Demand For Fuel Economy in the Indian Passenger Vehicle Market*

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Abstract

As the Indian automobile market continues its rapid expansion, concerns over the consequences of increased fuel consumption continue to grow. One potential response is fuel economy regulation. One justification for fuel economy standards is the failure of consumers to choose optimally, due to myopia or market constraints. We evaluate the optimality of consumer responses to fuel economy in India by focusing on the choice between petrol and diesel vehicles. Our first test asks whether it would be cheaper for the buyer of a petrol (diesel) vehicle to own and operate an otherwise identical diesel (petrol) vehicle. To do this we estimate hedonic price functions and fuel efficiency frontiers to predict what the chosen petrol (diesel) vehicle, described in terms of weight, power, and other characteristics, would cost as a diesel (petrol) vehicle, and what its fuel economy would be. We use these results to estimate the break even period—the time it takes for the difference in purchase price between otherwise identical diesel and petrol vehicles to equal the present discounted value of fuel savings—and compare this to expected vehicle life. Because this assumes that each petrol vehicle is available in diesel form, we also compare the difference in purchase price plus operating cost between the chosen petrol vehicle and the average diesel sold. This is a lower bound to the difference between what a petrol owner is willing to pay for a more powerful, but less fuel efficient petrol car and the average diesel car.

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1 Introduction

As a result of India's economic boom, demand for passenger vehicles has grown steadily and swiftly over the last decade. In April 2002, Indian nationwide passenger vehicle sales were approximately $50,000$; by April 2008 monthly sales had tripled to approximately $150,000$ (see Figure 1). To put these figures in perspective, January 2008 monthly sales in the United States were approximately 1 million, while over $650,000$ vehicles were sold in China in the same month. Despite the recent worldwide economic slowdown, the Indian automobile market is projected to account for a significant share of global vehicle sales and for this reason continues to attract investment from major US, European, and Japanese firms. With such rapid growth and change, many in India are advocating for strong legislative action to avoid the many economic, security, and environmental concerns that inevitably accompany the expanded use of motorized transportation.

As the number of cars on Indian roads swells, the Indian government and civil society have begun the debate on the appropriate legislative response to the market failures associated with automobiles. These include air pollution, congestion, safety, greenhouse gas emissions, and foreign oil dependence. Echoing the concerns that led to the 1975 Energy Policy and Conservation Act in which the United States enacted Corporate Average Fuel Economy (CAFE) standards, much of the Indian debate has centered on fuel economy. Many pollutants, including greenhouse gases emissions, are proportional to fuel consumption. Although most economists would consider fuel economy standards a second best approach to reducing fuel consumption (Austin and Dinan 2005; Jacobsen 2008; Parry, Walls, and Harrington 2007), compared to raising fuel taxes, there is some agreement on the use of fuel economy regulation as a counter measure to consumer myopia (Portney, Parry, Gruenspecht, and Harrington 2003).

It may be the case that car buyers discount future fuel expenditure at a higher discount rate than they use in other markets. This might be due to incomplete information about, or inaccurate expectations of, future fuel prices and vehicle fuel economy. In response to this,

the Indian government has recently required that fuel economy information (kilometers per liter) be made available to potential buyers.

The extent to which consumers are forward looking is an essential element of economic and environmental policy making. Knowledge of this aspect of Indian consumer behavior, however, remains scarce. Among the unanswered questions are: Given the cost of additional fuel economy, do consumers respond rationally? Do consumers compare the cost of buying a more fuel efficient vehicle to the present discounted value of fuel savings? This paper attempts to answer these questions.

We evaluate consumer responses to fuel economy by focusing on the choice between petrol and diesel vehicles. Diesel vehicles, holding all other characteristics constant, are more expensive, but have lower operating cost than their petrol counterparts. In addition to the higher fuel economy associated with diesel vehicles, operating cost is decreased by the state regulated price of diesel being approximately 30% lower than that of petrol. Exploiting this difference between petrol and diesel vehicles allows us to construct two rationality tests which we apply to owners of petrol and diesel hatchbacks and owners of petrol and diesel sedans. We present separate tests for each of the 2002 to 2006 model years.

Our first rationality test asks whether it would be cheaper for the buyer of a petrol (diesel) vehicle to own and operate an otherwise identical diesel (petrol) vehicle. To do this we must predict what the chosen petrol (diesel) vehicle, described in terms of weight, power, and other characteristics, would cost as a diesel (petrol) vehicle, and what its fuel economy would be. This is accomplished by estimating hedonic price functions and fuel economy frontiers for Indian passenger vehicles. We use these results to estimate the break even period—the time it takes for the increase in purchase price of a diesel (v. a petrol) vehicle to equal the present discounted value of fuel savings from owning a diesel (v. a petrol) vehicle. The break even period also depends on miles driven, which are, on average, higher for owners of diesel vehicles. If the markets for new and used vehicles operate efficiently, the break even period for owners of diesel vehicles should be shorter than the life of the vehicle.

For owners of petrol cars the break even period should be longer than expected vehicle life. Furthermore, if the break even period for petrol owners is declining over time, we would expect the market share of diesel vehicles to increase over time.

The drawback of this rationality test is that it assumes that all petrol (diesel) vehicles (described in terms of weight, power, safety features, etc.) are available in diesel (petrol) form. In reality, this is not true. For example, the set of diesel hatchbacks on the market during our period of analysis (2002-2006 model years) was small, and not all combinations of characteristics were available in diesel form. Our second rationality test compares the purchase price and operating cost of the chosen petrol vehicle with the purchase price and operating cost of the average diesel vehicle sold in that year.

Since we are allowing the entire vector of characteristics to change, however, we can no longer hold utility constant, and can not base our rationality judgment on the break even period alone. Instead, we assume a fixed vehicle life and consumer discount rate and compute the amount of money that a typical petrol vehicle owner has implicitly forgone in not purchasing the average diesel alternative. This is the lower bound on the difference between his willingness to pay for a more powerful but less fuel efficient petrol vehicle and his willingness to pay for the average diesel alternative. Judging rationality using this amount is more difficult. A large difference in the willingness to pay may simply reflect the fact that consumers place a high premium on power and other characteristics that would be lacking in the average diesel car. These preferences should be taken into account in evaluating the desirability of fuel economy standards.

