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The paper, just delivered by Messrs Soper and Webb, represents a notable step forward in the use of two-factor, two-commodity models.

Historically, this group of models reflects a permanent search for stable equilibrium. The history of economic thought in the last hundred years or so is littered with corpses of equilibrium models. There is fortunately a logic in their disappearance from the major scene, and the learning curve of their authors was steep enough. Because they still belonged to generations which were learning from the errors of their predecessors, models were gradually becoming more realistic and more policy-oriented and therefore more useful, on the whole.

The whole trouble started, probably, with Walras. We are reminded of two of his basic statements, namely that "if the system is at its equilibrium position, then any arbitrary departure from this position generates dynamic market forces which bring it back" and "no matter what the initial position from which the system starts, the dynamic working of the market forces bring it to its equilibrium position". Walras, while defining a position of equilibrium did not supply in this exchange equations any information as to the path by which that position could be reached.

Von Neumann's concept of equilibrium growth, probably, comes next. It establishes conditions for the existence of a path towards equilibrium, and some of its characteristics. Then entered Sir Roy Harrod with classical Keynesian doubts, pointing out that an economy, once off the path of "golden age" equilibrium growth, cannot automatically return to that path in conditions mainly of laisser-faire, but only through combatting unemployment or inflation. Another bridge on the difficult road towards equilibrium was then laid by Dorfman, Samuelson and Solow, in a shape of a Turnpike theorem.

While simpler relative stability models, established previously, considered time paths extending indefinitely into the future, the asymptotic property of the turnpike theorem was concerned with time paths extending for finite time. But, as Sir John Hicks noted, we still do not know how rapid is the convergence of the actual optimum to the Turnpike. The actual optimum path, being restricted by an initial capital stock, and the far future remaining largely uncertain, the Turnpike is left still beyond the immediate grasp of the policy-makers.

And, finally, the most recent group of models has been initiated by Shinkai and continued by Uzawa, Inada, Takayama and Kurz. While the previous builders had enriched the initial equilibrium models by embellishments concerning policy measures and the time elements, this last group, following the independent initiatives by Solow and Salter, tried to introduce some elements of technology. This was limited, in its first phase, to a condition that the consumption-goods industry is always more capital-intensive than the investment-goods industry. But, according to Solow, it seems paradoxical that an important property such as stability should depend on such a casual property of technology as this.

Moreover, the stability condition in this group of models depends upon two basic relations, namely the elasticity of factor substitution of both production functions, and the determining influence of the wage-rental ratio.

The role of both these relations can be easily explained. Whenever the elasticity of factor substitution is sufficiently high, the balanced growth path could be regained through the interplay of two movements. As was noted by Drandakis, a relative abundance of one of the factors could be accommodated by an inter-industry movement towards the industry which uses relatively more

of that factor. This also concurs with the Rybczynski theorem. Moreover, whenever alternative techniques of production of one or both of the goods exist, an intra-industry movement is of additional help. With changes in the equilibirum prices, a change in the factor proportions in the relevant industry will occur and, if factor substitutability is high enough, the absorption of the relatively abundant factor is ensured with only small inter-industry movements.

The change in relative prices brings us back, however, to the wage-rental ratio. Its determining role for equilibrium models was stressed strongly by both Sir John Hicks and Robert Solow. Hicks proves that, in a two-sector growth equilibirum model, if wages and the cost of machines are fixed in terms of consumption goods, the relative price system is determined before we say anything about saving or about the growth rate of the economy, given that earnings of the factors must be the same in both industries in conditions of equilibrium. Solow, in interpreting the Uzawa model, brings in an auctioneer who determines a value for the wage/rental ratio. Since each separate industry has a corresponding optimal machine/labor ratio and since all the machines and all the labor must find employment, the given value of a wage/rental ratio determines the division of the labor force between the two sectors and thus also the division of machinery and the two outputs. Both industries make optimal adjustments which yield unit costs; the competition takes care of the rest, setting the relative price ratio for the two commodities equal to the ratio of unit costs. This is a first equilibrium condition where wage/rental ratio determines relative prices. The second equilibrium condition requires that $\frac{wL}{rK} = \frac{P_2 Y_2}{P_1 Y_1}$, where Y_2 and Y_1 are the outputs defined from the first condition. The conditions together set a

unique relation between the wage/rental ratio and relative commodity prices.

We approach here the content of Messrs Soper & Webb's paper. Following Harrod, the authors felt that the return to equilibrium calls for policy measures. The exposition starts with references to the Phillips curve and, although the four panels of Figure 3 deal, independently, with restraints on both factors, we can reasonably guess that it is the labor-factor utilization which is of main interest to the authors. Moreover, their further reference to Gordon's statistical work, showing that prices of capital goods have risen faster than prices of consumption goods, seems to reflect, in an indirect way, the authors' idea that one of the answers to the return-to-equilibrium problem lies in the change of relative prices.

This is a formidable question and it has not and could not been exhausted in the paper. It is, nonetheless, the only question which deserves to be answered.

The results of a policy decision of this kind, while they may be absorbed more or less easily by the model, will almost certainly influence other economic variables outside the model. Thus, even in comparative statics, the assumptions will have to change. We cannot escape from this cybernetical inevitability, as our world is fatally cybernetical. After having introduced time, as well as some elements of technological choice and some elements of policy decision into the equilibrium models, one wonders what will come next?

By introducing more of a time element we can obtain a terminal path growth and a series of gradual adjustments. This appears useful if we consider that deviations from equilibrium are always acceptable but should remain bounded. By introducing more technology we may find, following Salter, that changing factor prices are liable to influence best-practice techniques. We may also

find that the marginal productivities of capital do not rise in the same proportion, since the elasticities of marginal productivities with respect to capital are not the same in the two sectors. And, as Baumol has proven not a long time ago, an attempt to achieve balanced growth in a world of unbalanced productivity must lead to a declining rate of growth relative to the rate of growth of the labor force. We will also find how relative factor prices decide the degree of outmodedness by changing standards of obsolescence. But the latter, in their turn, will influence the productivity of at least one factor:capital.

Decisional or instrumental variables must next be considered. One wonders where the neutrality of money in models ends. We can assume that money is neutral in a static model, but does it remain neutral in comparative statics also? - especially in models like that of Soper and Webb, where changes of relative prices are apt to alter the saving rate with all the implications that could bring about.

Finally, could our equilibrium model continue to be of a closed-economy type in the contemporary world?

I used my privilege of a discussant in avoiding to question the consistency of the model. It is an excellent paper and it is difficult to say much about an excellent paper, after one has called attention to its quality. I have tried simply to trace the difficult path which led to its appearance and the even more difficult path which leads on from now.

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AUTOMOBILE DEMAND IN DEVELOPING COUNTRIES*

A. G. Nowicki

Introduction

This desk study was undertaken to find a sound approach to the problem of projecting automobile demand in developing countries. It surveys demand in developed and developing countries, draws attention to the difficulties of forecasting demand in developing countries and suggests that demand projections based on a market saturation concept should be used in developing countries. Market saturation, its measurement and some of its implications for economic policy are outlined.

Although only a small proportion of the population in developing countries owns automobiles, automobile purchases are important in the total consumer spending. Since such purchases have a very high import component, they are usually very much the concern of governments. Automobile industries in most developing countries are still at an embryonic stage, but they are given high priority, and tariff and other industrial policies are frequently based on them. A knowledge of automobile ownership trends is also necessary in planning the supply of joint consumption goods such as gasoline, in road use projections, and in other aspects of regional and urban planning.

Forecasting the demand for automobiles is vital to the formulation of consumption, production and other policies in developing countries, but the forecasting methods used in developed countries are inappropriate. A new approach suitable to the nature of the demand in developing countries is suggested.

The demand for automobiles in highly developed countries such as the United States is primarily a demand for replacements. Although there is some additional demand for second and third cars and the total demand increases with population growth, most families do own automobiles. In forecasting demand the existing stock of automobiles is therefore as important as the income and price factors.

In developing countries car ownership is still increasing, the stock of automobiles is small, and replacement purchases are less important than in developed countries. Since the automobile is a status symbol as well as a means of locomotion, non-economic factors are also important in automobile purchases. The high import component of automobiles limits their availability; it cannot be assumed, as in developed countries, that an ample supply will meet the demand in the long run. The construction of domestic car manufacturing plants, however, usually raises car prices. Supply is therefore a distinct factor in determining purchases in developing countries.

All the factors—non-economic as well as economic and supply as well as demand—can be taken into account by focusing attention on the annual expansion of the automobile market and on the rate at which it becomes saturated at successive levels of growth. The annual demand by new owners can then be derived; it and the replacement estimates are the basis for annual total demand estimates. This method indicates the feasibility of automobile manufacture in a country and the effects of tariff and other tax policies. A new emphasis in the compilation of automobile statistics is necessary.

In both developing and developed countries, random influences disrupt the trends. Because of the importance of automobiles in consumption and production, many of the irregularities in the trends are caused by government policies. It is particularly important that a government understands the trends it seeks to disrupt, and the effects that its decisions will have.

1. Automobile demand: a general view

The techniques for projecting automobile demand in developed countries are based on sophisticated concepts of demand, income and prices, and in addition take into account problems of stocks, depreciation and replacement which have not yet been absorbed in the

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body of conventional economic theory. The data required for forecasts are therefore complex, but the techniques themselves are mathematically simple.

Demand

Conventionally, consumption demand is a function of income and prices, and it is usually divided into a normal part pertaining to necessities and a discretionary part which covers other expenditure. It is therefore the discretionary part that is important in purchases of consumer durables, particularly of automobiles. Since the discretionary part of the consumption function can be postponed, automobile purchases are heavily influenced by business fluctuations.

