A Note on National and County Car Ownership Projections in Ireland

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In recent years Irish transportation problems have attracted considerable public interest and controversy. The principal reason for this has been the rapid rise in car ownership levels which expresses itself most clearly in high density metropolitan areas where the problem of urban traffic congestion—particularly in the Dublin conurbation—has attained critical proportions. In addition, the Household Budget Inquiry 1965–66 [1] which investigated the expenditure patterns of urban households, showed that transport expenditure has increased more rapidly than spending on any other category since the last Inquiry in 1951–52 [2]: it has expanded from 4·39 per cent of household expenditure in 1951–52 to 9·59 per cent in 1965–66. There has been speculation about the impact of transport demand upon the capacity of transport networks and the question of how this demand can be satisfied at minimum cost to the community: that is taking account of social costs and benefits.

The number of private cars in Ireland increased from 52,000 in 1947 to 135,000 in 1957 and 314,000 in 1967. In terms of cars *per capita* ownership has increased from 0·018 in 1947 to 0·047 in 1957 and 0·109 in 1967. Blackwell [3] fitted an exponential trend to the time series data. The trend is of the form:

$$Y = ab^t$$

where Y = private cars *per capita*, a and b are constants and t is time. For two distinct time periods the trend shows that Y increased by a constant percentage annually (8·8 per cent between 1947–1957 and 9·5 per cent between 1958–1967) [4].

Given the present trends it is therefore a key research task to examine the pattern of transport demand as it has evolved over a number of years and to predict the likely future demands on the transport infrastructure.

It therefore becomes important to identify which variables influence car ownership and to examine how ownership levels are likely to change over the next twenty years. While other researchers have not usually disaggregated below national level in forecasting car ownership we hope in this paper to present predictions which will be of relevance at national and county level.

Review of Previous Literature

Car-ownership analysis has been undertaken at a series of spatial scales. At the level of the household relationships have been derived between household income and the percentage of households owning 0, 1 and 2+ cars. The hypothesis that these relationships are stable over space was tested in Britain by William Solesbury [5] with data obtained from the British Census County Volumes, 1966. In order to facilitate analysis this data was aggregated into 89 traffic zones using the British Ministry of Transport's standard classification. Solesbury concluded that the hypothesis was not discredited by the data and that a statistical relationship between household income and percentage of households owning 0, 1 and 2+ cars is constant over space at the level of 89 traffic zones. This particular approach has been extended to other users where, for example, in the modified form of category analysis it provides a method of trip generation for transportation studies.

J. C. Tanner [6] developed a method for forecasting which has been widely employed. His methodology, which is based on the use of the logistic curve, involves the definition of a "saturation" level. This saturation point, which Tanner has defined for Britain as 0·45 cars *per capita*, is determined on the basis of *a priori* reasoning aided by empirical trends in the United States and other countries. There exists a considerable degree of subjectivity in selecting this figure and in recent years there has been a tendency to consider a level of 0·45 *per capita* as being somewhat low.

Mogridge assumed a cumulative normal growth in car ownership which is dependent upon three assumptions: (a) an income distribution that is logarithmic normal, (b) a threshold level of income for car ownership, and (c) a constant rate of rise of income. [7] Using an econometric model the predictions of Mogridge agree closely with Tanner's empirical approach but his eventual saturation level, 0·66 cars per person, is much higher than Tanner's estimate. Although it was originally developed for forecasting at national level the logistic curve approach has been employed for smaller spatial units: Hermann [8] used this method to project car ownership in counties and county boroughs in Great Britain. His analysis, which extends to the year 2010, is closely linked with the 0·45 saturation level originally postulated by Tanner.

Quarmby and Bates [9] have developed an econometric model for forecasting car ownership in sub-national areas. The model seeks to explain car ownership per household in terms of income and density (number of residents per acre). While income may be regarded as a direct causal variable residential density bears only an indirect relationship to car ownership; its influence is manifest through other more directly casual factors such as income, and frequency of bus services. Use of the density variable therefore reduces the forecasting power of this model. Regression analysis was employed by Quarmby and Bates to derive the basic relations of the model from the National Travel Survey; it was found that the model overpredicted seriously when applied to historical data.

