reported in Table 6.6 are suggestive, they do not identify which firms are shifting the frontier over time. The technical change components of the Malmquist index only specify what happened to the frontier at the input level and mix of each firm, but not whether that firm actually caused the frontier to shift. Fare et al. (1994a) list the conditions to identify which firms have contributed to a shift in the industrial production frontier between year t and $t+1$. That is when

$$\textit{technical change} > 1$$

$$\textit{and}$$

$$\textit{efficiency change} = 1$$

then that firm has contributed to a shift in the production frontier. Firms meeting these criteria can be considered as the 'innovators' in Malaysia's mobile telecommunications production. Table 6.9 lists the firms that contributed to a shift in the frontier between 1996 and 2001.

Table 6.9: Firms shifting their frontiers in the periods 1996-2001

Year	Maxis	Celcom	TM Cellular	DiGi	TimeCel
1996-1997	✓	-	✓	-	✓
1997-1998	✓	-	-	-	-
1998-1999	-	-	-	-	-
1999-2000	✓	✓	-	✓	-
2000-2001	✓	✓	-	✓	-
Mean	✓	-	-	✓	-

The study finds that Maxis, TM Cellular and TimeCel were the initial innovators for the industry in 1996-1997. However, in the period of 1997-1998, only Maxis was the sole innovator in the industry. In addition, Maxis was the major innovator for the whole period of 1996 to 2001 with each year recorded a push in the frontier except for year 1998-1999. As a matter of fact, in this particular period no firm was considered to be the innovator. In the subsequent periods ahead, Celcom and DiGi had joined Maxis to become the innovator in the industry. The results also surprisingly indicate that TM Cellular which had the highest average annual inputs growth did not successfully maintained its position as the innovator for the year 1997 to 2001.

6.5 PRODUCTIVITY PERFORMANCE FOR THE ENTIRE INDUSTRY

Table 6.10: Malmquist productivity index for the entire industry, 1996-2001

Year	Malmquist TFP change	Technological change	Technical Efficiency change
1996-1997	1.628	1.613	1.009
1997-1998	1.180	1.353	0.873
1998-1999	1.370	1.269	1.080
1999-2000	1.782	1.589	1.122
2000-2001	1.297	1.315	0.987
Mean	1.435	1.421	1.010

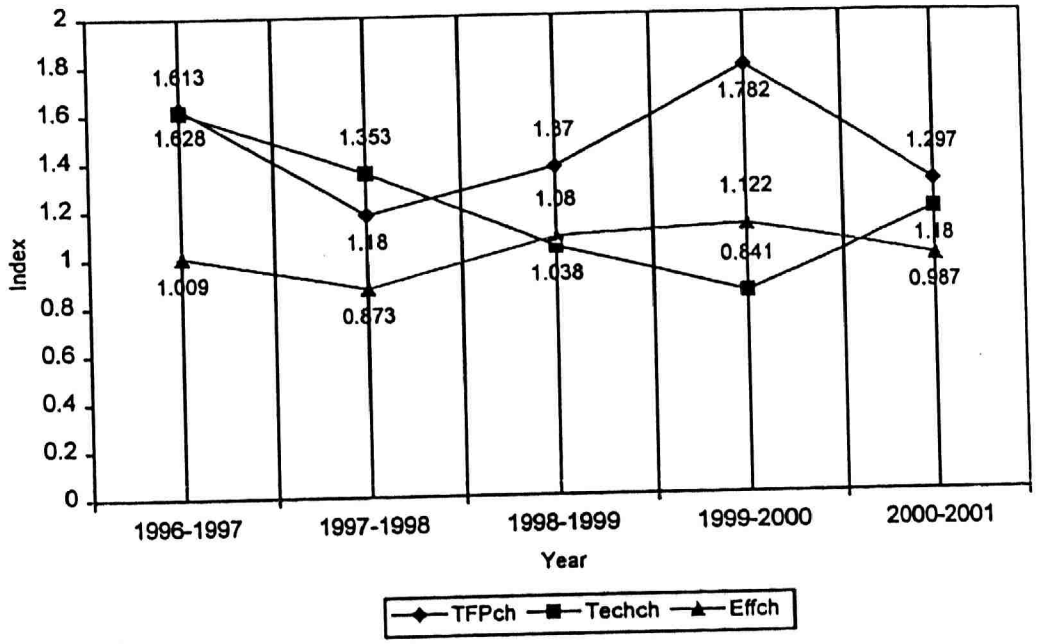
Table 6.10 reports the performance of Malaysian mobile telecommunications industry between 1996 and 2001. The columns in the table list the Malmquist index values of TFP change index, technical change component and the efficiency change component. Turning first to the geometric mean at the bottom of Table 6.10, it shows that TFP has grown significantly over the years with an average increase of 43.5 percent per year. The highest increase in TFP happened in year 1999-2000 with an improvement of 78.2 percent from 37 percent in the earlier period. For this period, the increase of TFP can be observed by the rapid diffusion of mobile services. Indeed, for the whole industry, the number of cellular subscribers has increased, on average by 99.7 percent in this period (refer Table 6.2).

On average, the improvement of TFP was ascribed to technical progress (42 percent) while efficiency change contributed only a small portion (1 percent) to the overall

TFP growth (43 percent). In other words, substantial growth in technical change and inconsistent growth in efficiency component suggest that increase of TFP in Malaysian mobile telecommunications industry arose from the innovation in technology rather than the improvement in efficiency. This is evidenced with the increase in the demand for accessibility as well as the need to improve quality services have driven the growth in investment of capital input particularly network infrastructures. Thus, relatively large increases in investments in both central office switching equipment and radio base stations were made during these periods. Unfortunately, these investments did not translate into technical efficiency improvement. Furthermore, with the patterns of efficiency change greater than one in almost all periods (refer Table 6.7), indicate that on average input employed in the industry could be reduced by a slight of 1 percent.

Figure 6.2 shows the evolution over time of TFP and its components for the five mobile telecommunication operators as a whole measured by means of the geometric mean of Malmquist productivity index for each period.

Figure 6.2: Malaysian Mobile Telecommunications Industry Productivity Performance, 1996-2001



6.6 IMPLICATIONS OF THE STUDY

The results obtained from this study have important implications for Malaysian mobile telecommunications industry. Essentially, the overall industry experienced an inconsistent trend in efficiency with a decline and a very small growth through out the period 1996 to 2001 (refer Table 6.7). This result indicates that Malaysian mobile telecommunication industry has great potential to increase its output through improved technical efficiency component. Given the high technological improvement within the industry, labor force should be well-equipped with knowledge in optimizing the technology

possessed. Thus, one area that needs particular emphasis is technological knowledge dispersion. Training and technical expertise should be constantly upgraded along with technological evolution. This can take the form of education and training program intended to improve managerial ability, or of extension programs designed to speed up the adoption of improved technologies.

Moreover, greater intensification of technology should also be accorded high priority. Existing technology has to be exploited further via infrastructure-sharing to reduce wastage resulting from under-utilization of assets. Though domestic roaming is underway and it has been significant to the industry, a lot more can be done to speed up technological adaptation and knowledge dispersion through healthy competition among the telecommunication companies and market liberalization for the industry.