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ESTIMATION OF FIXED TO MOBILE PRICE ELASTICITIES

PREPARED FOR BT

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1. KEY FINDINGS

We have been asked by BT to estimate the price elasticity of fixed-to-mobile (FTM) calls in the context of the current OFTEL consultation on calls to mobile.

A summary of elasticity estimates by day, evening and weekend call categories is given in the following table. Key points are that:

- We find a significant relationship between FTM call volumes and an index of fixed-to-mobile tariff across all mobile operators. This clearly rejects any hypothesis that consumers are ignorant about the general level of call charges, though (not least due to complexities of mobile numbering and mobile number portability) consumers may be less informed about the relative costs of calling different mobile networks.

- Reasonably robust elasticity estimates were obtained for day and weekend calls. Estimates for evening calls are subject to a greater margin of error, with a wider confidence interval than estimates for day and weekend calls.

- Call elasticities appear to be highest for the evening period and lowest for the daytime with the weekend being intermediate. These relativities are broadly in line with reasonable prior beliefs as:

  a) business callers, who can be expected to account for a greater proportion of daytime calls, are likely to be relatively less price sensitive than residential customers;

  b) it is possible that customers making calls close to the day/evening changeover time may be affected by the relative prices of day and evening calls, possibly delaying calls to obtain cheaper evening tariffs. Proportionately, the evening period volumes are likely to be more affected by call retiming as there are fewer evening call minutes than daytime call minutes. The weekend period is likely to be relatively unaffected by call retiming as there is no boundary similar to that between day/evening periods that could give rise to incentives to delay calls.

- We investigated call retiming between daytime and evening periods, but could find no evidence that it was occurring. However, this is not to say that that call retiming may not be potentially important. The available tariff data showed a very strong correlation between day and evening prices. Therefore, it was not possible to isolate and investigate separate effects of day and evening prices on evening call volumes.

		Long run price elasticity		Short run price elasticity	
		lower value	*upper value*	*lower value*	*upper value*
Daytime	***Range of significant estimates***	**-0.42**	**-0.33**	**-0.26**	**-0.17**
	Results by model:				
	Model	*estimate*	*95% confidence interval*	*estimate*	*95% confidence interval*
	1A (independent regression in levels)	-0.41	(-0.66, -0.17)		
	1B (SURE regression in levels)	-0.33	(-0.56, -0.11)		
	2A (independent regression in levels with lagged dependent variable)	-0.42		-0.26	(-0.49, -0.23)
	2B (SURE regression in levels with lagged dependent variable)	-0.40		-0.23	(-0.45, -0.01)
	3A (independent Error Correction Model)			-0.17	(-0.31, -0.03)
	3B (SURE Error Correction Model)			-0.16	(-0.44, 0.12)
		Long run price elasticity		**Short run price elasticity**	
		lower value	*upper value*	*lower value*	*upper value*
Evening	***Range of significant estimates***	**-0.95**	**-0.76**	**-0.58**	**-0.41**
	Results by model:				
	Model	*estimate*	*95% confidence interval*	*estimate*	*95% confidence interval*
	1A	-0.85	(-1.28, -0.42)		
	1B	-0.76	(-1.25, -0.27)		
	2A	-1.22		-0.35	(-0.77, 0.07)
	2B	-0.95		-0.41	(-0.80, -0.01)
	3A			-0.40	(-0.97, -0.16)
	3B			-0.58	(-1.15, -0.01)
		Long run price elasticity		**Short run price elasticity**	
		lower value	*upper value*	*lower value*	*upper value*
Weekend	***Range of significant estimates***	**-0.54**	**-0.43**	**-0.20**	**-0.20**
	Results by model:				
	Model	*estimate*	*95% confidence interval*	*estimate*	*95% confidence interval*
	1A	-0.54	(-1.03, -0.06)		
	1B	-0.43	(-0.85, -0.02)		
	2A	-0.24		-0.05	(-0.20, 0.11)
	2B	-0.25		-0.06	(-0.25, 0.13)
	3A			-0.20	(-0.36, -0.03)
	3B			-0.20	(-0.43, 0.04)

Not significant at 5%

2. DATA

We used the following data for the period from January 1997 to February 2001 on a monthly basis.