The rest of the paper is organized as follows. Section 2 provides a brief overview of the Indian passenger vehicle market. Section 3 presents our empirical strategy. In section 4 we describe the data used in our study and our estimates of the hedonic price function and fuel efficiency frontiers. Empirical results are presented in section 5 and section 6 summarizes and concludes.

2 Overview of the Indian Passenger Vehicle Market

Sales of passenger vehicles in India have been growing rapidly—from approximately 50,000 cars per month in 2002 to approximately 150,000 per month in 2008 (see Figure 1). The market is highly concentrated, with the top five manufacturers controlling nearly 90% of the market between 2002 and 2006. Maruti Suzuki accounted for 48% of sales, Tata Motors 18%, Hyundai 15%, and Mahindra and Toyota each accounted for 4% (see Figure 2). Figure 3 shows market shares by body type and fuel type for the same period.[1] The majority of passenger vehicles sold in India are small cars; hatchbacks constitute approximately 65% of the market, sedans about 17%, SUVs 12%, and vans 5%.[2] Approximately 85% of hatchbacks and 75% of sedans run on petrol, whereas virtually all SUVs run on diesel (only 3% are petrol). Given these characteristics, the rest of the paper focuses on hatchbacks and sedans only.

Fuel prices, shown in Figure 4, are set by the Indian government.[3] As noted in the introduction, diesel fuel is about 30% cheaper than petrol, with petrol currently selling at about 46 Rs. per liter and diesel at 33 Rs. per liter. Both fuels are expensive by US standards: petrol costs almost $5 per gallon at market exchange rates and diesel more than $3 per gallon.

Annual market share data reveals substantial changes in market composition, with new models being introduced and old models being discontinued almost every year. For example, three models of diesel hatchback had positive market share in 2002, but by 2006 the Tata Indica was effectively the only diesel hatchback model being purchased[4]. In this year the Tata

[1] All market share data come from the 2002-2006 waves of the J.D. Power Asia Pacific's Automotive Performance, Execution, and Layout (APEAL) study (an annual survey of over 5,500 new car buyers in India). Vehicle price and characteristics data come from Autocar India, an Indian car industry magazine (`www.autocarindia.com`), and Segment Y, a private automobile market research firm (`www.segmenty.com`). Additional data on body type classification and fuel type come from Carwale, a website that provides information for purchasers (`www.Carwale.com`).

[2] The remainder of the market is comprised of multi-use vehicles (MUVs), wagons, and coupes.

[3] Fuel prices vary by city. The prices shown in Figure 4 are Delhi prices, which are used throughout the analysis.

[4] For the 2006 model year J.D. Power reports 48 models with positive market share, the Tata Indica is the only diesel hatchback among these.

Indica captured 8.81% of the total passenger vehicle market, down from 9.35% in 2002, and 100% of the diesel hatchback segment, up from 96.49% in 2002. Another noteworthy change in model availability occured with the 2003 introduction of the Tata Indigo, a relatively cheap sedan offered in both petrol and diesel versions. In its first year the Tata Indigo captured about 7% of the petrol sedan segment and over 60% of the diesel sedan market, drastically lowering the purchase price of the sales weighted average diesel sedan. Figures 5 and 6 demonstrate the changing petrol and diesel composition of new vehicle sales for hatchbacks and sedans, respectively. For hatchbacks, diesel market share has remained constant at around 15%. For sedans, however, a clear trend of increasing diesel market share has taken place, from 11% in 2002 to 32% in 2006.

Tables 1-4 provide sales weighted summary statistics for prices and vehicle characteristics for hatchbacks and sedans. Comparing this information with data on US vehicle characteristics, from the United States Environmental Protection Agency, suggests that Indian cars are lighter and less powerful in terms of power to weight ratio than cars in the US. In 2006, for example, the sales weighted average weight of a vehicle purchased in India was about 1800 pounds for a hatchback and 2300 pounds for a sedan. In contrast, in the US, the average car weighed approximately 3500 pounds (Environmental Protection Agency 2008). In the same year, the average power to weight ratio (in horsepower per pound) was 0.032 for an Indian hatchback, 0.041 for an Indian sedan and 0.054 for an average car in the US. In view of their lighter weight and lower power ratio, it is perhaps not surprising that the average fuel economy of the Indian hatchback and sedan (28.3 and 22.3 miles per gallon in city driving, respectively)was greater than that of the average US car (19.4 miles per gallon).[5] Estimates of fuel economy technical frontiers (shown only for Indian cars in Table 8), however, suggest that Indian cars are not necessarily as fuel efficient as US cars, holding weight and power constant.[6]

[5]The figures for the US are the adjusted city miles per gallon rather than laboratory results, as reported in USEPA (2008, Table 1).

[6]When the average US car is put through a fuel economy technical frontier similar to that reported in Table 7, its predicted fuel economy is less than 16 miles per gallon.

Comparisons of the sales weighted average petrol hatchback with the sales weighted average diesel hatchback suggest that the diesel hatchbacks are heavier and less powerful than their petrol counterparts. The same is true for sedans. These differences in vehicle characteristics make it difficult to compare fuel economy by fuel type. In 2006, for example, the sales weighted average fuel economy of the diesel sedan was 28.80 miles per gallon; its petrol counterpart had a fuel economy of only 22.19 miles per gallon. Fuel economy for 2006 hatchbacks do not show such dramatic difference in fuel economy by fuel type. The diesel hatchback had a fuel economy of 28.86 miles per gallon while that of the petrol hatchback was 28.43 miles per gallon; however, diesel hatchbacks were much heavier than petrol hatchbacks.

Tables 1-4 also show the average list price and distance driven of the four vehicle types. Diesel hatchbacks are, on average, more expensive than petrol hatchbacks. Diesel sedans were more expensive than petrol sedans in 2002. In the years 2003 to 2006, however, diesel sedans were less expensive than petrol sedans. This reversal in the relative price for petrol and diesel sedans can be attributed to the introduction of the relatively cheap and instantly popular Tata Indigo in 2003. Additionally, owners of diesel vehicles appear to drive more each month, irrespective of body type. Diesel hatchback owners drive approximately 75% more than petrol hatchback owners per month while diesel sedan owners drive approximately 43% more per month than petrol sedan owners. Furthermore, on average, sedan owners appear to drive 22% more than hatchback owners.

