The one Lakh car, economic growth and CO2 emissions in India.

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Abstract: *The expansion of the transport sector is an essential part of the economic and social development of a nation. But in many cases transportation also has adverse environmental implications. Today these effects in India are relatively mild mainly due to the low number of cars in the country. At the same time the economic growth of India is creating new consumer segments. These new consumer segments, even though poor by western standards will by their sheer size create a large demand for cheap transportation. The expectation of this demand has incited automobile manufacturers to develop and launch new product lines of extremely cheap cars. Using household and manufacturer data this paper estimates a structural model of household demand for automobiles in India. Exploiting this model to simulate future demand the predictions are that during the next 20 years the number of cars in India will increase by 30 million due to economic growth and up to 8 million more due to the introduction of low-budget cars. As a consequence the CO2 emissions from private cars will increase by 634% where more than one sixth of the increase is due to the introduction of low-cost cars. The increase due to the development of low-cost cars is of the same magnitude as the decrease commonly attributed to technological advancements in energy efficiency in estimation models.*

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1 Introduction

Transport is an essential ingredient for economic and social development of a nation. But in many cases transportation also has adverse environmental implications. The transport sector is responsible for 20% of CO2 emissions in the world and one of the major sources of local pollution. Today India with 17% of the world's population is the source of less than 1.6% of these transports related emissions. [1] Mobility is to a large extent about busses, trains and two wheelers. At the same time the economic growth in India (and a number of other developing countries) is expected to transform this pattern and increase the demand for automobiles significantly. The Asian Development Bank has estimated that due to the increased wealth of the Indian households the number of cars in India will increase from 6 million to 41.6 million in the next 20 years.[2]

However India and a number of other large developing countries experience a period of unprecedented economic growth which is creating new consumer segments. These new consumer segments present a potential demand for low priced cars of a magnitude that has never existed before.[3] The expectations of this future demand has in turn incited automobile manufacturers to start developing new product lines of extremely cheap cars with performance and maintenance requirements adapted to the local markets. This demand driven supply of low-priced cars is generally not accounted for in forecasts of the development of the transport sector. In developing countries, cheaper cars would enable new consumer segments that previously could not afford a car, to buy one. If, at the same time, these consumer segments are growing, the impact on the demand for automobiles could be significant.

A crude way to test the potential impact of a price decrease of automobiles is to use Demographic Health Survey data (DHS) which includes household wealth as well as

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[1] Source Industrial Energy Outlook report #DOE/EIA-0484(2008)

[2] Asian Development Bank (2006). The forecast is done by Segment Y ltd and includes SUVs The figures on the number of cars presented in all other calculations in this paper do not contain SUVs. The ADB figure without SUV:s would be approximately 35 million.

[3] A parallel to the forces at play is the mobile telephony industry. It was originally an exclusive service restricted to small consumer segments in the rich, developed countries. However producers have reorganized production, distribution and sales in ways adapted to low income markets and utilized the existing technology in a more cost-efficient way. This has transformed mobile telephony into a cheap commodity available in almost every country in the world. Today India has almost as many mobile subscribers as the United States while China has twice as many.

information on household access to car and/or two wheeler. According to the 2005/2006 DHS data for India there is 6 million cars available to households today. Dividing this data into income groups and weighing each income group by its forecasted growth the estimated number of cars in 2025 would be 42 million cars[4]. Using the difference in ownership of two-wheelers and cars to calculate a simple price elasticity measure, the effect of a general price decrease of automobiles of 5% (10%) is to increase this figure to 47 (53) million cars in 2025 instead (*figure 2*). This is a 13% (28%) increase compared to the forecast that takes only economic growth into account. These "back of the envelope" estimations predicts that a demand driven supply of low-cost automobiles has the potential of significantly altering the future demand for automobiles in India

In previous estimations of the effects on climate related emissions due to the growth of the transport sector in countries in Asia the effects from economic growth has been included as the main driving force. The potential effects from innovations targeting the budget segment in the automobile sector on the other hand have not. The primary aim of this paper is to construct a structural model that makes it possible to estimate the additional effects on demand, and thus CO2 emissions, from the introduction of the ultra-low-cost car models announced to be introduced on the Indian automobile market. The contribution from this paper is that the method used, in addition to the effects of economic development, allows technical development of new, cheap car models to impact the estimations of the future number of cars. Normally technical development is modelled as reducing emissions also in the transport sector. In the scenario discussed in this paper technical development can also increase total emissions by affecting the demand for the product. This paper also compares the relative importance of these two innovations driven opposing effects on emissions.

The remainder of this paper is organized as follows: Section two gives some background facts and surveys some of the related literature. Section three presents the data and in section four the methodology used is discussed. Section five presents the results and section six concludes.

2 Background and related research

The first automobile arrived in India in 1898. During the next twenty years approximately 40 000 cars were imported. In the 1920:s cars were beginning to get assembled locally both

[4] Excluding SUV:s.

by foreign manufacturers like Ford and General Motors as well as by a few indigenous companies. After independence it was felt that India should build own competence in manufacturing cars and only companies committing to a local manufacturing plan could acquire a license. This lead to the exit of GM, Ford and most other foreign companies leaving only a few Indian companies or joint ventures on the market. Telco who later became Tata Motors started a joint venture with Daimler-Benz making trucks. Hindustan Motors built the Ambassador which for many years was synonymous with passenger cars in India and is still being sold. Premier Automobiles Ltd built the Padmini which is still used as the main taxi car in Mumbai although the production line was discontinued in 2000. Mahindra & Mahindra where the maker of a jeep based almost directly on the second world war workhorse Willy's jeep. These where pretty much all the companies and products around. Already the task of producing components locally was daunting and there were very (except in the case of Tata) little capacity for R&D. The manufactured cars were based on foreign models with very little local development made.[5] Quality was poor and cars were mainly looked at as a luxury article that did not receive a high priority from the government who believed trains and busses were right for India.

This changed with the creation of Maruti Udyog. This company was the brainchild of Sanjay Gandhi, son of the then prime minister of India, Indira Gandhi. He envisioned a "peoples car" for the growing Indian middle-class. The company initially failed to take off but following Sanjay's death the company got strong government support through Indira Gandhi giving it a strong boost. Maruti combined Japanese technology (it is a joint venture with Suzuki) with modern management and its Maruti 800 has been the largest selling car in India from its introduction in 1983 up to 2004 when the number one position instead went to the Maruti Alto. The government's liberalization policies in the 90s and the opening of the sector to foreign direct investments in 1993 initialized a rapid expansion. During the next couple of years almost all the global players entered the market offering new models targeted towards different segments of society. GM, Ford, Mercedes, Hyundai, Honda, Toyota and Skoda had all entered and set up factories, jointly or by themselves, by 2000. Very few of them though designed models especially for the Indian market. Instead they entered with existing, often older models not well adapted to this particular market. All this is set to change though. Due to rapid economic growth leading to higher disposable income India is quickly becoming a

[5] The Ambassador was based on the Morris Oxford Series III. The Padmini (originally called the Hindustan 10) was based on the Fiat 500.

market to important to miss. Lately also Renault, Nissan and Wolkswagen have announced plans for factories and BMW have started to compete in the luxury segment. The market is totally dominated by the small and compact car segment with 80% of the sales of which the Maruti Suzuki company has a 50% share. A presence in these segments is necessary for any volume sales.

