

Contractor Report 278

**Transport and Road
Research Laboratory**

Department of Transport

**Vehicle ownership and use forecasting
in low income countries**

**by K Button and N Ngoe
(Loughborough University)**

C



Transport and Road Research Laboratory
Old Wokingham Road
Crowthorne Berkshire RG11 6AU
Telephone 0344 773131
Fax 0344 770356 Telex 848272

Digest of Contractor Report 278

1991

Vehicle Ownership and Use Forecasting in Low Income Countries

by

Kenneth Button (Professor of Applied Economics and Transport)

and

Ndoh Ngoe (Research Associate)

Applied Microeconomics Research Group Department of Economics Loughborough University

This study is a macro-level analysis of trends in road vehicle ownership and use in low income countries (i.e. those with GNP per capita of less than \$ 3,000 in 1986). Initially a suitable data base is developed from published sources, and set against the background of previous work in the area. There is then an analysis of the main determinants of car ownership and use followed by medium term forecasts of ownership and use trends in selected countries.

The data base covers the period from 1966 to 1987 and relates to all countries within the given income bands save for both those where insufficient data exists and small island states. The countries are categorised into five main groupings according to income levels and base car ownership levels. A different ultimate saturation level of car ownership is taken for each category.

The analysis of car ownership patterns is based upon well established log-linear and quasi-logistic modelling techniques to encompass non-linearities in the key relationship between vehicle ownership and income levels. Incorporated in the models are parameters reflecting time trends, levels of urbanisation and labour force participation levels in addition to per capita income. Further, country specific dummy variables are deployed to capture nation specific effects. While a variety of variables was explored in terms of explaining levels of car usage, a time trend, GDP and fuel prices provided the most statistically significant set.

Similar exercises relating to commercial vehicles highlight the significance of a log-linear relationship between vehicle ownership and GDP and a time trend. Different coefficients, however, are appropriate for countries respectively in Sub-Saharan Africa, Asia and Latin America. Commercial vehicle use is seen to be principally influenced by GDP, the price of diesel fuel and the availability of road infrastructure.

Fuel use was modelled for only a small sub-set of the countries involved because of data constraints. The model, of a log-linear form, indicates a positive relationship between annual diesel fuel sales and the size of the commercial vehicle fleet while petrol consumption is related to the total car population and the price of petrol.

The various models permit the estimation of a number of key elasticities. In terms of car ownership, the income elasticities of demand range from 0.53 to 1.12 according to the broad category of country involved. The income elasticity associated with car use is found to be 0.71 while that with respect to fuel prices is -0.26. National levels of commercial vehicle ownership exhibit income elasticities ranging from 0.84 for Sub-Saharan African countries to 1.5 for Asian countries. Commercial vehicle use has elasticities of -0.13 and 0.51 with respect to diesel fuel prices and GDP respectively. Regarding fuel, the



Department of Transport

elasticity of aggregate diesel fuel consumption with respect to the size of the commercial fleet is 1.06 and elasticities of national petrol consumption with respect to petrol price and the size of the national car population are 0.01 and 0.8 respectively (although the former is not statistically significant).

Combining the parameters from various pooled models of vehicle ownership and use with projections of future values of the independent variables permits medium term forecasts to be developed. Making a range of assumptions regarding future annual growth rates of per capita income in the range 0% to 4% and applying World Bank demographic predictions for the years 2000 and 2025 a set of alternative scenarios is explored.

In broad terms what emerges is that there is likely to be a considerable upsurge in vehicle numbers in countries which already have relatively high levels of car ownership even if their incomes rise by only a modest amount in the medium term. In contrast, countries which at present have low levels of vehicle ownership, and which are generally the poorest as well, will experience only modest increase in their car population.

The authors of this Digest are employed by Loughborough University. The work reported herein was carried out under a contract from the Transport and Road Research Laboratory. The work forms part of the programme carried out by the Overseas Unit of TRRL for the Overseas Development Administration. The views expressed are not necessarily those of the Administration or the Department of Transport.

If this information is insufficient for your needs a copy of the full Report may be obtained, free of charge, (pre-paid by the Overseas Development Administration) on written request to the Technical Information and Library Services, Transport and Road Research Laboratory, Old Wokingham Road, Crowthorne, Berkshire.

Copyright Controller of HMSO 1991. The views expressed in this digest are not necessarily those of the Department of Transport. Extracts from the text may be reproduced, except for commercial purposes, provided the source is acknowledged.

TRANSPORT AND ROAD RESEARCH LABORATORY
Department of Transport



Contractor Report 278

VEHICLE OWNERSHIP AND USE FORECASTING IN LOW INCOME COUNTRIES

by K Button and N Ngoe
(Loughborough University)

The work reported herein was carried out under a contract placed on Loughborough University by the Transport and Road Research Laboratory. The research customer for this work is the Overseas Development Administration.

This report, like others in the series, is reproduced with the authors' own text and illustrations. No attempt has been made to prepare a standardised format or style of presentation.

Copyright Controller of HMSO 1991. The views expressed in this Report are not necessarily those of the Department of Transport. Extracts from the text may be reproduced, except for commercial purposes, provided the source is acknowledged.

Overseas Unit
Transport and Road Research Laboratory
Old Wokingham Road
Crowthorne, Berkshire RG11 6AU

1991

ISSN 0266-7045

**Vehicle Ownership and Use Forecasting
in Low Income Countries**

Kenneth Button
(Professor of Applied Economics and Transport)
and
Ndoh Ngoe
(Research Associate)
Applied Microeconomics Research Group
Department of Economics
Loughborough University
Loughborough
LE11 3TU

ABSTRACT

This study analyses trends in road vehicle ownership and use in low income countries (i.e. those with GNP of less than US\$3,000 per capita in 1986). It develops a suitable data base from published sources and, set against the background of previous work in the area, analyses the main determinants of car ownership and use.

The analysis is based upon established quasi-logistic modelling techniques to encompass non-linearities in the key relationship between vehicle ownership and income levels. A similar exercise is conducted for commercial vehicles. This analysis then forms the basis for forecasting future, medium term trends in vehicle numbers.

Additionally, for a limited number of countries, an analysis of the fuel consumption of the transport sector is conducted linking this to both the price of fuel and the growth in vehicle stocks.

1 INTRODUCTION

Car ownership and use is, in general, expanding throughout the world. Growth in the many poorer nations, while in absolute terms not on a scale to be found in the industrialized states, is, nevertheless occurring albeit at variable rates. There are, however, exceptions to this and in some instances, such as many African countries, the poor state of the national economies has resulted in slow or even declines in per capita car ownership over recent years. This, for example, has occurred in Madagascar, Malawi and Ethiopia between 1966 and 1988.

The implications for those nations where growth is taking place are being felt in terms of pressures on the national road networks together with high import bills for both vehicles and fuel. Since the growth in vehicle ownership is continuing hand-in-hand with rapid urbanization, 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 transport system. Since there are similar growth trends in commercial vehicle numbers and use, questions of road maintenance are compounded.

In this context, it is important for both transport infrastructure planning and for economic planning more generally to have reasonable car ownership and use forecasts together with robust forecasts of future commercial vehicle levels. From the perspective of aid giving agencies it is relevant to know whether similar trends in vehicle ownership patterns occur across a range of developing countries. Equally, in the sense that these forecasts are themselves not exogenous from the planning process, it is helpful to have

indications of the main determinants of vehicle ownership should actions to influence it become a policy consideration.

The use to which vehicle ownership and use models are put inevitably influence their ideal form (Button 1983). The forecasting requirements in the circumstances of low income countries revolve around the development of a tractable modelling framework explaining current trends in ownership and use. Data constraints argue for simplicity at this stage. For prediction purposes, the problems of projecting forward a wide variety of independent variables argues for a narrow range of such variables and restricting them to those variables 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 and forecasting in developing countries has relied heavily upon assumptions concerning crude constant percentage rates of change (Hine 1982). Systematic studies are small in number. Where they do exist, however, they provide both useful insights into earlier methods of analysis and act as comparative reference points for the findings of this study.

Macro studies of car ownership and use in low income countries are limited. The Transport and Road Research Laboratory (1979) looked at car and commercial vehicle ownership for 85 developing countries using national data for 1970 as the basis for a multiple regression model. There are also a number of individual, micro level case studies of specific countries relying on survey data - e.g. Cundill (1986a) on Kenya - and a certain amount of empirical work comparing models for industrialized with those for less developed nations (e.g. Khan and Willumsen 1986 and Silberston 1970). In addition to this, there have been studies -e.g. of the kind conducted by Stopher (1980) - of urban development looking at the likely implications of specific changes on transport demand.

However, the number of up-to-date analyses across low income countries is very small. Additionally, the number of models developed explicitly for forecasting purposes represents only a limited subset of these studies. In part this situation is explained by data limitations and the generally acknowledged difficulties of vehicle ownership and use forecasting even when a reliable set of base data is available.

The difficulties of developing models of widespread applicability employing the case study approach of Cundill(1986a) and others is that the results, while extremely relevant for the country examined, may lack general validity across all low income states. What they do, however, is to provide useful guide-lines as to appropriate methodologies to apply at the more aggregate level of analysis and to highlight the importance of certain key variables to include in that analysis.

Cundill's (1986a) work, in particular, also demonstrates that the basic modelling approaches developed in more industrialized economies can be applied, with suitable modifications, to low income countries. In this instance the usefulness of the household based quasi-logistic framework proved extremely robust when applied to disaggregate Kenyan survey data.

The more aggregate work which has been completed to date tends to focus on a narrow range of countries and to deploy relatively simple model specifications. In particular, as with Silberston (1970) 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.

The importance of economic growth measured, for example, in terms of gross domestic (or national) product per capita, emerges as the key variable from such models. Indeed, in Khan and Willumsen's (1986) work it was the only statistically significant variable in all but one equation specification they tested (the level of purchase tax also proved significant in a single equation). Similarly, gross national product per capita was found to be the most statistically significant variable in the cross-sectional, international study conducted by the Transport and Road Research Laboratory (1979) and of a cross-section using 1964 data of free market and centrally planned countries by Silberston (1970).

The Transport and Road Research Laboratory study also explored the temporal stability of the relationship between car ownership and income by comparing linear cross-sectional regressions for 1965 and 1973. The evidence suggests that over time the underlying relationship changes as societies become more car orientated - a result which 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).

In these aggregate studies a variety of additional variables was also examined, including total road length, vehicle taxation, vehicle import duty, fuel price and population density but unlike work relating to developed countries (Button *et al* 1982 and Tanner 1963) these variables were not generally found to exert a significant influence over vehicle ownership. Whether this reflects the quality of the data used, the appropriateness of the model specification adopted or a genuine lack of impact is, however, uncertain.

The use made of 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 confirm the importance of fuel prices but also produce rather inconclusive, and possibly contradictory, evidence on income effects. A negative coefficient for the gross national product per capita variable runs counter to initial intuitions but is explained by the authors in terms of the lower use made of second cars in relatively higher income countries.

Fuel use by transport in low income countries was researched on a case study basis by Cundill (1986b) in the context of Kenya. The conclusion was that the short run price elasticities of demand for both diesel and petrol, if at all significant, are extremely low.

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

3 THE DATA AND GENERAL TRENDS

The data on vehicle ownership across low income countries is variable in its quality. The main data sources employed in this study are 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.

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 is not readily available or, as in the case of small

island states, it was felt that special circumstances may influence underlying causal relationships.

The full list of countries included is set out in Table 1 together with details of per capita income (GNP) in 1986 in \$US, per capita car ownership levels and total commercial vehicle fleet. Also included are 1980 per capita GDP levels, expressed in the international units of account, the Special Drawing Right (SDR), which is used by the International Monetary Fund to reduce the effects of fluctuations in exchange rates; it is widely used in this analysis. Much of the estimation data relates to individual time series for each country dating back as far as 1967.

