THE ENVIRONMENTAL DIMENSION IN MOTOR TRANSPORT WITH SPECIAL REFERENCE TO TECHNOLOGY TRANSFER IN THE GLOBAL AUTOMOBILE INDUSTRY

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Abstract

This paper analyses automotive trade flows and technology transfer with reference to new international trade theories, and is designed to contribute to the practical application of these theories. The automobile industry in developing countries typically uses imported technologies, the development of which has been influenced by environmental protection requirements in the country of origin. The effectiveness of technological solutions to environmental problems depends upon infrastructure (broadly defined), and organisational and policy frameworks. A novel feature of the study is the construction of a technology index. The paper concludes with a case study of imported technology in the Indian car industry.

AIMS

This paper reports on a project on technology transfer and environment being undertaken at the Centre for Business and Environment at the University of Westminster. The project is designed to link analysis of international trade in cars (a macro analysis) with construction of an index which will capture environmental features of technology transfer. The aim of the project is to examine in depth the pattern of trade in automobiles, initially passenger cars, and the nature of technology transfer between developed countries and developing countries. It is envisaged that the study will contribute to the development of methodologies to analyse technology transfer.

THE CONTEXT

World automobile production (cars and light commercial vehicles less than 5 tonnes) is estimated to have reached 48 million units with the EU, USA, and Japan accounting for 29 percent, 24 percent and 23 percent respectively. In terms of market share these three trading blocks account for 70 percent of world sales. It is evident that in most developed countries traffic growth cannot be maintained at previous levels (Barrass & Madhavan, 1993, p.25), so that future growth opportunities will arise mainly in South East Asia, China, India, Latin America, and Eastern Europe. According to OECD forecasts for the period 1990-2030, numbers of vehicles and road traffic will rise by over 300 percent in non OECD countries, compared with increases of approximately 70 percent in OECD member states (OECD, 1995 pp.121-126).

Growth opportunities are levelling off in the traditional markets where the automobile industry is undergoing a process of restructuring due to continuing overcapacity. Within the EU completion of the single market (see Barrass & Madhavan, 1996, Chapter 3) has facilitated relocation of outsourcing and investment from high cost to low cost regions (European Commission, 1996).

Less developed countries account for about a quarter of world sales. It is predicted that there will be an increase in the share of developing countries given projected increases in per capita income and increase in population. According to some estimates, by the year 2015 the world's vehicle fleet will increase by 57 percent to 1 billion and that this will be the result of production in plants all over the world. The main producers in developing countries are S.Korea, India, Argentina, Malaysia, and China (Pemberton, 1996).

During the process of industrial modernisation most developing countries needed to acquire western technology across the board. In the case of automobile production this has taken place in various forms: direct imports of fully assembled cars or components, licensing, joint ventures. With the advent of economic reforms, and especially the liberalisation of trade the need for advanced technology and state of the art technology has gathered momentum (see Madhavan, 1989 and Spencer & Madhavan, 1989).

In response to globalisation of the automobile industry traditional manufacturers are adopting strategies appropriate for creating and maintaining competitive advantage. A particular problem for the automobile industry is the choice of technology that will help to satisfy both commercial and environmental objectives. The automobile industry has been the subject of a large number of regulations designed to reduce emissions and improve energy efficiency. The response of the industry to these pressures has been essentially in the form of technological changes such as the introduction of catalytic convertors and other improvements in vehicle design to reduce atmospheric pollution.

Although developing countries at present account for a very small proportion of total world output and an even smaller proportion of world exports, nevertheless they can be expected to play a significant role in the future. The twin forces of traditional manufacturers' search for markets, and the developing world's own expanding industrial base and consumer power are likely to increase the presence of developing countries in the global automobile industry and in technological exchanges.

