HOUSEHOLD CAR OWNERSHIP AND MODE CHOICE FOR THE JOURNEY TO WORK

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ABSTRACT: *Drawing on 1976 census data, the paper presents new evidence on the factors affecting car ownership. Special attention is paid to household income, household size, residential density and access to rail. Using the same set of data, the paper then shows how the mode choice for the journey to work depends on car ownership, as well as on distance to the CBD, access to rail, household size, household income and residential density.*

HOUSEHOLD CAR OWNERSHIP AND MODE CHOICE FOR THE JOURNEY TO WORK.[1]

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I. INTRODUCTION

Drawing on 1976 census data this paper presents some new evidence on the determinants of car ownership, with special reference to household incomes, household size, residential density and access to rail transport (section 2). Using the same set of data, we then show how car ownership affects the mode choice for the journey to work (section 3). There is a brief concluding section.

The form of the data obliges us to use cross section analysis of zonally grouped data. That is, the average number of cars per household or per capita or the proportion of trips to work in each census collector district is the dependent variable to be explained by the average characteristics of households in the district as well as by the characteristics of the area itself. But while the data dictates the method it does not justify it. Thus we feel it necessary first briefly to compare this approach to explaining and (ultimately) to forecasting car ownership with other methods.

Much of the early work on car ownership fitted a logistic growth curve to the time series of national car ownership data while employing an independently determined

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[1] We are grateful for comments from David Hensher, Lester Johnson and an anonymous referee.

estimate of saturation as the asymptote. Typically

$$C_t = S\,[1+be^{-aSt}]^{-1} \qquad (1)$$

in which for year t, C is the number of cars per capita and S is the saturation level, and a and b are constants to be determined. In the 1970's this extrapolative model was extended to reflect the influences of household income and car ownership costs. For example Tanner (1978) developed the modified logistic model,

$$C_t = S[\,1 + \frac{S-C}{C_o}\left(\frac{Y}{Y_o}\right)^{-bS}\left(\frac{P}{P_o}\right)^{-cS} e^{-aS(t-t_o)}]^{-1} \qquad (2)$$

in which Y is income per capita in constant prices, P is the cost of motoring in constant prices, Y_o and P_o are the corresponding values in the base year t_o and a,b and c are constants to be determined. But the model remained dependent on the concept of a saturation level, which was held to be unaffected by income or by motoring costs. Moreover it is not always clear whether the concept of saturation means a ceiling level of car ownership which is never exceeded or some average long term level of car ownership.

Perhaps more importantly, as the Leitch Report (1977) argues, time series models generally exclude important determinants of car ownership like household size, residential density and access to public transport. The effects of such socio-economic variables are most readily captured in cross section studies of regional and intra-urban pattersn of car ownership. Also it is arguable that the influence of transitory income effects is reduced in group based cross section studies which consequently provide better estimates of long-run income effects than do time series studies.

It is true that in practice cross section studies have not been unqualified successes. Some, for example Sleeman (1961) have been based on large regions with heterogeneous populations so that the zonal average statistic is not representative of the population. Others for example Buxton and Rhys [1972] and Pearman and Button [1976] have omitted factors like household size and access to public transport which appear to be important, see Oi and Shuldiner [1962] and Fairhurst [1975]. And few studies, Kain (1967) is a notable exception, have attempted to measure the simultaneous two-way relationship between car ownership and residential density. Most assume residential density affects car ownership but not vice versa.

However in the main these problems are contingent to those studies rather than inherent to the method. The major inherent problems in cross section studies, and important ones, are a general inability to capture the influence (i) of the costs of car ownership (as this is usually constant across the areas under study), (ii) of the business cycle and (iii) of possible disequilibrium effects. All these are better captured in time series studies.

A natural extension to cross section analysis of groups of households is cross section analysis of the choices of individual households. Typically such models, for example, Golob and Burns [1978], explain the probability of a household owning a given number of automobiles as a function of household income and other household characteristics, of the availability of public transport and of the household's accessibility to opportunities. Also within the individual choice framework, Lerman and Ben-Akiva [1976] and Train [1980] modelled the car ownership choice simultaneously with the journey-to-work mode choice.