Treacy [10] in 1963 was the first to undertake vehicle ownership projection in Ireland. Using the logistic curve technique he assumed a saturation level of 0·50 *per capita* for all vehicles in the year 2020 and with the added assumption of a constant population of 2·8 million forecast a trebling of the 1961 national vehicle ownership level by 1980. Blackwell, [11] in a wide-ranging paper dealing with most aspects of inland transportation, advances several suggestions to deal with the problem of car ownership projection. He experimented with a logistic function at national level incorporating a saturation level of 0·45. He also regressed private cars *per capita* on various transformations of an income variable and demonstrated, *inter alia,* that the elasticity of car ownership with respect to income is 3·2, i.e. each 1 per cent rise in GNP gives rise, on average, to a 3·2 per cent rise in car ownership with a one year time lag. [12] Most of the resulting equations were satisfactory but it should be noted that there was an underlying common upward movement in both time series data sets. This illustrates a basic problem in time series analysis; the existence of a growth trend means that most variables measured in absolute terms show a high degree of correlation which has no relevance for causal inference. Hence if the dependent variable, cars *per capita,* is regressed on time alone a better fit is obtained than with any of the income variables. This is normally overcome by using first differences of the relevant variables. When, for Blackwell's data, change in private cars *per capita* and change in income were regressed the values of the correlation coefficients dropped to very low levels. Thus it may be concluded that Blackwell's "explanatory" model is subject to severe limitations. In addition, Blackwell examined the variability of car ownership at county level using step-wise multiple regression analysis. He tested income *per capita* 1960 (Attwood and Geary [17]) and four population variables. Personal income *per capita* explained 80 per cent of the variation in car ownership by counties: the addition of the remaining demographic variables only marginally improved the level of explanation. Hayes and Sheedy [14] have arrived at much higher car ownership projections using the logistic curve method. It must be assumed they employed a higher saturation level—any reference to which is absent from their paper.

A Car Ownership Forecast for 1975 and 1980

This note attempts to develop a forecasting model which exhibits some of the following properties thought desirable in such a model:

(i) A forecasting model must be as time stable as possible. This will be validated by testing it over several time periods using historical data.

(ii) The model should contain relevant variables, such that alternative projections of these independent variables will produce logical changes in the dependent variable, car ownership.

(iii) The model should provide a good statistical fit to present car ownership data.

Our model is an attempt to assess the potential level of car ownership and no account has been taken of the following factors which may influence car ownership but lie outside the parameters of a forecast model and must be assumed to remain constant over time:

(i) Hire purchase and credit facilities

(ii) Renting of cars

(iii) Car parking restrictions, particularly in Central Dublin and Cork

(iv) Introduction of a road pricing system in congested areas

(v) Public transport pricing policy and innovation

(vi) Road congestion

(vii) Technical innovation in road vehicles.

In constructing a forecasting model the prime consideration is to provide an equation which accurately estimates the level of car ownership over time on a county basis. Hence the research is further constrained by the limited data that is available at this spatial scale. No attempt is made to provide a theoretical underpinning for the variables employed; the approach is purely empirical in character. Within our conceptual framework car ownership is expected to increase over time irrespective of the effect of income or the availability of hire-purchase credit: i.e. we are postulating an autonomous trend over time. It was decided to test the hypothesis that the higher the level of car ownership in a county the lower will be the rate of growth of cars per head. There is empirical evidence to support this formulation from Britain and the United States [15]. In addition to testing this hypothesis the stability over time of this relationship was investigated. Data from each of the Census years 1951, 1956, 1961 and 1966 were analysed taking the growth over three five-year and two ten-year periods. Linear, geometric and logarithmic growth functions were postulated for each period and were specified as dependent variables on the respective base year data. The linear proportional change in cars per thousand persons explained 55, 63 and 44 per cent of the variation in cars per thousand persons in the respective 5-year periods (equations 1, 2 and 3 Table 1) but the regression coefficients were not time-stable. A slightly higher explanation was achieved with the 10-year equations—75 and 72 per cent respectively—but a similar instability was present in the regression coefficients (equation 10 and 11 Table 1). A compound or geometric formulation of the dependent variable did not yield a higher level of explanation and semi-logarithmic and log–log transformations were then attempted. The log–log equations (Table 1 equations 4, 5, 6, 12 and 13) clearly demonstrated a stability of the