CARS AND THE ENVIRONMENT

The 1992 Rio summit on environment and development agreed a Treaty on climate change, which called on the signatories to formulate plans with a view to returning emissions of carbon dioxide to the levels prevailing in 1990. Developing countries were given three years to devise their plans following ratification of the Treaty. It was envisaged that developed countries would make a contribution through financial assistance (including the $2bn Global Environment Facility) and technology transfer. A follow up Agreement was concluded in Kyoto in December 1997, committing Japan, the US and the EU to reductions in greenhouse gas emissions of 6, 7, and 8 percent respectively; this Agreement also includes provision for a system whereby emission rights can be traded internationally.

In the context of the growing awareness and concern for the environment the future viability of the automobile industry not only in West but also in developing countries will depend upon the role of the private motor car in a multimodal communication system. This is illustrated by European Union transport policies which now emphasise "sustainable mobility" (Barrass & Madhavan, 1996, pp. 243-245), in which context the need is for "clean, lean-produced, intelligent, quality, value cars" for the year 2000 and beyond (European Commission, 1996 p.10).

Cars and the Environment - Developed Countries

Much progress has been made in North America and western Europe in limiting pollution. For example emissions of lead from motor vehicles were dramatically reduced with the use of unleaded petrol. The state of California adopted cleaner burning gasoline in 1996, and has a requirement that by 2003 10 percent of new cars should be "zero emission vehicles". European Union emission standards necessitate the use of catalytic convertors on new cars: in principle, this will dramatically reduce emissions of carbon monoxide, hydrocarbons and nitrogen oxides, although much depends on the durability and proper maintenance of the catalysts.

Technological developments are supplemented by "demand side" measures, such as the use of fiscal incentives. For example, the UK government is pledged to increase petrol excise taxes by 5 percent per annum in real terms, and has been actively considering road use charging (Department of Transport, 1996).

As steps have been taken to alleviate other forms of pollution from vehicles attention has increasingly focused on carbon dioxide emissions, and their contribution to the "greenhouse effect". There is - at present - no pollution control technology to reduce carbon dioxide emissions, which, for a given energy source, are directly related to levels of fuel consumption. Indeed the use of catalytic convertors and unleaded petrol has an energy penalty, which may increase fuel consumption by as much as 10 percent.

Since 1978 fuel consumption of new cars in western Europe has improved by approximately 20 percent; and fuel efficiency in vehicle operation could be improved in future by the periodic testing of emissions. There may be scope for further improvements, to reduce fuel consumption by perhaps 50 percent over the next 20 years, by technical improvements in engines and transmissions, weight reduction, and aerodynamic improvements (Rickard, 1991, p.135).

Environmental considerations are now a major influence on the development of automotive technology. The California ZEV requirement has stimulated work on battery powered vehicles, and Toyota and Honda have produced hybrid cars with petrol engines for use on the highway and battery power for urban driving. Other technologies under development include a hybrid gas turbine/flywheel system, and a hydrogen powered fuel cell (the latter is being developed by Daimler-Benz in collaboration with Ford).

Cars and the Environment - Developing Countries

Growing affluence and urbanisation in developing countries alongside increasing motorisation of the metropolitan cities have led to significant increases in traffic volumes. This has in turn given rise to increased energy consumption, and environmental damage from atmospheric pollution, particularly where traffic growth has led to congestion. Although car ownership rates are low compared to cities in developed countries, traffic management is less effective, and the main urban centres often have severe traffic congestion (see Madhavan, 1992).

These trends can be expected to continue. Increasing affluence will lead to higher rates of car ownership and to the purchase of larger and/or more powerful cars: these effects would tend to increase energy consumption and intensify the environmental impact of motor vehicles. These pressures appear to be unavoidable if developing countries seek to "catch up" with the vehicle ownership levels in developed countries.

Traffic growth is liable to lead to environmental damage, as a consequence of increases in the volume of polluting emissions. The share of developing countries, although considerably less than that of wealthier countries is by no means negligible. Moreover, cars in developing countries tend to be more polluting and less energy efficient than in developed countries, due to a combination of obsolescent technology, vehicle longevity, poor maintenance, and poor road surfaces.