However still only less than 3% of the Indian households own a car while more than 20% own a two wheeler. The reason for the low penetration of cars is that India today is a low income country with a per capita income of 32 589 INR per year (756 US dollars 2005 WDI). This income is unevenly divided with almost half the income held by the upper quintile and a large part of the population being extremely poor. However India's economy is growing rapidly and by 2025 it is expected that the middle income tier will have grown by more than 600% comprising one third of the population (*figure 1*).[6] A household in this segment is poor by western standards (200t – 500t INR / year, $5t-$12t) and is just on the brink of being able to afford a car at current prices. Economic growth in combination with cheaper cars thus has the potential of creating a very large increase in the demand for cars from this segment.

To target this potential market the Indian car manufacturer Tata Motors recently introduced an extremely low-priced car (the Tata Nano). Following Tatas initiative a number of companies announced their interest in this budget segment. A joint venture comprising Renault, Nissan and Bajaj announced their commitment to develop an almost equally low-priced car (the ULC) in the compact segment. Also Hyundai, Toyota and GM have announced their intention of marketing a low-priced small car in India. Car analysts believe that the Indian market could support at least 4-5 players in this ultra cheap segment.[7]

A few papers have addressed the development of the Indian transport sector and the associated environmental impact. The Asian Development Bank (2006) has sponsored a study of the climate effects from the on-road transportation in India (and other Asian countries). The projections of the increase in the number of cars in this study is based on expected economic and population growth as well as expectations on future road

[6] McKinsey global Institute (2007)
[7] Paul Blokland, Segment Y ltd, interview Auto Observer May 22, 2008.

infrastructure and scrappage rates. The result is that there will be 41.6 million cars and SUV:s in India in 2025, a 7 fold increase from 2005.

Singh (2006) uses aggregate data to address changes in road-based mobility (cars, busses, three and two-wheelers) in India and the expected effect on the environment. He assumes that the demand for road based transportation will follow the same trajectory as in European countries and that the major driving force of increases in transportation is economic growth. Singh's projections is that road transports in India will increase 3.5 times from 2001 to 2021. The share of cars in personal transports is expected to more than double in this time period. The changes in CO2 emissions associated with the increase of cars is calculated as either a business as usual scenario with no energy efficiency gains and an efficiency gain scenario (1% / year). In the BAU scenario the automobile related increase in CO2 emissions is 700% and in the efficiency gain scenario 570%.

3 Data

The demand system in this study is obtained by aggregating a discrete choice model of individual consumer behaviour. This requires producer data on sales quantities and car characteristics / prices as well as household data on wealth and possibly other demographic variables.[8]

The producer data used is from IndiaStats compilations of the Society of Indian Automobile Manufacturers. The limiting factor is the data for prices which is available from open sources for only 3 points in time, 2001, 2005 and 2008. Thus the dataset consists of three panels, one for each year and each with 25-32 car models giving a total of 94 datapoints. As can be seen from *table 3* the sales increases each year. Average constant prices on the other hand decreases slightly. Summary statistics in *table 1* shows that some of the variables have a very large span. Price varies between 2 – 73 lakh and sales goes from 37 – 230 000 units. The extreme upper price values and lower sales figures are mainly due to a few brands in the extreme luxury segment (see *table 2*). To test if these outliers drive the results the estimations are also done removing the related observations from the dataset.

[8] Micro data on consumer choices would improve the results but there is no data readily available on the consumption choices of households when it comes to automobiles in India. The available data is targeted towards large corporations and their budgets.

Adding to the data acquisition difficulties is the fact that producer data is published by manufacturer and class[9], not by model. Thus the sales data for each class and manufacturer has to be allocated to models. This task is significantly facilitated by the low number of models on the Indian market and in most cases each manufacturer has at most one model in each segment (in most cases they are only present in a few segments). For the few cases where this is not the case, annual reports and trade press on sales figures has been used to assign the aggregated sales figures to different models. Information on characteristics is from different manufacturers Internet sites.

The characteristics included are price, length, HP/weight, km / litre and a dummy for if the car is in the luxury segment or not. The whole Indian automobile market is divided according to length and the common perception of segmentation is according to this characteristic. HP / weight is a proxy for how sporty the car is and km/litre gives an indication on how expensive it is to drive and how environmentally friendly it is.

Most cars in India are built or at least assembled locally even if they are based on (often older) foreign models but a few luxury cars are imported (BMW) or based on the latest version available in the west (Mercedes). These luxury cars command an exceptional price premium compared to other cars in a way that is not reflected in the length, HP/weight and km/l characteristics. The dummy "luxury car" is introduced to capture the perceived advantages from these models[10].

Demographic data is from the National Health Survey 2005-2006 and comprises data from 109 000 households. It includes information on the wealth of the household based on household possessions. For poorer households this wealth measurement has been found to be more reliable than a measurement of disposable income or consumption in comparative studies.[11]

Data on the estimated future income distribution of households is taken from McKinsey (2007). They base their estimations on a proprietary database integrating historical household

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[9] In official statistics as well as in all references the Indian automobile market is segmented in 6 classes according to length.
[10] The luxury segment is defined wider than the extreme outliers discussed earlier and that are excluded from estimations when testing the effect of outliers.
[11] See Rutstein, Shea and Johanson (2004) for a discussion on the wealth index in health surveys.

surveys, macroeconomic and demographic data. The macroeconomic projections are based on the Oxford Economics Global Model while household data is mainly from NCAER's surveys.[12]

Data on future models of ultra cheap cars are based on manufacturer's announcements in the trade press.

4 Methodology

The aim is to estimate the relative change in CO2 emissions following changes in the household demand for automobiles. Household demand is assumed to be affected by changes in the size and distribution of household income as well as by the introduction of new, cheaper car models on the market. The changes in CO2 emissions will be estimated for a number of scenarios with differing assumptions on the changes in income, time of introduction of new cheap cars and the possibility of a stepwise introduction of more fuel-efficient technology. The latter is supposed to affect all cars on the market by an equal percentage reduction in CO2 emissions.

CO2 emissions are calculated in a stylized way. Emissions 2005 is normalized to one. Assuming that driving patterns for car owners are homogeneous and does not change, the mileage for mixed driving is used together with the estimations for the number of cars of each model to calculate the amount of fuel used. It is assumed that CO2 emissions are directly proportional to the amount of fuel used[13] and the resulting emissions are calculated as multiples of the emission level at the base year. Thus relative emission levels 2025 is calculated as

$$E^{2025} = \frac{N^{2005} + \sum_{t=2006}^{2025} \left(\sum_{j \in J^t} m_j^{-1} S_j^t M^t (1-T)^{(t-2005)} \right) - \delta^{2025}}{N^{2004} + \sum_{j \in J^{2005}} m_j^{-1} S_j^{2005} M^{2005}} \qquad (1)$$

[12] For a detailed description see McKinsey (2007) appendix B2. NCAER, India's National Council of Applied Economic Research.
[13] See ICCT (2007) appendix for a discussion on the actual size of multipliers for comparing standards using mileage and CO2 emissions respectively.

where there is J^t car models in year *t* indexed by *j* where each model has mileage m_j and S_j^t share of total sales in the given year *t*. The mileage for a given model *j* changes only due to T which is an (average) yearly improvement in fuel-efficiency. M^t is the number of households and N^t is the total number of cars divided by their respective mileage in a given year. The number of cars in 2005 is calculated as the number of registered vehicles 2004 plus the number of cars sold during 2005. The share of the number of cars of each type in 2005 is assumed to be equal to the share of sales in 2005 for that type and their respective mileage is used to calculate N^{2005}. δ^t is the total estimated age related scrapage rate divided by the relevant mileage in time *t*. There are no official figures on the scrapage rate and India is notorious for keeping its cars rolling long after retirement age.[14] Thus the rate of depreciation of the car pool is difficult to estimate. Looking at historical production numbers and comparing it to the current number of registered cars results in a life-time of almost 30 years for a car. Translating it to the actual time-period used would mean a total loss from age related scrapage corresponding to emissions from approximately 2 million cars affecting all scenarios equally (δ^{2025} in (1)).