There are, however, significant differences in the nature of the low income states (Berlage and Terweduwe 1988) and, therefore, a number of models sub-dividing the data set are explored in the subsequent analysis. This analysis in itself also provides support for the stratification adopted.

Figure 1 provides a series of plots of per capita car ownership for these countries over the period 1966 to 1987. Per capita car ownership is used as the basis for the subsequent analysis both to permit easy comparisons with other studies and to limit the statistical problems of heteroskedasticity (non-uniform variance) which can arise when employing data from countries of widely differing populations. For forecasting total car populations (also referred to as the 'car park'), per capita projections can easily be grossed up by applying forecasts of demographic changes.

The countries are grouped into five categories based upon average car ownership rates in the period from 1966 to 1987. These are:

- (A) less than 0.002 cars per person;
- (B) more than 0.002 cars per person but less than 0.01 and a per capita GNP of less than \$450 in 1986;
- (C) more than 0.002 cars per person but less than 0.01 and a per capita GNP of more than \$450 in 1986;
- (D) more than 0.01 cars per person but less than 0.02;
- (E) more than 0.02 cars per person.

The graphs indicate that countries in categories A and B, those with very low current levels of car ownership and, from Table 1, 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.

This simple observation has implications for any forecasting model specifications as well as highlighting the developments which are occurring in those low income countries where income is growing more rapidly. The implications 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 their populations as well.

4 THE CAR OWNERSHIP MODEL

Car ownership is ultimately the main determinant of traffic growth in low income countries, especially in urban areas. Developing a forecasting framework for car ownership requires an initial analysis of the influences which affect ownership.

4.1 The Quasi-Logistic Approach

The slow growth in car ownership in the lowest income countries observed in Figure 1, coupled with the much 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.

There are a number of functional forms which could be used to develop a non-linear model relating car ownership to income (Tanner 1979). Since ultimately there are likely to be limits, albeit possibly flexible ones (Button et al 1982), to the number of cars per person, the standard approach is to adopt a sigmoid function.

A variety of possible sigmoid shaped functions could be applied. Here, the main modelling thrust employs the quasi-logistic approach (sometimes referred to as the log-odds model) which has been used for both local and national level forecasting in industrialized countries. The model is easy to calibrate, flexible and relatively straightforward to interpret. It has also proved useful in work on less developed countries (Cundill 1986a).

While there are arguments for using household based models, in this approach, because of data restrictions, we relate the probability of an individual owning a car to a set of socio-economic variables, especially income. The relationship is assumed to be a sigmoidal one to allow for both the slow take-up of car ownership at low levels of income and the eventual approach to saturation in ownership at high levels of income.

Taking P as the probability of an individual owning a car, S as the ultimate saturation level of car ownership per capita, X_1, X_2, \dots, X_n as a set of socio-economic influences on ownership and a, b_1, b_2, \dots, b_n as parameters, then the model can be depicted as:

$$P = \frac{S}{1 + e^{-aX_1^{-b_1}X_2^{-b_2}\dots X_n^{-b_n}}} \quad (1)$$

Manipulating and converting equation (1) into natural logarithmic form yields the operational model seen in equation (2). Values of P for estimating purposes become the actual levels of per capita car ownership. The values of the parameters can then be determined by linear regression procedures i.e. applying least-squares techniques to:

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

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 the data limitations and the considerable distance that most low income countries are from the saturation estimates postulated for industrialized countries, the last 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 industrialized countries indicate an ultimate per capita saturation level of between 0.45 (Tanner 1974) and 0.55 (Mogridge and Eldridge 1970). Before adopting these or similar figures for low income countries, one should note, 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 suitable figure to use for saturation, an examination was conducted along the lines of that on UK car ownership by Tanner (1962 and

1978). This seeks 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 this growth ceases. Specifically, per capita car ownership for each country was plotted against annual changes in per capita car ownership (ΔP) between 1967 and 1987. Where the resultant relationship cuts the P axis (i.e. where there is no change in car ownership levels) provides a general indication of the saturation level.

The countries in the study are divided into the five categories listed above. As seen from Figure 2, the implied saturation level suggested by the plots are low compared to those favoured in models developed in industrialized countries. 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.)

One should perhaps note the volatility of 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 (indeed, the evidence from Figure 2 provides a basis for the groupings themselves). The value of S rises with the level of existing car ownership. 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. One also needs to take into account for forecasting purposes that the data suggests the saturation level moves up with time. 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.

Models employing saturation levels have, in the past, been criticized when used as forecasting tools because of their sensitivity to the S value adopted. Because the countries in this study are so far from any reasonable assumption of saturation this criticism has limited bearing here. However, to test the sensitivity of the results to the saturation level employed a series of parallel log-linear regressions were performed where no saturation level is assumed. These also have the advantage in terms of policy assessment of providing direct elasticities of the response of car ownership to changes in independent variables.

There is good reason to suppose that the relationship between car ownership and the major causal variables is not stable through time. This, for example, 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 (Transport and Road Research Laboratory 1979). Further, the effect seems to persist even as countries industrialize and, for instance, a similar picture emerges from pooled analysis of car ownership in the UK (Pearman and Button, 1976). The implication of this work is that over time the level of car ownership at most income levels rises.

Strictly comparable up-datings of the Transport and Road Research Laboratory calculations are not possible. However, taking the data set for the countries in this study and repeating similar linear regressions in constant 1980 US dollar prices for the years 1967, 1973 and 1983 provides evidence that this shift has continued. The specific results obtained, where C/P represents cars per thousand population, are:

$$C/P_{1967} = 4.46 + 0.0867GNP \quad (3a)$$

$$C/P_{1973} = 6.95 + 0.0950GNP \quad (3b)$$

$$C/P_{1982} = 11.54 + 0.1388GNP \quad (3c)$$

This phenomena is not unique to developing countries and in industrialized countries it has been explained in terms of the greater car orientation of younger generations as they move through the age spectrum (Burrell 1972). There is, in addition, likely to be something of a demonstration effect in low income countries as over time their populations attempt to emulate the consumption patterns of industrialized nations. In technical terms it suggests that some variable is being omitted from the analysis. Identification and quantification of this variable poses intractable practical problems. In order to capture some 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 problems 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 take account of these local features a set of dummy variables (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.

Having taken these factors into account, the resultant pooled equations relate per capita car ownership for all countries in the data set and for all years to the GDP of the countries at constant prices (Y), a vector of dummy variables (c_k) which takes up the effect of specific national deviations from the general car ownership-income relationship, and a time trend (T). The models is thus:-

$$P = \frac{S}{1 + e^{-(a + \partial_k \sum c_k) Y - bT}} \quad (4)$$

The operational form of the model thus becomes:

$$\ln\left(\frac{P}{(0.3-0.45)-P}\right) = a + b \ln Y + \partial_k \sum c_k + t \ln T \quad (5)$$

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:

$$P = e^{(a + \partial_k \sum c_k) Y} b e^{tT} \quad (6)$$

The main independent variable influencing per capita vehicle ownership at the national level is income. There is some evidence that income changes may exert a lagged effect on vehicle ownership (Tanner 1983b) but, given the problems of specifying the appropriate lag structure, current income is used here. This forms the backbone of the forecasting model.

Additional variables which may influence vehicle ownership include the price of fuel, the level of urbanization and the degree of industrialization. The importance of such variables was explored but there were inevitable problems of multicollinearity.

Calibration of vehicle ownership and use models involves the use of multiple least-squares regression. 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 heteroskedasticity which may accompany the wide variations in countries' populations.

4.2 The Effects of Income

The income variable employed is adjusted to 1980 prices. Current income levels are used and no lagged structures are included. 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 ultimately forecasting future ownership levels.

A simple tabulation by category of per capita income against per capita car ownership for all the countries in the study over the period (Table 2) confirms the positive relationship which has been found in most studies of car ownership.

Using per capita income in the pooled log-linear and quasi-logistic models for the five categories of low income countries defined above confirms the importance of income. The resultant equations are set out in Table 3 (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. Thus, for example, for a group A country a 1% rise in per capita GDP will produce a 0.532% rise in per capita car ownership, for group B a 1% GDP rise will result in a rise of 0.730% in per capita car ownership, etc.

In general, the size of the income elasticity increases as one moves through the five categories of country. 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 industrialized 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, industrialized 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 assumption, are constant elasticity models. They assume the 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 practical 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 4 provides details of the coefficients associated with the D_j 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.

4.3 Effects of Non-income Variables

In addition to income a variety of other variables may be thought to exercise some influence on the magnitude and pattern of car ownership.

Time Trend

The quasi-logistic and log linear equations set out in Table 3 include a time variable as well as income (with $T=1$ in year 1967). The variable proves, in both specifications, to be statistically significant at the 5% level and exerts a positive effect on car ownership; i.e. it conforms to the empirical findings of earlier Transport and Road Research Laboratory (1979) work and to the linear cross-section results cited above.

The implication of the quasi-logistic model specification is that the time trend effect (of the 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 characteristics of the data. The nature of the specification was selected for purely statistical reasons - i.e. to provide a good fit to the historic data - and the results are sensitive to the year chosen to be set equal to unity.

Urbanization

Jacobs and Fouracre (1974), Stopher (1980) and Thomson (1983) generally and, more recently, 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.

In terms of degrees of urbanization (percentage of population living in urban areas), 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 urbanization. Linear regressions for selected countries where significant results were obtained for the period 1980-1987 are shown in Table 5 and Figure 3.

From a forecasting perspective, it may be possible to extrapolate, using these linear models, future levels of car ownership in relation to urban growth for countries which have in the recent past exhibited a consistent relationship between the two.

Some strong caveats should, however, be attached. First, the link between car ownership and urbanization emerges as very location specific and hence questions of its generality and temporal stability arise. Second, in higher income countries there is evidence that urban areas exhibit lower car ownership levels than in rural areas suggesting that a linear relationship may flatten out and possibly turn down as development progresses (Pearman and Button, 1976). Third, levels of urbanization are themselves difficult to predict and are highly correlated with other factors such as recorded income levels.

Labour Force Composition

The progressive shift away from agriculture to manufacturing and service industries is changing the aspirations and attitudes of many people in low income countries. For modelling and forecasting purposes, however, the high correlation of the industrial mix of the labour force with such variables as income and urbanization makes it difficult to isolate its specific impact. Also, examination of the data plotted out in Figure 4 suggests that the actual correlation between car ownership and industrial mix is, in any case, in practical terms very small.

5. Car Usage

5.1 Modelling framework

Car use in any country depends primarily on the level of car ownership although other factors, such as income, the price of fuel, the degree of urbanization and the extent of the road network may also be important.

The modelling framework adopted to capture the effects of these latter 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 (1986).

The basic linearized form of the model used for calibration takes the form,

$$Km/V = e^{(K+\partial_k \sum c_k + aT + bT^2)} GDP^c \prod FL_j^{d_j} \quad (7)$$

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 are in SDRs in 1980 constant prices. For estimation purposes, the model is linearized as:

$$\ln(Km/V) = K + aT + bT^2 + \partial_k \sum c_k + c \ln GDP + d_j \sum \ln FL_j \quad (8)$$

Since the distinction between cars and commercial vehicles is sometimes obscure in official data and also because some countries have a sizable diesel car fleet, the subsequent analysis distinguishes between petrol (or gasoline) price and diesel price. Additionally, for completeness, 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 were also incorporated in the analysis. Finally, as with car ownership, country specific dummy variables are also included to reflect unspecified spatial effects.