Recent environmental protection requirements are beginning to address the problem of pollution. Measures to reduce emissions include both technical such as improved vehicle technologies, choice of fuels, inspection and maintenance, emissions testing, and non technical measures such as, traffic management, and support for public transport. Other measures such as scrappage schemes, and road pricing have yet to assume a significant role in the management of pollution by automotives in developing countries.

TECHNOLOGY TRANSFER

The present study is designed to derive insights into the processes of global trade in automotives, the nature of technological change in car manufacture in developed countries, and the main forces leading developing countries to acquire modern technology initially designed to achieve developed country environmental standards.

For the purposes of this paper, technology transfer is taken to mean technological exchanges between developed and developed countries which include exports from and imports into countries of fully, assembled vehicles, knocked down units (completely or semi-knocked down units), components, blueprints, etc. It also includes direct investment in subsidiaries and partner companies within a wide variety of organisational frameworks including inter alia joint ventures, licensing arrangements, purchasing arrangements, and other instruments of technical collaboration.

The scope for technology transfer depends upon the source and the user of technology; this is illustrated by the following schema, showing possibilities for exchange between developed countries (DCs) and developing countries (LDCs).

TABLE 1

Source of	**User of technology**	
technology	DC	LDC
DC	I	II
LDC	III	IV

Case I Transfer between DCs: differences in specifications can be associated with non tariff barriers to trade; vehicle models (whether traded or manufactured in transplant operations) have to be adapted to the requirements of the market - e.g. Ford and GM produce different models for the US and European markets.

Case II DC technology used in LDCs: also subject to adaptation; but environmental, safety regulations tend to be less stringent, and less vigorously enforced. Exports to, and manufacture in, LDCs generally calls for use of technology imported from DCs

Case III LDC technology is not usually suitable for exports to, or manufacture, in DCs.

Case IV LDC technology is used in LDCs; but although it is fitted to conditions in LDCs it can be more expensive than DC technology, because R&D costs cannot be so widely spread.

The LDCs therefore may have a choice between indigenous technology and imported technologies which are designed primarily for use in the exporting country, and which it may not be possible to use properly due to infrastructural deficiencies. On the other hand, it can be argued that the technology transfer affords LDCs cheap access to advanced technologies.

Currently one of the main concepts in automotive manufacturing is that of "system" or modular supply. This refers to a holistic approach which involves not just the physical elements (such as supply of components) but also the transfer of responsibility for R and D as well as a complete (sub) system to the supplier. Given developing countries' need to buy technology, and their lack of research and investment capabilities, continued dependence on DC technology can be expected to continue in the future. However, the operation of the learning curve must not be forgotten because outsourcing from developed countries will help to amass technical know how in developing countries. In new models in developed countries levels of outsourcing can be as high 65 to 75 percent of ex-factory value (European Commission, 1996, p.2).

The current situation with regard to the nature of technology transfer from developed countries to motor manufacturers in the developing world raises a very large number of issues. The most important one is the suitability of the state of the art technology transfer given that there are significant differences between developed and developing countries in terms of industry structure and market conditions. While imported technology is liable to be over-specified in important respects, it may also be unsuited to relatively small scale production and its products may be ill equipped for low standard infrastructure. Moreover, developing country markets are also constrained by restrictions on imports of cars and components, and also of oil, as governments seek to protect the balance of payments.

This leads to the question: what should be the nature of technology transfer? Given that environmental problems are already acute in the major cities of the developing world what would be the most appropriate technological characteristics for cars for export to or production in developing countries?

Environmental priorities and policies differ between importing and exporting countries and this will have an impact on production in exporting countries (should the same environmental standards be incorporated in models for export to countries with minimal requirements?). Furthermore, the effectiveness of technological solutions to environmental problems may be constrained by lack of infrastructure, proper traffic management skills etc.