3 Theoretical Framework

Break Even Period Analysis

Our first approach to evaluating consumer rationality asks whether it would be cheaper for the buyer of petrol (diesel) vehicle to own and operate an otherwise identical vehicle in diesel (petrol) form. If the buyer maximizes utility as described below, it would be irrational for him to own a petrol vehicle if the otherwise identical diesel vehicle were cheaper. Formally,

we assume that the consumer selects the vector of vehicle characteristics (Z) to buy, miles to drive (K) and fuel type (d) to maximize his utility, which is additively separable in the utility of the chosen vehicle $u(Z, K)$ and all other goods (x),

$$\max_{x,Z,K,d} U(x, Z, K) = x + u(Z, K) \tag{1}$$

The vector of vehicle characteristics (Z) includes weight, power, automatic transmission and so forth. Fuel type (d) does not enter the utility function, but enters the consumer's budget constraint through its effect on vehicle price, $P(Z, d)$, fuel price (denoted p_d for diesel and p_p for petrol) and fuel economy (kpl),

$$y = x + P(Z, d) + K \sum_{t=0}^{T} \frac{1}{(1+r)^t} \frac{dp_d(t) + (1-d)p_p(t)}{kpl(Z, d)} \tag{2}$$

In equation (2) y denotes wealth, r the discount rate, and T the expected life of the vehicle. In solving this problem the consumer computes the optimal x, Z, and K conditional on his choice of fuel type ($d = 0$ for petrol and $d = 1$ for diesel). The fuel type that yields the highest utility is then chosen.

Using $*$'s to denote the optimal choice of vehicle characteristics and miles driven, we can say that the buyer of a petrol vehicle is irrational if his chosen (Z_p^*, K_p^*) bundle is cheaper in diesel form,

$$P(Z_p^*, 0) + K_p^* \sum_{t=0}^{T} \frac{1}{(1+r)^t} \frac{p_p(t)}{kpl(Z_P^*, 0)} > P(Z_p^*, 1) + K_p^* \sum_{t=0}^{T} \frac{1}{(1+r)^t} \frac{p_d(t)}{kpl(Z_P^*, 1)} \tag{3}$$

This is simply to say that, all else equal, cheaper is better. If the same (Z_p^*, K_p^*) bundle can be purchased more cheaply in diesel form, the consumer is not choosing optimally. (A similar statement can obviously be made for diesel buyers.) Calculation of (3) requires that we predict the price and fuel economy of the Z_p^* vector of characteristics as a diesel vehicle. Implementing this test of rationality requires estimating an hedonic price function to predict

vehicle prices and a fuel economy frontier to predict kilometers per liter as a function of Z and d. Both the hedonic price function and the fuel economy frontier are described in section 4.

An equivalent way to calculate the rationality of petrol car buyers is to calculate the break even period $\hat{T}$ that would make the additional cost of Z_p^* in diesel form equal to the PDV of fuel savings,

$$P(Z_p^*, 1) - P(Z_p^*, 0) = K_p^* \sum_{t=0}^{\hat{T}} \frac{1}{(1+r)^t} \left(\frac{p_p(t)}{kpl(Z_p^*, 0)} - \frac{p_d(t)}{kpl(Z_p^*, 1)} \right) \tag{4}$$

and compare $\hat{T}$ to T. $\hat{T} < T$ suggests that the petrol car buyer is irrational. For the owner of a diesel vehicle $\hat{T}$ would be calculated analogously, but using the (Z_d^*, K_d^*) vector. Since $\hat{T}$ in both cases is the time required for the accumulated operating cost savings from a diesel vehicle to cover the difference in purchase price, for a diesel owner, $\hat{T} > T$ would indicate irrationality. Equivalently, we could calculate the discount rate r' that would make the break even period $\hat{T}$ equal to the life of the vehicle. An r' value that exceeds the market interest rate would also indicate consumer myopia.[7]

As in the literature on consumer purchases of energy efficient appliances, a high discount rate may represent lack of information (e.g., people may not be well informed about differences in fuel economy across vehicles), failure to compare the difference in purchase price to the difference in operating costs over the life of the vehicle, or lack of access to credit markets. We are able, indirectly, to test whether consumers are poorly informed about fuel economy across vehicles by comparing fuel economy estimates provided by new car buyers (available through the J.D. Power APEAL survey) with estimates of fuel economy reported in AutoCar India, an Indian car magazine that uses test runs to estimate fuel economy. As for credit markets, they appear to be well functioning; over 70% of new cars in India are

[7]Note that our definition of rationality treats the purchaser in equations (1) and (2) as the sole owner of the vehicle. Rationality thus assumes that both the new and used car markets operate efficiently. An alternative would be to evaluate the rationality of new car buyers, conditional on prices in the used car market. Data on the used car market in India are, however, not readily available.

financed by auto loans at an average interest rate of $12 - 14\%$.[8]

Willingness To Pay Analysis

One problem with the above rationality test is that it assumes that the chosen Z vector for a petrol car is available in diesel form, and vice versa. This is not always true. Figures 7-16 show bundles of vehicle characteristics available in the market for hatchbacks and for sedans for the model years 2002-2006. The dark dots represent available petrol models while the grey dots represent diesel models. For the first test of rationality to be valid, there need to be diesel bundles close to petrol bundles. This appears to hold for sedans, but not necessarily for hatchbacks. This casts doubts on the validity of our break even analysis for petrol car owners, especially hatchback owners. We therefore compare the cost of the chosen petrol vehicle with the cost of the average diesel vehicle, i.e., with what is purchased in the market, rather than with the otherwise identical diesel vehicle.

