An Econometric Model of Television Ownership

COLM McCARTHY
JUNE RYAN

Précis: A Modified Log-Reciprocal model is proposed for time-series television ownership and is found to describe closely the British and Irish data. A similar model also fits the British time-series on the percentage of colour receivers and gives more plausible extra-sample predictions than the Logistic model also estimated. Experiments with Irish cross-section data suggest that income is the dominant influence with population density having a weak negative effect. Taking these factors into account, areas with multi-channel reception do not appear to have systematically higher ownership rates than the single-channel areas.

SINCE television licensing was introduced in Ireland in the early nineteen-sixties, the number of sets has increased from under 100,000 to over half a million, a compound annual growth rate in excess of 15 per cent. As is commonly the case with durable consumer goods, the rate of growth in ownership was very rapid initially but has since levelled off. Indeed, the total number of sets licensed declined slightly in 1974.

We attempt answers to a number of questions in this paper. Has the process of growth in ownership ceased? How rapidly can ownership of colour sets be expected to develop? Would the introduction of additional channels in areas not presently receiving them result in increased ownership rates in these areas?

While not devoid of interest in their own right, these questions are of particular concern under existing arrangements in Ireland, where broadcasting is financed through license fees to a great extent.

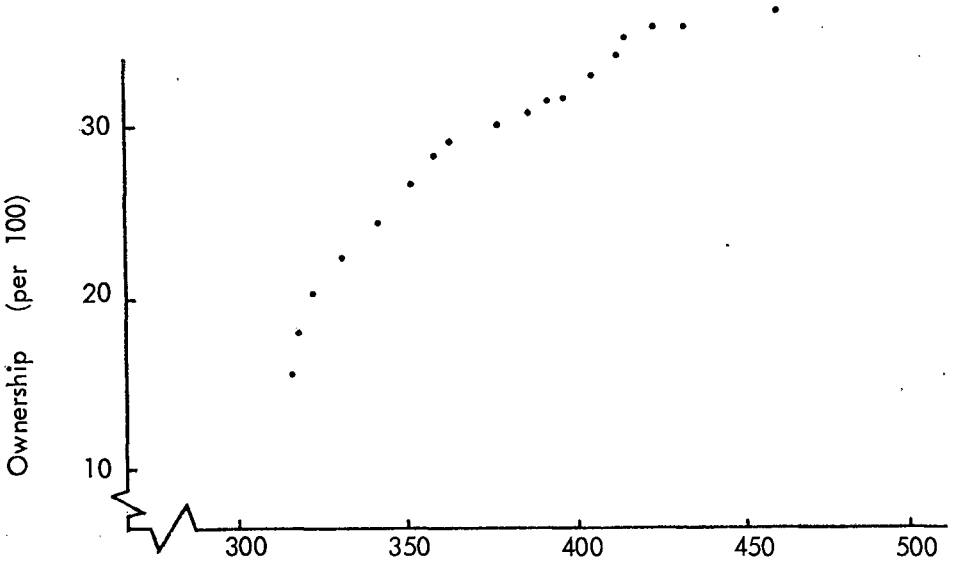
The first section considers the time-series data for Ireland and the UK and proposes a Modified Log-Reciprocal curve as the most appropriate functional form for describing them. Parameter estimates are presented in the second section followed by some experiments using Irish cross-section data. Section four deals with ownership of colour sets, followed by a summary and conclusions.

1. *Time-Series Data*

Ownership curves for durable consumer goods are generally held to be sigmoid in shape, that is, they exhibit rapid growth at low incomes, experience a point of inflexion and taper off to finite *per capita* saturation levels, with the income-elasticity going to zero. Of course, sales of new equipment need not go to zero, but the demand becomes solely a replacement demand. The most widely studied area has been car ownership, not surprisingly, and Logistic models for the Irish data will be found in Blackwell (1968) and McCarthy (1972), (1974a).

