MODELLING VEHICLE OWNERSHIP AND USE IN LOW INCOME COUNTRIES

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1. INTRODUCTION

This paper examines the factors influencing the ownership of vehicles in low income countries and the use which is made of them. It is also concerned with forecasting, and this practical orientation colours the overall approach of the study. We are concerned with developing a robust framework of analysis which also permits future patterns of vehicle use and ownership to be predicted. The *raison d'être* underlying the work is very much a perception that considerably improved forecasting models of vehicle ownership and use are required for economic planning purposes in less economically developed countries. Previous work in this area has been fragmented and often case-specific.

Car ownership and use is expanding throughout the world. While much of the current expansion is in the developed world, growth in many poorer nations is, nevertheless, occurring. The implications for these latter nations are being felt in terms of pressures on road networks together with high import bills for vehicles and fuel. Since the growth in vehicle ownership is continuing hand-in-hand with rapid urbanisation, the strains are particularly severe in cities (Bayliss, 1981). Rising vehicle fleets also impose strains on the vehicle maintenance facilities available and the administrative structure required to police and regulate the road system. Road traffic also contributes significantly to local, transboundary and global environmental degradation.

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It is important for transport infrastructure planning, and for microeconomic planning more generally, that reasonable car ownership and use forecasts are available for these countries, together with robust forecasts of future commercial vehicle levels.[1] From the perspective of aid-giving agencies it is relevant to know whether similar trends in vehicle ownership occur across a range of developing countries. As these forecasts are themselves not exogenous to the planning process, it is also helpful to have indications of the main determinants of vehicle ownership, since actions to influence it become a key policy consideration.

The use to which vehicle ownership and use models are put inevitably influences their ideal form (Button, 1983). The forecasting requirements for low income countries revolve around a tractable modelling framework explaining current trends in ownership and use. Data constraints argue for simplicity. For prediction purposes, the problems of projecting forward a wide variety of independent variables argue for a narrow range of such variables and restricting them to those for which readily available forecasts exist. It is also helpful if these variables encapsulate wider changes in the national economy, such as national income, so that longer term interactions between transport and other policy areas can be evaluated.

2. PREVIOUS WORK

The traditional method of traffic modelling in developing countries has relied heavily upon assumptions concerning crude constant percentage rates of change (Hine, 1982). Systematic studies going beyond this are remarkably small in number. Macro-level studies of car ownership and use in low income countries are limited. At the macro level, the UK's Transport and Road Research Laboratory (1979) looked at car and commercial vehicle ownership for 85 developing countries using national data for 1970. There are also a number of individual, micro-level case studies of specific countries relying on survey data (for example, from Kenya by Cundill (1986a)) and a certain amount of empirical work comparing models for industrialised nations with those for less developed nations (for example, Khan and Willumsen (1986); Silberston (1970)). In addition to this, there have been studies of urban development looking at the likely implications of changes on transport demand (for example, Stopher, 1980).

The difficulties in developing models of general applicability by employing the case study approach of Cundill (1986a) and others is that the results, while extremely relevant for the country examined, may lack validity across all low income states. They do, nevertheless, provide useful guides as to appropriate methodologies to apply at the aggregate level and highlight the importance of certain key variables to include in that analysis. The aggregate work which has been completed to date, however, tends to focus

[1] The importance of appropriate transport provision in the development process has been explored by Thomas (1977). The particular importance of good car ownership and use forecasts was highlighted by Moavenzadeh and Gletner (1984) who pointed out that, in general, passenger traffic grows at two to three times that of freight traffic in developing countries.

on a narrow range of countries and to deploy relatively simple model specifications. In particular, as with Silberston (1970), Dunkerley and Hoch (1986), and Khan and Willumsen (1986), there is a tendency to rely almost exclusively upon linear, semi log-linear and log-linear regression models of vehicle ownership which ignore the well established, long-term nature of the sigmoid growth path in per capita car ownership. Additionally, from the forecasting perspective, they tend to incorporate a wide range of explanatory variables which are themselves difficult to project forward. Work at the TRRL (1979) exploring the temporal stability of the relationship between car ownership and income also found that over time the underlying relationship changes as societies become more car orientated.This result confirms theoretical arguments presented by Button *et al.* (1982) and is consistent with empirical findings in the context of developed countries (Pearman and Button, 1976).