THEORETICAL FOUNDATIONS: TRADE AND TECHNOLOGY TRANSFER

The research underlying this paper draws on different concepts in economic theory. It is set within the broad framework of the "new theories" of trade which seek to explain intra-industry trade (see for example Grubel and Lloyd, 1975, Helpman and Krugman, 1985). These theories emphasise the role of technology, economies of scale, product differentiation and the structure of demand as the basis of trade. Linder (1961) defines intra-industry trade as trade in products which are close substitutes, others explain intra-industry trade in terms of similar factor intensities in production. Trade in automotives between developed countries, and between developed and developing countries (trade in different varieties of cars) fits in with Linder's theory of trade, which has its roots in Ricardian, and Heckscher-Ohlin theory.

Posner (1961) also offers insights into the nature of technology gaps, suggesting that systematic and endogenous factors influence the initial location of technological advantage and underpin technological innovations. High incomes, high demand for innovations, scarce and skilled labour, and high wage rates determine technological advancement in industry. Bhagwati (1964) draws attention to differences in tastes and demand across countries which reflect differing levels of economic development, and suggests that this is consistent with the development of industries producing similar products and forms the basis for intra-industry trade.

The research also draws upon the theory of commodity characteristics (the consumption technology model) set out in Lancaster (1971). In this model demand for products is essentially demand for a set of characteristics (attributes) the product possesses: the consumer maximises utility with reference to an optimal bundle of characteristics subject to a budget constraint. The present project sets out a methodology for measuring product characteristics with reference to cars. In a recent study of costs and induced innovations (i.e. development of new technologies in response to environmental regulations) in the US automobile industry Berry et al. (1996) estimated "hedonic cost functions" and compared product level costs with their characteristics. In order to examine the change in the fuel efficiency of new cars they calculated a "divisia" index of mpg per hp/wt class. This study comes closest to the present project in the literature on environmental issues and automobiles.

There is a vast literature (in the fields of economics, engineering, transport studies, development) on technology transfer. Studies of technology transfer between developed and developing countries hitherto have been at the general level primarily in the context of industrialisation and economic development. These studies range from the practical (design of agricultural implements, traffic management systems) to the theoretical and normative. However, there are very few studies of the global automobile industry at the level of disaggregation envisaged in this project, nor incorporating the environmental dimension. The analysis is supported by case studies which will help to put technological change in the wider context of organisational and strategic issues surrounding technology transfer from developed to developing countries.

ORGANISATION OF THE PROJECT

The principal aim of the research project is to understand the nature of technology transfer between developed and developing countries with respect to cars and to identify those technological features in cars that are designed to protect the environment.

The project comprises four stages.

Stage I - a systematic study of trade flows (exports and imports of passenger cars) which forms the basis of the analysis which follows. The analysis of trade in cars is to be followed by an examination of trade in components (better to capture outsourcing etc.) in a subsequent study.

Stage II - construction of a technology index for principal car manufacturers starting at the level of the model range.

Stage III - setting out the main elements of export/import function using the technology index as one of the explanatory variables.

Stage IV - analysis of principal findings and conclusions.

The present paper reports on the progress to date of completing stages I and II. For stage I the analysis is done at the level of the countries; the data main source is reports by the UK Society of Motor Manufacturers and Traders (SMMT). For stage II the basic unit of analysis is individual car models of the main car manufacturers and vehicle specifications from the Motor Trade Monthly Guides to Used Car Prices.

Insights provided by analysis of trade flows and vehicle technologies are complemented by case studies, initially of technology transfer (a case-study for India is summarised below), and subsequently of the influence of environmental standards and regulations on such transfers. These case studies will cover trade in vehicles and components, and technology transfer through collaboration agreements, joint ventures, and equity holdings. The impacts on importing countries will be examined in terms both of development of indigenous automotive industries and of the environmental impacts of production, usage, recycling and disposal of motor vehicles and their components, and the car industry's response to environmental pressures. These exercises will be undertaken in subsequent stages of the project.

THE TECHNOLOGY INDEX

The Technology Index developed in Stage II is a novel feature of the research programme. Automotive technology varies, over time and between countries, due to market conditions, consumer preferences, legal/regulatory requirements: the Index attaches a numerical measure to these variations. It is designed to assist the analysis of trade in motor vehicles (and eventually automotive components) with particular reference to environmental performance and energy efficiency.