Television broadcasting on a regular basis was commenced in the United Kingdom in 1936 and there are now over 30 sets per 100 population in that country, one of the highest ownership rates in the world. The UK time-series data are plotted in Figure 1 against real Consumers' Expenditure and a sigmoid pattern is

FIGURE 1: *UK ownership data consumers' expenditure (1970 £)*

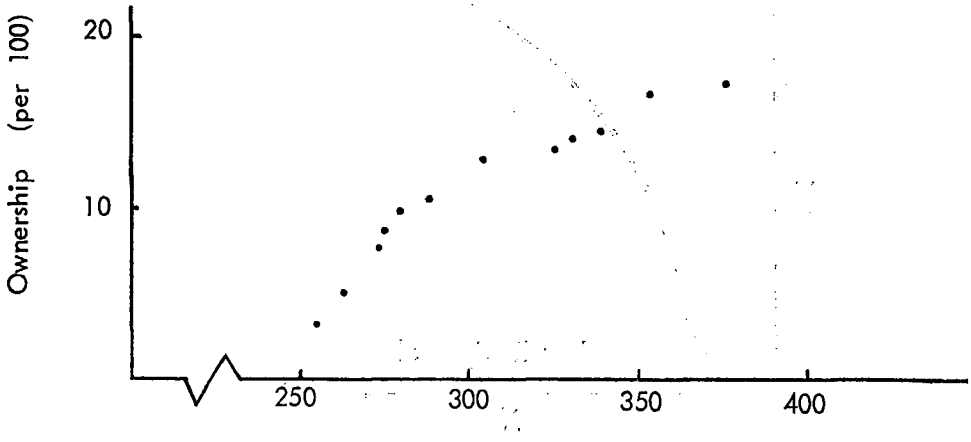


evident. It would appear that a threshold effect is in operation, in that a positive expenditure level would correspond to zero ownership. Finally, the point of inflexion seems to occur at a fairly low ownership level, which would rule out symmetric functions such as the logistic, which have the property that the point of inflexion occurs at half-way to saturation.

The Irish data are not available so far back, since licensing was only introduced when the domestic channel commenced broadcasting—of course, certain areas of the country where British stations could be received already had significant

ownership levels at that time. Figure 2 plots the Irish *per capita* ownership rate against real Consumers' Expenditure and a pattern broadly similar to the British one is discernible.

FIGURE 2: *Irish ownership data consumers' expenditure (1968 £)*



- 2(a) -

Data and sources are given in the appendix.

The series plotted in the two Figures exhibit three significant features:

(*a*) they asymptote to finite *per capita* ownership levels, which one would expect on *a priori* grounds

(*b*) their points of inflexion occur at low ownership levels and

(*c*) there seems to be a threshold effect, also a reasonable *a priori* expectation.

A simple three-parameter model having these properties is the Modified Log-Reciprocal

$$Y_t = e^{\alpha + \frac{\beta}{X_t + \gamma}} + U_t \qquad (1)$$

where Y_t = per capita ownership

X_t = real Consumers' Expenditure

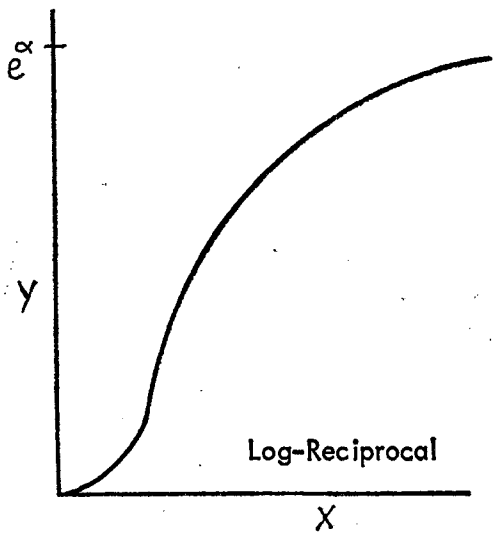
t = time

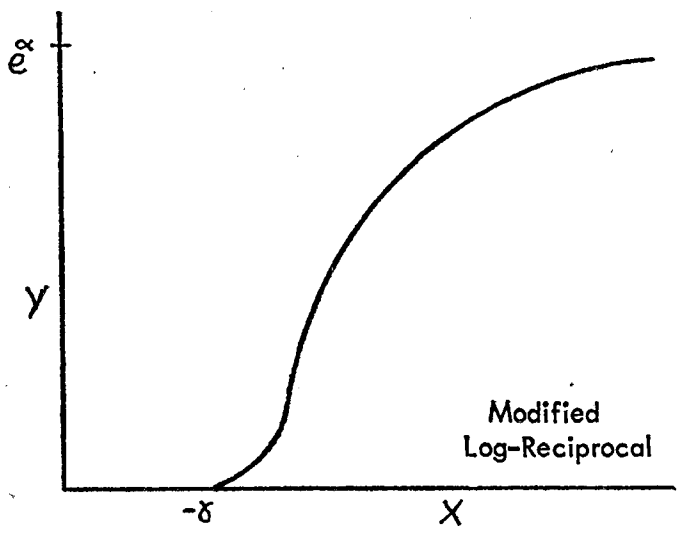
α, β, γ = numerical coefficients

e = the base of the natural logarithm

and U_t = a random disturbance.