The use made by road vehicles in low income countries is also under-researched. Linear and log-linear models estimated by Khan and Willumsen (1986) across a range of country types confirmed the importance of fuel prices but also produced rather inconclusive, and possibly contradictory, evidence on income effects.

What does emerge from this body of work is the general persistence of the relationship between car and commercial vehicle ownership and the rate of economic growth. Further, superimposed on that is the tendency for this growth rate of car ownership to fall as ownership rises. Fuel price and income are important influences on vehicle use at least in the short term.

3. THE DATA AND GENERAL TRENDS

The countries selected for study embrace the majority of nations with per capita incomes of less than US$3,000 in 1986. Excluded from the analysis are countries where data are not readily available[2] or, as in the case of small island states, it was felt that special circumstances may influence underlying causal relationships. Much of the estimation data relates to individual time series for each country dating back as far as 1967.

Per capita car ownership is used for the analysis to permit easy comparisons with other studies and also to limit the statistical problems of heteroscedasticity which can arise when employing data from countries of widely differing populations. For 'car park' forecasts (that is, the total number of vehicles in a country), per capita projections can easily be grossed up by applying forecasts of demographic changes.

General analysis of low income economies has indicated that differences exist and that grouping of countries is useful (Berlage and Terweduwe, 1988), so a number of models sub-dividing the data set are explored in our analysis. The analysis itself also provides

[2] Data on vehicle ownership across low income countries is variable in its quality. The main data series employed in this study draw upon published sources for various years supplied in publications of the World Bank, the International Monetary Fund, the United Kingdom Society of Motor Manufacturers and Traders, the United States Department of Energy, and the International Road Federation. This is supplemented, especially at the case study level, by data drawn from a variety of specific analyses of trends in transport in low income countries.

support for the stratification adopted.[3] Using data for the period 1968-87, upon which the subsequent models are based, the countries are grouped into five categories:

(A) less than 0.002 cars per person;
(B) less than 0.01 cars per person but more than 0.002 and a per capita GNP of less than $450;
(C) less than 0.01 cars per person but more than 0.002 and a per capita GNP of more than $450;
(D) less than 0.02 cars per person but more than 0.01;
(E) more than 0.02 cars per person.

4 THE CAR OWNERSHIP MODEL

The slow growth in car ownership observed in the lowest income countries, together with the more rapid rises in those countries which exhibit both higher existing levels of car ownership and of per capita income, suggests the use of a non-linear forecasting framework. Since ultimately there are likely to be limits, albeit possibly flexible ones (see Button *et al.*, 1982), to the number of cars per person, the standard approach is to adopt a sigmoid function. A variety of sigmoid functions could be applied. Here the main modelling thrust employs the quasi-logistic (or 'log-odds') approach which has been extensively used for forecasting in industrialised countries. It has also proved useful in earlier work on less developed countries (Cundill, 1986a).

Taking P as the aggregate ratio of total registered vehicles to population, S as the ultimate saturation level of car ownership per capita, X_1, X_2, ... X_n as a set of socio-economic influences on ownership and a, b_1, b_2, ... b_n as parameters, then the model can be depicted as:

$$P = \frac{S}{1 + e^{-a} X_1^{-b1} X_2^{-b2} \ldots X_n^{-bn}} \tag{1}$$

Manipulating and converting equation (1) into natural logarithmic form yields:

$$\ln\left(\frac{P}{S-P}\right) = a + b_1 \ln X_1 + b_2 \ln X_2 + \ldots + b_n \ln X_n \tag{2}$$

The saturation level may be treated in three ways: as a firm, long-term probable maximum level of cars per capita; as a short-term maximum level of car ownership given existing constraints and conditions; and as a statistical parameter necessary in a forecasting model (Button *et al.*, 1982; Button, 1987). Given data limitations and the considerable distance of most low income countries from the saturation estimates postulated for

[3] Graphical examination of the basic data indicates (Button and Ngoe, 1991) that countries in categories A and B, those with very low current levels of car ownership and also low incomes, have experienced very limited growth in their car ownership per capita since the mid-1960s. In contrast, those countries which already had a somewhat higher level of per capita car ownership, and generally income, have also experienced a relatively rapid increase in the level of their per capita ownership. The implications of this for the transport systems and the environments of countries in groups C, D and E is compounded when it is remembered that not only are their per capita car ownership rates growing but also their populations.

industrialised countries, the third approach is adopted here. The saturation level is seen as a technical aid to improving the quality of the ultimate forecasts generated.