The Index can be used to measure technical change over time, and for international comparisons of technological development. It comprises a weighted average "score" of various features and options which are now normally available for cars sold in developed countries. The weightings are judgemental, but emphasise the environmental and energy efficiency aspects of modern vehicle technology. The scoring depends - inter alia - upon the width of the range of options offered (and it is assumed, notionally, that a "base" variant exists - for example without a radio - even if it is not actually available in the market). Because of the emphasis on variations, this method is suitable only for cars which are (at least in developed countries) "mass market" vehicles rather than premium or sports models.

Motor vehicle technology is of course extremely complex, the result of years of learning experience and research and development, influenced by numerous factors, and embodying numerous compromises between the various facets of vehicle specification. Such a complex reality does not easily lend itself to summarisation in a single number, so clearly this Index has its limitations. Nevertheless, it is a useful tool for focusing on technological change and on the role of technology transfer in the international economy. In doing so, it serves the purpose for which it is designed. as a guide to further research.

Constructing the technology index

This project aims to develop an index based on car physical characteristics - body style, transmission, engine type & size, fuel type & consumption, etc. - and price and sales volume information. The physical characteristics are available (in the UK) in trade used car publications. Price and sales volume are available from such bodies as the Society of Motor Manufacturers and Traders (SMMT).

The index number for each model range is calculated on the basis of the number of variants. level of equipment etc. The index has a large number of components some of which closely relate to technical change, some of which relate to environmental friendliness.

The Index in the following formulation can be used to measure changes over time:

$$\frac{(\Sigma C_i)_t \times 100}{(\Sigma C_i)_0}$$

where C_i is the model's score in category i. The overall score in year t is the sum of the C_is for that year; to calculate the index number (and hence the change over time) this score is expressed as a percentage of the score in the base year 0. Model characteristics (the C_is) taken into account in the present calculation (together with their weightings) are: Body Type, Powertrain Efficiency, Safety, Comfort, Engine Electronics, Insurance rating, and the Fuel system. The elements of the Technology Index specification are set out in Annex Table 1.

This Index could be used to indicate change within individual model ranges, and (weighted by relative sales volumes) aggregated across manufacturers to show change within model categories, or aggregated to show changes in the market at national level. The exercise could be expanded to undertaken comparative analysis for North America, Japan and the European Union - and these regional indices could be aggregated (with appropriate weightings) into a 'Developed World' Technology Change Index.

Developing country markets could be assessed with reference (initially) to available developed country indices, and (ultimately) to the 'Developed World' Technology Index. In the first instance this would entail the (approximate) matching of car models available in LDC markets with those in the developed country indices; eventually indices could be constructed for comparative purposes in developing countries. It is anticipated that this procedure would provide significant insights into the rate of technology transfer from developed to developing countries.

An example of calculation of the Technology Index

The Technology Index has been calculated for the Ford Fiesta 1,100/1.1 for the UK, 1988 – 1993; details of this calculation are set out in Annex Table 2. Raw scores (in the Column "RS") are calculated, as described in Annex Table 1, for features of the Ford Fiesta model. These scores are then weighted in accordance with the Raw Index Weights (expressed as percentages). The Sum of the Weighted Scores (Column "WS"), divided by 100, gives the Raw Index Number. The index for a given year is expressed as the Raw index Number for that year as a percentage of the Raw index Number for the base year (in this example 1988).

The calculation shows that by 1993 the Index had increased to 136 (1988 = 100), indicating that the technological development of this model had showed significant progress.

As with all index number calculations, care has to be taken that there is a like-with-like comparison; in the case of the technology index, there is a specified model, and the index measures the changes over time in features of that model. So in the above example the model is the variant of the Ford Fiesta defined (by its engine size) as the "intermediate option" in the Fiesta range.

Definition of the car model, and subsequently its equipment levels which constitute the index components, requires a detailed specification. In the UK, the Society of Motor manufacturers and Traders (SMMT) has provided information for the period 1988 to 1997. A problem with these data is that model descriptors (name, engine size, body description) often remain unchanged when the body is restyled (restyling often includes significant component changes).