FIGURE 3: *Log-reciprocal functions*





We would expect the parameter α to be positive, since e^{α} is clearly the upper asymptote, β should be negative for (1) to be a growth function, while γ should also be negative, since $-\gamma$ has the interpretation of the threshold income level. Thus as X_t approaches γ, Y_t approaches zero, given β negative. Finally, the point of inflexion will occur at $e^{\alpha-2}$, which is roughly one-seventh of the saturation ownership level. The general shape of the function is plotted in Figure 3, along with the two-parameter Log-Reciprocal

$$Y_t = e^{\alpha+\beta/X_t} \tag{2}$$

which has no threshold effect. This latter version can be estimated as

$$L_n. \, Y_t = \alpha+\beta/x_t \tag{3}$$

which is linear in the transformed variables, so Ordinary Least Squares is operational [Johnston (1972)]. No linearising transformation exists for (1), so it must be directly estimated by a non-linear technique.

2. *Parameter Estimates*

The most appropriate independent variable to use in the regressions would be some measure of consumers' net wealth or of consumers' holdings of durables. In the absence of such data the (real) value of consumers' expenditures on goods and services has been used.

Estimates of equation (1) for the British and Irish data are given in Table 1. Standard errors of parameter estimates are shown in parentheses throughout. The computations involve direct minimisation of the residual sum of squares in (1) using a programme based on Hartley's (1961) modification of the Gauss-Newton procedure. Under an additive Normal disturbance assumption, this yields Maximum Likelihood estimates—see Goldfeld and Quandt (1972).

TABLE 1: *Estimates of equation* (1)

Country/period	$\hat{\alpha}$	$-\hat{\beta}$	$-\hat{\gamma}$	R^2	DW	*Saturation (per 100)*
United Kingdom (1955–1973)	3·67 (0·042)	49·54 (7·15)	278·6 (5·06)	0·999	0·85	39·34
Ireland (1962–1973)	3·10 (0·066)	39·54 (8·08)	234·7 (5·03)	0·998	1·33	22·14

The dependent variables are ownership rates per 100 persons. Both equations fit the data very closely and the economic implications of the estimates are plausible. The two threshold parameters are even closer together than they appear, since the Irish expenditure variable is in £ (1968) while the British is in £ (1970). Estimates

of threshold effects from time-series are less easily interpreted than corresponding estimates from consumer panel data. In the latter case there is no aggregation of income distribution effects and no shifting in the availability of the commodity across the observation units. Both problems must be present with the time-series data used here, so the threshold estimates cannot be interpreted literally.

The saturation parameters differ substantially. It will be recalled that the saturation level is given by e^{α} and approximate confidence intervals around the estimates of e^{α} can be found by using the estimates of the standard error of α. The 95 per cent interval for the UK saturation level is 36·24 to 42·71, for the Irish 19·44 to 25·22, so the estimates are significantly different from one another at a high level.

The use of *per capita,* rather than per-household definitions for the dependent variables explains some of the difference—average household size in the UK is presently about 3·06, in Ireland about 4·1, so if the two saturation levels were expressed on a per-household basis, the British figure would be 1·2, the Irish 0·91. A lower evasion rate in the UK could also be a contributing factor. Saturation ownership rates in excess of one per household are not implausible on prior grounds —indeed current ownership levels for cars in the United States exceed one, but nevertheless the British estimate looks rather high. However, the 95 per cent confidence interval, translated into per-household terms, has a lower bound of just 1·11.

The R^2 statistics indicate unusually close fits to the data, even allowing for the time-series nature of the exercise. There is some evidence of residual autocorrelation with the British equation but the Irish Durbin–Watson statistic is not significant at 95 per cent for the given number of degrees of freedom.

So far as we are aware, the Modified Log-Reciprocal model has not been used before in this area, but it seems to have a number of advantages over, for example, the Lognormal model used in Bain's (1964) study of UK television ownership. These are principally the ease with which Maximum Likelihood estimation can be accomplished and the ready economic interpretation of the parameters. However, given the huge range of sigmoid functions available there may well be other formulations along similar lines which would prove equally satisfactory.