Evidence from the UK and other industrialised countries indicates an ultimate per capita saturation level of between 0.4 and 0.7 (see Mogridge, 1983). Before adopting these or similar figures, it should be noted that there is considerable evidence that different countries, and indeed regions within countries, seem ultimately to be heading for different saturation levels (Button *et al.*, 1982).

In arriving at a figure for saturation, an examination was conducted along the lines of that on UK car ownership by Tanner (1962 and 1978) . This sought to examine the data over time to see if there is any discernible slowing down in the growth of per capita car ownership and the point at which growth ceases. Specifically, per capita car ownership for each country was plotted against annual changes in per capita car ownership between 1967 and 1987. The point where the resultant relationship cuts the P axis (that is, where there is no change in car ownership levels) provides a general indication of the saturation level.[4]

The implied saturation level suggested by the resultant plots for each of the five categories of country are low compared to those used in models for industrialised countries, with a maximum saturation level of about 0.25 cars per capita emerging.[5] Further, the implied saturation level increases as one moves from country group A through to country group E. Indeed, incorporating countries with somewhat higher income levels (up to US$4,000 in 1986) suggests that saturation may be at a somewhat higher level - about 0.4 cars per capita. There is also a high degree of volatility in the observations for the lowest income countries which seems to reflect as much upon the quality of the data for these countries as the actual levels and changes in vehicle ownership. When modelling car ownership for the five groups of countries various saturation levels are, therefore, adopted. Since the ultimate saturation level is some distance away, especially in the lowest income countries, the level of uncertainty involved in estimating long-run saturation is large. Therefore, levels in the range 0.3 to 0.45 cars per capita are assumed for S and estimations of other parameters, together with subsequent forecasts, are based upon this range. To test the robustness of the results to the saturation level employed, a series of parallel log-linear regressions were performed where no saturation level is assumed.

As pointed out above, there are reasons to suppose that the relationship between car ownership and major causal variables is not stable through time. This is consistent with the finding, based on a large sample of developing countries, of a shift in the linear relationship between per capita car ownership and per capita GNP in 1965 and 1973 (TRRL, 1979).[6] This phenomenon is not unique to developing countries and in industrialised countries it has been explained in terms of the greater car orientation of younger

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4 Strictly, the approach adopted by Tanner assumes a slightly different cumulative sigmoid growth path in per capita car ownership. His underlying model is of the form $P = S/[1 + be^{(-aST)}]$ where T is time. For our purposes, which are to gain a general idea of possible saturation, the framework offers a useful starting point.

5 For a full set of calculations see Button and Ngoe (1991).

6 The TRRL regression shifted from $C/P1965 = -0.93 + 0.03GNP$ to $C/P1973 = -2.20 + 0.05GNP$ using similar notation to our analysis. Such shifts are also supported in a series of cross-sectional calculations on a wide range of low income countries for 1967, 1973 and 1983 (Button and Ngoe, 1991).

generations as they move through the age spectrum (Burrell, 1972). There is also likely to be something of a demonstration effect in low income countries as over time their populations attempt to emulate the consumption patterns of industrialised nations. In technical terms it suggests that some variable is being omitted from the analysis. In order to capture part of its effect, however, a time trend (T) is included in the models used here (with $T = 1$ for 1967). Given the specification of the quasi-logistic model, this in itself poses difficulties since the parameter associated with time will be sensitive to the base year selected. In a forecasting context, the usefulness of the base year chosen, therefore, depends upon the overall explanatory power of the model specification. Equally, the alternatives of either specifying a more complex time function or adopting a linear trend in the exponential formulation pose their own difficulties. Some sensitivity analyses to the assumption made were, therefore, conducted.

Cross-sectionally, countries vary in many ways which are impossible to quantify. In order to allow for these local features a set of dummy variables (c), one for each country, is included in the model. These take the values of unity if an observation relates to a country and zero otherwise. They are specified so that the error term varies across countries.