5.2 Elasticities

Data from 17 countries were used for calibration purposes; limitations in the data prevented the full range of countries from being employed. The resultant regression coefficients (excluding the country dummies) are set out in equation 9. The coefficients relating to the national dummies are shown in Table 6. The regression explains 89.7% of the variation in car use across the seventeen countries included in the pooled model. The signs of all coefficients correspond to expectation and are statistically significant at the 5% level.

$$Km/V = e^{(4.144 + \partial_k \sum c_k + 0.017T - 0.0027T^2)} GDP^{0.713} PP^{-0.261} DP^{-0.074} (C/P)^{-0.29} \quad (9)$$

Where Km/V is kilometres travelled per car, c_k is the regression dummy for country 'k', T is a time trend with T = 1 in 1967, GDP is per capita GDP (SDR) in 1980 prices, PP and DP are petrol and diesel prices in SDRs per 100 litres and C/P is cars per capita.

The model specification allows the direct identification of income and fuel price elasticities. The estimated income elasticity is 0.713 -i.e. in forecasting terms, with every 1% rise in GDP per capita car use rises by 0.713% - which is, as expected positive. This is somewhat higher than the elasticity of 0.434 found by Khan and Willumsen (1986) in their log-linear

model of mixed industrialized and low income countries although the fit of their model was somewhat poorer (i.e. $R^2 = 0.43$) and the specification less detailed.

The petrol price elasticity is -0.261 which is very similar to the average figure of -0.25 which Tanner (1983a) found across 14 industrialized nations although lower than the -0.368 found by Khan and Willumsen (1986). The latter, however, was not statistically significant. The implication for forecasting purposes, therefore, is that a 1% rise in petrol prices in low income countries decreases car use by about 0.26%.

The low diesel price elasticity of -0.074 possibly reflects the rather special nature of the diesel fleet - cross-country vehicles - and its relatively small size vis-a-vis overall national car parks.

6. Commercial Vehicles

6.1 Vehicle Numbers

Commercial vehicles embrace goods vehicles and buses. The size of national bus fleets appear to be highly dependent upon local conditions, urban public transport policies and regulations (Case and Latchford 1981). Because of these difficulties the focus here is on commercial goods vehicles.

Commercial freight vehicle numbers are almost inevitably determined by the level of economic activity in a country. In consequence, log-linear regression analysis relating commercial goods vehicle numbers per capita (GV/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 urbanization, length of road network, etc.

Given the somewhat different natures 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 more widespread use of smaller vehicles in many Asian countries. One might anticipate the number of goods vehicles in Asia, because of their smaller size, to be more sensitive to the state of the national economy. Again dummy variables (c_i) are included in each set of estimations to reflect particular national differences; these are given in Table 7.

$$GV/P_{SA} = e^{(-10.019 + \sum c_i)} GDP^{0.841} T^{0.013} \quad (10a)$$

$$GV/P_{AS} = e^{(-15.077 + \sum c_i)} GDP^{1.500} T^{0.012} \quad (10b)$$

$$GV/P_{LA} = e^{(-14.376 + \sum c_i)} GDP^{1.406} T^{0.028} \quad (10c)$$

The GDP and T terms in these equations are defined as for equation 9.

As the coefficients associated with GDP indicate, the elasticity of goods vehicle numbers is relatively high. Further, the higher elasticity associated with Asian countries is in line with expectations. In this case a 1% rise in per capita GDP causes a 1.5% rise in goods vehicles per capita. A similar rise for African countries only generates a 0.84% increase in goods vehicles per capita.

6.2 Goods Vehicle Use

The growth in freight traffic of most countries is closely related to the macro-economic performance of those countries (e.g. as measured by gross domestic product), availability of complementary infrastructure (e.g. road length) and the cost of freight transport (e.g. as indicated by fuel prices). Each low income country, however, also has its own particular characteristics. The latter 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 was used to determine factors influencing variations in the annual distance travelled by goods vehicles. Equation 11 provides details of the key coefficients with the dummy variable coefficients (C_i) set out in Table 8. The model specification explains over 93.2% of the variation in kilometres travelled per vehicle.

$$Km/V = e^{(8.26 + \sum C_i - 0.017T)} GDP^{0.519} DP^{-0.134} RL^{-0.166} \quad (11)$$

In this equation Km/V represents annual kilometres travelled per goods vehicle and RL represents road length in kilometres. GDP and DP are defined as for equation 9.

The elasticities with respect to both diesel fuel price and gross domestic product are both of the expected sign and are statistically significant. The diesel fuel elasticity shows that a 1% rise in its price reduce the use of a goods vehicle by 0.134%. Equally, for forecasting purposes, a 1% rise in GDP results in a 0.51% 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 with the lack of any genuine underlying relationship.

7 FUEL USE

Petrol and diesel fuel used in transport form not only an important element in low income countries' expenditure but in most cases represent a substantial component of imports. Diesel and petrol are examined separately. Data limitations, however, restrict analysis to a limited number of countries. Because of the quality of the data and the problems of specifying appropriate lag structures the analysis is confined to short term effects. However, it is anticipated, that the long term price elasticities would be greater than their short term counterparts estimated here.

Pooled log-linear regression analysis showed the best statistical fit to be obtained by relating tonnes of diesel fuel sales annually (DF) to the commercial vehicle (trucks and buses) park (CV). This explains 78.7% of the variation over time and across countries in diesel fuel consumption. The price of diesel fuel proved insignificant which is in line with Cundill's (1986b) findings for Kenya and Oldfield's (1980) findings for the United Kingdom. The resultant equation is:-

$$DF = e^{0.585} CV^{1.056} \quad (12)$$

In other words, a 1% increase in commercial vehicle numbers increases aggregate diesel fuel consumption by 1.056%.

Figure 5 provides a plot of petrol consumption against both price (normalized to 1980 special drawing rights to achieve cross-country compatibility) and the national car population for those years and those countries where comparable data exists. The visual impression is one of a relationship of petrol consumption with the car park but no obvious relationship with fuel price.

Regression analysis confirms this. When petrol consumption in metric tonnes (PF) is related to both the total car park (CP) and the price of petrol in 1980 constant prices, in SDRs per 100 litres (PP). The subsequent linear relationship, equation 13, explains 71.7% of the variation in petrol use.

$$PF = e^{3.090} CP^{0.797} PP^{0.006} \quad (13)$$

The elasticity effects of the number of cars on petrol sales is 0.797. The fuel price variable is, however, statistically insignificant and, in any case, its low value indicates a near zero price elasticity of demand for petrol.

The more general evidence, therefore, offers support to Cundill's (1986b) specific findings with regard to Kenya. That is, that raising petrol and diesel prices may be a useful way for governments of low income countries to raise revenue but such actions are ineffective means, at least in the short term, of regulating fuel sales.

8 FORECASTS OF CAR OWNERSHIP

Forecasting vehicle and fuel use is essentially a matter of deploying the appropriate elasticities developed above. This is equally true of commercial vehicle numbers. The elasticities provide guides as to the responsiveness of vehicle use to changes in the key determining variables.

Of rather more long term importance in the context of low income countries is the forecasting of vehicle ownership. 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 applying predicted values of the independent variables, income and time, to the model developed in section four. Here for practical reasons we focus on forecasts for a selection of countries from our list - an identical methodology can be applied to each of the countries as desired.

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, Asian Development Bank, etc. 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%. These cover the range of predictions made by the major international institutions in recent years.

The results for a selection of countries (including representatives from each of our five broad groupings) set out in terms of cars per thousand population are seen in Figure 6. Actual car ownership levels per thousand head of population for the period from 1967 together with the levels predicted by the model are also shown for comparative purposes.

Noting the scale on the vertical axes, 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 9.

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 (i.e. 1% 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 for 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 they tend to obscure the actual magnitude of the pattern which emerges. If one makes the relatively conservative assumption of a 1% 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%, slightly above the Asian Development Bank's prediction, it will have 1.63 million extra cars. The Cameroon, on the same basis would find its car park rising from 0.09 million vehicles to 0.14, on a 1% annual income rise assumption and to 0.22 million on a 4% annual income rise assumption. These are very significant numbers of cars to cope with.

9 Discussion and Conclusions

Simple examination of trends over the past twenty years shows clearly 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 levels vehicle ownership per capita 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 coverage and quality of the data employed.

Given the data limitations, the study has generated results which are both intuitively reasonable and cross-reference well with work conducted elsewhere. It indicates that as low income countries become more prosperous there is an inevitable and rapid rises in their car ownership and use. Commercial goods vehicle numbers also rise. Reinforcing this income effect there is also a separate temporal effect as car ownership levels at any given level of income

rises over time. This may be due to 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.

In summary, the modelling and forecasting conducted shows:

1. That per capita car ownership in low income countries can be related to per capita income by means of a sigmoid model based on the quasi- logistic form.
2. That over time there is a gradual change in the relationship between car ownership and income, so that for a given income level car ownership can be expected to rise over time.
3. That in the case of low income countries, car ownership is so far away from ultimate saturation level that the overall model is only marginally sensitive to the saturation level selected.
4. That factors other than income and a time effect provide little statistical improvement to the overall car ownership model.
5. That car use is influenced by both income levels and petrol price although the model coefficients suggest that use is relatively insensitive with respect to the latter.
6. That commercial vehicle numbers are mainly determined by income factors although this effect differs between Asian and African countries mainly due to the variation in the types of vehicles used.
7. That fuel consumption by transport in low income countries shows no significant relationship to fuel price.
8. That, even with quite modest growth in income, many of the low income countries which already have significant vehicles fleets can expect a very rapid growth in these fleets over the next ten to fifteen years.

10 ACKNOWLEDGEMENTS

This work was carried out under the supervision of Mr. J Hine of the Overseas Unit of the Transport and Road Research Laboratory. It benefited considerably from discussions with Mr Hine and Dr. M Cundill of the TRRL. The authors also gratefully acknowledge the assistance rendered by Mrs Reynier of the Overseas Development Administration's Library; Mr. J. E Davies of Loughborough University Library; the International Road Federation; Shell International. The work described in this report forms part of the programme of the Overseas Unit of Transport and Road Research Laboratory and is published by permission of the Director.

11 REFERENCES

- BARRETT, R. 1986. Urban Transport in West Africa. in Proceedings of Seminar H of the 14th Annual Meeting of the PTRC (PTRC, London).
- BAYLISS, D. 1981. One Billion New City Dwellers - How will they Travel?. Transportation Vol. 10, pp. 311-343.
- BERLAGE, L and D. TERWEDUWE. 1988. The Classification of Countries by Cluster and by Factor Analysis. World Development Vol. 16, pp.1527-45.
- BURRELL, J. 1972. Recent Developments in Car Ownership Forecasting. in Proceedings of PTRC Seminar on Urban Traffic Model Research (PTRC, London).