While in pure theory demand is generally regarded as depending on price alone or on price and national income, in practice other economic and non-economic factors come into play and may be as important as, or even more important than, price and income. The prestige of car ownership is one such factor.

Demand for transportation and car ownership

The demand for new passenger cars is distinct from an individual's demand for transportation or for car usage. The transportation demand can usually be satisfied by using an old car for another year, while the demand for car usage can be met by purchasing a used car. The following factors are therefore important in car purchases:

A purchaser wishes either to obtain possession of a car or to exchange his present car for a new one. There are probably some differences in the manner in which these two groups of consumers behave. While the former predominates in developing countries, the latter is the most important in developed ones. For both groups, however, individual behaviour in car purchases belongs to behavioural categories in which "possession" is one of the explanatory variables;

In developed countries where ownership of private cars is widespread, the rate of increase in income is generally one of the least important variables in the demand function. Cars are purchased even without increases in income because the automobile, like all durable goods, is subject to an acceleration effect caused by the fact that the service desired is a function of income, while the service supplied is a function of the existing stock. In developing countries where the existing stock of automobiles is small, the influence of income changes is likely to be more important;

A car's service yield can be measured by the price a consumer pays for the use of car for one year, that is, the amount by which the car depreciates plus the interest foregone by holding capital in the car:

The rate of depreciation is determined by a number of factors, the most important being the elasticity of the supply of new cars. In periods of limited supply, depreciation falls and can even become negative. In the United Kingdom, 18-month old cars were more expensive than new cars[1] from 1940 to 1952. In the United States, annual car depreciation was about 9 per cent in 1945 and is now about 25 per cent. Low depreciation is typical in developing countries where constraints on supply, due to balance of payments difficulties are common; they are not common in developed countries;

The interest foregone depends largely on other investment opportunities, and on the monetary situation in general.

In developed countries, depreciation and interest are generally not very important, but in developing countries they may be a means of preserving the real value of one's money. The rapid growth of automobile stocks in Brazil, for example, has been stimulated in this way.

Income elasticity of substitutive groups

All classic demand treatises[2] postulate that the income elasticity of the market demand for given goods equals a weighted average of the demand elasticity in different social groups: a change in groups thus leads to changes in weights and in average elasticities. With a few exceptions however, like Engel's Law which it equals in simplicity and appropriateness, this theory has not been applied to studies of automobile demand in developed countries. In any case it does not appear to be a very useful concept in automobile studies in developing countries, where the automobile purchasing groups tend initially to be rather homogeneous.

L. D. Taylor[3] calculated that habit-linked expenditures represent 40 per cent of consumption expenditures in Sweden, while H. S. Houthakker[4] places the level at 60 per cent for the United States. Assuming that these calculations suggest the correct order of magnitude for the stable component of expenditures, the calculation of elasticities for non-habitual expenditures becomes a difficult matter; this has been shown in empirical studies.[5] The difference between the income elasticity for food and that for car purchases is particularly large. In developed countries the former is far below the latter. France is probably typical; the income elasticity was 0.3 for food and 1.47 for car purchases in 1966. In developed countries the income elasticity of a commodity is an increasing function of its price relative to other commodities.[6]

However, this concept has little application in developing countries. First, the average elasticity for food is still very high in these countries; typical examples of

1 O'Herlihy (1965), pp. 2—3.
2 Wold (1952), p. 119, equation 8.
3 Taylor (1964).
4 Houthakker and Taylor (1966).
5 Houthakker and Taylor (1967), p. 227.
6 Houthakker (1957), p. 542.

income elasticity for food are Brazil 0.795, Ghana 0.840 and India 0.837. Second, the notion that the income elasticity of a commodity is an increasing function of its price relative to other commodities probably only applies to a very small group of goods, such as the more expensive durable consumer goods and housing, which are competitive with automobiles. The better the bargains offered in these competitive fields, the less consumers may be inclined to spend on automobiles, but such considerations may well be swamped by the symbolic value of cars in a developing society.

Income

Personal income is the major variable in aggregate demand function studies. The national accounts of the United States and other developed countries include the following classifications of personal income:

Y_1 the disposable income;
Y_2 the net disposable income (Y_1 minus depreciation and subsidies);
Y_3 the disposable income minus investment financing (business and professional);
Y_4 the disposable income minus investment financing minus personal consumption.

Some very incomplete adjustments have shown that Y_4 gives the best results in automobile purchase forecasting, but this factor cannot always be isolated in the accounts of developing countries.

Most analyses of income as a factor in demand in developed countries appear to be based on M. Friedman's "expected" income, which is defined as a moving average of disposable income, in which current income accounts for one third of the total weight, and past incomes are progressively declining weights. The aim of this concept is to isolate the share of income pertaining to habits. According to Friedman's income hypotheses, current consumption is determined by the "permanent" component of income, which changes less rapidly than "measured" income. The remaining measured income has no influence on current consumption. But since Friedman does not regard net investment in durables (such as cars) as current consumption, such investment may be related to either or both.

Some authors argue that a continuous habit persistence hypothesis is plausible.[7] Others have suggested that habits formed during the period of the most recent peak in living standards exert a significant influence on current consumption.[8] Under the latter hypothesis, consumers attempt to maintain that peak standard of living in the face of falling incomes but are sluggish in adopting higher standards when their incomes rise above a former peak standard of living.

However useful such notions may be in predicting the demand for automobiles in developed economies, their analytical value is negligible in developing countries with annual *per capita* incomes below $300.

The concept of the threshold

Nonetheless, an understanding of the structure of personal incomes is necessary to calculate the threshold income at which purchase of a car becomes possible. The income relevant to car purchase is household or unit income rather than *per capita* income. The threshold depends not only on the amount of disposable income spent on essentials but also on:

The relative saturation of demand for other durable goods and housing;
The introduction of new and cheaper models of automobiles;[9]
Factors such as higher investment in roads, increased urbanization, industrialization, the development of tourism etc.

J. S. Cramer's pioneering study[10] introduced a median tolerance income M that indicates the level of income (or total expenditure) at which exactly half of all households are motorists. Since 1948, the value of M (expenditure *per annum*) in the United Kingdom has declined from £2,050 to £1,300.

M. G. Vangrevelinghe showed that in Fanrce the median M fell from FF13,000 in 1956 to FF8,500 in 1962 (both calculated *per annum* in 1959 prices). It is expected to decline further to about FF7,000 by 1970. The income of car-owning families is higher than the average family income, but the ratio between the two is decreasing.[11]

The threshold can be shifted by instalment sales plans. In the United Kingdom the lengthening of the contract repayment period from two to three years is estimated to lead to sales increases of 5 to 10 per cent in the long run. In developing countries the effect is even more marked. It is estimated that in Argentina a similar lengthening of the instalment period would increase sales by 38 per cent in the long run. Introduction of instalment plans transforms automobile purchases from a one-payment "lump" expenditure into a divisible expenditure and thus moves the threshold income downwards.

Relationship between age of car and family income

In the United States the ownership of cars is too widespread for the threshold concept to be of value in projecting car demand. The important relationship is between the *per capita* income and the age, operating and replacement costs of a car. This was demonstrated

[7] Brown (1952), pp. 355—371; Klein (1954), p. 291; Klein and Goldberger (1955), p. 8.

[8] Modigliani (1949), pp. 371—441; Duesenberry (1949).

[9] An important factor in Italy; see Savino (1954), p. 546.

[10] Cramer (1959), p. 334.

[11] *Etudes et Conjoncture* (1965a), p. 19.

in 1954 by M. S. Farrell,[12] who found the length of ownership of cars to be inversely proportional to personal income. Families owning one-year-old cars had an income of $7,530 while those with seven-year-old cars had an income of $2,290. Families without cars had an income of $1,729.

The relationship of the age of cars to income is becoming increasingly important in other developed countries as car ownership expands. It has application to some developing countries like Argentina or Brazil, where car ownership is already quite widespread. But in most developing countries, it is not yet a major factor in the total car market.

In developing countries the actual expenditure on essentials is usually less than in developed countries, but the threshold for car purchase may be just as high. Because there are so few second-hand cars on the market, they are expensive. The second-hand cars are even more expensive when the supply of new cars is limited.

Social factors may complicate the car ownership pattern by creating more than one income threshold. In South Africa, average Europeans replace their cars after three years, while Africans usually buy second-hand cars and keep them as long as 18 years.[13]

Personal income and business income

There is a distinction between the acquisition of cars for personal use and for business purposes. In developed countries the latter accounts for a small and declining proportion of the total use, and car purchases are accordingly unresponsive to changes in business income. In its long-term forecasts for the United Kingdom, the National Institute of Economic and Social Research has assumed that if business income and personal income both increase by 1 per cent in real terms, car sales will increase by about 2 per cent; a business income increase of 1 per cent will lead to a sales increase of 0.5 per cent, while an equal increase in personal income would lead to an increase of about 1.5 per cent in car sales. In France about 95 per cent of all passenger cars are registered as privately owned, and 74 per cent of these are used for purposes other than business.

In contrast, business use is important in developing countries. Of the 16,280 passenger cars registered in the Republic of Korea in 1965, about 11 per cent were government vehicles; 55.5 per cent were explicitly registered as business cars and only 33.5 per cent for personal use, including professional use by doctors etc. (See table 1.) This pattern of car usage is fairly typical in developing countries. Business activity in the sense of commercial transactions rather than economic growth is therefore an important variable in the demand for cars in developing countries.

12 Farrell (1954).

13 *The Economist* (1967), p. 736.