This method is simple but fairly robust regarding the relative effects when introducing new low-cost car models and when allowing for a general increase in fuel-efficiency which is the main issues at interest here. In the case of cars announced but not yet introduced they are expected to be designed with low cost as the most important design parameter and not focusing on pioneering new fuel-efficient technology. If no other information is available it is assumed that they will be at best as fuel efficient as the best in their class today (2008).

To find the total number of cars of each type in the year 2025 the demand at two points in time, 2015 and 2025[15], is estimated using a structural model of consumer demand described below. It is assumed that the demanded number of cars each year grows linearly from 2005-2015 and from 2015-2025 and that this demanded quantity is also supplied.

A large literature deals with the problem of estimating demand and supply using consumer and producer data. Following McFadden (1973), discrete choice modelling was used as a basis for these types of studies. Berry, Levinsohn and Pakes (1995) (BLP) study extended the

[14] The ADB report (2006) includes scrapage rate in its estimations but does not publish the values actually used.
[15] Forecasted income distributions for households are available for 2015 and 2025 only.

methods to differentiated products in a study of the US automobile market. Their demand system was obtained by aggregating a discrete choice model using producer and consumer data [16]. This paper will follow the BLP strategy when estimating household demand for automobiles in India. The method is outlined below.

In a discrete choice model consumer *i* choose product *j* if utility for *j* is larger than for any other product $U_j > U_k \ \forall \ k \neq j$. The approach here is a random coefficient model allowing for consumer heterogeneity. The utility is assumed to be linearly additive and defined as $U_{ij} = x_j\beta + \zeta_j + \alpha_i p_j + \varepsilon_{ij}$ where x_j is a vector of observable characteristics of the car and ζ_j is unobserved (by the econometrician) characteristic(s) of the car.[17] An assumption made in most models of this type is that rich customers are less price sensitive than poor. A common way to include this assumption (see Train 2003) is by letting $\alpha_i = \frac{\alpha}{c_i}$ where c_i is wealth of consumer *i*.[18] Wealth is from the DHS data. The utility can be decomposed into a mean

$$\delta_j = x_j\beta + \zeta_j \qquad (2)$$

and a deviation from that mean

$$\mu_{ij} = \alpha_i p_j + \varepsilon_{ij} \qquad (3)$$

Assuming that the ε_{ij} are distributed extreme value (type 1) the market shares s_j for model $j \in [1..J]$ during the time period can be computed using a logit model integrated over consumers (time indexes omitted).

[16] A number of more recent papers have applied this methodology to different areas. For example Petrin (2002) used the same methodology to estimate the effects of the introduction of the Minivan on the US automobile market while Goldberg & Verboven (2001) applied it to estimate price discrimination in the European automobile market. Brenkers & Verboven (2005) estimates the effects of liberalizations in the EU rules on exclusivity in automobile distribution. (for an overview see Berry & Pakes (2007).

[17] All unobserved characteristics are assumed to be included in this one characteristic. For a discussion on this assumption see Berry & Pakes (2007) and the references there.

[18] Brenkers & Verboven (2005) uses a similar specification while Nevo (2001) interacts α with income and income squared. BLP in turn uses log(Income – price). Since the wealth parameter is not directly comparable to price the BLP specification is not suitable and the sparse data available suggests a choice requiring as few parameters as possible making the use of the inverse of wealth preferable to the combination of wealth and wealth squared.

$$s_j = \frac{1}{N_s}\sum_{n=1}^{N_s}\frac{e^{\delta_j+\alpha_i p_{j_i}}}{1+\sum_k e^{\delta_j+\alpha_i p_{j_i}}} \qquad (4)$$

The utility of the outside alternative[19] is normalized to 0 and thus $e^{U_0} = 1$ which is entered separately in the denominator in (4). The estimated vector of market shares $s = [s_1,...s_J]$ from the estimations in (4) are forced to comply with the real market shares $S = [S_1..S_J]$ from the market data by iterating over the vector $\delta = [\delta_1..\delta_J]$ according to the algorithm

$$\delta_{n+1} = \delta_n + \ln(S) - \ln(s) \qquad (5)$$

BLP shows that this is a contraction mapping converging to one and only one solution for δ .

The result from (4) and (5) depends on the choice of α . Minimizing a suitable objective function dependent on α iterating over (4) and (5) will then return a consistent estimate of α [20]. The objective function chosen here is the GMM estimator $\zeta' Z\Phi^{-1} Z'\zeta$ where $\zeta = \delta - X\beta$ and Z is a vector of appropriate instruments assumed to be orthogonal to ζ . The optimal weighing matrix Φ is $\text{var}(Z'\zeta) = Z'\zeta\zeta' Z$ which in the homoscedasticity case simplifies to $\Phi = Z'Z$. Since the data consists of a panel with multiple time periods the safest strategy would have been to allow for heteroscedasticity but the limited dataset causes problems in convergence of the estimates when using this more complex specification and therefore the assumption of homoscedasticity is made. β is estimated each iteration step by the linear estimator[21]

$$\beta = (X' Z\Phi^{-1} Z' X)^{-1} X' Z\Phi^{-1} Z'\delta \qquad (5)$$

The development of a new car model both from a technical as well as a production and support perspective is a project that stretches over a number of years. The design

[19] The outside alternative thus is all alternatives to buying a car in this time-perios. Thus for example owning a two-wheeler is part of the outside alternative. A two-wheeler naturally also produces CO2 and the potential effects from this will be discussed in the sensitivity analysis of the results.
[20] Standard error for α is calculated using the bootstrap method.
[21] Use (2) in the GMM estimator and take the derivative with respect to β . Variance is calculated using $(X' Z(Z' Z)^{-1} Z' X)^{-1}$

characteristics cannot be changed at short notice. The price on the other hand has no such restrictions. It is therefore possible that the prices are correlated with the unobservable characteristic ζ since they are easily changed with short notice in response to changes in customer tastes. Substituting or including appropriate instruments in Z will address this issue. The instruments suggested by BLP are the sum of the characteristics for competitors and the sum of characteristics for competing brands from the same manufacturer. These would act as price shifters since they affect the level of competition and predatory pricing in the characteristics space. If there are many models within the product portfolio of the same company (Z_{1j} high), a price cut for one of the models would affect the sales of the companies other models and thus the company would be more reluctant to lower the price. If on the other hand the outside competition is large (Z_{2j} high) a company would be more prone to cut prices. As in the estimations done by BLP it turns out that including many instruments based on different characteristics introduces numerical problems in inversion due to collinearity and here only length is used as a basis for the instruments:

$$Z_{1j} = \sum_{\substack{k \in A(j) \\ k \neq j}} length_k \qquad Z_{2j} = \sum_{k \notin A(j)} length_k$$

Where $A(j)$ is the set of car models from the manufacturer that makes model j.