Individual choice models may provide considerable insight into the factors determining choices. On the other hand problems arose with the selection of a reasonable choice set, with the related problem that the procedure may infringe the desirable axiom of independence from irrelevant alternatives, and with forecasting the characteristics of individual households. Forecasts of the choices of groups of households may be more accurate when based on the analysis of groups and forecasts of their characteristics.

We would argue then that certain socio-economic variables, such as household size and residential density, influence both spatial patterns of car ownership and the long run level of national car ownership and are usefully analysed through group based cross section analysis. The results should complement rather than substitute those in other studies.

The research reported in this paper, which is based on census collector districts (CCD) in Sydney, provides a finer set of data, including a wider range of independent variables, than has generally been used in cross section analysis of groups of households. We also employ a two stage least squares procedure to examine the simultaneous interactions of car ownership and residential density.

2. CAR OWNERSHIP IN SYDNEY

For this study 187 CCD within Sydney (excluding the outermost areas of Gosford, Wyong, Colo, Blue Mountains and Wollondilly) were selected randomly from the 1976 Census. As shown in Table 1 which provides a summary of the data collected, these districts contained an average population of 626 persons and 216 dwellings.

The Census provides data on the number of households in each district owning none, one, two or three or more cars. To obtain the results reported below, households were assumed to own not more than three cars. Regressions were also run on the assumption that households with 3 or more cars owned an average of 3.2 cars, but the effects on the estimated co-efficients were insignificant. On the basis of no more than 3 cars per household, cars per capita averaged 0.35 over all districts and varied from a low of 0.12 in one district to a high of 0.56 in another. Car ownership per household averaged 1.09 and varied from 0.24 to 1.90 per household.

Early studies of car ownership tended to model cars per capita. Chow (1960) did so because he argued that what mattered was disposable income. As larger households had to spend more on food and clothing, they had less available for cars so that income per capita was more relevant than income per household. Later studies have more often regarded the household as the car owning unit. However, there being no strong theoretical reason for preferring to model (and to forecast) cars per household to cars per capita, we modelled both.

To allow for the possible effects of the age distribution of the population, we also ran regressions with cars per person between the ages of 17 and 65 as the dependent variable.[1] However, as the 'explanations' (in terms of the R^2) were lower for this variable than for the others, (suggesting perhaps that households with children have as much need of cars as do households without them), no results are reported for this dependent variable.[2]

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[1] In our sample car ownership per person between the ages of 17 and 65 averaged 0.55 and varied from a low of 0.17 to a high of 1.01 person between these ages.

[2] As models with different dependent variables generally contain different amounts of variation to be explained, comparison of R^2s across models provides limited and sometimes misleading information.

Table I Data Summary (1976)

Variable	Mean	Standard Deviation
Population in CCD	626	252
Population employed	286	113
Median household income ($)	11173	2605
Dwellings in CCD	216	225
Separate Dwellings	130	83
Households - no car	40	30
Households - 1 car	94	40
Households - 2 cars	45	32
Households - 3 cars +	12	9
Distance to CBD (kms)	19	13
Distance to rail (kms)	3	4
Households per km^2 (in LGA)	795	688

The independent variables included in our study are income, household size, residential density, distance to the CBD, access to rail and employed persons per household. The following paragraphs describe why and how these variables are included.

1. If we maximise utility subject to a budget constraint and car ownership is an argument in the utility function, then unless cars are an "inferior" good, income will be positively correlated with car ownership. In our study income is represented by the median gross income per household in each CCD (MINC). The median figure is generally more representative of the population than the mean, which in any case is difficult to estimate given the open-ended nature of the Census scale for the income question, (the highest income group was $18,000 and above). No attempt was made to estimate disposable income which was not available in the Census and estimation of which would require a large number of assumptions. As the income tax scale is progressive the income elasticity of car ownership will be lower for gross income than for disposable income. When the dependent variable is cars per capita, median gross income per capita (IPC) is used.