TABLE 1. STOCK OF PASSENGER CARS IN THE REPUBLIC OF KOREA

Year	Passenger cars[a]			
	Government	Private	Business[b]	Total
1952	748	970	731	2,449
1953	1,031	1,581	1,049	3,661
1954	1,214	1,814	1,989	5,017
1955	1,511	2,684	2,361	6,556
1956	1,423	3,984	3,021	8,428
1957	1,501	4,300	3,942	9,743
1958	1,686	4,426	4,654	10,766
1959	2,129	3,899	6,106	12,134
1960	1,950	4,224	6,602	12,776
1961	1,095	1,925	6,789	9,809
1962	1,374	2,571	7,129	11,074
1963	1,491	3,322	7,866	12,679
1964	1,527	4,487	8,572	14,586
1965	1,649	5,580	9,051	16,280

Source: Ministry of Transport, Republic of Korea (1966) *1965 Yearbook*, Seoul.

[a] Figures for the end of the year.

[b] Taxis and minibuses.

Prices

For car-owning families, the relevant elasticity is the change in the quantity of new cars bought relative to a change in the used-car prices. In countries where there are many car owners, this elasticity will probably be below unity because a low trade-in price will not deter many car owners from replacing their cars. However, in developing countries where fewer families own cars, a change in used-car prices will influence families more strongly, and the elasticity will therefore by quite high. On the other hand, if the supply of cars is insufficient due to rationing, the elasticity may be near zero.[14] No matter how high the prices of used cars rise, families will not sell because they cannot buy a replacement.

A rise or fall in car prices should be compared to the price movements of other goods. It has been suggested that the income elasticity of a commodity is an increasing function of its price relative to other commodities.[15] This appears to be valid in Italy and Spain. Prices are also correlated to stocks, that is, the level of ownership of automobiles. In intricate demand functions calculated for the United States the price exponent was found to be as high as —0.74, indicating that an increase of 1 per cent in price would induce consumers to reduce their replacement purchases by 0.74 per cent.[16] This applies only to a minor degree in countries with lower car ownership levels where replacements represent only a small fraction of sales. (See Italy in figure 1.)

14 Tobin (1952); Tobin and Houthakker (1950/1951).

15 Bandeen (1957).

16 Roos and Szelisky (1939), p. 52. This calculation for pre-war United States is confirmed by Chow (1960, p. 149) who found a price elasticity of —0.7 for the early fifties.

Such considerations have little relevance for developing countries. An analysis of marginal price elasticities is a pointless exercise when increased or decreased import duties tend to alter car prices substantially: in this case there will probably be no response to a price decrease or increase within a 0 to 10 per cent range, but beyond this range a sharp response may occur as many customers abruptly enter or leave the market.

Since prices are also correlated to a car's durability and costs of operation, an index of durability could be used theoretically to convert the price into the replacement cost. The durability and costs of operation are indicative of quality and are probably more important than price alone in car purchases.

The price elasticity of automobiles is not as high as might be expected because of their durability and because there are other ways to obtain automobile transportation than to buy new cars: consumers can keep their existing cars with the cost of repair bills; obtain replacements from the used-car stocks of dealers; or use public transport.

Stocks, depreciation and replacement

The simplest regression, where gross investment is taken as a linear function of income and initial inventory, is also the most satisfactory for countries with a high level of car saturation. H. S. Houthakker and J. Haldi calculated this regression for four different levels of income and stocks in the United States. Although there is some overlap, the four "Engel curves" for different levels of initial inventory are on the whole clearly separated, gross investment being highest when initial inventory is smallest. The regression coefficients all have the correct sign and are highly significant.[17]

A correlation between real *per capita* gross domestic product at market prices and the stock of automobiles per 1,000 population is also highly significant for the seventeen countries for which data were obtained (see figure 1). But only three of these countries—Argentina, Mexico and Spain—can be classed as developing countries, and they are relatively advanced. Also, since the straight line of regression crosses the abscissa at a level of about $300 *per capita*, almost all developing countries are eliminated from the picture.

In the market mechanism, the existing stocks supply the trade-in and used-car markets. The prices of used cars trade-in allowances influence a family's decision to replace its car, but they have only a limited effect on the total stock of cars. Only scrapped cars represent real replacements, and the increase in stock in any year is calculated by subtracting the number of scrapped cars from the new registrations.

Once a certain level of ownership is reached, the growth in the stock of cars becomes more and more

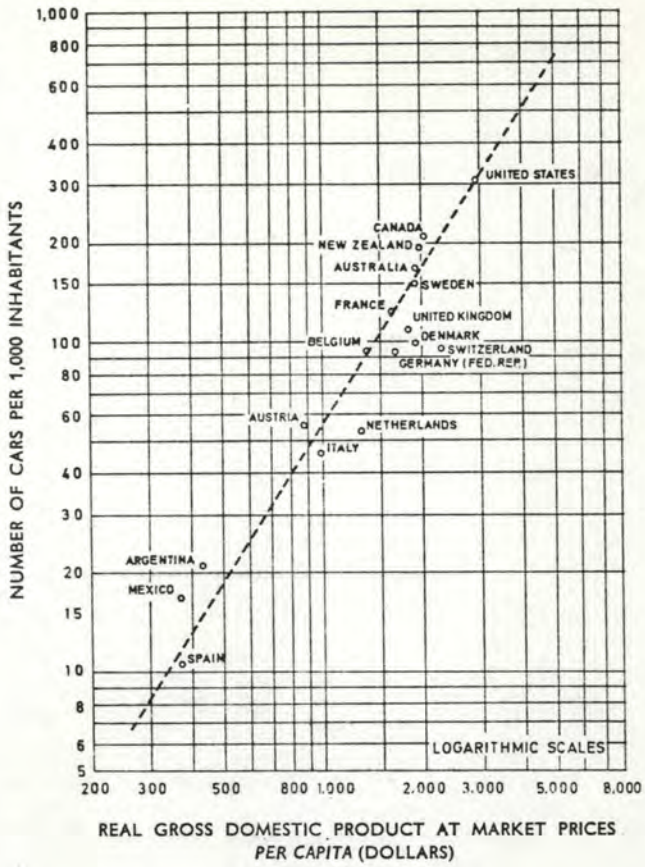

Figure 1. Automobile ownership and level of economic development in 1962. Source: Etudes et Conjoncture *(1965b)*

dampened through the increased number of scrapped cars: this can be demonstrated by calculating the changes in the ratio of scrapped cars to new registrations. Figure 2 shows this ratio for four developed countries. In the United States the ratio of scrapped cars to new registrations has risen from 53 per cent in 1955 to about 70 per cent at present.[18] The ratio in Europe is much lower. Italy is clearly still an "immature" car market despite the advances of the last few years; its very low level of replacement demand is about one tenth of the total in 1965, and replacements have not yet begun to rise. The other countries show signs of rapid increases in the number of scrapped cars. The United Kingdom was at Italy's level about ten years ago, but in 1965 the number of scrapped cars was about 42 per cent of new registrations. In the Federal Republic of Germany the 1965 figure was 35 per cent. In France this ratio is about 31 per cent; it is expected to reach 53 per cent by 1970.[19]

17 Houthakker and Haldi (1960).

18 *The Economist* (1967).

19 Data of the Institute of Statistics and Economic Studies in Paris.

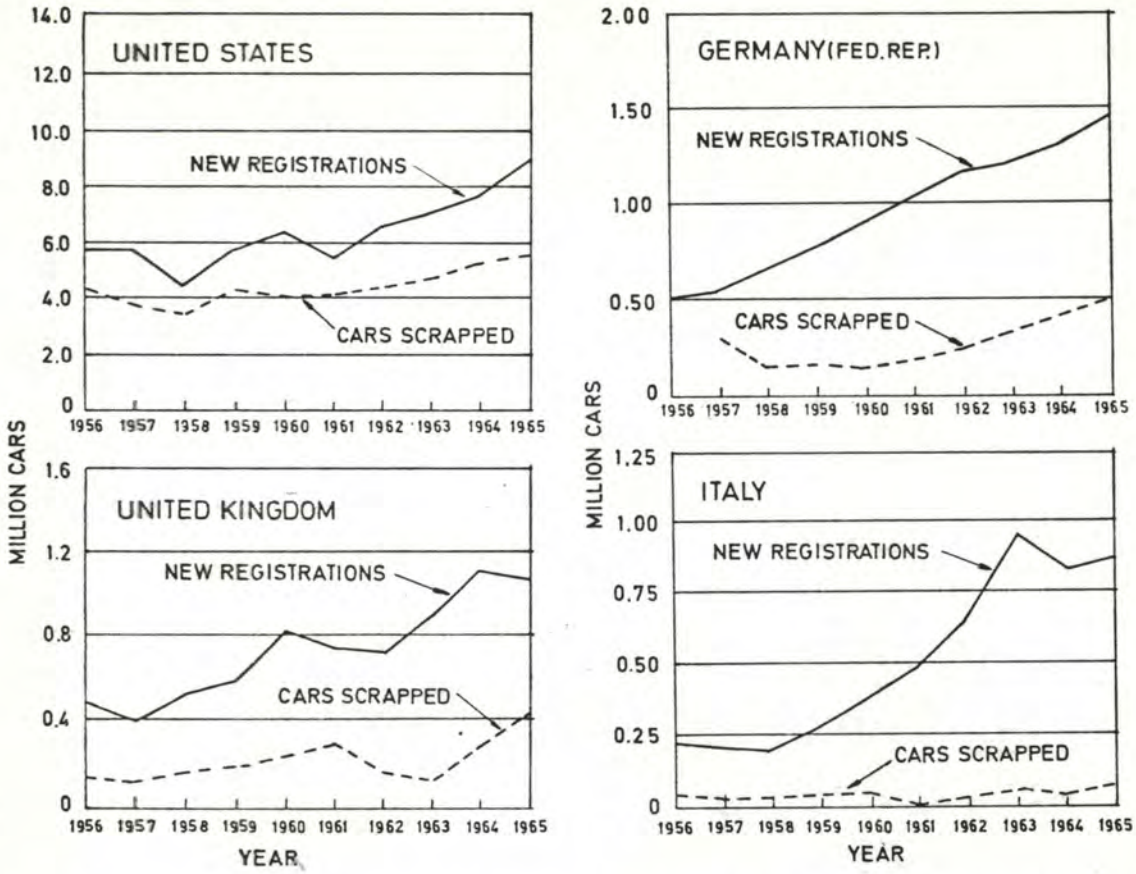

Figure 2. Annual registration of new cars and replacement of used cars in the United States, the Federal Republic of Germany, the United Kingdom and Italy from 1956 to 1965. Source: The Economist *(1967)*

The replacement ratio is also dependent on the average life span of a car. The following data show that the life span is decreasing:

Country	*Year*	*Life span (years)*
United States	1954	14
	1962—1964	10
Federal Republic of Germany	1954—1956	13.6
	1960	12.7
United Kingdom	1965	12
Sweden	1960	11.5

Source: United States, K. Boulding, "An Application of Production Analysis to the Automobile", Kyklos, Vol. 8, No. 2; Sweden, Wallander, "Studien i Bilismesns Economi"; Federal Republic of Germany, *Absterbe-Ordnungen für Kraftfahrzeuge*, Essen, 1962.