Having estimated the coefficients α, β of the model the estimations of future market shares are found by changing the distribution of income used so that it matches the expected future income distribution. Draws from this counter factual income distribution and the estimated mean utility from the previous step are then used in (4) when integrating the new market shares for each car over consumers. Introducing new cars is then a matter of defining the price and characteristics and based on the characteristics and their coefficients calculate a mean utility. This new combination of mean utility and price is then added to the list of cars and the resulting market shares are estimated. To find the expected total demand for each model the shares are multiplied by the expected market size which in this case is the expected number of households in India at the year of interest.

5 Results

The result from estimating the model

$$U_{ij} = \beta_0 + \beta_1 L_j + \beta_2 L_j^{\,2} + \beta_3 HP_j + \beta_4 KM_j + \beta_5 IL_j + \zeta_j + \alpha_i p_j + \varepsilon_{ij}$$

is shown in *table 4, column 1.* All coefficients are of the expected sign and significant at least at the 10% level. The length of the car is entered with its square and the coefficient for this variable is negative. The effect is that in the small to medium segments, length is an important factor for the perceived utility of the car while for more expensive cars the relative importance of length decreases. HP/weight and KM/litre are both positive. A car that is perceived as sporty and a car that is cheap to drive as well as more environmentally friendly increases utility. If the car is in the luxury segment, in this case a BMW or a Mercedes, the utility increases significantly. The price parameter α is negative as expected. The cars in the extreme luxury segment A6 are not very typical for the Indian automobile market. The impact of these non-typical brands for the results is tested in a second estimation. In the regression shown in *column 2* the extreme luxury cars are excluded from the data. The results does not differ in any significant way from those in *column 1* indicating that the results are not driven by these potential outliers.

The main results are based on simulations using this estimated model of user demand in combination with different assumptions on future income distribution and technological development. The first objective of this paper is to estimate the additional impact on CO2 emissions from including the announced low-cost cars in the estimations. This is done in *scenario 1* below. The second objective is to test the relative importance of the inclusion of low-cost cars in the model compared to the standard assumption of a general improvement in energy efficiency over time. This is done in *scenario 2*. The sensitivity of the results to the assumptions made on economic growth and rate of introduction of new cars is tested in *scenario 3*. In *scenario 4* the potential effects from the inclusion of CO2 producing two-wheelers in the outside alternative is discussed.

Scenario 1: BAU versus Low-cost: In the *BAU* (business as usual) and *Low-Cost* scenario the income and distribution is assumed to follow the MGI projections. The effect on CO2 emission in the BAU case when only taking income changes into consideration are compared to the case when the consumers are allowed to buy also the currently announced ultra-cheap cars. The cars are introduced in the model with the characteristics and according to the time-plan announced by each manufacturer. [22]

In 2005 the Indian households had 6.6 million cars and yearly sales were 850 000 cars. In 2007 sales had increased to 1 150 000 cars. In the BAU case, yearly sales in 2015 is predicted to be 1 775 000 cars and in 2025 2 500 000 cars, more than double the sales in 2007. The resulting accumulated number of cars in 2025 will then be 36 million, a 5.50 times increase compared to 2005.[23]

The low-cost case assumes the introduction of four low-cost cars: First the Tata Nano in 2008 at the price of one Lakh. Then in 2011 the iQ from Toyota at 1.3 Lakh, the ULC from Renault-Bajaj at 1.1 Lakh and a car from Hyundai at 1.5 Lakh. Running the simulation when including these four low-cost cars the sales figures in 2025 increases to 3 070 000 cars. The accumulated number of cars in 2025 would then become 44 million, a 6.6 times increase compared to 2005, 25% more than the BAU case (*figure 3)*. Splitting the different figures on car segments (*figure 4)* shows that all of the increase is in segment A1, the segment for compact cars. What is more important though is that the figures also show that the increase in segment A1 is mainly from households switching from the outside alternative (two wheeler or no car). Only a very small part of the increase in the segment is from households switching from higher segments (mainly segment A2).

The effects from these two different cases on CO2 emissions (keeping other factors constant) are shown in *figure 5*. In the business as usual case emissions increase 5.5 times relative to the 2005 level. This is the increase that should be expected taking only economic growth into account and no introduction of low-cost cars on the market. If instead the effect from the introduction of the Tata Nano and similar very small cheap cars is taken into account the effect is 6.34 times increase in CO2 emissions, 18% more than the BAU case. The reason that CO2 emissions increase less than the number of cars (25%) is that the additional low-cost cars are light and have small engines and thus are more fuel efficient than the average car.

Scenario 2: BAU versus Low-cost with technical development: A common assumption when studying economic growth and changes in emission levels is that of a continuous introduction

[22] On mileage see previous comments.
[23] All figures are exclusive of SUV:s. Only the segments M1:A1-A6 are included.

of energy efficiency improving technology. The rate of this improvement is declining over time and is expected to tend towards zero in the long run. The global trend for this improvement in 1995 to 2005 was estimated to be 1.03% per year (Nordhaus and Boyer 2000). In the period 2025 to 2050 it is assumed to decrease to 0.95% (0.97%) (Nordhaus and Boyer 2000, Nakicenovic et al. 1998)[24]. Gramlich (2008) finds the time trend in average mileage for the US automobile market from 1971-2007 to increase by 1.3%. However part of this is due to a trend towards demand for smaller cars with lower fuel consumption per se and not technical improvements in energy efficiency. To test the impact of these assumptions on the CO2 emissions due to automobiles in India, the general energy efficiency gain is modelled as a yearly percentage improvement in mileage similar for each car model (variable T in (1)). This improvement does not change the price of the cars. Based on the previously quoted estimations it is assumed that an average improvement of 1 % per year in the relevant time period is reasonably in line with standard assumptions and historical trends.

The result is that in the BAU case the predicted increase in relative CO2 emissions will be 4.7 times higher than in 2005. The effect of including a 1% yearly general energy efficiency improvement in the model is a 16% decrease of CO2 emissions compared to *scenario* 1. When combining the assumption of a general improvement in energy efficiency with the introduction of low-priced cars the increase will be 5.45 times that of the 2005 level. The introduction of low-priced cars thus results in 15% higher CO2 emissions than the BAU case. The 15% negative effect on CO2 emissions from the introduction of low-priced cars will thus almost match the 16% positive effects on emissions from general efficiency improvements counterbalancing all positive effects of 17 years of technical progress in this field (*figure 6).*[25]

Scenario 3: BAU versus Low-cost with economic shocks: The model in this paper is a static model where the entry and exit decisions of producers are exogenously decided. To model the effect of economic shocks (as well as the effects from many policy decisions) in a more realistic way requires a dynamic model where these decisions are endogenised. Keeping these limitations in mind a stylized way to test the sensitivity of the predictions made with this

[24] The high alternative is due to Nakicenovic et. al. which is also the source for the IIASA (scenario B in this case). These measurements apply to the assumed global rate of decline in carbon intensity.
[25] Mileage for 2008 models are used in the calculations making the difference up to 2025 17 years.

model to economic shocks of the type currently affecting most industries and not least the automobile industry are made by creating three sub scenarios:[26]

1. In the first it is assumed that income growth is delayed with four years.
2. In the second it is also assumed that the producer's entry decision in the low-cost car segment is delayed with 4 years compared to what has been previously announced.
3. In the last scenario only the currently realised entry (Tata Nano in 2008) is included and all other announced entries in the low-cost automobile segment are assumed not to be realised.