3. *Irish Cross-Section Data*

Ross (1972) has calculated estimates of Irish county income, 1969 being the most recent year covered. The availability of these data has facilitated a number of cross-section inquiries and equations relating television ownership rates to income and certain other variables are discussed in this section. The variables are:

Y_i = television ownership per 100 persons,

X_i = *per capita* income,

M_i = a dummy variable for multi-channel reception,

D_i = population density per 1,000 acres

i = the county index.

Ideally, one would like to use the same X-measure in the cross-section regressions as was used in the time-series. However, no data on consumer expenditures by county are available.

The calculation of both Y_i and D_i requires estimates of county population for 1969,a non-census year. The estimates used here are taken from McCarthy (1974a) where the method of interpolation is described. The dummy variable for multi-channel reception is given the value 1 for counties on the East coast and those close to the border, zero for the rest. All the data are shown in the appendix.

In the light of the time-series results, a non-linearity in income is to be expected. The range of variation in Y_i covers only a region above the point of inflexion, so this can be catered for by using a semi-log term in X_i. Results are shown in Table 2.

TABLE 2: *Equation estimates, Irish county data, 1969*

Dependent variable	*Intercept*	*Independent variables*				$\bar{R}^2$
		X	*Ln. X*	*M*	*D*	
Y	—4·20	·048				·406
		(·011)				
Y	—4·02	·048		—·644		·388
		(·011)		(1·29)		
Y	—9·81	·065			—·0019	·430
		(·016)			(·0013)	
Y	—9·77	·065		—·031	—·0019	·404
		(·017)		(1·36)	(·0015)	
Y	—99·51		19·16			·419
			(4·40)			
Y	—99·29		19·15	—·439		·396
			(4·48)	(1·28)		
Y	—120·38		22·76		—·0011	·415
			(5·91)		(·0012)	
Y	—120·15		22·72	—·032	—·0011	·388
			(6·25)	(1·38)	(·0013)	

Perhaps the most striking features of Table 2 are the low proportion of variance explained and the very slight difference made by allowing for non-linearity in X. Income is the only highly significant variable, although there is some support for a negative influence from population density. It has often been observed that this latter variable has a negative effect on car ownership. The multi-channel dummy seems to have no effect whatsoever, but it is doubtless a very crude measure which could perhaps be refined.

It has already been observed that the Irish time-series models suggest that saturation is being approached, so one would expect ownership rates in the different counties to have converged to a great extent. However, convergence has been much slower than with cars—in 1969, for example, the lowest car ownership rate was 8·5, the highest 13·7. For television sets, the lowest was 6·3, the highest 23·1. There

may be factors at work which explain these differences but which are not captured in the equations we have estimated. For example, no account has been taken of the quality of reception in the various counties which must have some effect on the desirability of owning a television set. While it is known that there are significant variations in the quality of reception, we understand that county-by-county data on this magnitude are not available. Needless to say, nothing is known of cross-section variations in evasion rates, which could also explain the low explanatory power of these equations.

To conclude this section, it is of interest to note the "outlying" counties in the regressions (the list is virtually the same for them all). Counties with much higher rates than the model would predict are Carlow, Louth, Waterford and Westmeath. Those with much lower rates than predicted are Cavan, Clare, Kilkenny and Wicklow.

4. *Ownership of Colour Sets*

In 1968, about one-eighth of one per cent of the television sets licensed in the United Kingdom could receive colour transmissions. That figure is now over 20 per cent and continues to rise. It seems obvious that a high percentage of all sets will ultimately be able to receive colour. This development is of considerable financial importance to broadcasting companies financed by licence fees which involve a higher rate for colour sets. The evidence in Section 2 suggests that overall television ownership rates in the Republic of Ireland are very close to saturation, so the trend towards substitution of colour for black-and-white receivers will probably constitute the main source of revenue buoyancy for RTE.

In order to gain some impression of the development of colour ownership in the United Kingdom, we fitted some time dependent sigmoid functions to the data on the percentage of colour receivers. Since only six observations are available, concentrated on a portion of the function, this exercise is necessarily somewhat limited.

The functions fitted were

$$Y_t = \frac{a}{1 + be^{ct}} + U_t \tag{4}$$

which is the three-parameter Logistic growth function, and

$$Y_t = e^{a + b/t} + U_t \tag{5}$$

which is the two-parameter Log-Reciprocal function encountered earlier. The symbols are

Y_t = percentage colour receivers

t = a time index, 0 in 1967

a, b, c = numerical coefficients

e = base of the natural logarithm

U_t = a random disturbance

The saturation levels were constrained to equal 100 per cent for the Logistic and both 100 per cent and 90 per cent were used for the Log-Reciprocal. In the latter case scaling t at 0 in 1967 amounts to constraining the predicted Y to 0 also in that year. The results are given in Table 3. A starred parameter indicates a constrained value.