2. Persons per household (HHSIZE) is included as a possible explanatory variable because large households are perceived to have a greater demand for cars than small households have - a one or even two person household has less use for two cars than does a family of say four persons. But unfortunately the

situation is not so simple. Holding other factors constant, notably income, a family of four has less discretionary income to use for the purchase of a car. Thus no strong prior prediction about the relationship between household size and car ownership is possible.

On the other hand, there are presumably some economies of scale. It is unlikely that a family of four needs twice as many cars as a family of two. Thus we would expect household size to be negatively correlated with car ownership per capita.

3. There are several reasons why residential density may be negatively related to car ownership.

With higher densities more activities can be reached without mechanised access to public transport and in Sydney there is better access to ferries and higher bus frequencies. In the absence of direct measures of access to these forms of public transport, measures of residential density provide a proxy. High density is also correlated with congestion and high land prices, and hence with high car parking costs, which will deter car ownership.

In our study two specific measures of density were tried, namely households per km^2 in the local government area containing each CCD (HHKM2) and dwellings as a proportion of total dwellings in each CCD (SEPDW). The correlation between these two measures (r=-.31) is not strong, see Table 2.

4. The distance from each CCD centre to the central business district (DCBD) also reflects residential density (the correlation with households per km^2 is - 0.69). Like density it reflects congestion, access to public transport and land prices. However, it may be a better proxy than density for these variables and pick up factors not caught by the density variable, hence its inclusion in this study.

5. Rail travel is a potential substitute for the car and any reduction in its price, including the access price, could reduce the demand for cars. Thus the distance from each CCD centre to the nearest rail station (DRAIL) is included here as a potential determinant of car ownership. However, it should be recognised also that households without cars have an incentive to locate near the railway so that the correlation between DRAIL and car ownership is itself not proof that railways reduce car ownership.

6. Employed persons per household in each CCD (EMPHH) was adopted as it is sometimes suggested [Train, op.cit.] that cars are purchased for the journey to work. However, EMPHH

turned out, not surprisingly, to be strongly correlated with household size (r = 0.75) so that its independent effect is difficult to gauge. When the dependent variable is cars per capita, employed persons as a proportion of the population in the census collector district (EMPCAP) is used as the independent variable.

The simple correlations between these variables is shown in Table 2. Except for the correlations between $HHkm^2$ and DCBD and between EMPHH and HHSIZE, they give no cause for concern about multicollinearity.

Table 2 - Correlations between the Independent Variables

	DCBD	DRAIL	$HHKM^2$	MINC	SEPDW	HHSIZE	EMPHH
DCBD	-						
DRAIL	0.26	-					
$HHKM^2$	-0.69	-0.30	-				
MINC	0.18	0.17	-0.25	-			
SEPDW	0.28	0.07	-0.31	0.35	-		
HHSIZE	0.50	0.04	-0.40	0.37	0.25	-	
EMPHH	0.21	-0.02	0.19	0.36	0.03	0.75	-

Ideally the demand equation to be tested would be derived from a postulate of utility maximisation. However, as is well known (Layard and Walters 1978) although the linear (additive) demand function can be derived from the Stone-Geary separable utility function, it implies that households will spend a constant proportion of their marginal income on motor cars which is not realistic. On the other hand, the log-linear form of the demand function implies constant elasticities of expenditure which also may not be entirely realistic, and it cannot be derived from any utility function. In any case, when household incomes and tastes differ, market demand curves can not readily be derived from individual preference functions. Accordingly, we followed the practice in similar cross-section studies and estimated both linear (additive) and log-linear (multiplicative) demand functions. Only the latter are reported as a greater proportion of the variance was explained in these equations. Also assuming that elasticities are reasonably constant, this property facilitates comparisons between the results.

The major results are shown in Table 3. Equations 3 to 6 deal with cars per household. Equations 7 and 8 concern cars per capita. The degree of variance in car ownership explained by the equations (as measured by the R^2) is high compared with most other studies of this type. Nearly all co-efficients have the expected sign and are significant at the 95 per cent level of significance.

The main conclusions to be drawn from the cars per household equations are as follows. The income elasticity of demand is around one. It does not vary significantly with the inclusion or exclusion of other variables. This result may be compared with an elasticity of 1.3 to 1.5 (Buxton and Rhys 1972) 1.1, (Evans, 1969) 0.9 (Bates et.al. 1977) and around 0.7 (Pearman and Button 1976, & Kain 1967).