In the first case the overall impact of the shocks for both the BAU scenario and the low-cost scenario on the predictions from the model is to decrease the CO2 emissions approximately 10% compared to the case with no economic shock. If the producer's entry decision in the low-cost car market is postponed with 4 years the total decrease is 12%. In the case where the economic shock stops the entry for all announced cars in the low-cost segment the impact is larger, in the order of 20%. The total impact of the predicted introduction of cheap cars on CO2 emissions would in this case be as low as 5%, compared to 16% without any economic shocks.

Scenario4: Low-cost + two-wheelers:

A number of users switching from the outside alternative can be assumed to switch from using a two-wheeler to a car. This would decrease the addition of CO2 from the switch since that household also generated emissions before the switch. The sensitivity of the results to this effect is discussed in this scenario.

In the extreme case where all switches from the outside alternative were from households previously using a two-wheeler to cater to the same transport need the resulting increase in relative CO2 emissions is predicted to be 6 times that of the level at 2005. This is an increase by 11% from the BAU scenario. The effect on CO2 estimations from including the effects from low-priced cars thus lies somewhere between 18% and 11%. However not all households are switching from a two-wheeler and many of those that do will not stop using the two-wheeler even though buying a car. Also it is expected that a larger portion than before of new car buyers will live in rural areas where commuting distances are larger and thus CO2

[26] The objective is only to give an idea of the sensitivity of the results to changes in the MGI forecasts and not to make any real world predictions of the outcome of the current economic downturn.

emissions per car larger[27]. Thus the lower bound of 11% is not very realistic and the end result can be expected to be closer to the 18% bound.

6 Conclusion

The simulations in this paper predict that economic development alone leads to an expected 36 million cars in India by the year 2025 (up from 6 million 2005). The introduction of ultra-low-cost cars is predicted to increase this figure with up to 8 million more cars in this time perspective. As a consequence of this increased household demand for cars the CO2 emissions increases with 634% where more than one sixth of the increase is due to the introduction of low-cost cars. The predicted size of the increase in CO2 emissions due to low-cost cars matches the decrease commonly assumed to occur as a result of general development and introduction of more fuel efficient technology. These results show that omitting technological development that targets costs potentially leads to significant underestimations when estimating the future demand and the corresponding environmental effects in the developing world. The developing markets, at least when they comprise 1/6 to 1/2[28] of the worlds population, creates new rules and the standard assumption that we can count on technological development to help us decrease emissions should be more thoroughly tested in these cases.

7 Future enhancements

The model used in this paper entails some un-intuitive results when it comes to substitution between models. Due to the assumptions on the error term the model will for example predict that a small number of people will be prepared to substitute an extremely cheap car for a luxury car, something that we do not expect to happen in real life. This problem is addressed by the “Pure Characteristics Demand Model” in Berry and Pakes (2007) and it would be interesting to apply their later work to the modelling in this paper.

Prior to the introduction of the “One Lakh Car” by Tata Motors the low budget segment in India was supplied using older designs from the product portfolios of existing auto makers. The company to break this pattern by investing a large amount of R&D money in a low-budget design was an outsider with little to lose from declines in sales of existing budget

[27] Discussions with Hormazd Zorabjee Editor for Autocar India and Darius Lam assistant editor for Autocar Professional (India).

[28] One can assume that the automobile makers also has other developing markets than India in mind when developing their low-cost brands.

models. Immediately following the announcement of their new car many of the existing manufacturers announced that they were going to follow suit. Why now? The development in dynamic structural models during the last couple of years has made it possible to create models where the entry and exit decisions of companies are endogenised (for an overview and references to examples se Ackerberg et al 2006). Using these techniques would enable an analysis also of the forces behind the technological development taken as exogenous in this paper.

One of the weaknesses in this paper is the sparse data underlying the estimations of the structural model and the simplifications and constraints this has entailed. Recent discussions with experts on the Indian automobile sector have lead to an agreement where they have made a much richer dataset available. Including this data in the paper would be a natural next step.

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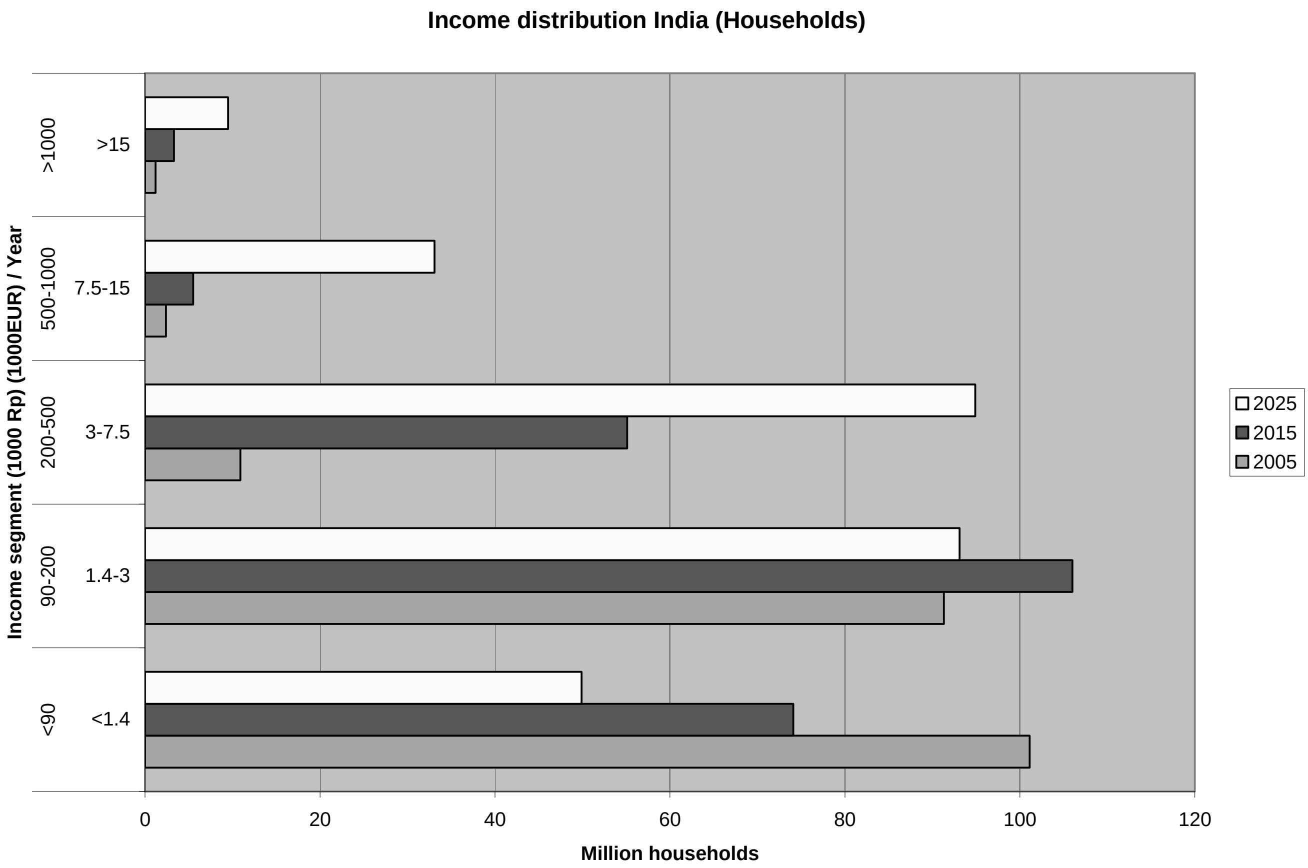
5 Figures and graphs