Having taken these factors into account, the resulting pooled equations relate per capita car ownership for all k countries in the data set, and for all years, to the GDP of the countries at constant prices (Y), the vector of country-specific dummy variables (c_k) , and a time trend (T):

$$P = \frac{S}{1 + e^{-(a + \Sigma\delta_k c_k)} Y^{-b} T^{-t}} \tag{3}$$

The operational form of the model becomes:-

$$\ln\left(\frac{P}{S - P}\right) = a + b\ln Y + \Sigma\delta_k c_k + t\ln T \tag{4}$$

where S takes a value between 0.3 and 0.45.

In addition to this, and to test the sensitivity of the model to both the importance of the saturation level and the nature of the time trend adopted, a log-linear regression with a linear time trend of the following form was also developed:

$$P = e^{(a + \Sigma\delta_k c_k)} Y^b e^{tT} \tag{5}$$

Multiple least-squares regression is used for estimation. The quality of the data suggests that more sophisticated techniques would add little to the usefulness of the results although the use of per capita based variables does reduce potential problems of heteroscedasticity which may accompany the wide variations in countries' populations. The main independent variable influencing per capita vehicle ownership at the national level is income. Additional variables which may influence vehicle ownership include the price of fuel, the level of urbanisation and the degree of industrialisation. The importance of such variables is explored, but there are inevitable problems of multicollinearity. The basic equation for the quasi-logistic model then extends to

$$P = \frac{S}{1 + e^{-(a + \Sigma\delta_k c_k)} Y^{-b} \Pi V_1^{-u_1} T^t}$$

TABLE 1

Regression Coefficients for Log-Linear and Quasi-Logistic Models

Country Grouping	*Constant (a)*	*Income (b)*	*Time (t)*	*Assumed Saturation Level*	*Adjusted Coefficient of Multiple Determination*
		Log-Linear Specification			
A	-9.42	0.532 (0.199)	0.015 (0.004)	–	0.84
B	-9.22	0.730 (0.075)	0.013 (0.002)	–	0.89
C	-10.28	0.881 (0.063)	0.015 (0.003)	–	0.83
D	-12.09	1.124 (0.110)	0.038 (0.003)	–	0.79
E	-9.60	0.952 (0.089)	0.032 (0.002)	–	0.92
		Quasi-Logistic Specification			
A	-8.70	0.571 (0.191)	0.109 (0.026)	0.30	0.84
B	-8.24	0.699 (0.076)	0.103 (0.015)	0.35	0.90
C	-9.83	0.943 (0.066)	0.088 (0.000)	0.35	0.82
D	-11.80	1.100 (0.138)	0.261 (0.032)	0.40	0.67
E	-10.74	1.160 (0.112)	0.244 (0.023)	0.45	0.90

where V_1 is the matrix of additional variables and u_1 the associated vector of coefficients.

The income variable employed is adjusted to 1980 prices. Current real income levels are used. While there are theoretical reasons to anticipate a time lag between a change in income and its effect on vehicle ownership, specification of this relationship is difficult (Tanner, 1983b) and poses problems for the ultimate forecasting of future ownership levels.

Using per capita income in the pooled log-linear and quasi-logistic models for the five categories of low income countries confirms the importance of income. The results are set out in Table 1 (excluding the set of values for the country-specific dummy variables). The explanatory power of all the models is high, the coefficients are significant and all coefficients take the expected sign. Further, comparisons between the quasi-logistic models and the log-linear model indicate a considerable degree of similarity. This suggests that the saturation levels adopted are unlikely to be dominating the quasi-logistic results.

The income coefficients derived from the log-linear specification offer direct estimates of income elasticities.[7] In general, the size of the income elasticity increases as one

[7] These elasticities are somewhat lower than the E_d 1.65 found by Dunkerley and Hoch (1986) in their study although they do admit their "... income elasticities are higher than other, rather sparse results reported in the literature for the transport sector of developing countries."