The decreased life span of passenger cars is caused by:

The additional demands of driving in heavy traffic and parking difficulties;

The shorter technological life span of new models due to built-in obsolescence;

Increased obsolescence due to higher living standards.

The last factor is probably the most important in developed countries. In developing countries, poor roads and improper maintenance decrease the life span to such an extent that there is probably only a small difference in the life span of cars in developed and developing countries.

Forecasting methods

The methods for forecasting automobile demand in developed countries can be divided into three categories: complex projection methods, less complex projection methods and simple projection methods.

Complex projection methods involve calculating the threshold of access to motorization and the number of families with incomes above the threshold. The analysis of income distribution data is required. When these data are known, the underlying mathematics are simple. (See appendix 1.)

Less complex projection methods are based on estimates derived by least-squares regression. Since both the retail price and the number of new cars sold are endogenous variables, an estimate by least squares gives biased results; nevertheless, the bias is likely to be

negligible by comparison with errors in the data. The use of elaborate techniques in order to avoid this bias is uneconomical. (See appendix 1.)

Simple projection methods can be used after establishing the co-variance between automobile demand and other leading macro-economic indicators. This co-variance has different values at different levels of economic development even among developed countries.

Figure 3 shows the co-variances (one in absolute and another in marginal terms) of automobile sales with such basic indicators as the index of industrial production in the United States and also a co-variance of new car registration (percentage of car population in the previous census) with consumer spending (percentage increase with constant prices) in the United Kingdom. The curves of automobile demand run

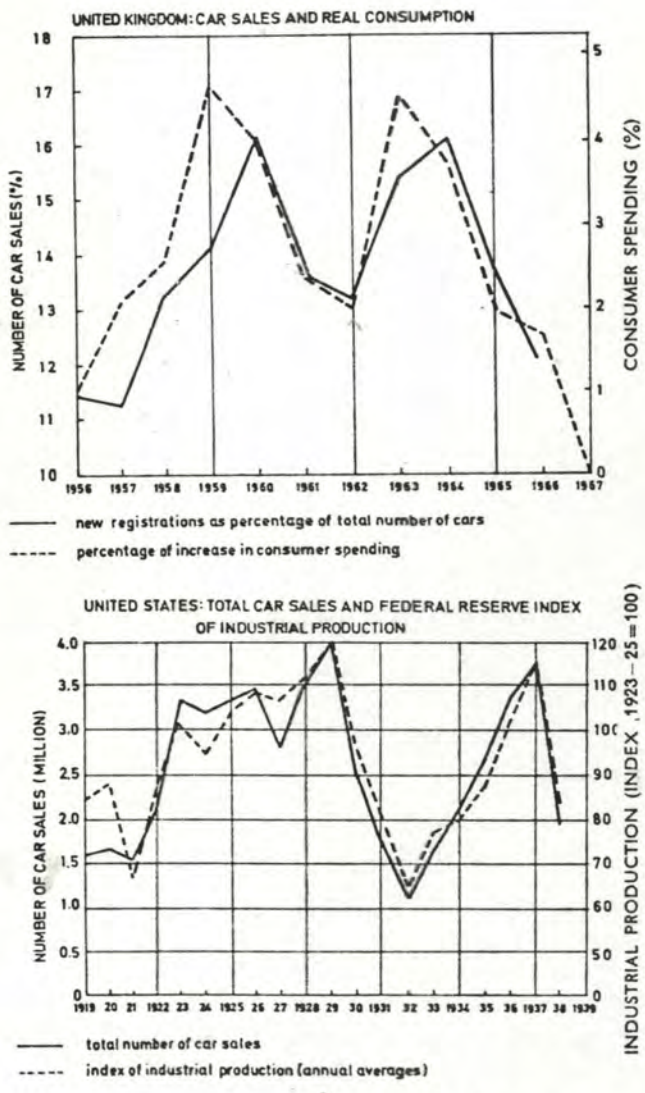

Figure 3. Relationships between car sales and leading indicators in the United States and the United Kingdom. Source: calculated from statistics published in United Nations Statistical Yearbook *and in various issues of the* Quarterly Economic Review, *National Institute, London*

almost exactly parallel to those of the above indicators. This simply shows that purchases of cars at a certain level of development are subject to the same type of business fluctuations as other, more aggregated phenomena, although there may be a time lag both on the uprise, where car sales increase in anticipation of a favourable business climate and decline prior to a period of business restraint or even a recession. Thus, a 1.5 per cent increase in real consumption is preceded by a 12 per cent increase in new car registration, while a 4 per cent increase in consumption is preceded by a 17 per cent jump in car sales. A decrease in the elasticity coefficient is the result of various dampening factors, such as an increased stock of cars, rising car prices or a limited production.

Another simple forecasting method is to calculate the ratio of expenditure on automobiles to increments of income. Table 2 shows this ratio for different percentages of economic growth in three countries: the ratio has a marked upward tendency; in some countries a very high "marginal rate of automobile consumption" —more than 10 per cent—is attained at a comparatively early stage of economic growth.

2. Automobile demand in developing countries

Structure of income

Brazil is one of the very few countries where the pattern of income distribution has been taken into account in projections of automobile demand. The growth of passenger car sales[20] was forecast by means of the following equation:

$$1 + q = \frac{(1 + r)^{\alpha}}{(1 + p)^{\alpha - 1}},$$

where q is the potential rate of growth of automobile stocks,

r the growth of GNP in constant prices,

p the population growth,

α the Pareto income distribution coefficient, which is the parameter of the income distribution curve calculated as the elasticity of the number (Y) of income-receiving units, persons or families to the lower income limit x, i.e.

$$\frac{\mathrm{d} \log Y}{\mathrm{d} \log x} = -\alpha.$$

With the gross national product in constant prices growing at 6.1 per cent *per annum*, population at 2.4 per

[20] Derived from an equation for q in Confederação Nacional da Indústria (1960):

$$q = \frac{(1 + r)^{\alpha}}{(1 + p)^{\alpha - 1}} - 1.$$

TABLE 2. FINANCING NEW AUTOMOBILE PURCHASES FROM INCOME INCREMENTS
(marginal rate of automobile consumption)

	GNP per 1,000 inhabitants, 1964 prices ($)	*New cars per 1,000 inhabitants* (%)	*Additional income per new car* ($)	*Additional income spent on each new car* (%)
	(1)	(2)	(3)	(4)
Italy				
1955	620,000	3.4		
1960	794,000	7.7		
Increment over 1955	174,000	4.3	40,500	4.2
1963	953,000	18.8		
Increment over 1960	159,000	11.1	14,300	11.9
Spain				
1955	350,000	0.6		
1960	403,000	1.6		
Increment over 1955	53,000	1.0	53,000	3.2
1964	567,000	4.1		
1966	645,000	8.8		
Increment over 1964	78,000	4.7	16,600	10.3
France				
1955	1,306,000	10.1		
1960	1,575,000	14.0		
Increment over 1955	269,000	3.9	69,000	2.5
1963	1,756,000	21.9		
Increment over 1960	181,000	7.9	23,000	7.4

Source: Author's estimates.

Note: The percentages of income increments are channelled into purchases of new cars: calculate in column 1 the increase in GNP/1,000 inhabitants over a longer period of time and compare it to the increase in registration of new cars per 1,000 inhabitants over the same period (column 2). An increment of income per additional new car (column 3) can then be easily established. Finally, given $1,700 as the average price for a European car, the percentage of additional income spent on new cars will be determined (column 4).

cent and an income distribution coefficient[21] of 1.7, the growth of car sales can be calculated:

$$1 + q = \frac{(1.061)^{1.7}}{(1.024)^{0.7}} = 1.087.$$

The annual sales are calculated from the difference between the potential stocks of the preceding and current years. Brazilian forecasters add to the annual sales the number of vehicles needed to replace the existing stock. It has been estimated that the average life of passenger cars is about 20 years. If the ages were equally distributed from one to twenty, annual replacements would have to be 5 per cent of the stock. However, life-span data are lacking in Brazil. The estimate of scrapped cars is 2.2 per cent of the stock and sales were 10.2 per cent. Thus, replacement sales amounted to only one fifth of the total sales; the remainder represents purchases by new buyers who crossed the income threshold.