Table 1: Data used

Data	***Variable name***	***Source***
Total retail call minutes to mobile phones from BT fixed lines split by day, evening, weekend for each operator	$\min_{tip}$	BT
Day, evening and weekend retail tariffs for calls to each operator	tar_{tip}	BT
Total handsets for each mobile operator	handset	BT
Real household income	house_inc	ONS

Note: Throughout we use the index t to indicate the months, index i to indicate the operator and index p to indicate the period (day/evening/weekend.

As individuals who call mobiles are unlikely to distinguish between networks we have reduced the data by summing FTM minutes over mobile operators and calculating an average tariff weighted by market share, i.e.:

$$\min_{tp} = \sum_{\forall i} \min_{tip} \quad \text{and} \quad tar_{tp} = \sum_{\forall i} tar_{tip} \frac{\min_{tip}}{\min_{tp}}$$

Tariffs were converted into real 1997 prices using the retail price index. In order to account for the different number of weekdays and weekend days in each month, we have expressed call volumes on a per day basis. Average prices and volumes across the whole sample period are reported in Table 2.

Table 2: Average prices and quantities across sample period

	Day	***Evening***	***Weekend***
Average Price p/minute (1997 prices)	26.3	18.4	8.3
Total call volumes (millions of minutes per month)	233.6	100.4	69.7

3. ESTIMATIONS

In order to provide robust estimates of FTM elasticities, we have used three different econometric models:

a) a simple static model that relates the level of FTM minutes to levels of tariffs, mobile subscribers and household income;

b) a refinement of this static model that includes a lagged dependent variable and so can differentiate between long- and short-run price elasticities; and

c) an error correcting model that relates the *changes* in FTM minutes to the *changes* in tariffs, mobile subscribers and household income.

Models (a) and (b) are simple and have been often been used in the economic literature to estimate elasticities. However, they are open to potential criticism in this case because they may simply measure correlations between trended variables. In particular, FTM minutes and mobile subscribers are upward trended, while tariffs are downward trended. There is a danger that any estimates of relationships between these variables may be driven by correlations caused by the variables' overall trends and may fail to capture short-run relationships properly.

Aware of this potential criticism, we have also estimated model (c), which addresses this problem. Although more complex, it produces estimates that are robust to trends in the dependent and explanatory variables. In practice, the estimates produced by all three models appear broadly consistent.

For all three models, we have used two different estimation methods:

- Individual regressions for day, evening and weekend;
- Seemingly Unrelated Regressions (SURE) that additionally consider the possibility that errors in the day, evening and weekend models may be correlated.

The second technique is to be preferred as it makes use of additional information in the data in order to improve the efficiency of the estimates.

3.1. SIMPLE STATIC MODELS

We estimated two versions of a simple static model relating the level of FTM call volumes to tariffs, handset numbers and household income.

- Independent regressions without lags (Model 1A) for day, evening and weekend call volumes and tariffs, i.e. the following regression was estimated independently for day evening and weekend:

$$\ln(\min_t) = a + b_1 \ln(tar_t) + b_2 \ln(handset_t) + b_3 \ln(house\_inc_t) + e_t$$

- Seemingly Unrelated Regressions (SURE) (Model 1B) which allow for correlation between the residuals in the regressions for day, evening and weekend, in order to improve efficiency.

$$\ln(\min_{tp}) = a' + b'_{p1} \ln(tar_{tp}) + b'_{p2} \ln(handset_t) + b'_{p3} \ln(house\_inc_t) + v_{tp}$$

In these equations, the elasticities are best interpreted as long-run elasticities. Table 3 and Table 4 show that the estimated elasticities for day, evening and weekend. Prices have a significant effect on call volumes in all cases. These are robust to the estimation method.

As expected, the coefficient for total handsets is positive and significant in every case. Given that this coefficient is less than one and the model is in logarithms, doubling the number of handsets produces less than a doubling of fixed to mobile call minutes. Therefore, the average number of FTM minutes per handset falls as the number of handsets increases. This is consistent with later adopters of mobiles receiving less calls than early adopters.