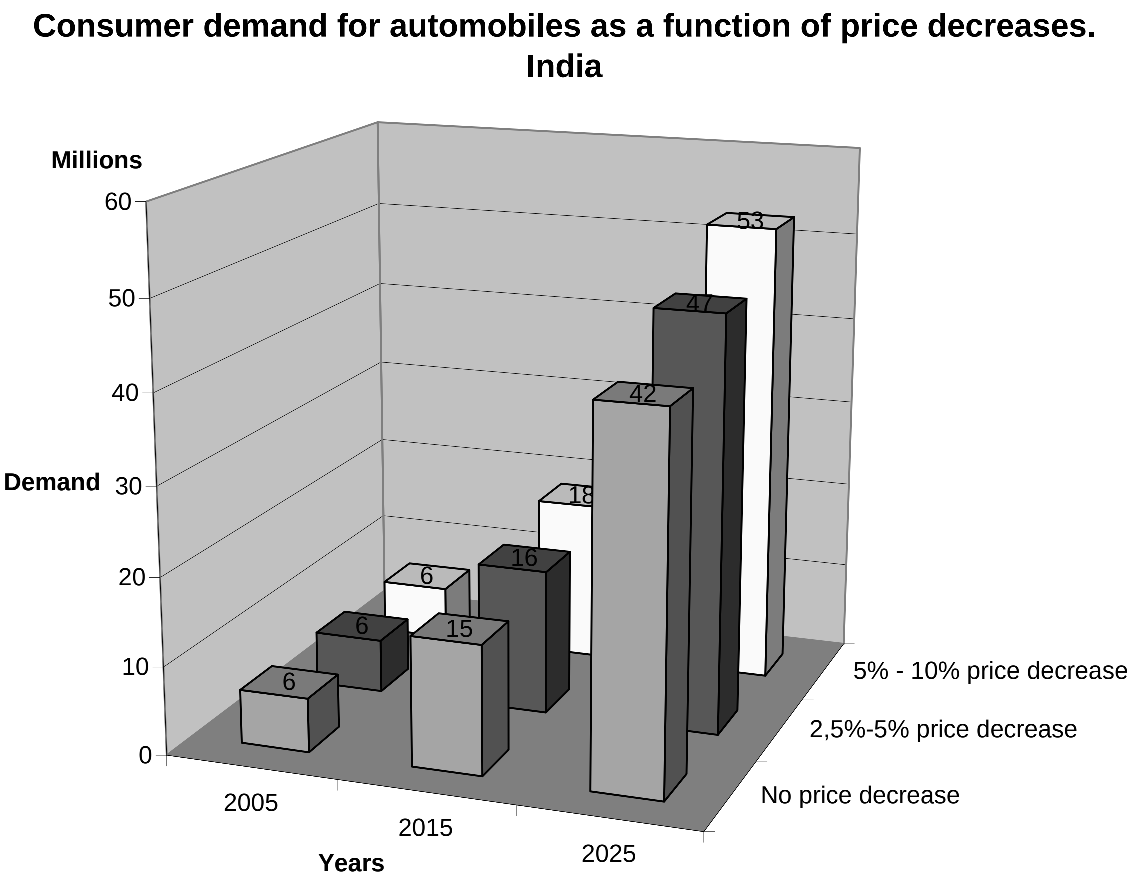
Figure 1



Data: *Source MGI.*

Note: *Number of households in each income group. 2015 and 2025 estimated. Income groups in INR and EUR (October 2008).*

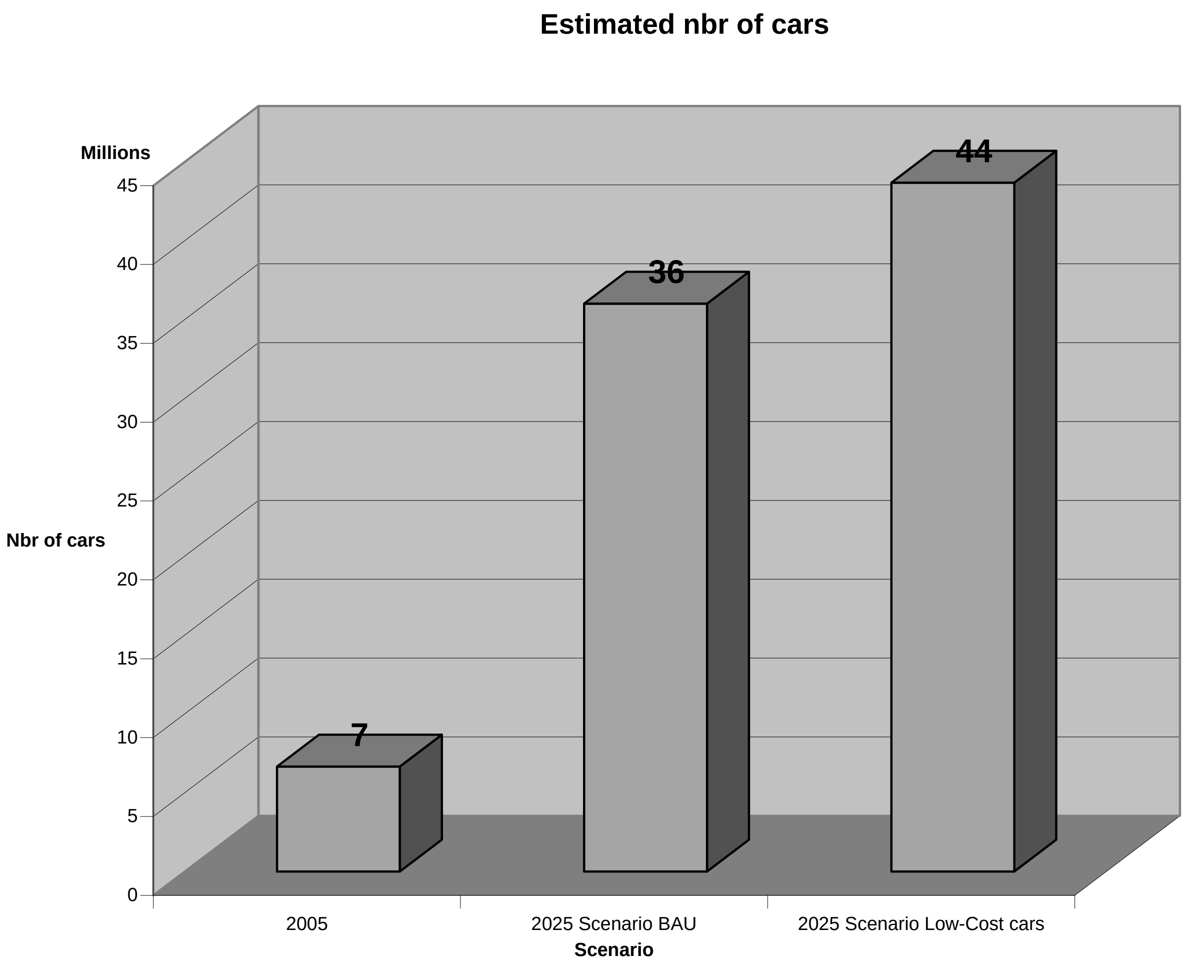
Figure 2



Data: *Authors estimations based on data from National Health Survey 2005-2006 and MGI .*

Note: *Estimated number of cars 2005, 2015 and 2025 with prices constant and with an aggregated price decrease of 2.5(5)% in 2015 and 5(10)% in 2025*