After the rate of scrapped cars has been established, the average car life and the annual rate of growth of car stocks can be included in one formula; this exercise is too lengthy and complex for this paper.

Argentine data illustrate the influence of income distribution on automobile sales. Data were obtained in an investigation of the distribution of expenditures among urban families according to the annual family income. Early in 1963, 454 family units were selected by standard random-sampling techniques in Argentine cities with populations larger than 10,000; they were interviewed in detail. The results indicate that the upper 28 per cent of family units (annual income early in 1963 of over 275,000 pesos or $2,000) were responsible for more than one half of all expenditures on durable goods in 1962. The upper 46 per cent of all family units (annual income above 200,000 pesos or $1,500) purchased more than three fifths of all durable goods in 1962.

Automobiles account for almost one half of all family expenditures on durable goods. Expenditures for cars are even more heavily concentrated than for furs and jewellery: the top quartile of the sample (income over $2,000) accounts for almost 90 per cent of all automobile purchases. The inclusion of families in the $1,500 to $2,000 income bracket adds a mere 4 per cent to this concentration. Purchases of other durable goods such

[21] Parameter a has been estimated for Brazil (Loeb and Kingston, 1958). The "normal level" is generally considered to be 1.5 (Davis, 1941, p. 2).

as refrigerators, washing machines and television sets are much less concentrated: here, the upper-income quartile accounts for no more than one fourth to one third of the total.

A similar relationship was found by L. R. Klein for developed countries with little or no expenditures at low income levels. Expenditures rose somewhat faster than the linear rate with increases in income in the low-income group, but thereafter the relationship becomes essentially linear.

Structure of automobile stocks

Colombian projections of automobile demand are not based upon any mathematical model but are derived from observations of the past.[22] From 1950 to 1955 the rate of growth of automobile sales was as high as 22 per cent *per annum*, but from 1958 to 1962 it had fallen to 8.3 per cent.

The elasticity of new car sales to the growth of gross domestic product *per capita* fell from 4.0 from 1950 to 1962 to 2.4 from 1954 to 1962. If the latter elasticity is applied to an expected GDP growth of 5.6 per cent *per annum* and a population increase of 3.1 per cent *per annum*, new sales should grow at a rate of 9 per cent *per annum* in the next few years. The average income elasticity of car sales in all of Latin America was about 1.7 in the late fifties.[23]

To the predicted figure of new car sales, Colombian forecasters also add a number of cars for replacement of scrapped cars. This estimate is far higher than for Brazil, for while it is based on the same 20-year life of a passenger car, it assumes that as much as 5 per cent of the total existing stock will be replaced annually. This estimate of the rate of replacement is clearly too high, for it implies that over 40 per cent of new car purchases are replacements of scrapped cars. The 1965 figures for Italy and France were 10 per cent and 31 per cent respectively. It would appear that lack of information about the actual composition of the car stocks has led to a considerable error.

Figure 4 compares the age structures of automobile stocks in Colombia and the United States.[24] The distribution curve for the United States is very regular; it increases from 2 per cent of the total for cars manufactured in 1953 to 13 per cent for cars manufactured in 1964. The distribution curve for Colombia is very uneven. Car vintages whose share in the total is disproportionately high correspond to years when import restrictions were relaxed and a backlog of accumulated demand could

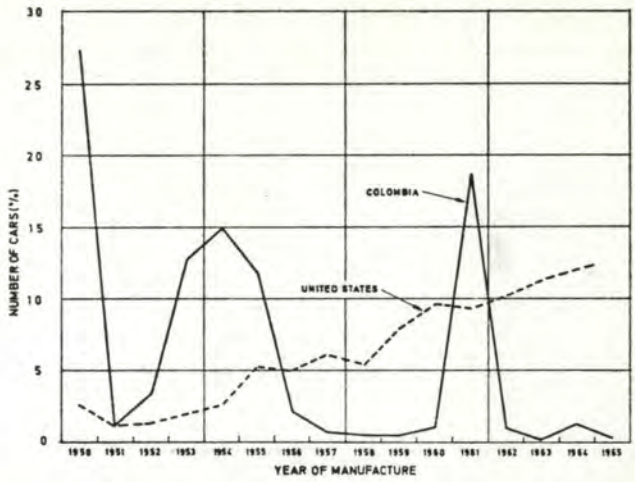

Figure 4. Distribution of the total number of cars in Colombia (mid-1965) and in the United States (end of 1964) according to the year of manufacture. Source: Lewin (1967), p. 742

be satisfied. In 1966 import licenses were issued more freely and more quickly than in 1965, and the total number of cars imported therefore rose from 1,825 during January to September 1965 to 7,401 during January to September 1966.[25]

Figure 4 shows that the 1957 to 1960 vintage automobiles account for only 1 per cent of the total for each of these years. If we assume that the life of a car is 20 years, sales in 1977 and replacements during 1977 to 1980 would be very small. But as almost 20 per cent of all cars (in 1965 the total stock was about 250,000 cars) were of 1961 vintage, in 1981 replacement demand would theoretically jump suddenly to 50,000 new cars and then fall again abruptly in 1982. The real saturation will undoubtedly reflect modifications of these trends, for the life of a car is not uniformly fixed at 20 years. At the same time, this example illustrates the need for a clear-cut government policy on car sales and also for a detailed knowledge of the structure of car stocks.

In the Republic of Korea, too, the car age structure is uneven, and forecasters take into account the volume of business purchases of passenger cars. (See table 3.) They assume that the growth of business car ownership is influenced not as much by income and price movements as by increasing demand for transport services as distinct from ownership. This demand is unlikely to be satisfied without an upward move in incomes, but the link between the two factors is not very clear. The rate of urbanization and other related factors may also be important. The forecast of growth in automobile purchases was therefore derived from a forecast of passenger transport based on highway improvements

22 Banco de la República (1966).

23 Gómez and Ruiz (1958).

24 See also Lewin (1967), p. 742.

25 International Monetary Fund (1967).

and on the relationship between the growth of the gross material product and the increase in transport flows.[26]

TABLE 3. AGE STRUCTURE OF PASSENGER CARS IN THE REPUBLIC OF KOREA

Year of manufacture	Passenger cars		Minibuses	
	Number	%	Number	%
Before 1945	1,545	14.3	58	1.9
Between 1946 and 1950	398	3.7	196	6.5
1951	210	1.9	3	0.1
1952	113	1.0	3	0.1
1953	360	3.3	7	0.2
1954	490	4.5	7	0.2
1955	1,358	12.6	11	0.5
1956	207	1.9	14	0.6
1957	216	2.0	62	2.1
1958	1,530	14.2	103	3.4
1959	352	3.3	16	0.5
1960	223	2.1	7	0.2
1961	209	1.9	12	0.4
1962	1,528	14.1	1,991	66.4
1963	1,745	16.2	207	6.9
1964[a]	327	3.0	300	10.0
Total	10,811	100.0	2,997	100.0

Source: Ministry of Transport, Republic of Korea (1966) *1965 Yearbook*, Seoul.

[a] First quarter of 1964.

In Morocco, car ownership has shifted from French to Moroccan nationals. Moroccan car statistics give both the age of registered automobiles and the nationality of the owners.

CAR OWNERSHIP IN MOROCCO

	1957	1963	1964
Percentage of cars less than		*Per cent*	
10 years old.....	—	54.5	57.2
Ownership of cars by nationality:		*Vehicles*	
Moroccan nationals	43,437	110,441	121,414
French nationals	64,852	53,195	50,410
Spanish nationals	3,431	12,470	12,590
Others	6,691	16,302	13,000
Total French nationals residing in Morocco	450,000		120,000

Source: Marchés Tropicaux et Méditerranéens (1966) February 22, p. 638.

From these figures, it would appear that the large increase in the number of car-owning Moroccans was connected to an upward shift in the age structure of the cars, which they had acquired from departing French residents.

The relatively small new additions to the total stock in recent years (5 per cent *per annum*) support this view. It seems likely that these additions consisted mostly of replacements by French residents and also by a small number of Moroccans in high-income groups. The French nationals there in 1964 on the whole received higher average incomes than those who were living in Morocco in 1957; this undoubtedly accounts for a rise in ownership among French nationals from one in seven persons in 1957 to one in 2.4 in 1964. While the more affluent French nationals probably replaced cars more rapidly than they did in 1957, the average Moroccan purchased a car from a French national but never can buy a replacement for it. In any case, forecasts of automobile purchases in Morocco must take into consideration the age structure of the automobile stock and the income sources and future intentions of the French community.

Restricted automobile supply

In developing countries it cannot be assumed that the supply of automobiles will meet demand at market prices. Governments may limit car imports to conserve foreign exchange, restrict local production in favour of other goods and ration the available cars to prevent profiteering by importers and local manufacturers.

Tunisia illustrates this point. As in Morocco, the demand for new automobiles diminished with the departure of French nationals; imports fell from 4,157 automobiles in 1955 to 2,903 in 1960. But in 1963 car imports were restricted to 1,700 units a year as part of a strict austerity policy (actual imports were 1,710 in 1963 and 1,774 in 1964). Post-independence registrations in Tunisia cannot thus be regarded as an indication of demand.

Countries which levy high import or sales taxes in order to restrict demand all face the same problem: if these taxes were reduced, demand will presumably rise rapidly as the income threshold at which purchasers enter the market is lowered. In the absence of price elasticity studies, this threshold is difficult to forecast. Attempts to evaluate price elasticity from hypothetical price changes are notoriously difficult exercises.