The coefficient for real household income is positive and just significant for weekend calls in one model, and negative but insignificant for daytime and evening in both models.

Table 3: Results for Model 1A

	Daytime calls		***Evening Calls***		***Weekend calls***	
	Coefficient	***t-stat***	***Coefficient***	***t-stat***	***Coefficient***	***t-stat***
Day tariff	-0.413	-3.390				
Evening tariff			-0.851	-3.986		
Weekend tariff					-0.542	-2.262
Total Handsets	0.473	8.860	0.756	11.034	0.712	5.787
Real household income	-1.017	-1.325	-1.565	-1.969	0.432	0.218
Constant	-0.249	-0.088	-2.600	-0.924	-10.350	-1.531
ovtest[1]		4.91		9.88		73.42
n_test[2]		5.91		14.78		23.05
dwstat[3]	(4,49)	0		0		0

Table 4: Results for Model 1B

	Daytime calls		***Evening Calls***		***Weekend calls***	
	Coefficent	***z-stat***	***Coefficent***	***z-stat***	***Coefficent***	***z-stat***
Day tariff	-0.332	-2.904				
Evening tariff			-0.760	-3.041		
Weekend tariff					-0.433	-2.048
Total Handsets	0.500	9.322	0.777	10.101	0.753	6.302
Real household income	-0.953	-1.205	-1.579	-1.523	0.665	0.353
Constant	-1.195	-0.431	-3.154	-0.887	-12.139	-1.827
Breusch-Pagen[4]	chi2(3)	33.184		Pr	0.0000	

[1] Ramsy RESET test for omitted variables

[2] Joint skewness and kurtosis test for normality of residuals

[3] Durbin-Watson test statistic

3.2. SIMPLE LAGGED DEPENDENT VARIABLE MODELS

The next set of models introduces limited dynamics, in that the short and long-run impact of prices is allowed to vary by including lagged call volumes as an explanatory variable. Again, we estimated this model using both independent regressions for day, evening and weekend and using the SURE method across all three call categories.

The equation estimated for independent regressions with lagged variables (Model 2A) is:

$$\begin{aligned} \ln(\min{}_t) &= h + f_1 \ln(tar_t) + f_2 \ln(handset_t) \\ &+ f_3 \ln(house\_inc_t) + f_4 \ln(\min{}_{t-1}) + w_t \end{aligned}$$

The equation for SURE with lagged variables (Model 2B) is:

$$\begin{aligned} \ln(\min{}_{tp}) &= h' + f'_{p1} \ln(tar_{tp}) + f'_{p2} \ln(handset_t) \\ &+ f'_{p3} \ln(house\_inc_t) + f'_{p4} \ln(\min{}_{t-1,p}) + u_{tp} \end{aligned}$$

In these models, ϕ_1 and ϕ_{p1}' indicate short-run price elasticities, which together with the coefficients for the lagged dependent variable can be transformed into long-run elasticities. More specficially, the long run elasticities are given by:

$$Elasticity = \frac{f_1}{1 - f_4}$$

We estimated a number of models with several lagged prices as explanatory variables, but found these not to be significant. Table 5 and Table 6 report the results for these models.

We continued to find significant price impacts for day and evening calls. In this cases, short-run effects were significantly smaller than long-run effects of price changes. However, for weekend calls, the impact of prices, although negative, was not significant.

As with the simple static models, mobile handset numbers had a highly significant effect. Again, an increase in handsets produces a less than proportionate increase in FTM minutes, other factors held equal. As with the previous models, we could find no significant effect of household income.