TABLE 1: *Linear relationships of the proportional change in car ownership per thousand persons on census years for three 5-year and two 10-year periods in absolute, log–log and log–log with parallel slope forms*

Equation No.	Y	X	$\bar{Y}$	$\bar{X}$	a	b	S.E.(b)	t	r	d.f.
1.	Prop. Change Cars/000 persons 1951–56	Cars/000 persons 1951	0·548	29·619	0·983	−0·0147	0·0027	***	−0·743	24
2.	Prop. Change Cars/000 persons 1956–61	Cars/000 persons 1956	0·439	44·764	0·807	−0·0082	0·0013	***	−0·795	24
3.	Prop. Change Cars/000 persons 1961–66	Cars/000 persons 1961	0·584	63·547	1·055	−0·0074	0·0017	***	−0·665	24
4.	Log Prop. Change Cars/000 persons 1951–56	Log Cars/000 persons 1951	−0·652	3·342	1·902	−0·7642	0·1446	***	−0·733	24
5.	Log Prop. Change Cars/000 persons 1956–61	Log Cars/000 person 1956	−0·850	3·773	2·029	−0·7633	0·1134	***	−0·809	24
6.	Log Prop. Change Cars/000 persons 1961–66	Log Cars/000 persons 1961	−0·563	4·134	2·461	−0·7315	0·1985	**	−0·601	24
7.	Equation no. 4 assuming parallel lines and homogeneous variance				1·880	−0·7577	0·0844	***	−0·722	74
8.	Equation no. 5 assuming parallel lines and homogeneous variance				2·008	...	as at no. 7		...	...
9.	Equation no. 6 assuming parallel lines and homogeneous variance				2·569	...	as at no. 7		...	...
10.	Prop. Change Cars/000 persons 1951–61	Cars/000 persons 1951	1·235	29·619	2·296	−0·0358	0·0042	***	−0·869	24
11.	Prop. Change Cars/000 persons 1956–66	Cars/000 persons 1956	1·284	44·764	2·348	−0·0238	0·0030	***	−0·848	24
12.	Log Prop. Change Cars/000 persons 1951–61	Log Cars/000 persons 1951	0·172	3·342	2·799	−0·7860	0·0827	***	−0·889	24
13.	Log Prop. Change Cars/000 persons 1956–66	Log Cars/000 persons 1956	0·226	3·773	3·103	−0·7626	0·0918	***	−0·861	24
14.	Equation no 12 assuming parallel lines and homogeneous variance				2·770	−0·7772	0·0598	***	−0·879	49
15.	Equation no. 13 assuming parallel lines and homogeneous variance				3·158	...	as at no. 14		...	

regression coefficients over time within each set of equations. It was decided to examine whether the three 5-year regressions differed significantly or whether one overall equation could be derived from them. The variables associated with the equations were tested for homogeneity of variance using Bartlett's test [16] which proved not significant at the 5 per cent level ($\chi^2 = 5 \cdot 62$; $d.f. = 2$; $p < 0 \cdot 10$). Homogeneity of residual variances was assumed and the three regression coefficients were compared using the variance ratio test [17]. This showed that the regression slope coefficients do not differ significantly at the 0·05 level hence justifying the assumption of parallel slopes in the 5-year equations. When the regression constants were tested it was discovered that they were significantly different at the 0·001 level. A similar series of analyses was performed on the 10-year equations the only difference being the use of the F— test to test homogeneity of variances. Almost identical results were obtained justifying the assumptions of homogeneity of variance and parallel slopes (equations 14, 15 Table 1). The coefficients of determination for the respective equation sets were 52 and 77 per cent respectively.