3. FORECASTING AUTOMOBILE DEMAND IN DEVELOPING COUNTRIES

The forecasting techniques applied in highly developed countries are not suitable for developing countries not so much because of the lack of pertinent statistics but rather because the structure of automobile demand is so different. The structure of the market suggests a

[26] *Korea transportation survey*, Seoul, June 2, 1966, Chapter III, p. 25. It is worth mentioning that although the Transportation Mission, which was financed by IBRD, consisted of more than ten prominent experts from four leading European consulting organizations, no rigorous model was used to project the increase in automobile demand. The Mission's conclusions were that: "The future use of private cars will be stimulated by the improvement of Korean highways and, as soon as import restrictions are removed or lessened the number of cars will increase. Therefore the past trend does not give good indications for future transport. The Mission adopted, arbitrarily, an annual growth rate of 16% for transport by private cars."

forecasting approach based on a concept of growing markets, which, in turn, indicates the necessary statistics. Once the principal market trends are established, the effects of changes in government policies can be considered.

A model of automobile markets in developing countries

In all developing countries car owners and purchasers are rich people by local standards, and a car is a luxury purchase. This is particularly true of initial car purchases in a developing country by the very affluent, by large business enterprises and by government authorities, so that prices tend to be almost irrelevant. Large luxury cars are purchased, and the saturation of these groups of consumers is very high.

As cars become more familiar and the road network improves, new and larger purchasing groups enter the market. Their exact nature and size depend on a country's particular characteristics, but they have some general features in common. There are additional purchases by government authorities and business enterprises, but most of the purchasers are owners of businesses (either for personal or business use), high-ranking government officials, business executives and professional men. As car ownership progresses downward from the very high to the moderately-high income group, the price becomes a more important factor. Both price elasticity and income elasticity rise. Smaller cars whose upkeep will entail less expense are bought. Changes in car prices and income levels produce a greater effect. As the income threshold below which a car cannot be bought is approached, and the amount of discretionary income available to the consumer diminishes, the proportion of car owners in each income group also falls.[27] But the numbers in each successive lower-income group are increasing, and car saturation therefore usually continues to grow at an increasing rate until shortly before the income threshold is reached; then it begins to decline sharply. (See table 4.)

TABLE 4. UNITED KINGDOM CAR OWNERSHIP BY INCOME UNITS IN 1953

Gross income of income unit (£)	*Car-owning income units (%)*
0—99	1.4
100—199	0.3
200—299	3.3
300—399	5.1
400—499	7.4
500—599	10.2
600—699	16.8
700—799	28.9
800—999	30.2
1,000—1,499	51.5
1,500—1,999	60.3
2,000 and over	75.4

Source: Klein (1955), p. 410.

[27] This concept is illustrated by Klein (1955), p. 410, in a table reproduced here as table 4.

As the threshold is reached the market ceases to expand to new, lower-income groups. Unless there is a substantial change in the ratio of car prices to incomes, further sales to new customers will depend on:

Increased ownership saturation within existing groups of consumers;

Additions to the higher-income groups as a result of population growth;

Improving levels of income with the result that new groups cross the threshold;

Sales of second and third cars to income units already owning one car.

The basic determinant of the income threshold for car ownership is the relationship of car prices (including black market prices in conditions of restricted supply) to income, but social habits are also important. The degree to which cars are regarded as symbols of social and economic status influences the extent to which consumers will purchase them rather than save the money and prefer them instead of other goods and services. In general, patterns of car ownership tend to include owners of medium-sized businesses and professional workers but not clerks, blue-collar workers and farmers. The car market in developing countries is thus clearly not a mass market; a country with signs of a mass consumption pattern of cars is becoming a developed country.

Supply factors influence the rate of market penetration in developing countries. When the supply of cars is limited, countries sometimes ration the supply of cars, but more often they adopt indirect methods such as sales taxes, import controls and tariffs, and local production schedules: all these tend to raise the income threshold for car purchase.[28]

Gasoline, service and sales facilities, and roads are also of importance in this connexion. In developing countries cars are concentrated in cities partly because this is where the high-income groups live, but also partly because cities have roads (ill-kept and congested though they may be). Service facilities expand wherever cars are concentrated and so does sales pressure; this is particularly true of instalment plans which help to lower the income threshold. Service facilities also develop after the first impact of car ownership, since the tendency is for the rate of car purchases to accelerate.

The attention of international car manufacturers is attracted as car ownership grows. Those already marketing cars in the country increase their efforts, and others become interested in the new market so that sales facilities multiply. The stimulus of expanding sales leads to the formulation of government policies on local assembly and manufacture, particularly if there are pressing problems of balance of payments, while the

[28] Baranson (1969) demonstrates how local production raises car prices.

large international companies exert even greater efforts to come in "on the ground floor".

The lack of alternative transport and other services tends to increase the pressure to purchase cars, and in particular accounts for the high volume of business purchases of cars in developing countries. To a certain extent these purchases represent "fringe benefits" to business and government executives. This is probably more important than in developed countries, but in developing countries businesses frequently have a greater need for cars and other transport and communications facilities than in developed countries. In countries where telephones are a rarity, cars are frequently sent with simple business messages ordinarily transmitted by telephone in developed countries, although this is at high cost to the enterprise and adds to the already serious traffic congestion.

The business reasons for car ownership tend to be most pressing in periods of rapid economic growth, particularly booms in industrialization; such periods also coincide with a rapidly increasing personal demand for cars. However, as the supply of telephones increases, the rate of growth in the demand for business cars tends to decline. The lack of public transport in some cases extends car ownership to clerical and blue-collar workers who purchase cars on the instalment plan in order to travel to work and cover the cost by carrying fellow employees.

Both demand and supply factors therefore tend to impose a three-stage pattern in the growth of car saturation in a developing country. The first stage is a period of slow growth as cars are introduced in the country through purchases by the wealthy: sales and service facilities are expanded; roads are built. The second stage is a period of rapid growth when car ownership is a reality to a very high proportion of income earners from the wealthy down to the income threshold for car ownership: cars become readily available; business demand for cars is high; the road network is expanded. In the third stage there is a much reduced rate of growth after the principal market has been established and saturated; sales depend on additions to the upper-income groups and on car replacements (figure 5).

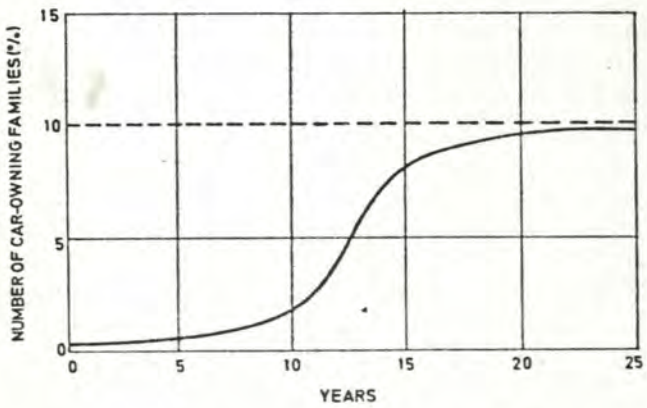

Figure 5. A model curve of the saturation of the market for automobiles in a developing country

The model curve in figure 5 focuses attention on the saturation of the car market and on new car sales in the early stages of car market growth when replacements are negligible. As the market progresses towards saturation, replacements become an important factor and have to be taken into account. Ultimately, as a country's economy develops and car ownership becomes widespread, replacements swamp purchases by new consumers. Therefore forecasting methods must be based on replacement models.

Calculating the demand for automobiles in developing countries

A three-stage growth pattern with a slow build-up, a steeply accelerating middle slope and a decelerating approach to an upper asymptote is a familiar economic phenomenon that is usually described in mathematical terms as an S-shaped growth function. H. T. Davis[29] fitted a logistic function to the growth of automobile production in the United States between 1913 and 1927 and extrapolated the curve to 1939 to indicate the extent of overproduction in 1929 and underproduction from 1930 to 1936. The expected production rate was again attained in 1937.

The logistic curve is obtained from the function:[30]

$$y = \frac{k}{1 + e^{a+bx}} \text{ where } b < 0.$$

At first sight, fitting and S-shaped curve to past new-car sales in a developing country and extrapolating future sales would appear to be the most logical forecasting method, but there are difficulties in its application. The model suggesting this approach is best applicable in the early stages of a car market, for at this point there are not enough data from which to extrapolate future trends with confidence. By the time data are available, replacement sales are swamping new sales and other forecasting methods are more appropriate. The fact that new-car sales data are not usually available for developing countries is an added, though minor, complication. In most cases they can be calculated from import and local production figures.

A more complex forecasting alternative is to convert the model of market expansion into an S-shaped curve by estimating the constants. The model of car saturation lends itself best to this approach because reasonable saturation prospects are not too difficult to estimate. Sales to new consumers can be calculated once the saturation path is plotted, and additional sales due to

[29] Davis (1941), pp. 210—211. Davis followed Kuznets (1930), who showed the appropriateness of the logistic function to the growth of product demand by fitting it to some 50 series.

[30] James and James (1968), p. 223.

multiple ownership and replacement can be estimated separately and added. Experience with consumer durable saturation suggests that the best fit is likely to be obtained with the Gompertz curve which has the following function:

$$\log y = \log k + (\log a)\, b^x,$$

or

$$y = ka^{b^x},$$

where $0 < a < 1$,

$0 < b < 1$.

At $x = 0$, $y = ka$, and as x approaches infinity, y approaches k. The increments in y as x increases are such that the differences in the increments of $\log y$ are proportional to the corresponding differences in $\log y$.[31] This curve generally provides a better fit for car saturation than the logistic curve because the inflexion point appears earlier and is also somewhat sharper.