- BUTTON, K J. 1983. The Practical Problems of Traffic Forecasting - The Prediction of Car Ownership. in K.J. Button and A.D. Pearman (eds) The Practice of Transport Investment Appraisal. (Gower, Aldershot).
- BUTTON, K J. 1987. Scenari di Sviluppo del Possesso ed Uso Dell'automobile in Italia, in M. A. Giusti (ed) Scenari Dell'Italia al 2000. (Franco Angeli, Milan).
- BUTTON, K J, A D. Pearman and A S. Fowkes. 1982. Car Ownership Modelling and Forecasting. (Gower Press, Aldershot).
- CASE, D. and J C R. LATCHFORD.1981. A Comparison of Public Transport in Cities in South East Asia Department of the Environment and Transport TRRL Report SR 659 (Transport and Road Research Laboratory, Crowthorne).
- CUNDILL, M A. 1986a. Car Ownership and Use in Kenya. Department of Transport, TRRL Research Report 48. (Transport and Road Research Laboratory, Crowthorne).
- CUNDILL, M A. 1986b. Effect of Prices on Petrol and Diesel Sales in Kenya, Department of Transport, TRRL Research Report 49. (Transport and Road Research Laboratory, Crowthorne).
- HINE, J L. 1982. Road Planning for Rural Development in Developing Countries: A Review of Current Practice, Department of the Environment and Transport TRRL Laboratory Report 1046 (Transport and Road Research Laboratory, Crowthorne).
- INTERNATIONAL MONETARY FUND. various years. International Financial Statistics. (International Monetary Fund, Washington).
- INTERNATIONAL ROAD FEDERATION. various years. IRF World Road Statistics (International Road Federation, Geneva).
- JACOBS, G D. and P R. FOURACRE. 1974. Urban Transport in Developing Countries. Traffic Engineering and Control, Vol.15, pp.926-928, 931.
- KHAN and L G WILLUMSEN. 1986. Modelling Car Ownership and Use in Developing Countries. Traffic Engineering and Control, Vol. 27, pp.554- 560.
- MOGRIDGE, M J H and D ELDRIDGE. 1970. Car Ownership in London. G L C Intelligence Unit Research Report 10 London (Greater London Council, London).
- OLDFIELD, R H. 1980. Effect of Fuel Prices on Traffic. Department of the Environment Department of Transport TRRL Supplementary Report 593 (Transport and Road Research Laboratory, Crowthorne).
- ORGANISATION FOR ECONOMIC COORDINATION AND DEVELOPMENT.1983. Long Term Perspectives of the World Automobile Industries. (OECD Interfutures, Paris).
- PEARMAN, A D. and K J. BUTTON.1976. Regional Variations in Car Ownership. Applied Economics, Vol. 8, pp. 231-233.
- SILBERSTON, A. 1970. Automobile Use and the Standard of Living in the East and West. Journal of Transport Economics and Policy, Vol. 4, 3-14.
- SPENCER, A H. and S. MADHAVAN.1989. The Car in Southeast Asia. Transportation Research, Vol. 23A, pp. 425-437.
- STOPHER, P R. 1980. Transferring Urban Transport Planning Methods to Developing Countries. The Highway Engineer. October, pp. 8-14.
- TANNER, J C. 1962. Forecasts of Future Numbers of Vehicles in Great Britain. Roads and Road Construction. Vol. 40, pp.263-74.
- TANNER, J C. 1963. Car and Motorcycle Ownership in the Counties of Great Britain, Journal of the Royal Statistical Society, Vol. 126A, pp. 276- 284.

TANNER, J C. 1974. Forecasts of Vehicles and Traffic in Great Britain. Department of the Environment TRRL Laboratory Report 650 (Transport and Road Research Laboratory, Crowthorne).

TANNER, J C. 1978. Long-term Forecasting of Vehicle Ownership and Road Traffic. Journal of the Royal Statistical Society Vol. 141 App. 14-63.

TANNER, J C. 1979. Choice of Model Structure for Car Ownership Forecasting. Department of the Environment Department of Transport TRRL Supplementary Report 523 (Transport and Road Research Laboratory, Crowthorne).

TANNER, J C. 1983a. International Comparisons of Car and Car Usage. Department of the Environment and Transport TRRL Laboratory Report 1070 (Transport and Road Research Laboratory, Crowthorne).

TANNER, J C. 1983b. A Lagged Model for Car Ownership Forecasting. Department of the Environment and Transport TRRL Laboratory Report 1072 (Transport and Road Research Laboratory, Crowthorne).

THOMSON, J M. 1983. Towards Better Urban Transport Planning in Developing Countries (World Bank, Washington).

TRANSPORT AND ROAD RESEARCH LABORATORY. 1979. Investigations into Vehicle Ownership in Developing Countries, Department of the Environment Department of Transport TRRL Leaflet LF758 (Transport and Road Research Laboratory, Crowthorne).

UNITED NATIONS. various years. UN Statistical Year Book. (United Nations, New York).

UNITED STATES DEPARTMENT OF ENERGY. various years. International Energy Annuals (US Department of Energy, Washington).

WORLD BANK. various years. World Bank Annual Report (World Bank, Washington).

TABLE 1
Key Variables From Low Income Countries (1986)

Country	Population (m) 1986	GDP(SDR) per head 1980	GNP per head (\$US) 1986	Cars per head 1986	Commercial vehicles ('000) 1986
Ethiopia	43.5	84	120	0.00082	19.0
Burkina Faso	8.1	154	150	0.00198	14.0
Bangladesh	103.2	108	160	0.00048	35.0
Malawi	7.4	158	160	0.00189	17.5
Zaire	31.7	171	160	0.00284	80.0
Mali	7.6	-	180	0.00197	7.5
Burma	38.0	135	200	0.00163	45.0
Madagascar	10.6	269	230	0.00330	45.0
Uganda	15.2	1031	230	0.00211	15.0
Burundi	4.8	181	240	0.00202	7.5
Tanzania	23.0	217	250	0.00202	50.0
Togo	3.1	325	250	0.00726	12.0
Niger	6.6	346	260	0.00364	22.0
Benin	4.2	251	270	0.00417	12.0
India	781.4	199	290	0.00154	1000.0
Rwanda	6.2	177	290	0.00119	11.0
Kenya	21.2	343	300	0.00604	110.0
Zambia	6.9	513	300	0.01377	50.0
Sierra Leone	3.8	287	310	0.00612	11.0
Haiti	6.1	225	330	0.00492	14.7
Pakistan	99.2	225	350	0.00489	183.2
Ghana	13.2	1059	390	0.00417	45.0
Sri Lanka	16.1	197	400	0.00932	132.0
Senegal	6.8	382	420	0.01264	23.8
Liberia	2.3	465	460	0.00469	6.2
Indonesia	166.4	388	490	0.00628	1133.3
Philippines	57.3	565	560	0.00622	500.0
Morocco	22.5	633	590	0.02422	202.6
Zimbabwe	8.7	599	620	0.03046	80.0
Dominican Republic	6.6	956	710	0.01591	66.0
Papua New Guinea	3.4	703	720	0.00551	30.5
Cote d'Ivoire	10.7	940	730	0.01822	90.0
Honduras	4.5	541	740	0.00862	52.7
Thailand	52.6	560	810	0.01088	824.0
El Salvador	4.9	560	820	0.01990	65.0
Botswana	1.1	914	840	0.01493	24.5
Cameroon	10.5	561	910	0.00827	65.0
Paraguay	3.8	1107	1000	0.01608	30.2
Peru	19.8	653	1090	0.01964	214.9
Turkey	51.5	868	1110	0.01910	553.1
Tunisia	7.3	1029	1140	0.03714	159.0
Mauritius	1.0	935	1200	0.03512	12.0
Columbia	29.0	939	1230	0.02899	391.4
Chile	12.2	1941	1320	0.05230	263.0
Costa Rica	2.6	1684	1480	0.03269	68.0
Jordan	3.6	869	1540	0.04414	57.0

Continued on next page.

TABLE 1

Key Variables From Low Income Countries (1986)

Continued

Country	Population (m) 1986	GDP(SDR) per head 1980	GNP per head (\$US) 1986	Cars per head 1986	Commercial vehicles ('000) 1986
Syrian Arab Republic	10.8	1177	1570	0.01019	160.0
Brazil	138.4	1303	1810	0.07225	2100.0
Malaysia	16.1	1367	1830	0.07491	310.0
South Africa	32.3	2295	1850	0.09402	1179.9
Mexico	80.2	2078	1860	0.06484	2250.0
Uruguay	3.0	2129	1900	0.06667	100.0
Hungary	10.6	1639	2020	0.14518	189.1
Portugal	10.2	1879	2070	0.12118	525.0
Yugoslavia	23.3	1864	2250	0.12498	301.2
Panama	2.2	1469	2300	0.06364	43.6
Argentina	31.0	4087	2330	0.12574	1434.7
South Korea	41.5	1182	2350	0.01601	627.2
Algeria	22.4	1476	2370	0.03237	458.0
Gabon	1.2	2962	2590	0.01496	17.5
Greece	10.0	2991	3080	0.13011	625.0

Note: The 1980 GDP figures are in expressed in the international unit of account the Special Drawing Right (SDR) used by the International Monetary Fund to reduce the effects of floating exchange rates in interanational transactions. In December 1980 1 SDR was equivalent to US \$1.28 or £ 0.53. In December 1986 1 SDR was equivalent to US \$1.22 or £ 0.83.

TABLE 2
Cross Tabulation of Per Capita Car Ownership by Per Capita Income

Cars per Capita	Gross Domestic Product Per Capita (Special Drawing Rights)									
	< 101	101-250	251-500	501-750	751-1000	1001-1501	1501-2000	2001-2500	2501-5000	>5001
>0.0200				39	29	99	97	39	114	14
0.0200-0.0100			22	80	56	27	10		4	3
0.0100-0.0067		22	67	44	12	15		2		3
0.0067-0.0050		9	54	26	9	13	1	1	3	
0.0020-0.0030		37	23	16	1	6				
0.0030-0.0025		33	15		2	1	4			
0.0025-0.0020		38	4	2	4	10	2			
0.0020-0.0013	4	53	3	2		1				
0.0013-0.0001	7	46	1							
<0.0001	10	29	1							

Note: Special Drawing Right equivalents are used here as a means of standardizing incomes across countries. The general picture is unaltered if other, conventional standardization procedures are employed.

TABLE 3
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 (1.056)	0.532 (0.199)	0.015 (0.004)	-	0.84
B	-9.22 (0.043)	0.730 (0.075)	0.013 (0.002)	-	0.89
C	-10.28(0.395)	0.881 (0.063)	0.015 (0.003)	-	0.83
D	-12.09 (0.743)	1.124 (0.110)	0.038 (0.003)	-	0.79
E	-9.60 (0.619)	0.952 (0.089)	0.032 (0.002)	-	0.92
Quasi-Logistic Specification					
A	-8.70 (0.982)	0.571 (0.191)	0.109 (0.026)	0.30	0.84
B	-8.24 (0.431)	0.699 (0.076)	0.103 (0.015)	0.35	0.90
C	-9.83 (0.039)	0.943 (0.066)	0.088 (0.000)	0.35	0.82
D	-11.80 (0.887)	1.100 (0.138)	0.261 (0.032)	0.40	0.67
E	-10.74 (0.741)	1.160 (0.112)	0.244 (0.023)	0.45	0.90

Note: Income (b) is GDP per capita expressed in 1980 constant prices in SDRs and for Time (t), t = 1 in year 1967.