Of the three variables (including DCBD) which stand partly or wholly for residential density, the most significant in terms of the t-statistic is DCBD. Broadly speaking as the distance from the CBD doubles, car ownership per household rises by 13 per cent. The second most significant density variable is SEPDM. Equation 3 indicates that in addition to the DCBD effect as the proportion of separate dwellings doubles, car ownership per household rises by 24 per cent. The variable $HHkm^2$ is significant when the other two variables are excluded (Equation 5).

Access to rail is always a significant factor in car ownership. As distance from a railway station doubles, car ownership per household rises by around 6 per cent. However, as noted above, the causal direction of the relationship between car ownership and distance to rail is not obvious.

Household size is also significant, being correlated positively with cars per household. The estimated elasticity of cars per household with respect to household size is greater (rising to 0.4 to 0.5) where residential density, with which household size is (inversely) correlated, is excluded from the equation.

On the other hand, car ownership per household is found to fall significantly (Equations 3,4,5) as the number of persons employed per household rises. This presumably reflects other things, notably income, being equal, the greater demand that women at home have for a car compared with women who seek paid employment.

The pattern of these results is strongly confirmed by the car per capita Equations 7 and 8. The income elasticity of demand with respect to both household and per capita income remains around 1. The co-efficients with respect to SEPDW, DCBD and DRAIL scarcely change and the co-efficient for EMPCAP is similar to that for EMPHH.

As predicted the co-efficient on household size changes to be significantly negative in Equation 7. A one per cent fall in household size leads to nearly a one per cent increase in car ownership per capita. However, when income per capita is substituted for income per household as an explanatory variable in Equation 8, household size is no longer significant. This may be due to the positive relationship between household income and size so that when household income is dropped from the regression it is still reflected in household size. This suggests that even when predicting cars per capita, income per household may be a more satisfactory determining variable.

Now, as noted above, the ordinary least squares (OLS) procedure does not allow for the possibility that car ownership and residential density are jointly determined. They may affect each other or both reflect another variable such as income or size of household. For example, income may affect car ownership directly, and indirectly through its impact on residential density. In this case, although the OLS equations may provide an adequate basis for purely predictive purposes, the coefficients are biased estimates of the parameters.

These biases can be eliminated by the two-stage least squares (TSLS) procedure, amongst others. Table 4 shows the results of using TSLS on the assumption that residential density is determined by car ownership, household income (as affluent households generally prefer more space), distance from the CBD (to reflect land prices) and household size.

As it turns out, (Equation 12), car ownership is not a very significant factor in the level of residential density (i.e. density and car ownership are not jointly determined). Accordingly, the coefficients for MINC and EMPHH do not change much between Equations 9 and 11. On the other hand, the model of joint determination expressed in Equation 11 suggests that residential density has a greater negative impact and household size and distance to rail a smaller positive impact on car ownership than does the simpler OLS model.

Table 3 - Main Car Ownership Results [a]

(t-statistics in brackets)

Equation	3	4	5	6	7	8
Dep. Var.	LCHH	LCHH	LCHH	LCHH	LCPC	LCPC
Constant	-9.20(-17.3)	-9.87(-18.7)	-10.40(-18.4)	-9.70(-16.9)	-9.20(-17.2)	-9.80(-18.7)
LMINC	0.92(15.7)	0.99(16.8)	1.10(17.2)	0.98(15.1)	0.92(15.7)	-
$LHHKM^2$	-	-0.01(-0.25)	-0.16(-3.9)	-	-	-0.01(-0.3)
LSEPDN	0.24(4.0)	-	-	-	0.23(3.9)	-
LDCBD	0.12(6.3)	0.13(5.9)	-	-	0.11(6.3)	0.13(6.0)
LDRAIL	0.06(4.2)	0.06(3.9)	0.07(4.1)	0.11(5.7)	0.06(4.2)	0.06(3.9)
LHHSIZE	0.18(2.1)	0.31(3.4)	0.53(6.2)	0.40(5.9)	-0.95(-14.5)	0.09(1.3)
LEMPHH	-0.13(-1.5)	-0.21(-2.3)	-0.42(-4.6)	-	-	-
LEMPCAP	-	-	-	-	-0.13(-1.5)	-0.21(-2.3)
LIPC	-	-	-	-	-	0.99(16.8)
R^2	.84	.83	.80	.74	.77	.75

a. L represents log.