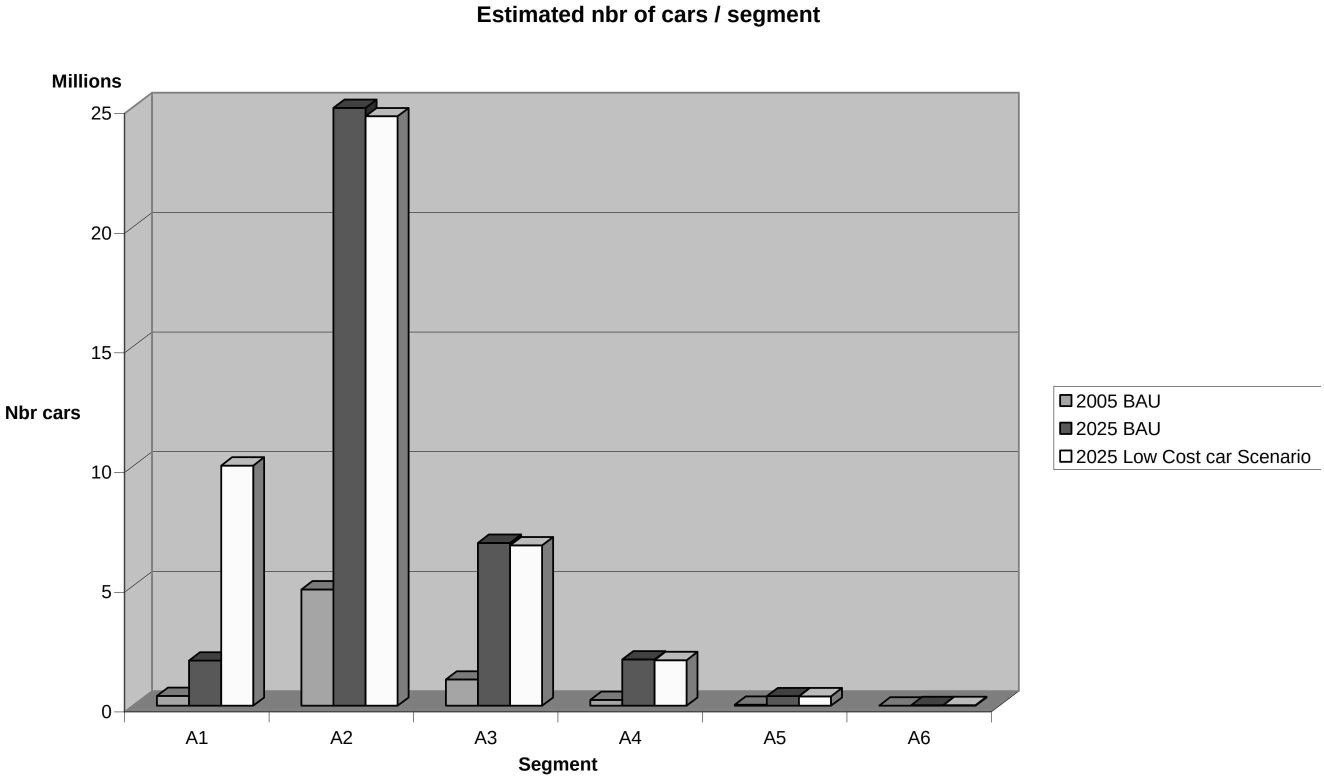
Figure 3



Data: *Authors estimations based on demographic data from National Health Survey 2005-2006 and MGI(2007) combined with producer data from IndStat and other sources (see text).*

Note: *Actual number of cars 2005 ´compared with BLP type estimations of number of cars 2025. Two estimation scenarios, BAU and 4 low-cost cars introduced. Tata Nano 2008 1 lakh, the iQ from Toyota at 1.5 lakh, the ULC from Hyundai at 1.3 lakh and a noname at 1.1 lakh.*

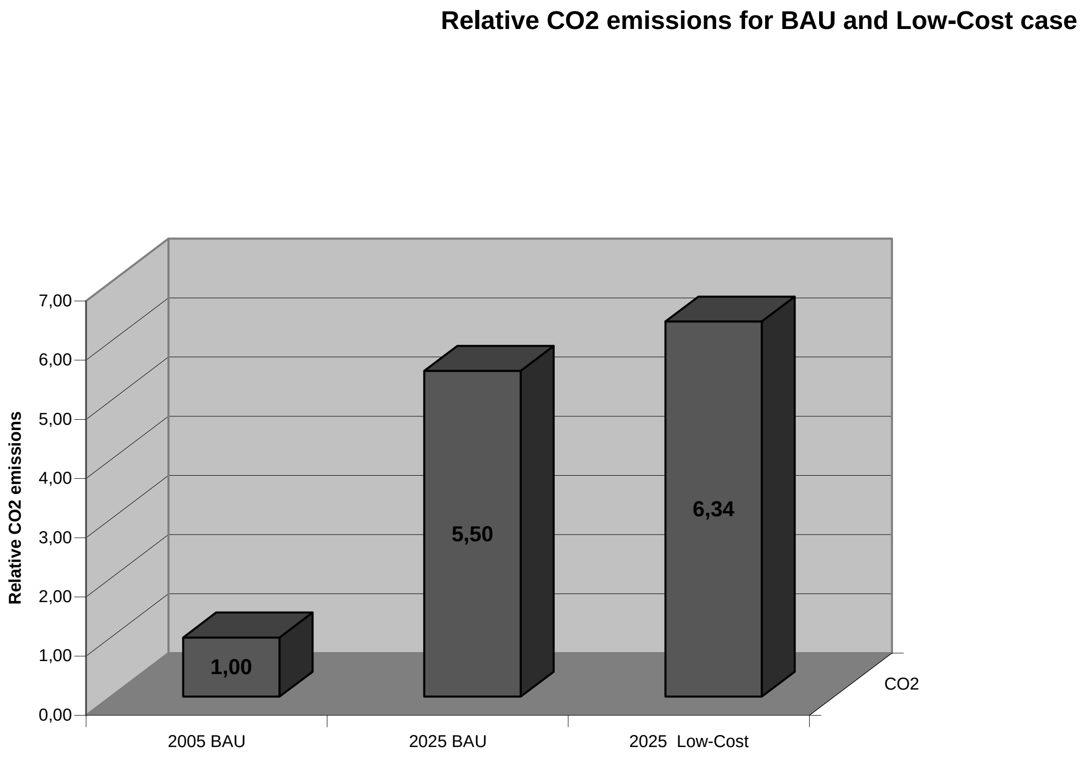
Figure 4



Data: *Authors estimations based on demographic data from National Health Survey 2005-2006 and MGI(2007) combined with producer data from IndStat and other sources (see text).*

Note: *Actual number of cars 2005 ´compared with BLP type estimations of number of cars 2025. Two estimation cases, BAU and 4 low-cost cars introduced. Tata Nano 2008 1 lakh, the iQ from Toyota at 1.5 lakh, the ULC from Hyundai at 1.3 lakh and a noname at 1.1 lakh. Divided on segments according to length.*