Our second rationality test compares the purchase price and operating costs of the chosen petrol vehicle with the purchase price and operating costs of the average diesel vehicle sold. Let x^* denote the income remaining after the petrol car buyer purchases Z_p^* and drives K_p^*. Let x' denote the income remaining if he drives K_p^* kilometers but purchases Z_d', the vector of characteristics of the average diesel vehicle. If the buyer is rational he prefers (x^*, Z_p^*, K_p^*) to (x', Z_d', K_p^*),

$$U(x^*, Z_p^*, K_p^*) > U(x', Z_d', K_p^*) \tag{5}$$

However, there is some amount of money, $\hat{x}$, that would make the buyer as happy with the average diesel vehicle as with his chosen car,

$$U(x^*, Z_p^*, K_p^*) = U(\hat{x}, Z_d', K_p^*) \tag{6}$$

[8] http://www.rupeetimes.com/news/car_loans/auto_loan_interest_rates_slashed_by_bank_of_india_1079.html http://www.financialexpress.com/news/auto-lenders-set-to-revise-interest-rates/407419/ http://www.carazoo.com/article/1606200801/Car-Loans---More-Than-Meets-the-Eye

His willingness to pay for his chosen car above what he is willing to pay for the alternative car is thus $\hat{x} - x^*$. Since $\hat{x} > x'$, the buyer's willingness to pay for Z_p^* must be greater than $x' - x^*$. The latter is the difference between the cost of buying and operating his chosen car minus the cost of buying and operating the average diesel vehicle,

$$P(Z_p^*, 0) - P(Z_d', 1) + K_p^* \sum_{t=0}^{T} \frac{1}{(1+r)^t} \left(\frac{p_p(t)}{kpl(Z_p^*, 0)} - \frac{p_d(t)}{kpl(Z_d', 1)} \right) \tag{7}$$

It is difficult to say how large (7) must be for a petrol car buyer to be irrational.[9] What $\hat{x} - x^*$ in fact measures is the petrol car buyers preferences for his chosen vehicle rather than a more fuel efficient, but less powerful, diesel vehicle.

4 Data and Estimation

We perform the rationality tests described in the previous section using data on vehicle sales and kilometers driven from the J.D. Power APEAL survey, an annual survey of new car buyers in India.[10] This data set provides information on market share by model and fuel type as well as buyer characteristics such as distance driven, income, and education level. We compute separate measures for hatchback and sedan owners, and compute each measure for the model years 2002 through 2006.

In computing the break even period for (e.g.) petrol hatchbacks we use the sales-weighted vector of characteristics of petrol hatchbacks (for each model year) to estimate Z_p^*. The characteristics, which are described more fully below come from AutoCar India and Carwale.com. K_p^* is the average kilometers driven by owners of petrol hatchbacks in each model year. The price of Z_p^* as a diesel vehicle—and as a petrol vehicle—is calculated from the hedonic price

[9] A similar expression could be computed for the purchasers of diesel vehicles. We compute equation (7) only for petrol car buyers since the assumptions underlying counterfactual break even analysis are satisfied for diesel car buyers.

[10] The APEAL survey covers $5,500$ new car buyers each year. We have data on the percent of buyers purchasing each model for each of the years 2002-2006. Summary statistics describing the buyers of each model are also provided; however we did not have access to individual buyer data.

function for hatchbacks, described below. The fuel economy of Z_p^* (in petrol form and diesel form) is calculated from our estimated fuel economy frontier for hatchbacks, also described below. Calculation of the break even period also requires estimates of petrol and diesel prices over the life of the vehicle. We assume that fuel prices are equal to those observed in the year of purchase. We use discount rates of 10% and 15% on the grounds that the average interest rate on a new car loan in India is approximately 12 to 14%.

Estimates of how much more a petrol hatchback owner is willing to pay to drive his car as a petrol rather than as a diesel vehicle require comparing the cost of Z_p^* in petrol form, $P(Z_p^*, 0)$, with the cost of Z_p^* in diesel form, $P(Z_p^*, 1)$. All price and fuel economy estimates are based on the hedonic price and fuel economy frontiers described in the next section. In computing equation (7), T, the life of the vehicle, is assumed to be 11 years for hatchbacks and 12 years for sedans (Rogers 2009).

Estimates of Hedonic Price and Fuel Economy Frontiers

To compute the purchase price of a (Z, d) vector, we estimate a semi-log hedonic price function for the j^{th} vehicle of the form

$$\log P(Z_j, d_j) = \sum_{i=1}^{n} \alpha_i z_{ij} + \beta d_j + \epsilon_j \tag{8}$$

where d is the diesel indicator variable, equal to 1 for diesel and 0 for petrol.[11] The technical frontier is estimated using the same list of vehicle characteristics, according to the specification

$$\log kpl(Z_j, d_j) = \sum_{i=1}^{n} \alpha_i z_{ij} + \beta d_j + \epsilon_j \tag{9}$$

In order to avoid the problems of multicollinearity frequently reported in previous hedonic price function analyses, we restrict the use of explanatory variables to a parsimonious list.

[11] Alternatively the equation $\log P(Z_j, d_j) = \sum_{i=1}^{n} \alpha_i z_{ij} + \gamma_i d_j z_{ij} + \beta d_j + \epsilon_j$ could be used in place of equation 8. Inclusion of these diesel interaction terms leads to loss of statistical significance which complicates the simulation and analysis of counterfactuals.

The variables included are chosen based on precedent in the literature and their link to desirable vehicle properties (Atkinson and Halvorsen 1984; Ohta and Griliches 1986; Dreyfus and Viscusi 1995; Espey and Nair 2005). To capture the many facets of luxury and safety, two index variables are constructed as described below.

The key variables in our analysis are:

- ***Price*** - list price of vehicle in Delhi converted to January 2008 lakhs (100,000 rupees) using the urban non-manual worker CPI
- ***Kerb Weight*** - mass of vehicle in metric tons
- ***City Fuel Economy*** - fuel economy under urban driving conditions in kilometers per litre
- ***Power Ratio*** - ratio of power (in horsepower) to kerbweight. This variable is a key indicator of vehicle performance.
- ***Luxury Index*** - the sum of the indicator variables for air conditioning, power steering, central locking, power windows, alloy wheels, leather seat, power mirrors, cd player, and Carwale.com luxury rating (0-none, 1-luxury, or 2-super luxury)
- ***Safety Index*** - the sum of the indicator variables for airbags, rear seat belts, anti-lock braking system, and traction control
- ***Automatic*** - an indicator variable for transmission type (0-manual or 1-automatic)
- ***Diesel*** - an indicator variable for fuel type (0-petrol or 1-diesel)

Tables 5 and 6 summarize the means and standard deviations of each variable, by model year, for hatchbacks and sedans. Note that in estimating hedonic price functions and fuel economy equations we use data on all models that appeared in AutoCar India, unweighted by sales.

The hedonic price functions and fuel economy technical frontier estimation results are presented in Tables 7 and 8. In both tables, column 1 includes both hatchbacks and sedans, column 2 includes hatchbacks only, and column 3 includes sedans only. From columns 2 and 3 of Table 7 it appears that choosing diesel over petrol results in an approximately 15% increase in vehicle price for hatchbacks and an approximately 19% increase for sedans. Similarly, diesel hatchbacks appear to be 19% more fuel efficient than petrol hatchbacks, while diesel sedans are 28% more efficient (see Table 8).