TABLE 4
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 Republic	0.420	Zimbabwe	0.059
Bangladesh	-0.910	Madagascar	0.085	Philippines	0.046	Cote d'Ivoire	0.320	Mauritius	-0.544
Burundi	0.134	Uganda	-1.950	Papua New Guinea	-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	Columbia	0.630	South Africa	-0.150
		Kenya	0.000	Paraguay	-0.420	Jordan	0.875	Mexico	-0.712
		Sierra Leone	0.420	Syrian Arab Republic	-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

TABLE 5
Regression of Cars per Thousand Population Against Percentage of
Population Living in Urban Areas for Selected Countries (1980-1987)

Country	Constant (a)	Urbanization (b)	Coefficient of Determination
Burundi	1.563	0.072	0.31
Niger	1.710	0.119	0.55
India	-1.450	0.120	0.75
Kenya	8.260	-0.110	0.70
Pakistan	-10.460	0.504	0.45
Senegal	16.835	-0.105	0.42
Indonesia	-0.940	0.273	0.95
Morocco	2.154	0.480	0.88
Dominican Republic	26.840	-0.184	0.70
Cote D'Ivoire	-15.060	0.745	0.84
Cameroon	-0.754	0.194	0.76
South Korea	-45.270	0.912	0.86
Columbia	-66.450	1.400	0.85
Brazil	10.483	0.820	0.84
South Africa	32.079	1.066	0.71
Yugoslavia	-20.033	3.135	0.90
Argentina	-237.000	4.285	0.72

TABLE 6

Coefficients of Dummy Variables Associated With Car Use

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

TABLE 7

Coefficients of Dummy Variables Associated with Commercial Goods Vehicle Ownership

Sub-Sahara Africa Country	Coefficient	Asia Country	Coefficient	Latin America 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	Columbia	-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
Cote d'Ivoire	-0.543				
Botswana	0.156				
Cameroon	-0.616				
Kenya	0.000				

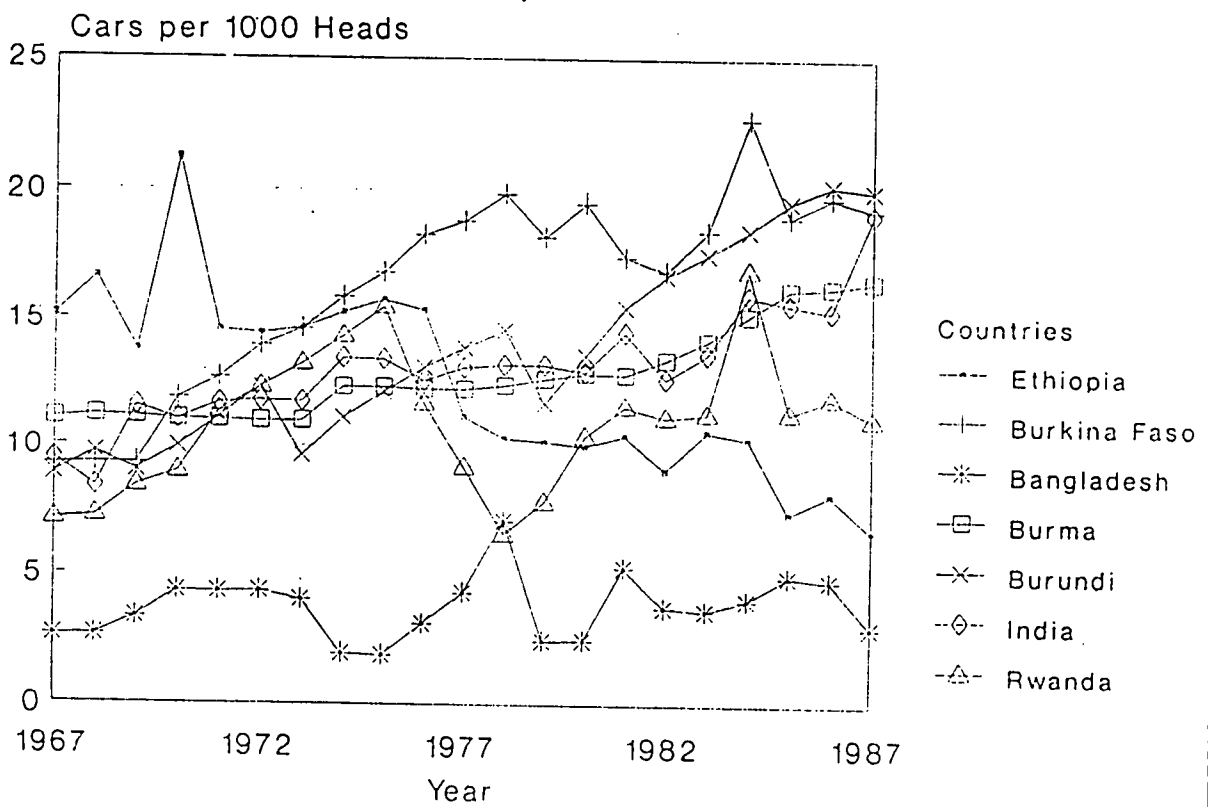
TABLE 8
Coefficients of Dummy Variables Associated with Commercial Goods Vehicle Use

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	Columbia	0.994	Greece	-0.012
Senegal	1.500	Chile	0.033		

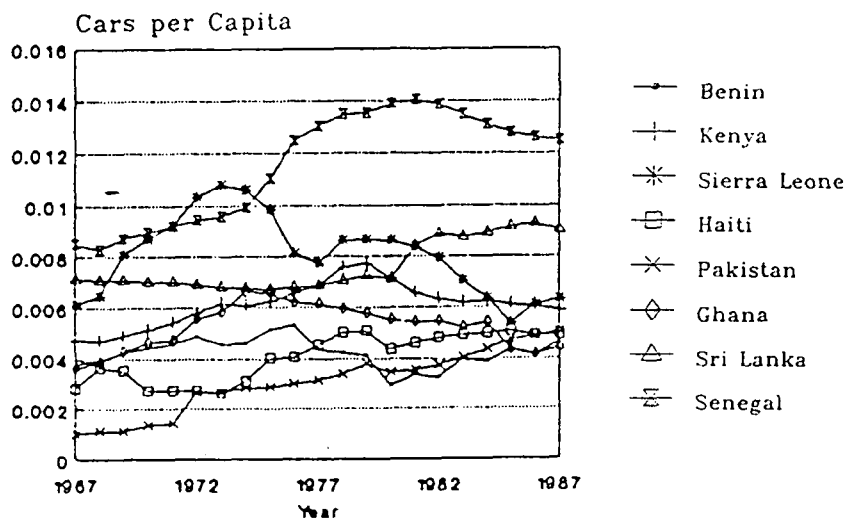
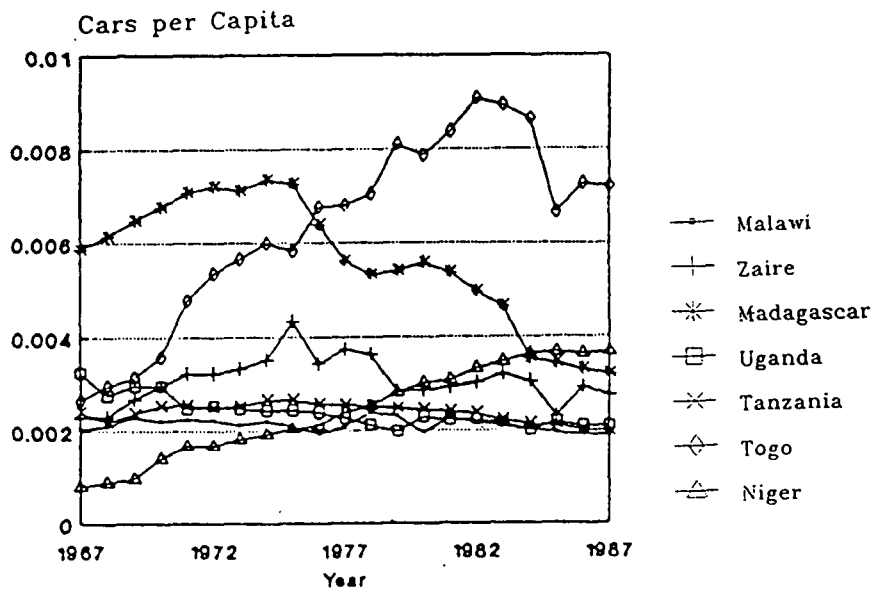
TABLE 9
Forecast National Car Park Increases to 2000 and 2025

Country (Group)	Assumed annual rate of per capita income growth	Forecast national car park increases (1986=100)		
		1986	2000	2025
Burkina Faso (A)	1%	100	143	286
	4%	100	183	394
Rwanda (A)	1%	100	177	499
	4%	100	224	951
Togo (B)	1%	100	149	335
	4%	100	205	751
Haiti (B)	1%	100	96	161
	4%	100	128	351
Pakistan (B)	1%	100	148	340
	4%	100	196	739
Cameroon (C)	1%	100	162	440
	4%	100	255	1309
Gabon (D)	1%	100	215	632
	4%	100	355	1922
Algeria (D)	1%	100	141	341
	4%	100	232	1000
Mauritius (E)	1%	100	146	209
	4%	100	219	544
Malaysia (E)	1%	100	149	284
	4%	100	216	628