A Gompertz curve can be calculated from reasonable assumptions about the values of the upper asymptote and inflexion point, the time taken to reach them and the initial saturation. The initial saturation can be estimated quite arbitrarily since it has relatively little influence on the shape of the curve. Taking the number of families in a country as an approximation of the income units, it can be assumed that at the beginning of the growth of the car market, saturation will be 0.1 per cent of all families. The inflexion point and the time taken to reach it are the critical values; they can be estimated by observing the development patterns of car sales and stocks. In Argentina and Thailand, the inflexion point was reached about 1956 (figure 6). The asymptote can be estimated from the income threshold for car purchases in a country at current prices, the likely saturation of the market which has evolved from this threshold and the time needed to reach this level of saturation. The number of families above the threshold and their ultimate "car saturation" as a proportion of the total number of families will not vary greatly among developing countries at similar stages of development, but the number of years to reach the saturation point will vary. A rapidly developing country will require much less time to reach this point than a struggling one. Once the pattern of saturation is calculated, annual demand can be derived, and the growth of car stocks cumulated; replacement demand must of course be added.

Separate saturation models can be constructed for second-car ownership and for business ownership, and annual sales can then be derived for this component of demand and added to personal demand. This may be worth-while in countries where business demand for cars is an important component of total demand, but otherwise simpler projections based on past sales will suffice. The demand for second cars is generally too small to warrant much attention.

31 *Ibid.*, p. 163.

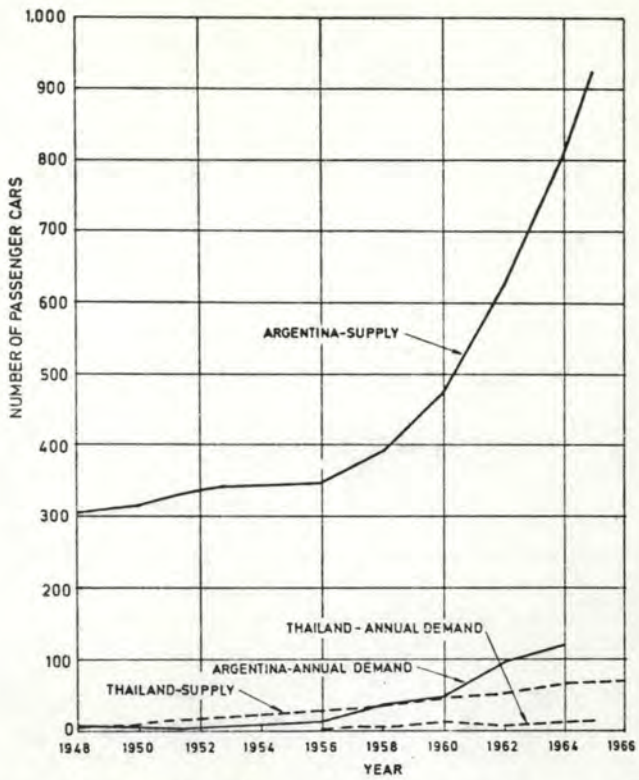

Figure 6. Supply and annual demand for passenger cars in Argentina and Thailand from 1948 to 1966. Source: calculated from data in United Nations Statistical Yearbook *and data in national annual trade statistics*

Major shifts in incomes, car prices or social habits will, of course, affect saturation by shifting its path to a new curve; these shifts must consequently be incorporated in current forecasts. The saturation pattern will also be influenced by short-term fluctuations in business conditions, changes in the money market and other factors which may accelerate or postpone the decision to purchase a car. Because of the prestige attached to the possession of a car and also its intrinsic value, such fluctuations are, however, unlikely to affect the long-term saturation pattern to any major extent.

The degree to which the techniques outlined can be used in formal econometric models will largely depend on the statistical information available. The income threshold for car purchases is always difficult to estimate. The data on income distribution in developing countries are too incomplete to calculate the number of income units above the threshold. In the early stages annual stock increments can be regarded as new-car sales if stock figures are available, for the number of scrapped cars will be negligible. The number of new-car sales can usually be calculated by adding imports and local production; it can serve as a check on stock figures and also as a basis for scrapped car estimates (see table 5 for data on selected countries for which annual figures were calculated if not available).

The saturation approach to forecasting strengthens the argument for more precise car statistics similar to those published for developed countries. The tendency to publish statistics only of stocks rather than annual sales as well as stocks has been encouraged by the United Nations Statistical Yearbook which gives only the former.[32] One hesitates to add to the burdens of statisticians in developing countries by suggesting the publication of new series, but annual car sales figures are essential to accurately forecast the demand for cars, because they provide the basis for reasonably sound scrapped car estimates. They are, moreover, easy to collect: consult the car registration files and separate the new registrations from the re-registrations. There is a case for classifying the registrations according to the type or size of car. The market for cars can be regarded as the sum of the markets for all the various types of cars; this can also be usefully incorporated in forecasts. In developed countries car manufacturers find the monthly publication of new car registrations according to the type of car a very useful aid in production planning. The United Nations Statistical Yearbook might therefore publish new registrations as well as stocks and thus encourage countries to provide more precise annual, new-registration data.

Some countries in the initial stages of car saturation have neither the statistics nor the need for elaborate econometric forecasts. The concept of changing slopes of growth and of the saturation asymptote associated with an income threshold can nevertheless help them to formulate car policies.

Implications for policy

The general pattern of the market for cars is relevant to the formulation of certain government policies in developing countries. Initially, annual sales are usually more important, but the growth in the stock of cars is also a significant factor in economic policies and plans.

As car saturation begins to grow, governments generally become aware that car sales can be revenue earners either through import duties or sales taxes. Once the demand of wealthy private persons, government officials and business executives is satisfied, duties and taxes will retard the rate of saturation and raise the income threshold which constitutes the basis of the market and thus reduce the extent of the market. If governments wish to reduce spending on luxuries as well as to raise revenue, this policy should be adopted.

Countries with balance-of-payment difficulties frequently try to restrict car imports. The market saturation pattern suggests that in the early stages high duties or taxes are not likely to be a very effective means of restricting demand, but that they nevertheless become increasingly effective as successively lower income groups become consumers.

Import restrictions will reduce demand to the required level if they are strictly enforced. But unless they are accompanied by stringent rationing, a black market in cars will develop under the pressure of unsatisfied demand. Such black market prices are likely to fall with the increase in saturation and the new demand of lower-income groups. Very high tariffs or sales taxes will have the same effect as restrictions in reducing the number of imported cars and will probably channel them to the same consumers who would otherwise purchase cars in the black market. Therefore, high tariffs and sales taxes are preferable because they do not encourage disregard for laws.

TABLE 5. ANNUAL DEMAND FOR CARS IN SELECTED COUNTRIES
(1,000 cars)

Country	*1948*	*1950*	*1952*	*1954*	*1956*	*1958*	*1960*	*1962*	*1964*	*1966*	*1967*
Argentina	7.4	1.9	2.3	4.6	11.2	35.7	48.2	96.0	119.5		
Production and assembly	—	—	—	1.5	2.3	20.7	45.1	93.9	119.0		
Imports	7.4	1.9	2.3	3.1	8.9	15.0	3.1	2.1	0.5		
Colombia	6.2	6.4	5.0	16.7	2.0	0.6	6.8	6.2	4.0		
Assembly	—	—	—	—	—	—	—	2.0	0.9		
Imports	6.2	6.4	5.0	16.7	2.0	0.6	6.8	4.2	3.1		
Morocco											
New registrations									8.2	6.7	10.2
Thailand											
New registrations					1.4	2.6	12.1	6.2	11.0		

Source: For Argentina and Colombia, production and assembly figures come from United Nations *Statistical Yearbook*, and imports from country annual trade statistics. For Morocco, registrations beginning in 1964 are published in the *Bulletin Mensuel de Statistique, Service Central des Statistiques*. Thailand publishes new registrations after 1964 in the *Quarterly Bulletin of Statistics* issued by the National Statistical Office.

[32] Stock figures are given in the United Nations *Statistical Yearbooks*, Transport, "Motor Vehicles in Use", by country, year and passenger as compared with commercial vehicles. Production figures, including the number of firms and domestic content, are given in Baranson (1969), table 12, p. 79, "Manufacturing and assembly operation in developing countries by regions, 1965".

The economies of scale in the automobile industry are so great that car assembly and manufacture can begin spontaneously only in very large, relatively prosperous developing countries or in those which serve as distribution centres for a region. For most developing countries the establishment of an automobile industry involves a deliberate government choice which must be supported by appropriate policies.

There are various options available in the establishment of an automobile industry; the size of the domestic market is one of the most important factors to be taken into account. Despite the complexity of the problem, some general rules can be stated:

The domestic market for automobiles in a developing country will tend to stabilize as saturation approaches the asymptote; this is the annual level of demand at which local production plans can aim. A danger in planning local production arises out of the tendency to regard the upswing—particularly in its last, most steeply accelerating phase just before it begins to decline—as a linear demand trend, and then extrapolate future demand and production from it;

The estimate of annual domestic demand as the saturation level is approached should indicate whether a country should encourage the establishment of an automobile industry unless there are exceptionally good prospects for exports. If the annual demand appears to be large enough, then the country still must decide whether it should merely encourage the assembly of knocked-down cars or ultimately aim at the manufacture of car parts. If the latter alternative is chosen, then the percentage of car components which can be manufactured economically for a given market must be determined;

The scale of the market and the type of manufacturing activity chosen will determine the number of economic manufacturing units. Since economies of scale grow with the backward integration of automobile production from assembly to manufacture, and since car manufacturers tend to integrate their production backwards for fear that the component suppliers will build up a monopoly, a country which only envisages assembly can safely encourage wider entry into the industry as compared with one whose ultimate objective is the entire car manufacturing process. Experience in developing countries suggests that it is difficult to restrict entry into manufacturing after several assemblers have been permitted to enter a country.