TABLE 2

Country Dummies for Quasi-Logistic Models

Group A		*Group B*		*Group C*		*Group D*		*Group E*	
Ethiopia	0.464	Malawi	–0.564	Liberia	0.156	Zambia	0.910	Morocco	–0.271
Burkina Faso	0.337	Zaire	–0.351	Indonesia	–0.436	Dominican Rep.	0.420	Zimbabwe	0.059
Bangladesh	–0.910	Madagascar	0.085	Philippines	0.046	Côte d'Ivoire	0.320	Mauritius	–0.544
Burundi	0.134	Uganda	–1.950	Papua N.G.	–0.501	El Salvador	0.755	Chile	–1.033
Burma	0.248	Tanzania	–0.653	Honduras	–0.230	Peru	0.995	Costa Rica	–0.870
India	0.000	Togo	–0.041	Thailand	0.000	Turkey	0.000	Brazil	0.000
Rwanda	–0.123	Niger	–1.040	Botswana	–0.435	Tunisia	0.720	Malaysia	–0.280
		Benin	–0.148	Cameroon	–0.296	Colombia	0.630	S. Africa	–0.150
		Kenya	0.000	Paraguay	–0.420	Jordan	0.875	Mexico	–0.712
		Sierra Leone	0.420	Syria	–0.745	Algeria	0.141	Uruguay	–0.520
		Haiti	–0.110			Gabon	–0.720	Hungary	0.030
		Pakistan	–0.473					Portugal	0.380
		Ghana	–1.060					Yugoslavia	0.063
		Sri Lanka	0.603					Panama	–0.310
		Senegal	0.399					Argentina	–0.660

moves through the five categories of country which proxy position in the economic development process. The indication, therefore, is that car ownership becomes more sensitive to income as income and car ownership increase. This is the opposite result to that of Tanner (1983a) in relation to mainly industrialised countries. It can be explained, however, by the fact that low income countries are at the beginning of their sigmoid growth path with each of the five groups somewhat further along it. Hence each successive group becomes more sensitive to income effects as they are further up the steep portion of the curve. In contrast, industrialised countries are nearer to their saturation level and thus become less sensitive to income changes as they reach the more horizontal portion of their curve.

The log-linear equations, because they have no saturation level, are constant elasticity models. They assume that income elasticities are the same at all levels of income. While it is often useful to have an indication of the sensitivity of car ownership to income changes, and for forecasting purposes it is acceptable to assume constancy of the elasticities over a limited income range, for longer term forecasting a less rigid model is needed which makes allowances for movement towards a saturation level. The quasi-logistic curve is preferred for that reason.

Table 2 provides details of the coefficients associated with the c_k variable in the quasi-logistic specification. These indicate the degree to which the quasi-logistic relationship differs between countries. For forecasting purposes, in predicting for any individual country the appropriate dummy is added to the constant term in the quasi-logistic model.

TABLE 3

Coefficients of Dummy Variables Associated with Car Use

Country	Coefficient	Country	Coefficient	Country	Coefficient
South Korea	0.000	Indonesia	1.602	Jordan	1.570
Malawi	1.754	Cameroon	0.495	Hungary	0.430
Rwanda	1.285	Turkey	1.609	Yugoslavia	0.760
Kenya	1.238	Tunisia	0.192	Argentina	–0.087
Sierra Leone	2.035	Colombia	0.528	Greece	0.261
Senegal	1.533	Chile	0.350		

The quasi-logistic equations set out in Table 1 include a time variable as well as an income variable (with $T = 1$ in year 1967). The time variable proves, in both the log-linear and quasi-logistic specifications, to be statistically significant at the 5 per cent level and exerts a positive effect on car ownership; that is, it conforms to the empirical findings of earlier TRRL (1979) work and to the linear cross-section results cited above.

The implication of the quasi-logistic specification is that the time trend effect (of increasing car ownership for each income level) appears to diminish over time. This diminution is a consequence of the model specification, it is not derived from any particular characteristic of the data. The nature of the specification was selected for purely statistical reasons, that is, to provide a good fit to the historic data, and the results are sensitive to the year chosen to be set equal to unity.

Jacobs and Fouracre (1974), Stopher (1980) and Thomson (1983) generally, and Spencer and Madhavan (1989), in the specific context of Asia, and Barrett (1986), in the context of Africa, have highlighted the fact that much of the growth in car ownership in developing countries occurs in urban areas. This contrasts with the situation in most industrialised countries where availability of better public transport and the imposition of traffic restraint measures has tended to lead to relatively more rapid growth away from urban concentrations (Mogridge, 1983). In terms of the percentage of population living in urban areas, however, the statistical analysis of low income countries reveals no consistent overall relationship with per capita car ownership. What one does find, however, is that for many individual countries there does seem to exist a positive, linear relationship between car ownership and level of urbanisation (Button and Ngoe, 1991).