It is logical at this point to test the reliability of the models on historic data. The two more recent equations (numbers 9 and 15) were applied to 1959, 1960, 1964 and 1965 data to give predictions for 1969 and 1970 respectively.[1] The predictions are compared with actual values in Table 2 and the differences tested as suggested by Ackoff [19]. The 5-year model significantly over predicted, while the 10-year model significantly under predicted in both 1969 and 1970. Ackoff recommends that the constant should be altered, the adjustment to be equal in magnitude to the estimated bias. When the respective constants are adjusted to omit the bias the tests of significance associated with $\bar{D}$ all prove non-significant with one exception. The 1970 10-year forecast is under-predicting a fact which is understandable when the change of date discussed above is taken into account. The two forecasting models now become:

$$\text{5-year} \quad \log Y = 2 \cdot 430 - 0 \cdot 7577 \log X$$
$$\text{10-year} \quad \log Y = 3 \cdot 293 - 0 \cdot 7772 \log X$$

where Y is the proportional change in cars per thousand persons in a five or ten year period as appropriate and X is the number of cars per thousand in the base year.

To apply these equations in the future some further consideration must be given to the constant. The constants in equations 7, 8, 9 and 14, 15 show successive increases from one time period to the next. In using the models for 1975 predictions from 1970 data the constant in the 5-year equation was increased by an increment of 0·345 to 2·775 (0·345 being the mean increase in the value of the

1. Both years were taken due to the fact that 1970 published car statistics show a sharper increase on the previous year than is usual which may be attributed, in part, to the change of date in recording the Census from 10th August to 30th September.

TABLE 2: *An evaluation of the reliability of the models to predict historic data*

Model	*Regression Equation* *Coefficient*	*Constant*	*Year*	*Actual*	*Model Prediction*[1]	*Difference Actual-Predicted*	*S.E. Diff*	*t*
				X_A	X_P	$\bar{D}$	$S_{\bar{D}}$	
5-year	—0·7577	2·569	1969	117·48	123·48	—6·00	2·14	*
			1970	129·75	133·48	—3·74	1·05	**
		2·430	1969	117·48	118·51	—1·03	2·13	N.S.
			1970	129·75	128·40	1·35	1·04	N.S.
10-year	—0·7772	3·158	1969	117·48	110·40	7·08	2·33	**
			1970	129·75	116·04	13·71	1·56	***
		3·293	1969	117·48	118·62	—1·14	2·34	N.S.
			1970	129·75	124·41	5·33	1·56	**
								a.e.=25

1. Predictions given were obtained by applying the equations quoted in columns 2 and 3 of this table to data from 1959 and 1964 for 1969 predictions, and 1960 and 1956 for 1970 predictions.

constant in equations 7, 8, 9). Similarly the constant in the 10-year equation was increased by 0·388 to 3·681 in forecasting 1980 from 1970 data.

The respective models were applied to the 1970 data and cars per thousand persons estimated for each county for 1975 and 1980. The forecasted values are presented in Table 3, together with cars per thousand persons for each census of population year back to 1951. The most spectacular growth, as expected, is forecast to occur in the western counties, with car ownerships per thousand persons in Mayo likely to increase by 116 per cent between 1970 and 1980 compared to 140 per cent between 1961 and 1970 and 160 per cent between 1951 and 1961. The projected increase in Meath, at the other end of the scale, forecasts a 80 per cent increase in the period 1970–1980 with the comparative figures having been 95 and 73 per cent for the last two decades respectively. Car ownership per thousand persons at national level will increase by 93 per cent between 1970–1980.

The number of private cars per thousand persons for 1975 and 1980 at national level was determined by weighting the ratio for each county by the population of the county in the 1966 census. No population projections are available at county level. However the Central Statistics Office does provide national population projections and these projections were used to arrive at a national total private cars value for 1975 and 1980. These figures together with ratios (cars/000 persons) from other authors are presented in Table 4.[2]

2. All national total private car forecasts have been derived using the population figures presented in Table 4.

TABLE 3: *Private Cars per Thousand Persons at County and National level[1] in the Census of Population years 1951 to 1966 and 1970[2] with Forecasts for 1975 and 1980.*