For example, the SMMT sales volume statistics suggests that the largest selling Ford Escort over the past decade is the 1575cc petrol 5 door model. However there have been "restyling" changes, which affect the index calculation in ways which are apparent only after painstaking interrogation of the data. This is a problem that has significant effects on the index calculation for most large volume models.

Limits to technology transfer

The study so far has identified a number of issues relating to technology transfer in the automobile industry. These include taking stock of the trade in cars between developed and developing countries, the technological basis of car manufacture in these sets of countries, and the challenges facing them with regard to achieving aims of environmental protection and energy efficiency. The study has also suggested a method of measuring technological change. The index can also be used to make comparisons over time and between countries. This could provide an objective basis on which to make recommendations about the appropriateness of technology transfer. It is acknowledged that a number of other considerations have to be taken in to account in this regard, for instance, the amount of technical absorption, availability of reliable sources of electricity, and skilled labour (Auto India, 1997).

Furthermore when developing countries import modern technology in order to manufacture cars several important considerations arise. Taking the example of the catalytic convertor even when mass produced for European markets the catalytic convertor increases the average cost of a car by several hundred dollars, and the performance of the convertor depends upon regular maintenance: lack of maintenance would severely reduce its value in limiting emissions.

Moreover, the effectiveness of technological solutions to environmental problems depends upon:

• Infrastructure (broadly defined): for example there must be supplies of unleaded petrol, facilities for maintenance of catalytic convertors, and the capability to recycle materials.
• The usage and lifespan of vehicles: an ageing stock of heavily used and poorly maintained vehicles will have a greater impact on the environment (other things being equal) than modern well-maintained vehicles.

Imported technologies may represent a second best solution, inasmuch as environmental priorities and policies differ between countries importing and exporting technologies. In addition to the pre-requisites noted we need to add the organisational requirements. Although in most developing countries car manufacture is undertaken in the private sector, technology imports have been closely regulated. In addition to the macro economic policy framework and vehicle standards, governments have also set the agenda for industrial development and regulate technology transfers. Car manufacturers may have to run the gauntlet of policies which are ambiguous and which may not be consistent with the achievement of commercial objectives. Although the conditions for the successful transfer of automotive technology varies between countries, the study of the history of Suzuki in India is salutary.

7 CASE-STUDY THE INDIAN CAR INDUSTRY

The arrival of Suzuki marked the dawn of the modern Indian car industry. The Maruti, a Suzuki in all but name, is now the market leader with around 70 percent of the market for passenger cars and vans, and a turnover which more than doubled between 1993 and 1997. The Indian car market is small by international standards - annual sales of new vehicles are of the order of ½ million.

According to market analysts, the passenger car market is expected to grow by 30 percent and car sales expected to reach around 800,000 per year or even a million by the next century (Narayan, 1996, p.92).

There is now a large number of technological partnerships in the Indian car industry, at various stages of development. Among the parties involved are Hindustan Motors and GM, Mahindra & Mahindra and Ford, Telco and Daimler-Benz, DCM and Daewoo: models produced are the GM Astra, Ford Escort, the Fiat Uno, E-Class Mercedes, and the Cielo. Others fruits of joint ventures include the Skoda Felicia (a joint venture between VW and Eicher Group), the Lancer (Mitsubishi and Hindustan Motors). Hyundai has entered into production on its own.

One of the recent wave of new joint ventures, between Premier Automobiles (PAL) and Peugeot of France, has already encountered difficulties: the model selected for manufacture in India, the Peugeot 309, has not sold well because it is perceived as dated, and the venture has incurred massive losses and its future is in doubt. PAL is now concentrating on a collaboration with Fiat, to produce the Uno and (in the longer term) the Palio.