Table 4 TSLS and OLS Results, Compared

(t-statistics in brackets)

	OLS		TSLS	
Equation	9	10	11	12
Dependent Variable	LCHH	LHH_KM^2	LCHH	LHH_KM^2
Constant	-10.4(-18.4)	0.53(0.4)	-9.7(-14.2)	-3.1(-0.9)
LMINC	1.1(17.2)	0.10(0.7)	1.04(14.3)	0.47(1.03)
$LHHKM^2$	-0.16(-3.9)	-	-0.50(-5.7)	-
LEMPH	-0.41(-4.6)	-	-0.30(1.5)	-
LHHSIZE	0.53(6.2)	-0.21(2.1)	0.27(2.3)	-0.16(-1.4)
LRAIL	0.07(4.1)	-	0.03(-2.9)	-
LCHH	-	-0.08(-0.7)	-	-0.45(-1.3)
LDCBD	-	-0.26(-7.6)	-	-0.20(-2.8)
R^2	0.79	0.48	0.72	0.45

3. CAR OWNERSHIP AND THE JOURNEY TO WORK

In our sample an average of 286 persons out of 626 per census collector district were working. Of these census data show that an average of 140 drove to work by car and 27 travelled to work as car passengers.

The factors likely to affect the mode choice for the journey to work include access to a car and to public transport and the degree of congestion on the roads. As remarked above, the latter two are correlated positively with residential density and inversely with distance from the CBD. Car usage may also be positively related to house income because cars generally save travel time (which has higher opportunity cost for high income persons), and beca parking can be expensive. Finally, other things being equ the larger the household the greater the need for the car at home. Thus all the variables employed previously are potential determinants of modal choice.

Table 5 summarises the results. All variables are in logs. LDWK is the proportion of the workforce who drive themselves to work. LTWK is the proportion who travel to work by car. Other variables are as before.

Table 5 Use of Car for the Journey to Work

(t-statistics in brackets)

Equation	13	14	15	16	17
Dependent Variable	LDWK	LDWK	LDWK	LTWK	LTWK
Constant	.39(0.3)	3.5(24.1)	1.01(0.8)	.25(8.5)	3.9(33.1)
LDCBD	.15(5.1)	.21(5.9)	.17(5.6)	.06(3.1)	.15(6.2)
LDRAIL	.03(1.2)	.04(1.6)	.02(0.8)	.07(4.3)	-
$LHHKM^2$	-	.08(3.9)	-	-	-
LCHH	.52(4.6)	.75(10.7)	.63(5.8)	-	.60(10.2)
LHHSIZE	-.52(-5.7)	-.43(-4.7)	-.52(-5.5)	-.38(-4.9)	-.47(-6.1)
LSEPDW	.06(2.9)	-.04(1.9)	-	.22(2.1)	.06(3.0)
LMINC	.35(2.7)	-	.31(2.4)	-	-
r^2	.71	.72	.70	.73	.71

The results provide strong support for the hypotheses that distance from the CBD, car ownership, household size, household income and residential density are all significant determinants of the proportion of people who drive themselves to work. Apart from the perverse signs for $HHkm^2$ and SEPDW in Equation 14, which may be explained by the multicollinearity between the variables including DCBD, all the variables are significant at the 95 per cent level and have the expected signs.

Particular attention is drawn to the coefficients (elasticities) with regard to DCBD (which varies from .15 to .21 in Equations 13 to 15), to CHH (whose elasticity varies from .54 to .75 in these equations) and to HHSIZE (whose elasticity is around -.5 in these equations). Note too that household income significantly affects the choice of mode to work (Equations 13 and 15) and that where it is dropped as in Equation 14, car ownership becomes still more important.