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[4] Breusch-Pagen test for independence of equations

Table 5: Result for Model 2A

	Daytime calls		*Evening Calls*		*Weekend calls*	
	Coefficent	*t-stat*	*Coefficent*	*t-stat*	*Coefficent*	*t-stat*
Day tariff	-0.258	-2.210				
Evening tariff			-0.348	-1.677		
Weekend tariff					-0.050	-.0645
Lag of dependent variable	0.380	3.335	0.713	5.012	0.795	5.118
Total Handsets	0.304	4.918	0.208	1.800	0.142	0.997
Real household income	-1.046	-1.664	-0.669	-0.876	0.244	0.295
Constant	1.282	0.565	0.572	0.244	-2.741	-1.020
ovtest		1.94		3.22		3.96
n_test		14.88		9.63		10.39
dwstat	(5,48)	0		0		0

Table 6: Results for Model 2B

	Daytime calls		*Evening Calls*		*Weekend calls*	
	Coefficent	*z-stat*	*Coefficent*	*z-stat*	*Coefficent*	*z-stat*
Day tariff	-0.229	-2.068				
Evening tariff			-0.407	-2.017		
Weekend tariff					-0.057	-0.591
Lag of dependent variable	0.432	3.720	0.573	5.943	0.779	13.126
Total Handsets	0.281	3.679	0.324	3.453	0.157	2.257
Real household income	-0.982	-1.392	-0.837	-1.066	0.225	0.286
Constant	1.198	0.487	-0.348	-0.129	-2.863	-1.028
Breusch-Pagen	chi2(3)	16.106		Pr	0.0011	

3.3. ERROR CORRECTION MODELS

Finally, we estimated an error correction model that, unlike the previous models considering the levels of call minutes, would be robust to trends in the data. This model considers the relationship between *changes* in calls minutes and *changes* in explanatory variables. It also includes an "error correction" term that represents convergence back to a long run relationship between the variables.[5]

Again we estimated this model using independent regressions (Model 3A):

$$\Delta \ln(\min_t) = l + g_1 \Delta \ln(tar_t) + g_2 \Delta \ln(handset_t) + g_3 \Delta(house\_inc_t)$$
$$+ g_4 \Delta \ln(totalBTcall_t) + p_1 e_{t-1} + u_t$$

and using SURE (Model 3B) to allow for error correlations across call categories:

$$\Delta \ln(\min_{tp}) = l' + g'_{p1} \Delta \ln(tar_{tp}) + g'_{p2} \Delta \ln(handset_{tp})$$
$$+ g'_{p3} \Delta(house\_inc_{tp}) + p'_1 v_{t-1,p} + u_{tp}$$

The elasticities estimated by these models are best interpreted as short-run elasticities.

Table 7 and Table 8 present the results of the error correction models. Prices had negative impacts on quantities in all cases, except these effects were only significant for day and weekend calls using independent regressions and for evening calls using SURE. The reduced level of significant relative to Models 1 and 2 is to be expected as here we are removing trends from the data.

Comparing the elasticities to those from Table 3 and

Table 4 one can see that the short -run elasticites are much smaller than the long run elasticities. Moreover, the evening elasticity is notably greater than both the day and evening elasticities, as in the levels regressions.

Again, real household income was generally significant. Handset numbers were sometimes significant, again with a positive coefficient less than one as we would expect.

Overall, the estimates of Model 3A and 3B appear broadly consistent with the short-run elasticities estimates obtained from Models 2A and 2B. However, lower levels of significance are inevitable due to these regressions being in changes rather than levels.

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5 This error correction variable is the lagged residual from the corresponding regression in levels.

Table 7: Results for Model 3A

	Daytime calls		***Evening Calls***		***Weekend calls***	
	Coefficent	***t-stat***	***Coefficent***	***t-stat***	***Coefficent***	***t-stat***
Day tariff	-0.170	-2.495				
Evening tariff			-0.404	-1.446		
Weekend tariff					-0.196	-2.385
Total Handsets	-0.791	-2.151	-0.288	-0.730	-0.299	0.292
Real household income	0.007	0.007	-0.580	-0.533	2.008	1.862
ECV	-0.539	-4.867	-0.294	-2.060	-0.168	-1.219
Constant	0.051	3.252	0.039	2.079	0.048	3.172
ovtest		1.06		1.10		2.30
n_test		12.90		11.60		11.96
dwstat	(5,48)	0		0		0