With several manufacturers seeking to build their market share, it is likely to become intensely competitive. Maruti's joint owners (Suzuki and the Indian government) agree on the need for additional investment, to expand and modernise its production capacity to replace models which are outdated. But there has been a fundamental disagreement on how it should be financed. Suzuki favours an injection of new equity; but the government is unwilling either to match any new investment or to see its share diluted below 50 percent. An initial expansion programme is being financed in the manner preferred by the government, from retained profits and the issue of debt. However much more investment will be needed in the longer term, for further capacity increases and for new models; and this will require equity finance.

So the status quo is not an option, and the two partners face some stark choices. The government must consider whether it should remain in the business of car manufacturing, in competition with major multinationals; and if it does so, how to resolve issues of investment financing and sourcing of new technology, whether from Suzuki or an alternative collaborator. Suzuki has the option to sell its share to the government, and walk away from Maruti; if it did so it would lose its present dominant position in the Indian car market, although this would happen in any case if new investment is severely restricted.

However, the government's role was always ambiguous - it was both an investor and the market regulator. And - perhaps paradoxically - deregulation in the 1990s has highlighted the tensions of this dual role. With the end of industrial licensing and the opening for foreign investment the government can no longer protect Maruti as it did in the past. The major car manufacturers which have recently entered the Indian market naturally expect to compete with Maruti on a level playing field.

For the Indian firms in joint ventures a deep fear is that they could be nudged out by foreign firms. Meanwhile, foreign firms see potential threats of a slow down in economic growth, changes in Government policy , and exchange rate fluctuations all of which could make joint ventures less attractive.

The story of Suzuki in India is a cautionary tale for all joint ventures which followed in its wake. The Maruti saga highlights the pitfalls of technology transfer and points to the organisational pre-requisites for transferring technology successfully.

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Annex Table 1: Elements of the Technology Index Specification

Characteristic Category	Reason for inclusion	Category Components	Component weighting within category	Raw Index Weights
No of engine variants	Greater no. suggests technical sophistication	Petrol/unleaded/diesel models	No of variants (in points): 1 = 0; 2 = 4; 3 = 7; 4+ = 10	10
Body Type	A proxy for flexible production	Hatch/saloon/estate	Saloon = 10 hatch = 20 estate = 30	5
Powertrain efficiency	Increasing no indicates technical change and pollution reduction	Engine capacity (CC)/ Average MPG	$\frac{\text{MPG x 1000}}{\text{CC}}$	20
Safety equipment	Seen as an indicator of technical progress	ABS brakes/ Side Impact bars/ cage/airbag	Each item = 10	15
Comfort equipment	Seen as an indicator of technical progress	Electric windows/radio/power steering/ auto transmission	Each item = 5	15
Engine electronics	Use of components increases fuel efficiency	Ignition/fuel injection	Each item = 10	10
UK insurance rating	A proxy for road safety	Insurance group	100/ ins group	5
Fuel system	Increasing number suggests reduction in polluting emissions	Leaded/ unleaded/cataleptic converter	Leaded = 10 unleaded = 20 cat = 30	20

Annex Table 2 Calculation of Technology Index - Example 1 (Ford Fiesta 1,100/1.1)

Year	1988		1989		1990		1991		1992		1993		Weights
	RS	WS	RS	WS	RS	WS	RS	WS	RS	WS	RS	WS	
Variants	10	100	10	100	10	100	10	100	10	100	10	100	10
Body Type	20	100	20	100	20	100	20	100	20	100	20	100	5
Powertrain Efficiency	42	842	46	913	49	984	49	985	49	984	49	985	20
Safety	0	0	0	0	0	0	0	0	0	0	0	0	15
Comfort	10	150	10	150	10	150	10	150	10	150	10	150	15
Engine Electronics	0	0	0	0	0	0	0	0	0	0	0	0	10
Insurance	25	125	25	125	25	125	25	125	25	125	25	125	5
Fuel system	10	200	10	200	20	400	30	600	30	600	30	600	20
Raw index no.		1517		1588		1859		2060		2059		2060	
Base year 1988		100		105		123		136		136		136	

RS: Raw Score
WS: Weighted Score