County	Number of private cars per thousand persons							Population 000's 1966
	Actual					Forecast		
	1951	*1956*	*1961*	*1966*	*1970*	*1975*	*1980*	
Carlow	37	53	74	108	126	178	243	34
Cavan	23	33	57	99	134	186	252	54
Clare	19	31	51	90	123	174	239	74
Cork	35	50	72	110	144	198	265	340
Donegal	17	30	47	77	104	153	215	109
Dublin	47	57	76	112	137	189	255	795
Galway	20	33	48	78	110	160	223	148
Kerry	18	33	52	87	119	170	234	113
Kildare	36	59	76	113	147	201	268	66
Kilkenny	36	54	72	110	147	200	267	60
Laois	34	57	78	111	143	196	262	45
Leitrim	19	36	60	77	108	158	221	31
Limerick	29	47	64	101	128	180	245	137
Longford	28	43	65	105	139	192	258	29
Louth	35	48	67	110	132	185	250	70
Mayo	15	26	39	68	94	142	203	116
Meath	45	60	78	125	152	206	273	67
Monaghan	29	41	58	94	134	187	253	46
Offaly	30	47	66	99	126	178	243	52
Roscommon	20	34	48	86	115	166	230	56
Sligo	23	34	50	85	115	165	229	51
Tipperary	38	61	80	118	147	200	267	123
Waterford	36	49	70	101	132	184	249	73
Westmeath	35	50	70	100	131	183	249	53
Wexford	32	49	66	112	143	197	263	83
Wicklow	35	48	68	114	145	199	265	60
Total	33	47	66	103	132	184	249	2,818

1. The national value of cars/000 persons for 1975 and 1980 have been derived using the 1966 Census of Population county populations as weights.
2. The 1970 values have been derived using mid-year estimates of county populations.

This table shows that the models developed in this paper forecast car ownership levels similar to Blackwell's logistic curve estimate with a saturation level of 0·45. The final projection of Blackwell which is the mean (an empirical choice) of his two other projections, also shown in Table 4, is close to the actual car ownership level in 1970. His projection for 1975 lies below the one derived in this paper from the 5-year model while for 1980 his total cars figure differs from our 10-year models forecast result by 31,000 vehicles.

TABLE 4: *Forecasts of Car Ownership per Thousand Persons and Total Private Cars at National Level, 1975 and 1980.*

Value	*Actual*	*Forecast*[1]			*Description of Forecast Method*
	1966	*1970*	*1975*	*1980*	
Cars 1000 Persons	103	132	184	249	Models in this paper
	103	133	179	240	Final projection (Blackwell)
	103	136	170	221	Regression analysis (Blackwell)
	103	139	188	258	Logistic curve (Blackwell)
	103	139	204	263	Logistic curve (Hayes and Sheedy)
Total Private Cars (000's)	296	389	567	817	Models in this paper
	296	392	552	786	Final projection (Blackwell)
	296	371	525	724	Regression analysis (Blackwell)
	296	409	580	846	Logistic curve (Blackwell)
	296	409	630	861	Logistic curve (Hayes and Sheedy)
Population[2]	2,818	2,944	3,086	3,277	Central Statistics Office

[1]Values underlined are actual values which occurred in 1970. Previous workers give projections for this year.

[2]Value for 1970 population is mid-year estimate provided by C.S.O.

Sources: J. Blackwell, *Transport in the Developing Economy of Ireland, op. cit.*
R. N. Hayes and J. P. M. Sheedy, *Report on Administration of the Arterial Road Programme—1966.*
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Conclusion

The models derived in this note show that the number of cars in the country will more than double from 389,000 to 817,000 within ten years. Our national projections of cars per thousand persons implies an annual average rate of growth of 6·9 per cent per annum in the 1970–75 period and 6·3 per cent per annum in the 1975–80 period. They suggest that even with a moderately restrictive attitude to private car ownership on the part of authorities, car ownership might still rise to the order of 0·45 *per capita*. Our forecast evidence also indicates that if car ownership can be described by a logistic curve then the rate of increase of ownership in Ireland has not yet started to level out towards a saturation point.

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