In addition to the effects of fuel type on purchase price and fuel economy, several results are worthy of remark. Almost all coefficients in Table 7, except for those on *safetyindex* and the *y2003* indicator variable in column 3, are statistically significant with signs that agree with our expectations. Vehicle price varies positively with weight, power ratio, luxury, automatic transmission (relative to standard), and diesel fuel type (relative to petrol). Safety index has a positive and statistically significant coefficient when hatchbacks and sedans are pooled, though not when the hedonic price function is estimated for each separately. Additionally, year dummies indicate a nearly monotonic decline in quality adjusted purchase price: holding the various vehicle characteristics constant, vehicles are becoming cheaper. It should be noted, however, that vehicle characteristics are likely not being held constant. Thus the quality adjusted drop in purchase price may not translate into lower unadjusted prices.

As shown in Table 8 fuel economy decreases with vehicle weight, power to weight ratio, and automatic transmission. Diesel cars have significantly higher fuel economy than petrol cars, holding other characteristics constant. Fuel economy also varies positively with *luxuryindex* and *safetyindex*, though these coefficients are not always statistically significant and are not substantial in magnitude. Year dummy coefficients are generally negative, but rarely statistically significant and exhibit no clear time trend. The results of column 1 show that sedans, all else equal, are approximately 6% less fuel efficient than their hatchback counterparts.

5 Results on Fuel Economy and Vehicle Choice

Break Even Period Analysis

Tables 9 to 12 summarize the results of the break even analysis for owners of petrol hatchbacks, diesel hatchbacks, petrol sedans, and diesel sedans. In each table the characteristics of the "chosen" vehicle are the sales-weighted vehicle characteristics for that vehicle segment. The regression results in Tables 7 and 8 are used to predict the price and fuel economy for both the segment representative vehicle (the chosen vehicle) and the counterfactual vehicle, in which only fuel type has been switched. The break even period is presented for each model year using 10% and 15% discount rates .

The break even period for owners of diesel vehicles (both hatchbacks and sedans) is always lower than the life of the vehicle, suggesting that buyers of diesel vehicles are indeed rational. For owners of diesel hatchbacks, the break even period is between 1.5 and 2.5 years. This is the outcome of a modest price premium for a diesel hatchback (about $70,000$ rupees) but fuel savings of $3,000$-$4,000$ rupees per month. Because the fuel cost savings from driving a diesel hatchback are increasing over time the break even period is falling over time. The break even period for owners of diesel sedans varies between 5.2 and 2.7 years, and is also falling over time. This is due both to rising fuel cost savings and a narrowing of the spread between the price of the average diesel sedan and its counterfactual petrol counterpart.

If drivers of petrol cars are rational, their break even period—the length of time it takes a diesel version of their car to pay for itself—should be greater than the expected life of their car. This does not appear to be the case for owners of either petrol hatchbacks or sedans. Although data on vehicle life in India is scarce, Rogers(2009) suggests that the median lifetime of a small car is between 11 and 12 years, while it is between 12 and 13 years for a medium-sized car. In contrast, the break even period ranges from 3 to 6 years for petrol hatchbacks and from 5 to 10 years for petrol sedans. The break even period for owners of petrol hatchbacks is longer than for owners of diesel hatchbacks since owners of

petrol hatchbacks, on average, drive fewer miles than diesel hatchback owners. The initial price premium for a diesel hatchback, however, still pays for itself in less than 6 years. The longer break even period for petrol sedans reflects the substantial price premium for a diesel sedan (between 150,000 and 170,000 rupees). For both petrol hatchbacks and sedans length of the payback period is falling over time. As above, this is due to an increase in the price of petrol and diesel fuel and a decreasing diesel price premium.[12]

Because the time it takes a diesel vehicle to pay for itself in fuel savings is falling over time for both diesel hatchbacks and diesel sedans, we would expect the market share of diesel vehicles to be increasing for each segment.[13] This is indeed true for sedans, but not for hatchbacks. As Figure 6 shows, diesel sedan sales rose from 11% of the sedan market in 2002 to 33% in 2006. In contrast, the diesel share of hatchback sales remained approximately constant at 15% over this period (see Figure 5). Indeed, by 2006 only one diesel hatchback, the Tata Indica, had positive market share. We discuss this point further below.

Heterogeneity and Myopia in the Car Market

The preceding results suggest that more buyers of petrol cars should be switching to diesel; however, the break even analysis is based on the mean number of kilometers driven by owners of petrol hatchbacks and sedans. Buyers who drive fewer kilometers may well be rational. Tables 11 and 12 also report the maximum number of kilometers that the owner of a petrol hatchback or sedan could drive each year and have a break even period that equals the life of the car. These numbers are much smaller than mean distance driven, and generally decrease with each model year. In 2006 a petrol car driver who buys the sales-weighted average petrol hatchback would have to drive no more than 500 km (approximately 300 miles) each month for the purchase of the petrol hatchback to be rational—less than half of the mean

[12]This analysis assumes that the maintenance costs of diesel and petrol vehicles are the same. If maintenance costs are higher for diesel vehicles, this would increase the break even period.

[13]Formally, the probability of purchasing a diesel vehicle, is an increasing function of the difference in utility between the optimal diesel vehicle and the optimal petrol vehicle. The latter is an increasing function of the difference in operating costs between the two vehicles, and a decreasing function of the difference in purchase price.

distance driven (1140 km). For owners of petrol sedans the maximum K is approximately 900 km, compared to a mean distance of 1350 km. Unfortunately, we do not have data on the distribution of monthly distance driven by vehicle type, which would enable us to estimate the fraction of buyers who fail the rationality test.

Another way to present the results of our first rationality test is to calculate the discount rate that would make the break even period equal the life of the car. This is presented in Tables 11 and 12 for the owners of petrol hatchbacks and sedans who drive the mean distance traveled. As expected, given the declining break even period, the discount rate r' is increasing over time; for petrol hatchbacks the rate increases from 27% in 2002 to 49% in 2006 while for petrol sedans the increase over the same period is 17% to 28%. Given that the average interest rate on a new car loan is between 12 and 14%, these discount rates are high.