The establishment of a local car manufacturing industry raises the cost of cars. While it is now well established that inexperience and other factors contribute to high costs, the principal cause is the lack of economies of scale.[33] This ist not simply due to limited markets but also to market fragmentation by a relatively large number of production units. In an industry highly subject to increasing returns to scale, classical arguments for competition do not hold. The choice in any case is not between monopoly/duopoly and competition, but between monopoly/duopoly and oligopoly, and the latter, which is characteristic of car production in developing countries, is probably an independent and additional cause of high prices. A monopoly with a technically efficient production structure can ultimately be exposed to competition from imports; if, however, there are several production units, this will not be possible.

The importance of high car prices in developing countries is directly related to the problem of economies of scale in production. By raising the income threshold for car purchase, increased prices reduce the total size of the market, lower the saturation level and shorten the time to reach saturation. This reduces the scale of production in the period during which the industry is being established and also lowers the ultimate production level.

Sales taxes have a similar effect. Governments which are trying to encourage the growth of an economic local car manufacturing industry should not a the same time regard cars as a luxury item which must be taxed at high rates. They are more likely to increase their revenues by taxing the industry itself, particularly if they do not dissipate such revenues in unnecessary concessions to manufacturers.

The scale of the market should be used as a yardstick to evaluate the need for incentives for car manufacturers. A forecast of a promising market is an incentive in itself and may obviate the need for direct incentives such as taxation concessions. On the other hand, manufacturers can receive extremely high incentives, either directly through taxation concessions or indirectly through high tariffs and favourable exchange rates, or even all three; yet none will be effective in establishing an economic automobile manufacturing industry if the prospective market is small.

Protective measures are likely to be necessary in developing countries, even in promising markets, to overcome the inevitable problems of the infant industry, but the pattern of saturation suggests that subsidies, provided that they are viable in other respects, may be better than tariffs. Subsidies are also easier to abolish after the market levels off towards saturation.

The short-term effects of fiscal and other government policies which temporarily change the relation between price and income will depend on the degree of market saturation. In the early stages when price and income elasticity is low, these effects are not likely to be very marked; as the final saturation level is approached,

[33] Baranson (1969) demonstrates this and also shows that the additional production cost rises with the percentage of total production in the developing country: in this connexion, it should be remembered that economies of scale are an important factor in the manufacture of complex components.

however, demand will be extremely sensitive to such measures. However, to the extent that such changes are transitory, they will merely result in a temporary dampening or acceleration of the saturation pattern. After a period of business restraint, a government should expect a sudden rise in car sales, which reflects a pent-up, unsatisfied saturation demand.

The main purpose of automobile forecasting in developing countries is to provide annual car demand estimates; this is true even for such broad planning problems as the annual increments required for road expenditure or the extent to which an increasing demand for gasoline will exert pressure on the balance of payments and justify the construction of oil refineries and the establishment of a petrochemical industry. This can be calculated from annual demand forecasts with due allowance for scrapped cars. The availability of roads and supplies such as gasoline, moreover, will influence the annual demand for cars and the ultimate saturation level. High gasoline prices, for example, have a similar effect on the car market as high car prices; they influence the use of cars as well as their purchase. Long-term government policies on road construction and gasoline procurement will affect the future demand for cars; the government policies will in their turn be influenced by car purchasers who soon become formidable political lobbyists. Seemingly simple decisions about car prices and income relationships will thus eventually affect much wider areas of the economy than is apparent at first sight.

APPENDIX 1

METHODOLOGY

Complex projection methods involve calculation of the income threshold of access to motorization and the number of families with incomes above the threshold. This method is more adapted to developing countries, where income distribution is largely skewed, than to developed countries, where it is more normal. Studies of family budgets and analyses of income distribution are being carried out in some developing countries. Data on incomes can usually be obtained from domestic revenue authorities, while family budgets are frequently an object of research by

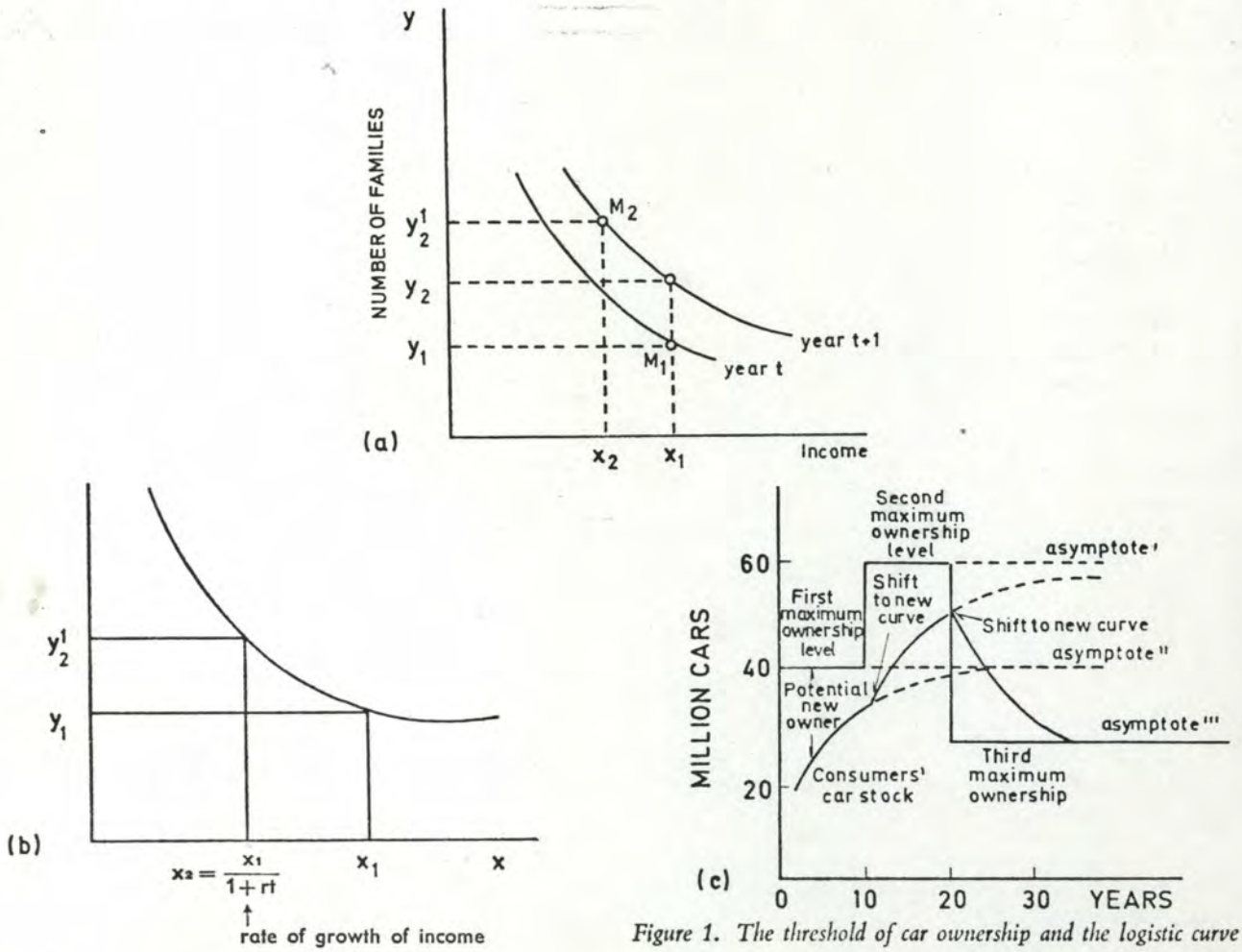

Figure 1. The threshold of car ownership and the logistic curve

development centres of national universities. Once this information is obtained, the underlying mathematics is simple.

Let x be the income threshold. (See figure 1a.) Given the normal Pareto curve of income distribution, each point $M_1 (x_1, y_1)$ represents the number of families y receiving an income exceeding x at a given time t. An increase in incomes will shift the curve to the right. At the same time, the threshold is decreasing with the passage of time. Therefore the new point will be $M_2 (x_2, y_{\frac{1}{2}})$. We should therefore distinguish three separate phenomena:

Connexion between x and y through a Pareto Law: $y = (A/X^a)$, where A and a are constants;

Upward shift of this curve with growing incomes. During a short period of time, there is no deformation of the curve as it shifts, i.e. the distribution of income does not change. Instead of shifting the curve toward growing incomes, we can simply divide the threshold x by $(1 + r)^t$, or, in first approximation, $(1 + rt)$ if r is low, where r is the rate of annual increase in the average income. (See figure 1b);

Downward shift of the threshold with the passage of time. This is due to various factors apart from the income effect such as diffusion of car use, imitation effect, relative fall in prices of cars as compared with other goods etc. The mathematical formula is:

$$y = \frac{A}{\left(\frac{x}{1+rt}\right)^a},$$

where y is the number of families receiving an income greater than x;
x the threshold below which car purchase is impossible. This threshold is, in principle, moving downwards with the passage of time;
r the yearly growth of income;
t the time.

Therefore, x becomes a logistic factor, decreasing in relation to time, and its asymptote ([111]) is defined by a certain income below which purchase of a car is out of the question. (See figure 1c.)

The following generalized formula is for less complex projection methods based on estimates derived by least-squares regression:

$$R = a_1 \Delta Y + a_2 \Delta \frac{P}{M} + a_3 \Delta S + a_4 \Delta X + a_0,$$

where R is the retail sales of new cars;
Y the real disposable income;
P the real retail price of new cars;
M the average credit terms (number of months in the average automobile instalment contract);
S the stock of used cars in circulation;
X the first difference of a dummy shift variable to account for the special conditions of the automobile market in years of severe import controls.

APPENDIX 2

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