FIGURE 1
Per Capita Car Ownership Growth in Low Income Countries 1966-1987

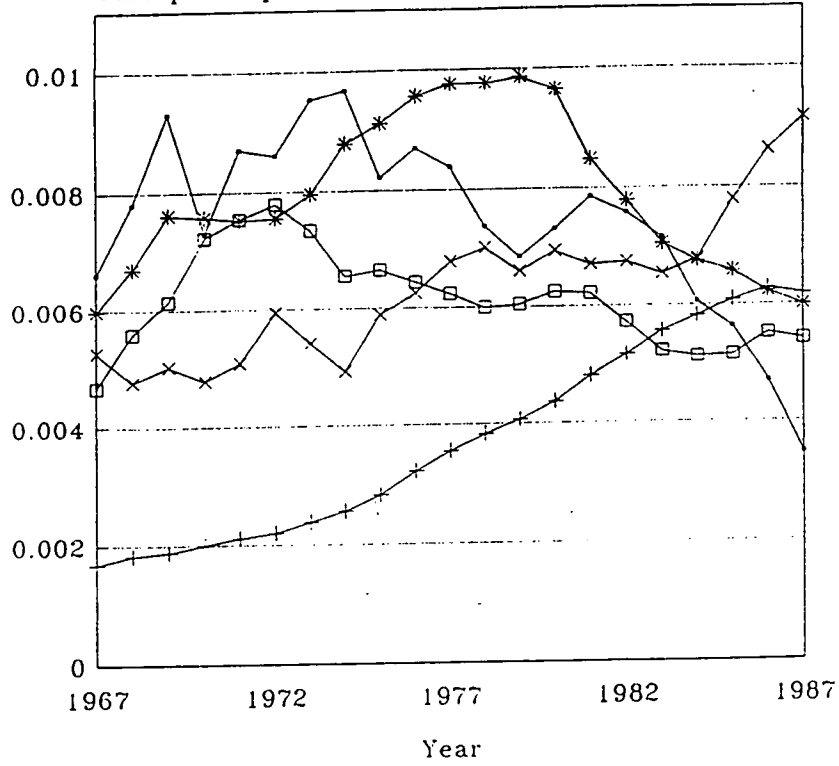


Group A



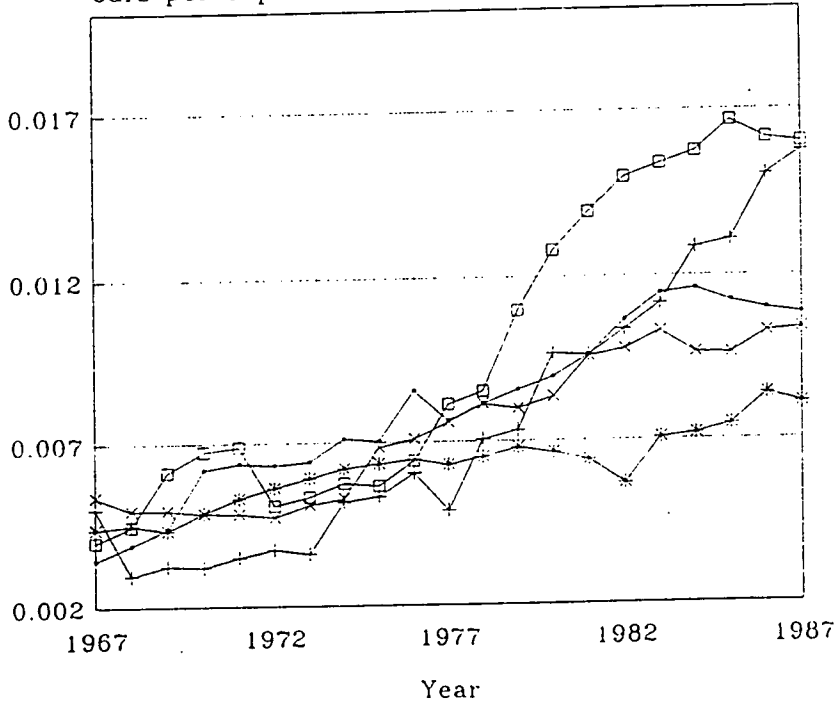
Group B

Cars per Capita



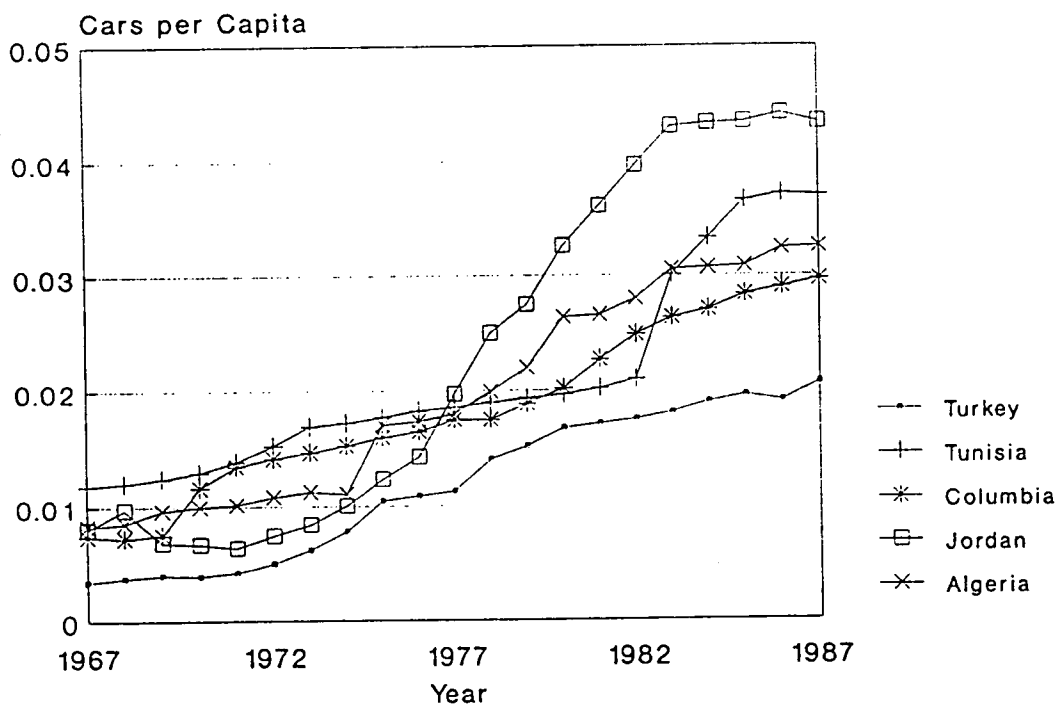
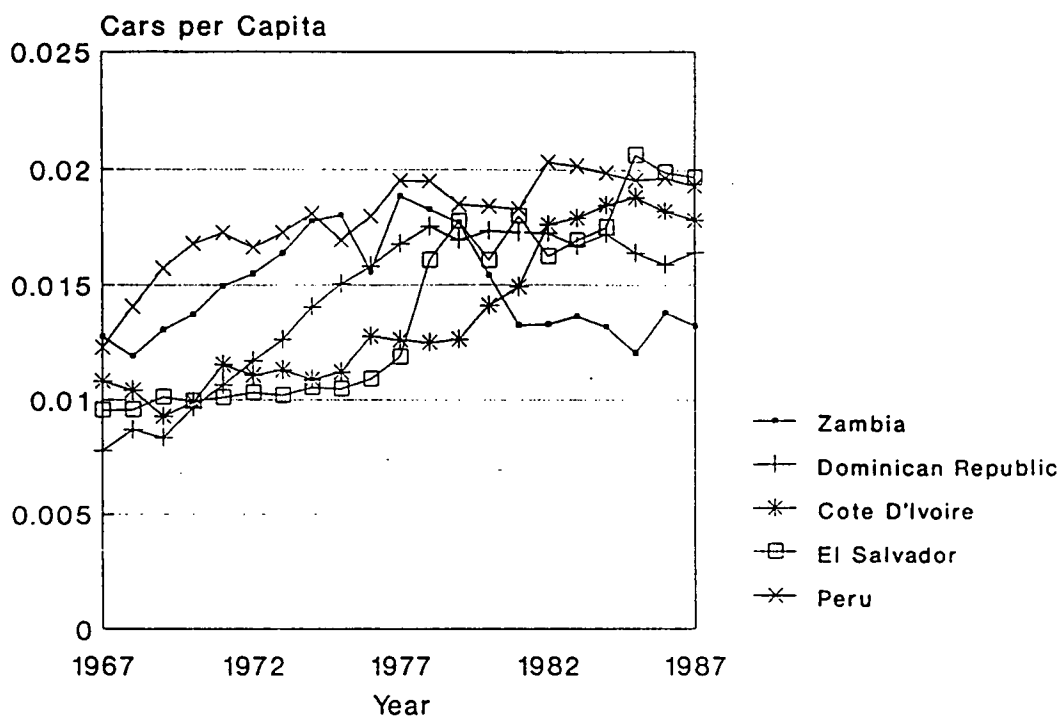
- Liberia
- +— Indonesia
- *— Philippines
- Papua New Guinea
- x— Honduras
- Guinea

Cars per Capita

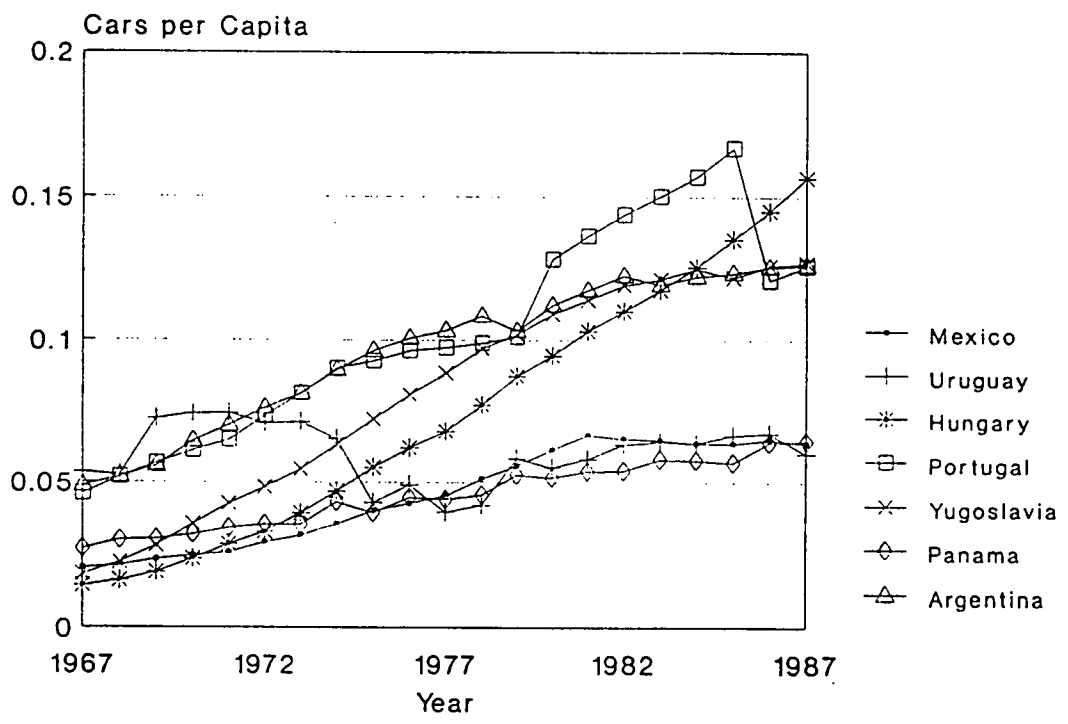
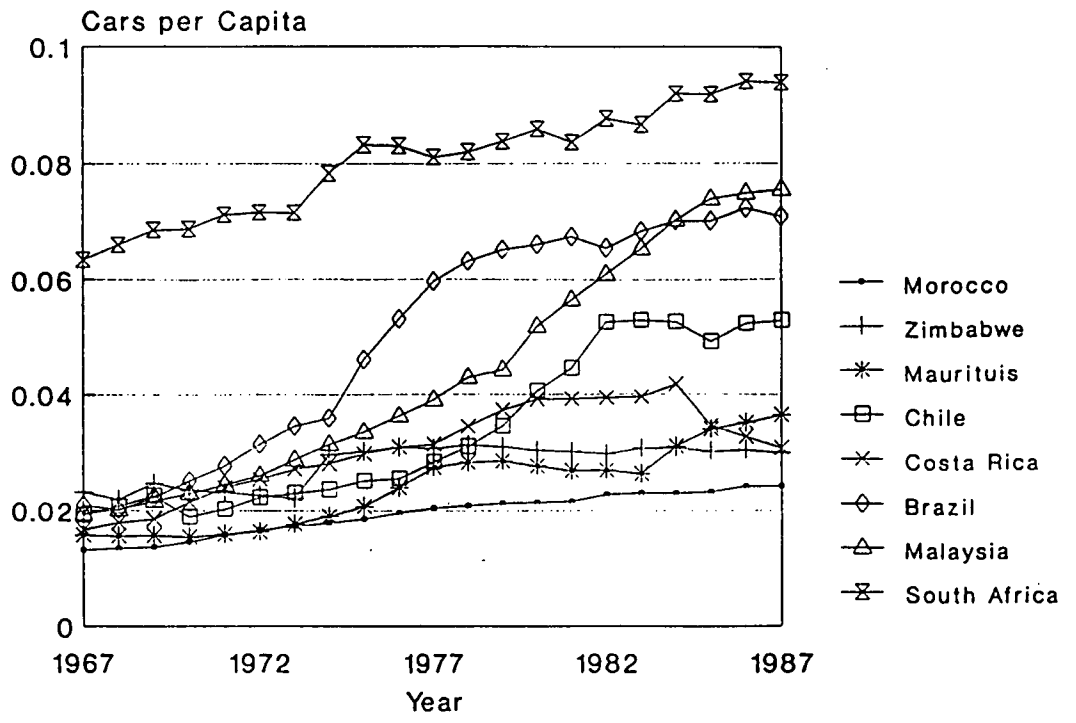


- Thailand
- +— Botswana
- *— Cameroon
- Paraguay
- x— Syrian Arab Rep.