In the literature on the purchase of energy efficient appliances (Hausman 1979; Jaffe, Newell, and Stavins 2003) high discount rates are interpreted as reflecting either lack of information on the part of buyers, failure to take this information into account when making purchases, or market failure. The latter can include failure of capital markets (buyers can't borrow to cover the cost of more energy efficient appliances) or agency problems—home buyers fail to install such appliances because they believe that the housing market does not fully price their benefits.

In the case of the Indian car market we can speak to the first issue by comparing owners' assessments of fuel economy with figures published by AutoCar India on city and highway kilometers per liter. The two sets of figures agree very well. A regression through the origin of buyers' estimates of fuel economy on published estimates of city fuel economy yields a coefficient of 0.83 ($s.e.$ = .0087); when highway fuel economy is added to the equation, the coefficient on city fuel economy equals 1.00 ($s.e.$ = .10) and the coefficient on highway fuel economy is 0.12 ($s.e.$ = .078). Buyers' assessments of fuel economy agree very well with published figures, and consequently, high discount rates for petrol vehicles cannot be

explained by a lack of information on fuel economy.

As for the question of market failure, high discount rates do not appear to be driven by a lack of credit. Over 70% of new car purchases are fincanced by auto loans, with interest rates ranging from 12 to 14% (see footnote 8). Lack of data on the secondary market for passenger vehicles prevents us from evaluating whether the high discount rate is driven by the failure of the used car market to fully price fuel economy.

On the basis of the analysis in this and the previous section, can we conclude that purchasers of petrol hatchbacks and sedans are irrational, at least those purchasers driving distances above the maximum K? This conclusion would be warranted if it were the case that petrol car owners could in fact purchase otherwise identical diesel vehicles. The next section explores whether this assumption is true.

Willingness To Pay Analysis

The preceding analysis assumes that buyers of petrol hatchbacks and sedans could buy their chosen car as an otherwise identical diesel vehicle in which only the fuel type has been changed. To examine whether this is the case we plot bundles of vehicle characteristics available in the diesel market on graphs showing the mean sales-weighted characteristics of the chosen petrol hatchback and chosen petrol sedan for each model year (Figures 7-16). A comparison of available bundles of characteristics for diesel and petrol hatchbacks in Figures 7-11 shows that very few hatchbacks are available in diesel form. As for sedans, there appear to be close substitutes for some, but not all, models. This suggests the possibility that petrol hatchback and sedan owners are not irrational but are placing a high premium on other vehicle characteristics than fuel economy.

To explore this possibility further we calculate the difference in purchase price plus operating costs between the chosen petrol vehicle and the average diesel vehicle sold in each year. This difference (equation 7) represents the present value of the money a petrol car owner forgoes by not buying a diesel car and, as argued in section 3, is a lower bound to his

willingness to pay to own his chosen petrol vehicle above what he is willing to pay for the average diesel alternative.

As Table 13 shows, the money a petrol hatchback owner forgoes by not buying the average diesel fluctuates across the 2002 to 2006 model years. It averages Rs. $49,000$ at a 10% discount rate and Rs. $26,000$ at a 15% discount rate. These amounts are approximately 10% and 5% of the cost of a new petrol hatchback. The amounts are lower bounds to what the owner is willing to pay for a more powerful, but less fuel efficient vehicle above what he is willing to pay for the average diesel alternative.

The situation is somewhat different for owners of petrol sedans. The lower bound to what they are willing to pay for a more powerful, but less fuel efficient vehicle, is much larger in absolute terms than what hatchback owners are willing to pay, and much larger relative to the purchase price of the car. These amounts are shown in Table 14. The drastic change between the years 2002 and 2003 is explained by the 2003 introduction of the Tata Indigo, a low price sedan that captured approximately 60% of the diesel sedan market and approximately 7% of the petrol sedan market. By drastically lowering the purchase price of the average diesel sedan, this model increased the difference in purchase price plus operating cost between the chosen petrol sedan and the average diesel sedan. Focusing on the period 2003 to 2006, the lower bound to the difference in what sedan owners will pay for a more powerful but less fuel efficient car (relative to what they are willing to pay for the average diesel alternative) ranges from Rs. $198,000$ to Rs. $265,000$ (or about 27% of the cost of the car) using a 15% discount rate.

6 Summary And Conclusions

One justification for fuel economy regulation is consumer myopia. If consumers fail to appreciate the cost savings associated with buying a more fuel efficient vehicle or, equivalently, if they discount them at a higher rate than they exhibit in other markets, fuel economy

standards may be warranted. We have attempted to address this question by calculating the length of time it would take for the fuel savings associated with a diesel vehicle to just equal the additional purchase price of the vehicle, compared with an identical petrol vehicle (i.e., the break even period). If buyers consider fuel savings rationally, this period should be shorter than the life of the vehicle for owners of diesel vehicles; for owners of petrol vehicles it should be longer. We have also calculated the discount rate that makes the break even period equal to the life of the vehicle for buyers of diesel and petrol vehicles.

Using a 10% or 15% discount rate, the owner of the average diesel car indeed seems rational. The break even period for the model years 2002 to 2006 is between 1.5 and 2.5 years for diesel hatchback owners and between 2.5 and 5.2 years for diesel sedan owners. The break even period has been falling over time, due largely to increases in the spread between the cost per kilometer of driving a petrol and a diesel vehicle.

Similar calculations for owners of petrol vehicles suggest that they are myopic. People who buy petrol vehicles have longer break even periods (partly because they drive fewer kilometers per year than diesel owners), but these periods are shorter than average vehicle life. At a 15% discount rate they range between 3.1 and 5.7 years for hatchback owners and 5.5 and 10 years for owners of petrol sedans, compared to median vehicle lives of 11 and 12 years, respectively. Equivalently, the discount rates that equate the break even period to the life of the vehicle in 2006 are 49% for petrol hatchback owners and 28% for petrol sedan owners.

We note that this apparent myopia is not the result of Indian car owners failing to appreciate differences in fuel economy among vehicles. When an owner's assessment of fuel economy from the J.D. Power APEAL survey is regressed on published fuel economy data from AutoCar India, the two are in very close agreement. It is, however, the case that the assumption underlying our calculations—that the buyer of a petrol vehicle can purchase an identical vehicle (in terms of power weight ratio, vehicle weight, etc.) in diesel form—may not be true. Buyers of petrol vehicles may indeed have to sacrifice power (and other

characteristics) when they switch to the diesel version of their car.