5. CAR USAGE

Car use depends primarily on the level of car ownership although other factors, such as income, the price of fuel, the degree of urbanisation and the extent of the road network may

also be important. The modelling framework adopted to capture the effects of these additional variables, and also to reflect the non-linearity of the underlying relationships found in previous work on the topic in developed countries, is that developed by Tanner (1983a):

$$Km/V = e^{(K + \Sigma\delta_k c_k + aT + bT^2)} GDP^c \Pi FL_j^{d_j} \quad (6)$$

where, Km/V represents kilometres per vehicle, T is a time trend, GDP is gross domestic product per capita and FL is the price of fuel type j (per 100 litres), all values being in 1980 constant price Special Drawing Rights (SDRs). For estimation purposes, the model is linearised as:

$$\ln(Km/V) = K + aT + bT^2 + \sum\delta_k c_k + c\ln GDP + \sum d_j \ln FL_j \quad (7)$$

Since the distinction between cars and commercial vehicles is sometimes obscure in official data, and also because some countries have a sizeable diesel car fleet, the subsequent analysis distinguishes between gasoline price and diesel price. Additionally, a number of other variables, such as the length of the national road network, relative diesel/petrol prices and the size of the car park are also incorporated in the analysis. Finally, country-specific dummy variables are included to reflect unspecified spatial effects.

Data limitations prevent the full range of countries being used for estimation purposes, - data from seventeen states being employed. The resultant regression coefficients (excluding the country dummies) are set out below.

$$KM/V = e^{(4.144 + \Sigma\delta_k c_k + 0.010T + 0.002T^{-2})} GDP^{0.713} PP^{-0.261} DP^{-0.074} CP^{-0.290} \quad (8)$$

$$\text{Adj.}R^2 = 0.897$$

where c_k is the regression dummy for country k, T is a time trend with $T = 1$ in 1967, GDP is per capita GDP (in SDRs) at 1980 prices, PP and DP are petrol and diesel prices in SDRs per 100 litres and CP is cars per capita. The signs of all coefficients correspond to expectation and are statistically significant at the 5 per cent level.

The coefficients relating to the national dummies are shown in Table 3.

6. COMMERCIAL VEHICLES

Commercial vehicles embrace goods vehicles and buses. The latter are highly dependent upon local conditions, urban public transport policies and regulations (Case and Latchford, 1981). Modelling and forecasting at the aggregate level is, therefore, unlikely to yield useful results, so the focus is on commercial goods vehicles.

Freight vehicle numbers are almost inevitably determined by the level of economic activity in a country. In consequence, log-linear regression analysis relating commercial vehicle numbers per capita (CV/P) to the Gross Domestic Product per capita (GDP) forms the foundation for modelling in this area although examinations were also made of other economic variables such as levels of urbanisation, length of road network, and so on. Given the different nature of goods vehicles in Sub-Saharan African (SA), Asian (AS) and Latin American (LA) countries the data is divided along Continental lines. The differences stem from, for instance, the greater use of smaller vehicles in many Asian

TABLE 4

Coefficients of Dummy Variables Associated with Commercial Goods Vehicle Ownership

Sub-Saharan Africa		Asia		Latin America	
Country	Coefficient	Country	Coefficient	Country	Coefficient
Ethiopia	–1.916	Pakistan	0.193	El Salvador	1.042
Burkina Faso	–0.523	Indonesia	0.316	Paraguay	–0.058
Malawi	–0.373	Philippines	0.958	Peru	0.721
Zaire	–0.313	Thailand	0.839	Colombia	–0.544
Burundi	–1.808	India	0.000	Chile	–0.166
Tanzania	–0.731			Costa Rica	0.354
Niger	–0.970			Mexico	–0.207
Benin	–0.320			Panama	–0.054
Rwanda	–1.212			Argentina	–0.319
Senegal	–0.573			Brazil	0.000
Côte d'Ivoire	–0.543				
Botswana	0.156				
Cameroon	–0.616				
Kenya	0.000				