TABLE 3: *Equation estimates for percentage colour, UK 1968–1973*

	a	b	c	R^2	DW
Logistic	100·0*	719·13 (114·75)	—·861 (·028)	·999	2·62
Log-Reciprocal 1	4·61*	—10·90 (0·51)	—	·958	1·35
Log-Reciprocal 2	4·50*	—10·38 (0·55)	—	·951	1·31

The Logistic model looks most satisfactory but there are so few degrees of freedom that it would be foolish to infer very much from Table 3. If we look at the forecasts which each model would yield for various future years, it becomes clear that the Logistic model is somewhat implausible. These are shown in Table 4.

TABLE 4: *Forecasts of percentage colour, United Kingdom, 1975–1990*

	Model		
Year	*Logistic*	*Log-Reciprocal 1*	*Log-Reciprocal 2*
1975	58	26	25
1980	99	43	41
1985	100	55	51
1990	100	63	57

What has happened is that the very rapid growth rate in the UK, which saw colour ownership go from virtually zero to 20 per cent in just six years, would imply satiation in less than ten years time if a (symmetric) Logistic pattern were followed.

The rate of growth of a logistic process at time t is given by

$$g_t = \frac{100}{Y_t}\frac{dY_t}{dt} = 100(c - cY_t/a) \tag{6}$$

which implies at, say, 33 per cent ownership a growth rate (of the ownership *rate*) of 57 per cent. This in turn would imply that 30 per cent of remaining black-and-white sets were replaced inside twelve months. The implications for replacement behaviour are such as to render the Logistic model estimates unacceptable.

The Log-Reciprocal models, by contrast, give more plausible forecasts. If the pattern of development of colour ownership in Ireland follows that of Britain, RTE can expect some revenue buoyancy from this source, since the licence fee for colour (now £27) exceeds that for black-and-white (£16). If this ratio is maintained, the tax base for television licensing will expand as viewers switch over to colour.

Over the next five years, a return to normal economic conditions would, using the equation of Section 2 and extrapolating current colour ownership levels along the third British curve, give an increase of about 5 per cent per annum in RTE's tax base. This is mostly due to the switch to colour, since the elasticity of the Irish ownership curve at present levels is only 0·1. Thus even if Consumers' Expenditure grew at 5 per cent per annum, higher than the historical average, overall television ownership would expand at only one-half per cent.

This source of revenue buoyancy is analogous to the Road Fund income from commercial vehicle licences in recent times. The total number of commercial vehicles licensed has grown only marginally and the rates of tax have been altered very little. However, transport operators have been moving over to heavier vehicles and since the tax rate is progressive with vehicle size there has been a substantial growth in the tax base as a result. See McCarthy (1974b).

5. *Summary and Conclusions*

A modified Log-Reciprocal model was proposed for time-series television ownership and was found to describe closely the British and Irish data. A similar model also fits the British time-series on the percentage of colour receivers and gives more plausible extra-sample predictions than the Logistic model also estimated.

For the Irish cross-section data, income is the only strongly significant variable, although population density has a weak negative influence. Three questions were posed at the outset. These were (i) Has the process of growth in ownership ceased? The answer seems to be no, but future growth rates in overall ownership will be small. (ii) How rapidly can ownership of colour sets be expected to develop? If the British experience is to be repeated here, colour ownership will expand rapidly enough to constitute a useful source of revenue buoyancy at existing licence fee differentials. (iii) Would the introduction of additional channels result in increased ownership rates? There is no evidence of higher ownership rates in multi-channel areas at present, taking certain other factors into account. What effect the introduction of RTE 2 might have is difficult to say, since the cross-section results given here do not bear directly on this question. But the implication is that the effect on ownership would be slight.

Institute of Public Administration, Dublin

ACKNOWLEDGEMENTS

The authors would like to thank participants at a meeting of the Economics Workshop at University College, Dublin, in November 1975, and an anonymous referee, for comments on an earlier draft. The usual disclaimer applies.

REFERENCES

BAIN, A. 1964. *The Growth of Television Ownership in the United Kingdom,* Cambridge: University Press.

BLACKWELL, J., 1969. *Transport in the Developing Economy of Ireland,* Paper No. 47. Dublin: Economic and Social Research Institute,

GOLDFELD, S. and R. QUANDT, 1972. *Nonlinear Methods in Econometrics,* Amsterdam: North-Holland Publishing Co.