This leads us construct an alternate test of the rationality of petrol car buyers in which we calculate the difference in the purchase price-plus-present value of operating costs between the chosen petrol vehicle and the average diesel vehicle sold each year. This is a lower bound to what a petrol buyer is willing to pay (above his willingness to pay for the average diesel car) for his more powerful, but more costly to operate, petrol car. Averaged across the 2002-2006 model years, this amount for hatchback owners is approximately Rs. $49,000$ using a 10% discount rate and Rs. $26,000$ at a discount rate of 15%. These amounts are lower bounds to willingness to pay, but are a small fraction of the purchase price of a hatchback (approximately Rs. $400,000$). Sedan owners are willing to pay a much higher amount in absolute and relative terms to own a more powerful but less fuel efficient vehicle. At a 15% discount rate they are willing to pay at least 25% of the car's purchase price (over Rs. $200,000$); at a 10% discount rate this amount increases to approximately 30% of the cost of a petrol sedan (over Rs. $220,000$) for model years 2003-2006.

We cannot, however, conclude from this information that buyers of petrol cars are necessarily myopic. They may simply place a high premium on power and other characteristics that would be lacking in the average diesel car. These preferences must be taken into account in evaluating the desirability of fuel economy standards. If, for example, auto manufacturers in India were to meet fuel economy standards by reducing vehicle weight and power, as was done in the U.S. (Klier and Linn 2008), this could result in a welfare loss to Indian consumers that would have to be balanced against the gains (e.g., to national security) from reducing dependence on foreign oil. Evaluating these tradeoffs requires estimating the structural model in equations (1) and (2), as well as modeling the supply side of the market. We are currently estimating a structural model of consumer choice using the data from the J.D. Power APEAL survey. This will allow us to examine the welfare implications of alternative forms of fuel economy regulation, including the possibility of removing the subsidy to diesel fuel.

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Table 1: Model Level Summary Statistics: Sales Weighted Petrol Hatchback Characteristics

VARIABLES	UNITS	2002	2003	2004	2005	2006
Price	2008lakhs[a]	4.72	4.06	4.00	3.72	3.96
	(2008 USD)	(12000)	(10300)	(10100)	(9450)	(10000)
Kerb Weight	MT	0.771	0.749	0.759	0.777	0.810
	(lbs)	(1700)	(1650)	(1670)	(1710)	(1790)
Power Ratio	hp/kg	0.0698	0.0732	0.0684	0.0713	0.0707
	(hp/lb)	(0.0317)	(0.0332)	(0.0310)	(0.0324)	(0.0321)
City Fuel Economy	kpl	12.4	12.3	11.9	12.0	12.1
	(mpg)	(29.1)	(29.0)	(27.9)	(28.2)	(28.4)
Luxury Index		2.37	1.67	2.07	1.92	2.17
Safety Index		0.657	0.0224	0.0562	0.156	1.25
Distance Driven	km/month	1030	1080	990	1090	1140
	(miles/month)	(641)	(670)	(615)	(678)	(708)
# of models		9	7	8	10	9

[a] 1 lakh=Rs. 100,000.
[1] Version level vehicle characteristics data come from AutoCar India. Model level market share data come from the JD Power APEAL survey.
[2] Each vehicle model is available in multiple versions. Model level vehicle characteristics are constructed as the unweighted average across all available versions of each model. The sales weighted average of these models is presented above.

Table 2: Model Level Summary Statistics: Sales Weighted Diesel Hatchback Characteristics

VARIABLES	UNITS	2002	2003	2004	2005	2006
Price	2008lakhs[a]	4.87	4.82	4.56	4.23	4.70
	(2008USD)	(12300)	(12200)	(11600)	(10700)	(11900)
Kerb Weight	MT	0.976	0.972	0.972	0.981	0.980
	(lbs)	(2150)	(2140)	(2140)	(2160)	(2160)
Power Ratio	hp/kg	0.0550	0.0557	0.0558	0.0546	0.0585
	(hp/lb)	(0.0249)	(0.0253)	(0.0253)	(0.0248)	(0.0266)
City Fuel Economy	kpl	13.1	13.8	13.8	12.3	12.3
	(mpg)	(30.7)	(32.5)	(32.5)	(28.9)	(28.9)
Luxury Index		1.66	2.23	2.02	2.01	2.86
Safety Index		0.0145	0.0288	0.0446	0.0120	0.0120
Distance Driven	km/month	1770	1720	2020	1810	2040
	(miles/month)	(1100)	(1070)	(1260)	(1130)	(1270)
# of models		3	3	3	2	1

[a] 1 lakh=Rs. 100,000.
[1] Version level vehicle characteristics data come from AutoCar India. Model level market share data come from the JD Power APEAL survey.
[2] Each vehicle model is available in multiple versions. Model level vehicle characteristics are constructed as the unweighted average across all available versions of each model. The sales weighted average of these models is presented above.

Table 3: Model Level Summary Statistics - Sales Weighted Petrol Sedan Characteristics

VARIABLES	UNITS	2002	2003	2004	2005	2006
Price	2008lakhs[a]	9.25	9.31	8.77	8.00	8.46
	(2008USD)	(23500)	(23600)	(22300)	(20300)	(21500)
Kerb Weight	MT	0.102	0.103	0.106	0.104	0.106
	(lbs)	(2240)	(2260)	(2340)	(2300)	(2330)
Power Ratio	hp/kg	0.0894	0.0923	0.0861	0.0887	0.0896
	(hp/lb)	(0.0406)	(0.0419)	(0.0390)	(0.0402)	(0.0406)
City Fuel Economy	kpl	9.93	9.67	9.74	9.24	9.43
	(mpg)	(23.4)	(22.8)	(22.9)	(21.7)	(22.2)
Luxury Index		4.27	4.70	4.93	4.49	5.15
Safety Index		0.715	0.628	0.866	0.856	1.38
Distance Driven	km/month	1280	1440	1240	1200	1350
	(miles/month)	(793)	(896)	(794)	(743)	(838)
# of models		14	12	14	14	18

[a] 1 lakh=Rs. 100,000.
[1] Version level vehicle characteristics data come from AutoCar India. Model level market share data come from the JD Power APEAL survey.
[2] Each vehicle model is available in multiple versions. Model level vehicle characteristics are constructed as the unweighted average across all available versions of each model. The sales weighted average of these models is presented above.