Group C

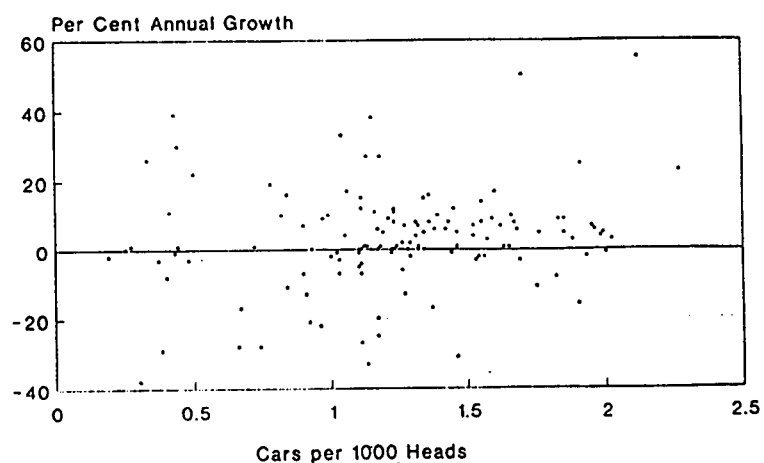


Group D

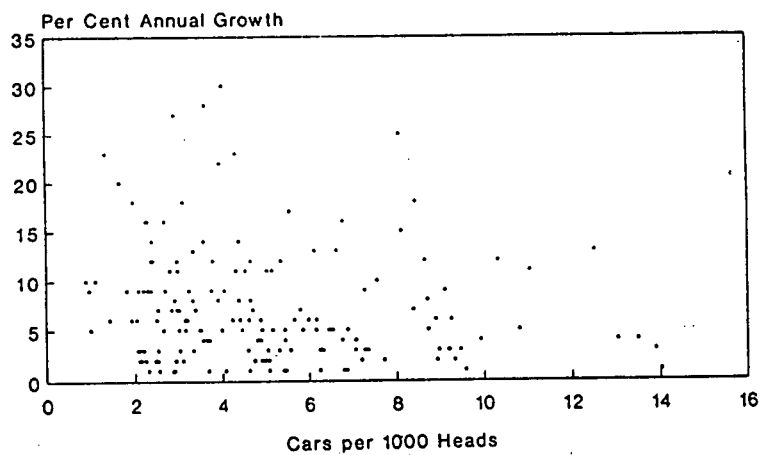


Group E

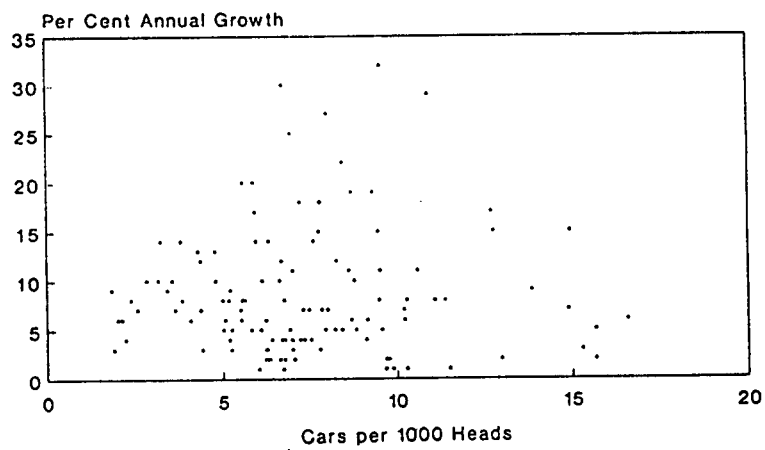
FIGURE 2
Plots of Per Capita Car Ownership by Country Against Change in Car ownership
Between 1967 and 1987



Group A



Group B



Group C

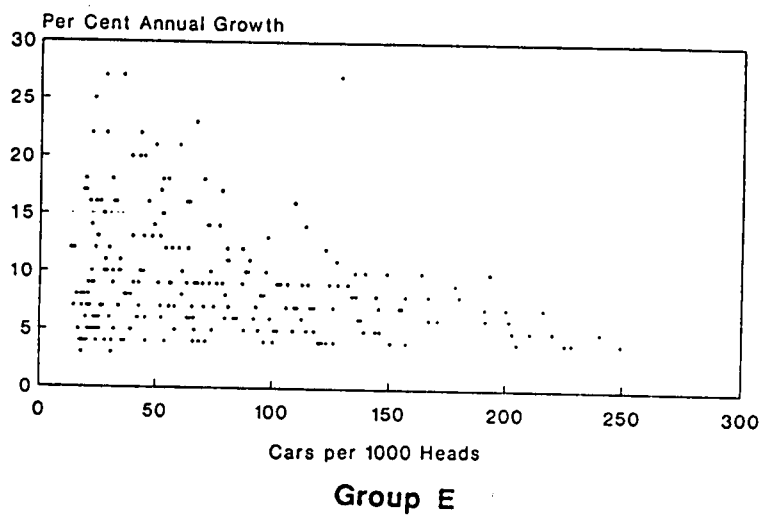
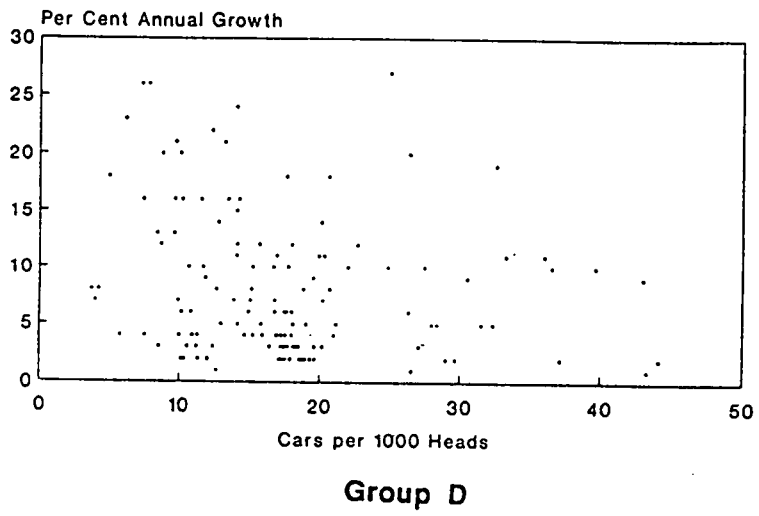


FIGURE 3
 Plots of Per Capita Car Ownership Against Levels of Urbanization

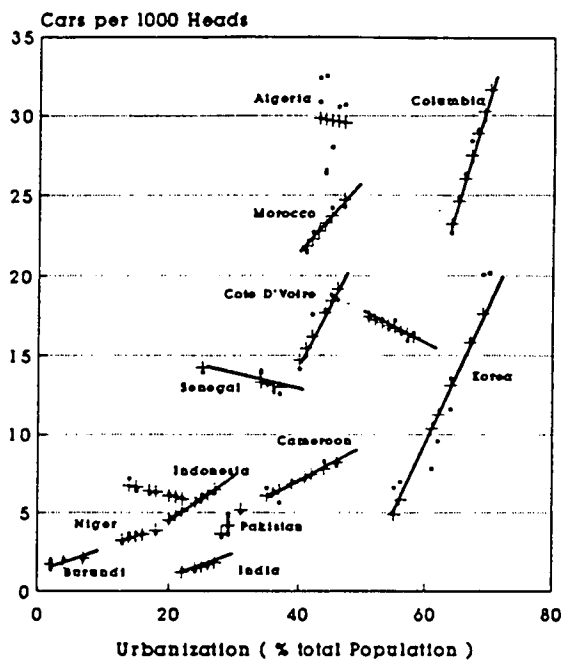


FIGURE 4
Plot of Per Capita Car Ownership Against Industrial Mix

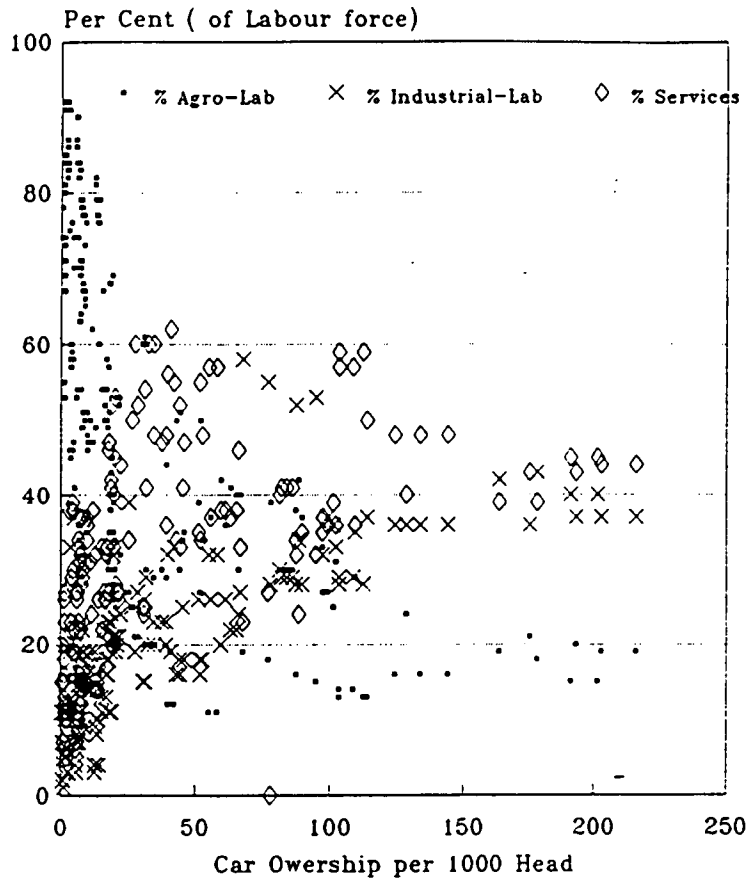
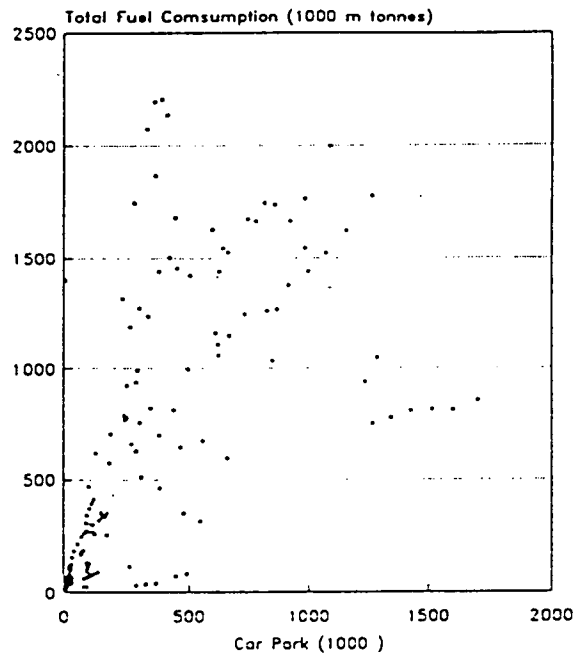
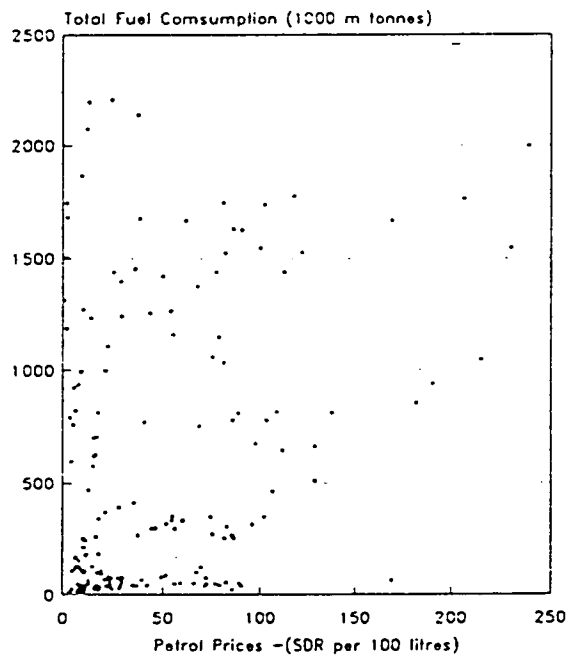