TABLE 5

Coefficients of Dummy Variables Associated with Commercial Goods Vehicle Use

Country	*Coefficient*	*Country*	*Coefficient*	*Country*	*Coefficient*
South Korea	0.000	Indonesia	1.711	Jordan	0.738
Malawi	1.499	Cameroon	1.159	Hungary	–0.190
India	1.789	Turkey	1.492	Yugoslavia	0.631
Kenya	1.947	Tunisia	–0.270	Argentina	–1.588
Sierra Leone	1.922	Colombia	0.994	Greece	–0.012
Senegal	1.500	Chile	0.033		

countries than in Africa or South America and the greater flexibility in supply likely to be associated with this. Again dummy variables are included in each set of estimations to reflect particular national differences. The results, excluding the dummy variable coefficients which are set out in Table 4, are:

$$CV/P_{SA} = e^{(-10.019 + \Sigma\delta_{kc}k)} GDP^{0.841} T^{0.013} \qquad \text{Adj. } R2 = 0.960 \qquad (9a)$$

$$CV/P_{AS} = e^{(-15.077 + \Sigma\delta_{kc}k)} GDP^{1.500} T^{0.012} \qquad \text{Adj. } R2 = 0.970 \qquad (9b)$$

$$CV/P_{LA} = e^{(-14.376 + \Sigma\delta_{kc}k)} GDP^{1.406} T^{0.028} \qquad \text{Adj. } R^2 = 0.941 \qquad (9c)$$

All the coefficients in equations 9(a) to 9(c) are significant at the 5 per cent level. The elasticity of commercial goods vehicle numbers with respect to *GDP* is relatively high. Further, the higher elasticity associated with Asian countries is in line with *a priori* expectations.

The growth in freight traffic of most countries is closely related to the macro-economic performance of those countries (for example, as measured by gross domestic product), availability of complementary infrastructure (for example, road length) and the cost of freight transport (for example, as indicated by fuel prices). Each low income country, however, also has its own particular characteristics. These are encapsulated by incorporating dummy variables in the analysis. Data limitations restrict analysis of truck use to 17 low income countries. Log-linear regression analysis is used to determine factors influencing variations in the annual kilometres travelled by goods vehicles. Equation (10) provides details of the key coefficients with the dummy variable coefficients set out in Table 5.

$$KM/V = e^{(8.26 + \Sigma\delta_{kc}k - 0.017T)} GDP^{0.519} DP^{-0.134} RL^{-0.166} \qquad \text{Adj.} R2 = 0.932 \qquad (10)$$

The notation is as before with the addition that *RL* represents road length in kilometres. The elasticities with respect to both diesel fuel price and gross domestic product are of the expected sign and are statistically significant at the 5 per cent level. The diesel fuel elasticity shows that a 1 per cent rise in its price reduces the use of a goods vehicle by 0.134 per cent. Similarly, for forecasting purposes, a 1 per cent rise in GDP results in a 0.51 per cent increase in kilometres per vehicle. The road length coefficient implies vehicle use falls with infrastructure availability; it is not, however, statistically significant (the associated standard error being 0.337). This result may stem as much from the quality of the data available and the consistency of definitions used as from the lack of any genuine underlying relationship.

7. SAMPLE FORECASTS OF CAR OWNERSHIP

Since the issue under discussion is centred on the development of a tractable forecasting framework for vehicle ownership and use, it is perhaps relevant to provide a few simple forecasts. These are for a number of representative countries and based upon general assumptions regarding trends in key independent variables. Where country-specific

TABLE 6

Car Park Forecasts for Selected Countries

Country	*Assumed Annual Rate of Per Capita Income Growth (%)*	*Index of Total National Car Park (1986 = 100)*		
		1986	*2000*	*2025*
Burkina Faso	1.0	100	143	286
	4.0	100	183	394
Rwanda	1.0	100	177	499
	4.0	100	224	951
Togo	1.0	100	149	335
	4.0	100	205	751
Haiti	1.0	100	96	161
	4.0	100	128	351
Pakistan	1.0	100	148	340
	4.0	100	196	739
Cameroon	1.0	100	162	440
	4.0	100	255	1309
Gabon	1.0	100	215	632
	4.0	100	355	1922
Algeria	1.0	100	141	341
	4.0	100	232	1000
Mauritius	1.0	100	146	209
	4.0	100	219	544
Malaysia	1.0	100	149	284
	4.0	100	216	628

predictions of the independent variables are available these would form a more robust input into the forecasting exercise.

Given the models set out above, forecasting vehicle use is essentially a matter of deploying the appropriate elasticities developed therein. This also holds true for commercial vehicle numbers. The elasticities provide guides as to the responsiveness of vehicle use to changes in the key determining variables. The forecasting of vehicle ownership is of rather more long-term importance in the context of low income countries. Ultimately this determines the strains which will be put on nations' infrastructure and the effects of traffic on the environment, including the global environment.