It is clear that if cities become more dispersed, car ownership and incomes rise and households continue to fall in size, the proportion of people driving to work will increase significantly. Because of the interactions between the variables, precise predictions are difficult. However, on the basis of these results, we believe that a one per cent increase in household income, through its impact on car ownership, household size and residential density, would increase the proportion of people driving to work by car by slightly under 1 per cent. Given that 50 per cent drove to work by car in 1976, a two per cent increase in income per household per annum would imply that some 54 per cent of the workforce was driving to work in 1981.

As shown in Equations 16 and 17 these driving to work results are confirmed by the travel to work results. However, as would be expected, the proportion travelling to work by car is more sensitive to distance to the railway than is the proportion driving to work.

4. CONCLUSIONS

This paper has provided quantitative estimates of the relationships between cars per household (and cars per capita) and income, household size, residential density and access to public transport in a large city. For example, it was shown that holding other things equal a 10 per cent increase in household size increased cars per household by 1.8 per cent, a 10 per cent increase in separate dwellings as a proportion of total dwellings increased cars per household by 2.4 per cent and a 10 per cent increase in distance from the CBD increased car ownership by 1.2 per cent. Such relationships may assist planners to forecast car ownership by district.

The paper also provided evidence for an income elasticity of around 1. In other research unpublished at this stage, we have found the income elasticity of car ownership from time series analysis to be around 0.8. When combined with the observation that some 70 per cent of households in our sample CCD had only one or no car in 1976, saturation in car ownership appears a distant prospect.

This has significant implications for the choice of mode for the journey to work which we found to be strongly related to car ownership as well as to income, residential density and household size. As a result of our findings, we predict that the proportion of persons travelling to work by car could increase from around 50 per cent in 1976 to some 54 per cent in 1981.

REFERENCES :

J. Bates with H. Gunn, M. Roberts and Martin and Vorhees Associates (1977) "A Disaggregate Model of Household Car Ownership", Departments of Environment & Transport, Research Report No. 20.

M.J. Buxton and D.G. Rhys (1972) "The Demand for Car Ownership: A Note "Scottish Journal of Political Economy", pp. 175-181.

G.C. Chow (1960) "Statistical Demand Functions for Automobiles and their Use for Forecasting" pp. 149-177 in "The Demand for Durable Goods" ed. by A.C. Herberger, Chicago University Press.

M.K. Evans (1969) "Macroeconomic Activity, Theory, Forecasting and Control", New York, Harper & Row.

M.H. Fairhurst (1975), "The Influence of Public Transport on Car Ownership", Journal of Transport Economics and Policy, Vol. IV no. 3, pp. 193-208.

T.F. Golob and L.D. Burns (1978), "Effects of Transportation Service on Automobile Ownership in an Urban Area" Transportation Research Record, 673, pp. 137-145.

J.F. Kain (1967), "Postwar Metropolitan Development: Housing Preferences & Auto Ownership", American Economic Association, Papers & Proceedings, Vol. LVII, No. 3.

R. Layard and A.A. Walters (1978), Micro Economics, McGraw-Hill Publishing Company.

G. Leitch, Chairman (1977), "Report of the Advisory Committee on Trunk Road Assessment", H.M.S.O., London.

S.R. Lerman and M. Ben-Akiva (1976), "Disaggregate Behavioural Model of Automobile Ownership", Transportation Research Record, 569, pp. 34-5.

W.Y. Oi and P.W. Shuldiner (1962), "An Analysis of Urban Travel Demands", Northwestern University Press.

A.D. Pearman and K.J. Button, 1976, "Regional Variations in Car Ownership", Applied Economics, 8, pp 231-233.

J.F. Sleeman, (1961), "The Geographical Distribution of Motor Cars in Britain", Scottish Journal of Political Economy, pp. 71-81.

J.C. Tanner, (1978), "Long-Term Forecasting of Vehicle Ownership and Road Traffic" Journal of the Royal Statistical Society, A. 141, Part 1, pp. 14-63.

H. Train (1980), "A Structured Logit Model of Auto Ownership and Auto Choice", Review of Economic Studies XLVII, pp. 357-370.