FIGURE 5
Plots of Petrol Sales Against Fuel Price and National Car Parks

Total Fuel Consumption vs Car Park

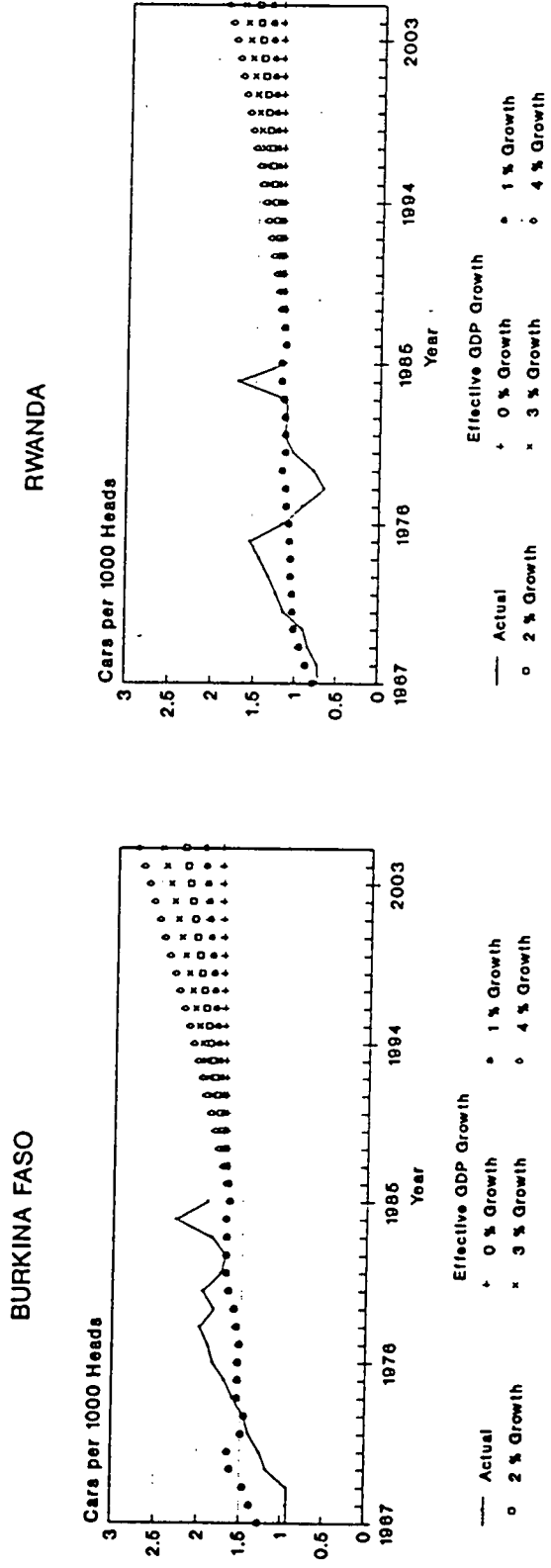


Total Fuel Consumption vs Petrol Prices



Constant 1980 prices

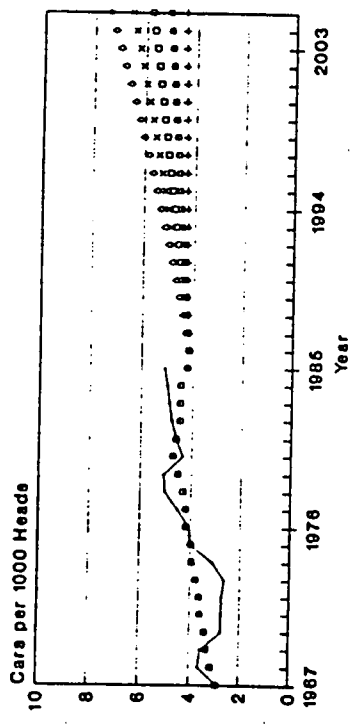
Figure 6
 Plots of Actual, Modelled and Forecast Levels of Cars per 1000 Head of Population for Selected Countries.
 (Forecasts Based upon Assumed Growths in GDP of 1%, 2%, 3% and 4%).



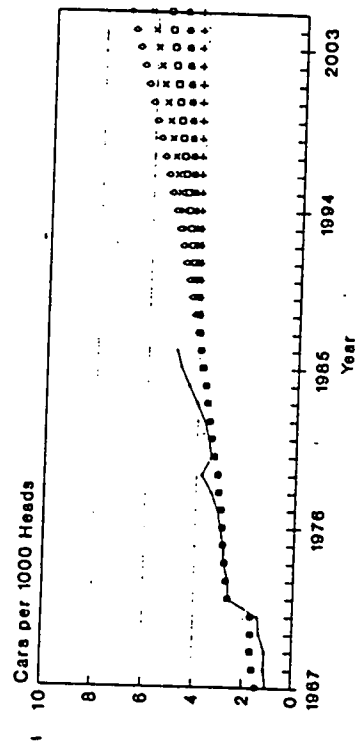
BURKINA FASO

RWANDA

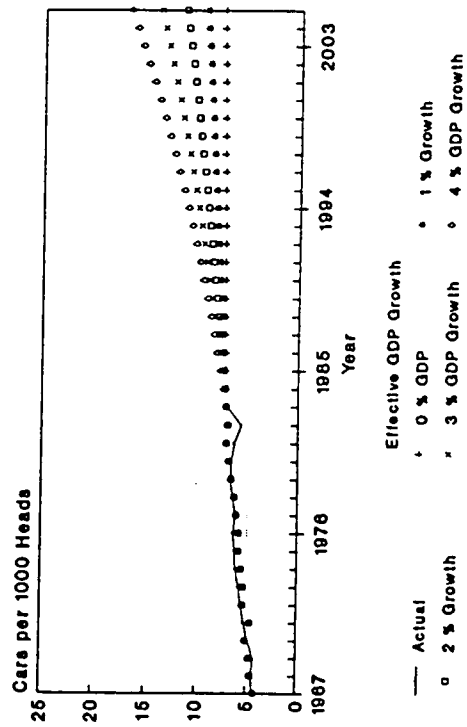
HAITI



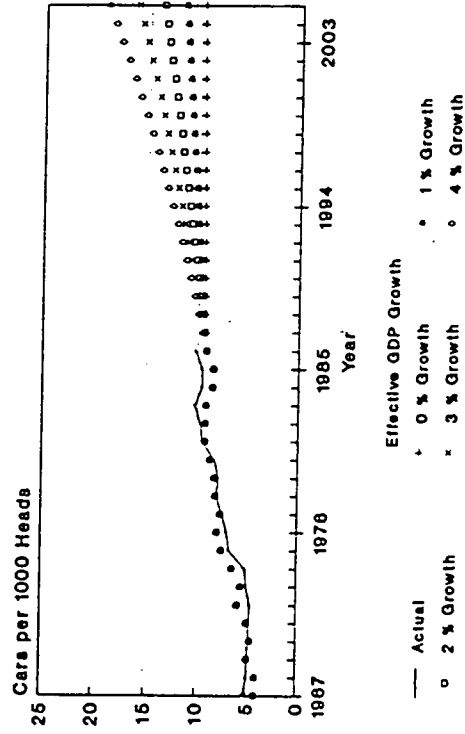
PAKISTAN



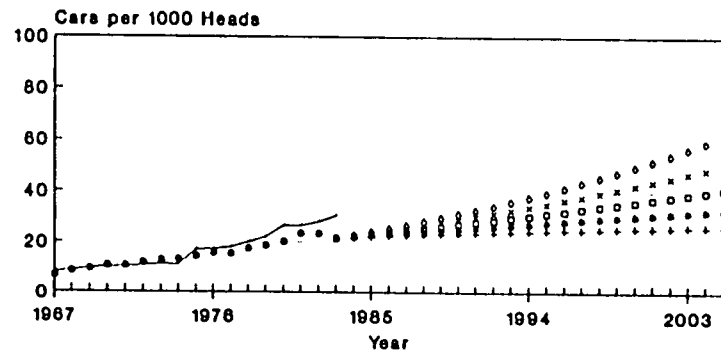
CAMEROON



SYRIAN ARAB REPUBLIC



ALGERIA



— Actual

○ 2 % Growth

Effective GDP Growth

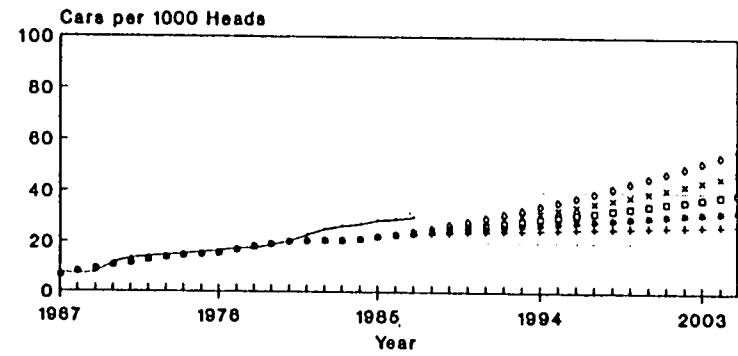
+ 0 % Growth

* 3 % Growth

◻ 1 % Growth

◊ 4 % Growth

COLUMBIA



— Actual

○ 2 % Growth

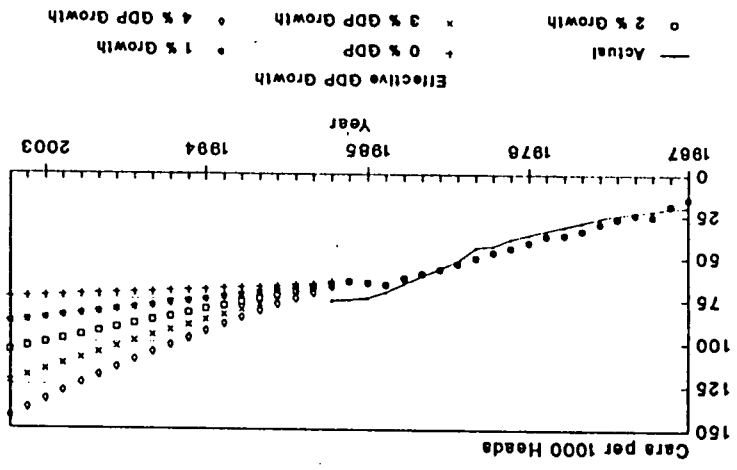
Effective GDP Growth

+ 0 % Growth

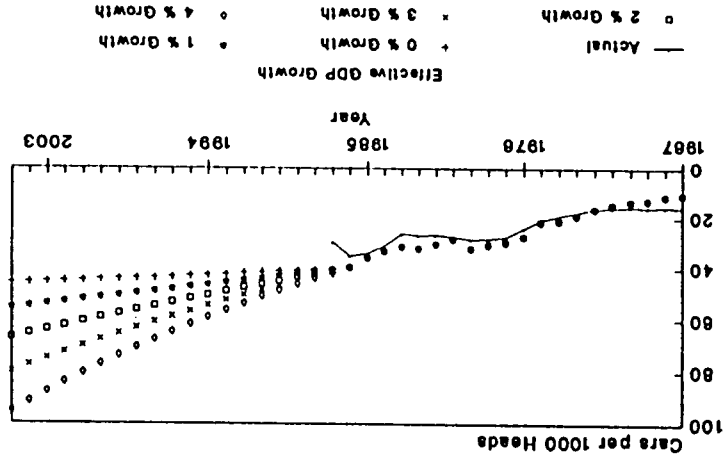
* 3 % Growth

◻ 1 % Growth

◊ 4 % Growth



MALAYSIA



MAURITIUS