Table 8: Results for Model 3B

	Daytime calls		***Evening Calls***		***Weekend calls***	
	Coefficent	***z-stat***	***Coefficent***	***z-stat***	***Coefficent***	***z-stat***
Day tariff	-0.156	-1.093				
Evening tariff			-0.577	-1.978		
Weekend tariff					-0.196	-1.615
Total Handsets	-0.820	-2.304	-0.163	-0.400	-0.243	-0.575
Real household income	-0.132	-0.125	-0.517	-0.412	1.853	1.475
ECV	-0.477	-4.279	-0.418	-4.351	-0.189	-3.065
Constant	0.053	3.394	0.033	1.803	0.046	2.524
Breusch-Pagen	chi2(3)	15.068		Pr	0.0018	

4. ALTERNATIVE SPECIFICATIONS

4.1. OVERALL BT CALL VOLUMES

Because changes in the number of BT's retail FTM minutes may depend on changes in the BT's overall market share of BT, we have in addition obtained quarterly data on BT call minutes from OFTEL market information (up to the second quarter 00/01, i.e. up to September 2000). As these figures are not broken down by period (day/evening/weekend), we have been provided by BT with the respective call splits on an annual basis from financial year 95/96 to 99/00 (from BT's published regulatory accounts) in order to allow us to interpolate BT call volumes by period.

We used a variety of interpolation methods, but found that total call volumes were not significant in any of our regressions and therefore dropped this variable from the further analysis.

4.2. INTERACTION BETWEEN TIME PERIODS

We investigated the issue of call timing in response to price differentials, particular across the day and evening periods where retiming is most likely. This retiming effect is of significance when using these results to estimate any welfare effects of varying call termination rates. In particular, our separate analysis of day, evening and weekend call categories may lead to an overestimate of the welfare loss/gain from increasing/decreasing FTM tariffs. In particular, if there is an increase/decrease in daytime rates this may not only lead to customers making less/more calls in the daytime, but also retiming some of these calls into the evening.

The difficulty in investigating this issue is that there has been little variation in the *relative* price of FTM calls in the day and evening in the period for which we had data. Table 9 shows that day, evening and weekend prices are closely correlated, both in levels and changes.

Table 9: Correlation coefficients for day, evening and weekend prices

	Correlations in levels			Correlation in changes		
	Day	**Evening**	**Weekend**	**Day**	**Evening**	**Weekend**
Day	1			1		
Evening	0.99	1		0.79	1	
Weekend	0.99	0.98	1	0.86	0.86	1

We specifically looked for any evidence of an impact of daytime prices on evening call volumes and evening prices on daytime call volumes. Collinearity problems made it impossible to use Model 1 or Model 2 with both daytime and evening prices in the same equations. However, we could include these cross-price effects in the error correction model (Model 3) where changes in day and evening prices were less correlated. However, we could find no evidence that daytime prices affect evening volumes or vice-versa with the available data.

4.3. THE PRICES OF CALLING INDIVIDUAL MOBILE NETWORKS

We also investigated whether there was any evidence that the volume of calls to individual mobile networks was affected by the specific price for calling that network, rather than an average price across all networks. It is difficult to explore this issue as the average price across operators is closely correlated with each operator's individual price. Nevertheless, the *changes* in individual operators' prices where sufficiently uncorrelated with the *changes* in the average price across all networks to permit estimation of an error correction model for volume of calls to a particular mobile operator in terms of that operator's price, average prices, handset numbers and income. We found no evidence to suggest that operator-specific prices had any extra explanatory power in addition to an average price across all networks.

5. CONCLUSIONS

To summarise, we find a significant relationship between FTM call volumes and an index of fixed-to-mobile tariff across all mobile operators. Reasonably robust elasticity estimates were obtained for day and weekend calls. Estimates for evening calls are subject to a greater margin of error, with a wider confidence interval than estimates for day and weekend calls. Call elasticities appear to be highest for the evening period and lowest for the daytime with the weekend being intermediate, which is in line with expectations because of (a) business customers, who we would expect to account for a larger proportion of daytime calls, are less price sensitive than residential customers and (b) the impact of delayed calls is proportionately larger on evening calls, with overall lower call volumes.