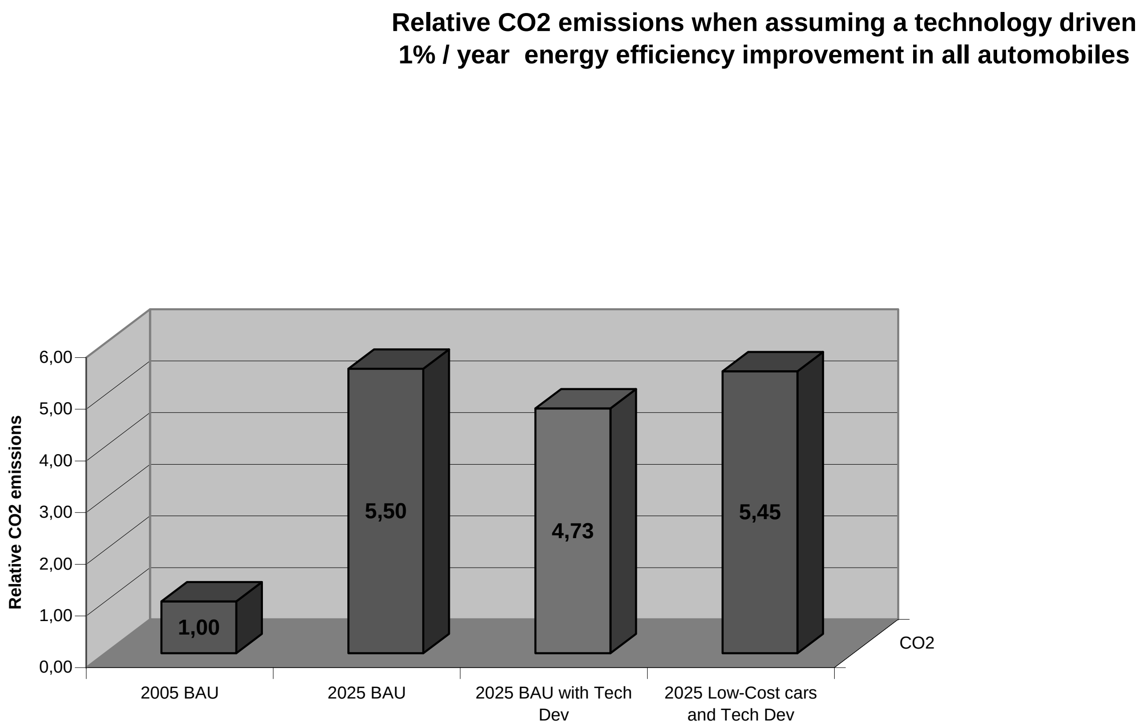
Figure 5



Data: *Authors estimations based on demographic data from National Health Survey 2005-2006 and MGI(2007) combined with producer data from IndStat and other sources (see text).*

Note: *Estimations of CO2 emissions. Normalised by base year 2005. Low-Cost case includes the following low-cost car:. Tata Nano 2008 1 lakh, the iQ from Toyota at 1.5 lakh, the ULC from Hyundai at 1.3 lakh and a noname at 1.1 lakh.*

Figure 6



Data: *Authors estimations based on demographic data from National Health Survey 2005-2006 and MGI(2007) combined with producer data from IndStat and other sources (see text).*

Note: *Estimations of CO2 emissions. Normalised by base year 2005. Low-Cost case includes low-cost cars. Tata Nano 2008 1 lakh, the iQ from Toyota at 1.5 lakh, the ULC from Hyundai at 1.3 lakh and a noname at 1.1 lakh. A general energy efficiency improvement of 1%/year assumed in Tech Dev cases.*

Table 1 Summary statistics of data

Variable	*Obs*	*Mean*	*Std, Dev,*	*Min*	*Max*
Sales	94	25367,5	40556	37	230000
Prices (const 2007 INR lakh)	94	11,85	14	2	76
Length	94	4214,62	488	3335	5163
Km/l mixed	94	12,43	3	8	20
HP / weight	94	0,09	0,02	0,045	0,152
Imported luxury car	94	0,117021	0,323169	0	1
Weight	94	1166,95	315	650	2155
Power	94	104,27	50	35	275
Width	94	1656,5	110	1410	1846
Z1	94	11929,87	8722	0	26210

Data: *Sales data from IndStat. Other characteristics from manufacturers Internet sites and trade publications.*
Note: *Sumary statistics on data. INR lakh is 100 000 INR.*

Table 2 Summary statistics of data divided by segment.

Variable	*Obs*	*Mean*	*Std. Dev.*	*Min*	*Max*
Segment A1					
Sales	3	86 297	13 315	71 102	95 924
Price (const 2007 INR lakh)	3	2,4	0,6	1,8	3,0
Segment A2					
Sales	27	59 701	56 814	752	230 000
Price (const 2007 INR lakh)	27	3,9	0,9	2,3	6,8
Segment A3					
Sales	30	14 445	11 238	142	38 639
Price (const 2007 INR lakh)	30	6,0	1,3	4,0	10,0
Segment A4					
Sales	14	4 553	5 302	37	17 328
Price (const 2007 INR lakh)	14	14,8	8,5	6,8	29,3
Segment A5					
Sales	17	943	902	42	3 286
Price (const 2007 INR lakh)	17	23,6	10,3	12,7	42,5
Segment A6					
Sales	3	200	190	44	411
Price (const 2007 INR lakh)	3	71,8	4,5	67,0	76,0

Data: *Sales data from IndStat. Current prices from vendors Internet sites..*
Note: *Sumary statistics on sales and prices divided on segments. INR lakh is 100 000 INR.*

Table 3 Summary statistics of data divided by year.

Variable	*Obs*	*Mean*	*Std, Dev,*	*Min*	*Max*
Year 2002					
Sales	26	14 678	23 678	37	95 924
Price (const 2007 INR lakh)	26	12,7	15,3	3,0	72,5
Year 2005					
Sales	31	27 515	38 846	42	150 000
Price (const 2007 INR lakh)	31	11,7	13,7	2,4	67,0
Year 2007					
Sales	37	31 079	49 822	186	230 000
Price (const 2007 INR lakh)	37	11,4	14,5	1,8	76,0

. **Data:** *Sales data from IndStat. Current prices from vendors Internet sites..*
Note: *Sumary statistics on sales and prices divided on year. INR lakh is 100 000 INR.*

Table 4 Regression results

	Reg 1	Reg 2
Length	17.59	15.67
	(9.93)	(9.41)
Length2	-0.98	-0.87
	(0.03)	(0.03)
Litre / km	1.34	1.28
	(0.02)	(0.02)
HP/weight	1.36	1.30
	(0.01)	(0.00)
Imported luxury	7.30	7.41
	(0.04)	(0.04)
α	-0.51	-0.52
	(0.05)	(0.05)
Const	-94.26	-85.63
	(204.74)	
N	94	91

Data: *Authors estimations based on demographic data from National Health Survey 2005-2006 and MGI(2007) combined with producer data from IndStat and other sources (see text).*
Note: *Estimation of utility function* $U_{ij} = \beta_0 + \beta_1 L_j + \beta_2 L_j^{\ 2} + \beta_3 HP_j + \beta_4 KM_j + \beta_5 IL_j + \zeta_j + \alpha_i p_j + \varepsilon_{ij}$ *where L is length. HP is HP/weight. KM is KM/litre and I is a dummy for imported luxury car.* ζ_j *is a. by the scientist. unobserved characteristic and* α_i *is an individual price coefficient.* ε_{ij} *is an error term assumed to be distributed extreme value. The index j represents car model and i indexes households. Reg1 includes all models, Reg2 tests if the results are driven by outliers by excluding the extreme(and fairly uncommon) luxury cars in segment A6 from the simulation. Standard deviation in parenthesis, in the case of* α *calculated using the bootstrap method (Horowitz 1999) .*