This type of forecasting exercise involves the implementation of the developed model and feeding into it predicted values of the independent variables. For practical reasons we focus on forecasts for a selection of countries from our list. The major exogenous variable in all forms of vehicle ownership forecasting is income. This is itself, however, difficult

to forecast even for a short period. Bodies such as the World Bank[8], Asian Development Bank, and others, provide periodic forecasts of growth rates for low income countries but, because they are regularly up-dated and modified, no single projection represents a stable input for transport forecasting purposes.

The approach adopted here is to employ sensitivity analysis and to offer a range of projections of future growth in per capita car and commercial vehicle ownership and use based upon alternative scenarios of how income may change in the future. The assumed rates of growth in per capita income are: 0, 1, 2, 3 and 4 per cent. These cover the range of predictions made by the major international institutions in recent years. From the results for a selection of countries the overall picture which emerges is that even on fairly conservative assumptions regarding income growth, many low income countries in our groups C, D, and E will experience very considerable growth in per capita car ownership in the medium term. The very poorest countries, using similar assumptions regarding income growth, will have much less dramatic rises in per capita car ownership.

In terms of national car parks, projections of population levels need to be applied to the national per capita car ownership forecasts. In aggregate terms, given the often very rapid upward trend in the populations of low income countries, this application has a magnifying effect. Demographic forecasting for low income countries is as difficult as car ownership forecasting and a variety of forecasts could be adopted. Here we use World Bank predictions of populations for the years 2000 and 2025 to provide a feel for the actual implications for the transport systems of the growth in vehicle numbers. The results of applying these projections to our models produce the car ownership forecasts, with 1986 as a base, for selected countries shown in Table 6.

As can be seen, the countries with relatively high car ownership levels at present can expect fairly rapid increases in their parks even if their income rises by quite modest amounts (that is, 1 per cent per capita per annum) in the medium term. A substantial part of this trend comes from the projected increase in population levels which, in some cases, exert a stronger influence on the car park forecasts than does the predicted rise in per capita ownership. The projected tripling of the population of Gabon by the year 2025 and a more than tripling of the population of Rwanda are examples of the importance of the demographic factor in national car park forecasting.

While presenting the sample forecasts in index form offers insights into differing growth rates, this tends to obscure the actual magnitude of the pattern which emerges. If one makes the relatively conservative assumption of a 1 per cent annual growth in per capita income to the year 2000, for example, Malaysia will have an extra 0.59 million cars, while if annual income per capita rises by 4 per cent, slightly above the Asian Development Bank's prediction, it will have 1.63 million extra cars. On the same basis, the Cameroon would find its car park rising from 0.09 million vehicles to 0.14, on an assumed 1 per cent rise in annual income and to 0.22 million on an assumed rise of 4 per cent in annual income. These are very significant numbers of cars to absorb.

8 For example, the World Bank (1984) indicates an annual per capita GDP growth of between 2.0 per cent and 2.3 per cent to the end of the century.

8. CONCLUSIONS

A simple examination of trends over the past twenty years clearly shows the rapid increase in car ownership which is emerging in many low income countries as their prosperity gradually begins to grow. While at the lowest income per capita vehicle ownership is static or falling, at higher income levels it appears to be following the classic sigmoid-shaped growth path which has been observed in industrial states. The increase in the overall car park moves ahead of the rate of increase in per capita car ownership as populations expand.

Surprisingly little detailed study has been made of the exact nature of the underlying relationships influencing both vehicle numbers and their use in low income countries. One of the major difficulties in this type of work is to establish a reliable and consistent data base. This has been attempted here, although it is clear that deficiencies exist in both the extent and quality of the data employed. A major step forward would be achieved if data sources were both more reliable and more consistent.

Given the data limitations, the study has generated results which are intuitively reasonable and cross-reference well with the limited work conducted elsewhere. It indicates that as low income countries become more prosperous there is an inevitable and rapid rise in their car ownership and use. Commercial goods vehicle numbers also rise. Reinforcing this income effect is a separate temporal effect as car ownership levels at any given level of income rise over time. This may result from a variety of factors and is not fully understood but, from a forecasting and transport planning perspective, it inevitably adds to the ultimate growth in traffic volume.

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