HARTLEY, H., 1961. "The Modified Gauss-Newton Method for the Fitting of Nonlinear Regression Functions by Least Squares", *Technometrics,* Vol. 3.

JOHNSTON, J., 1972. *Econometric Methods,* 2nd. Edn., New York: McGraw-Hill.

MCCARTHY, C., 1972. *Vehicle Number Projections, 1976–1991,* Report RT.104, Dublin: An Foras Forbartha.

MCCARTHY, C., 1974a. *Car Number Projections by County for 1985 and 1995,* Report RT.115, Dublin: An Foras Forbartha.

MCCARTHY, C., 1974b. *Forecasts of the Carrying Capacity of the Commercial Vehicle Fleet,* Discussion Series No. 3. Dublin: Institute of Public Administration.

ROSS, M., 1972. *Further Data on County Incomes in the Sixties,* Paper No. 64, Dublin: Economic and Social Research Institute.

For Appendix Tables see overleaf

TABLE A1: *United Kingdom time-series data*

Year	*Total licensed ('000)*	*of which colour*	*Total ownership rate (per 100)*	*Per capita consumers' expenditure (£1970)*
1955	4504		8·84	315·8
1956	5740		11·21	317·2
1957	6966		13·55	322·3
1958	8090		15·66	329·3
1959	9255		17·81	341·6
1960	10470		19·99	352·2
1961	11268		21·34	357·5
1962	11834		22·21	361·9
1963	12443		23·24	375·9
1964	12885		23·91	386·6
1965	13253		24·44	391·0
1966	13567		24·89	396·8
1967	14267		26·04	403·6
1968	15093	20	27·42	412·1
1969	15510	99	28·07	413·3
1970	15899	273	28·69	422·0
1971	15961	610	28·70	431·8
1972	16678	1635	29·89	456·1
1973	17146	3332	30·66	476·3

Source: all series are from the *Annual Abstract of Statistics*, Central Statistical Office, London, various issues.

TABLE A2: *Republic of Ireland time-series data*

Year	*Total licensed ('000)*	*Ownership rate (per 100)*	*Per capita consumers' expenditure (£1968)*
1962	92·7	3·28	255·4
1963	150·3	5·27	263·9
1964	221·9	7·75	274·4
1965	255·8	8·90	275·2
1966	287·7	9·98	279·5
1967	308·2	10·63	288·7
1968	376·5	12·94	305·3
1969	394·3	13·50	326·1
1970	415·9	14·13	331·8
1971	433·0	14·54	338·7
1972	498·2	16·53	353·5
1973	530·1	17·38	376·3

Sources: Television numbers from *Statistical Abstract of Ireland* Consumers' Expenditure from *National Income and Expenditure*, population data from *Annual Report on Vital Statistics*, all published by Central Statistics Office, Dublin. The data for numbers of current licenses issued refer to March 31st each year.

TABLE A3: *Irish cross-section data, 1969*

County	*Ownership rate (per 100)*	*Per capita income (£)*	*Population density*	*Multi-channel dummy*
Carlow	19·62	376	152·63	0
Cavan	6·33	328	113·29	1
Clare	9·64	368	94·03	0
Cork	14·84	428	187·59	0
Donegal	11·65	306	90·39	1
Dublin	18·82	551	3621·60	1
Galway	9·55	332	100·92	0
Kerry	10·62	348	96·60	0
Kildare	14·32	411	165·68	0
Kilkenny	10·52	368	119·27	0
Laois	12·80	322	105·36	0
Leitrim	11·27	289	77·28	1
Limerick	17·78	402	208·70	0
Longford	11·92	317	110·14	0
Louth	23·14	439	356·88	1
Mayo	9·56	314	83·53	0
Meath	11·71	334	120·43	1
Monaghan	9·57	343	143·60	1
Offaly	14·35	333	104·38	0
Roscommon	9·27	307	89·31	0
Sligo	11·78	333	113·62	1
Tipperary	12·81	385	116·66	0
Waterford	20·33	421	165·63	0
Westmeath	16·45	344	121·75	0
Wexford	15·10	351	145·85	1
Wicklow	9·90	372	127·09	1

Source: Television Numbers from Statistical Abstract of Ireland. *Per capita* Income from Ross (1972). County populations from McCarthy (1974a). The construction of the multi-channel dummy is discussed in the text. The data for numbers of current licenses issued refer to March 31st.