Table 4: Model Level Summary Statistics - Sales Weighted Diesel Sedan Characteristics

VARIABLES	UNITS	2002	2003	2004	2005	2006
Price	2008lakhs[a]	11.4	8.35	7.80	7.28	8.21
	(2008USD)	(29000)	(21200)	(19800)	(18500)	(20800)
Kerb Weight	MT	0.118	0.111	0.112	0.111	0.113
	(lbs)	(2600)	(2440)	(2460)	(2450)	(2500)
Power Ratio	hp/kg	0.0591	0.0587	0.0606	0.0620	0.0632
	(hp/lb)	(0.0268)	(0.0266)	(0.0275)	(0.0281)	(0.0287)
City Fuel Economy	kpl	13.1	12.0	12.7	11.7	12.2
	(mpg)	(30.8)	(28.2)	(29.7)	(27.4)	(28.8)
Luxury Index		4.80	3.74	3.91	3.77	4.33
Safety Index		0.842	1.03	0.805	0.835	1.38
Distance Driven	km/month	1870	1910	1750	1900	1920
	(miles/month)	(1160)	(1190)	(1090)	(1180)	(1190)
# of models		6	6	6	6	7

[a] 1 lakh=Rs. 100,000.
[1] Version level vehicle characteristics data come from AutoCar India. Model level market share data come from the JD Power APEAL survey.
[2] Each vehicle model is available in multiple versions. Model level vehicle characteristics are constructed as the unweighted average across all available versions of each model. The sales weighted average of these models is presented above.

Table 5: Version Level Summary Statistics - All Available Hatchback Characteristics

VARIABLES	UNITS	2002	2003	2004	2005	2006	2007	2008
Price	2008lakhs[a]	5.26	4.84	4.84	4.67	4.89	4.48	4.24
		(1.37)	(1.36)	(1.24)	(1.25)	(1.32)	(1.28)	(1.21)
Kerb Weight	MT	0.884	0.864	0.928	0.931	0.939	0.986	0.945
		(0.141)	(0.123)	(0.151)	(0.144)	(0.136)	(0.197)	(0.118)
Power	hp	63.2	62.8	65.2	68.9	69.2	68.7	68.1
		(16.6)	(13.4)	(14.9)	(16.2)	(16.9)	(15.6)	(14.8)
Power Ratio	hp/kg	0.0708	0.0725	0.0705	0.0739	0.0733	0.0700	0.0718
		(0.00984)	(0.00940)	(0.0121)	(0.0121)	(0.0118)	(0.0104)	(0.0103)
City								
Fuel Economy	kpl	11.8	11.9	11.7	11.1	10.9	11.3	11.5
		(1.90)	(1.68)	(1.78)	(1.61)	(1.58)	(1.17)	(1.28)
Highway								
Fuel Economy	kpl	17.4	16.9	16.2	16.2	15.8	15.9	16.0
		(1.35)	(3.85)	(1.71)	(1.66)	(1.43)	(1.26)	(1.39)
Luxury Index		2.51	2.29	2.78	2.90	3.02	3.05	3.20
		(1.90)	(1.59)	(1.53)	(1.58)	(1.81)	(1.70)	(1.59)
Safety Index		0.605	0.184	0.488	0.610	1.16	1.12	1.27
		(0.728)	(0.391)	(0.840)	(0.802)	(0.485)	(0.453)	(0.605)
Automatic	dummy	0.0465	0.0204	0.0244	0.0732	0.0233	0.0238	0.0204
		(0.213)	0.143)	(0.156)	(0.264)	(0.153)	(0.154)	(0.143)
Diesel	dummy	0.186	0.204	0.293	0.195	0.163	0.238	0.184
		(0.394)	(0.407)	(0.461)	(0.401)	(0.374)	(0.431)	(0.391)
# of versions		43	49	45	41	43	42	49

[a] 1 lakh=Rs. 100,000.
[1] Version level vehicle characteristics data come from AutoCar India.
[2] The unweighted average across all available versions is presented above with standard deviations in parentheses.

Table 6: Version Level Summary statistics - All Available Sedan Characteristics

VARIABLES	UNITS	2002	2003	2004	2005	2006	2007	2008
Price	2008lakhs[a]	10.1	12.7	13.7	14.2	15.4	15.1	15.7
		(4.48)	(9.79)	(14.7)	(16.3)	(16.9)	(16.1)	(15.3)
Kerb Weight	MT	1.14	1.13	1.17	1.19	1.23	1.23	1.27
		(0.133)	(0.188)	(0.209)	(0.218)	(0.237)	(0.209)	(0.209)
Power	hp	83.2	94.5	102	108	113	116	120
		(28.1)	(29.2)	(39.2)	(43.6)	(50.3)	(49.1)	(50.0)
Power Ratio	hp/kg	0.0735	0.0831	0.0858	0.0887	0.0900	0.0915	0.0922
		(0.0225)	(0.0172)	(0.0189)	(0.0216)	(0.0240)	(0.0232)	(0.0237)
City								
Fuel Economy	kpl	9.97	9.81	9.51	9.14	9.15	9.35	9.66
		(1.57)	(1.79)	(2.03)	(2.07)	(2.00)	(1.95)	(2.09)
Highway								
Fuel Economy	kpl	14.2	13.4	12.7	13.7	13.8	14.0	14.3
		(2.83)	(2.60)	(2.87)	(2.91)	(2.95)	(2.80)	(2.92)
Luxury Index		4.09	5.25	5.44	5.73	6.09	6.30	6.83
		(2.69)	(2.20)	(2.40)	(2.52)	(2.37)	(2.57)	(2.42)
Safety Index		0.853	1.00	1.32	1.65	2.10	2.07	2.46
		(1.11)	(1.40)	(1.45)	(1.49)	(1.37)	(1.20)	(1.17)
Automatic	dummy	0.0400	0.0556	0.152	0.230	0.247	0.270	0.304
		(0.197)	0.231)	(0.361)	(0.424)	(0.434)	(0.446)	(0.463)
Diesel	dummy	0.347	0.264	0.215	0.270	0.225	0.258	0.359
		(0.479)	(0.444)	(0.414)	(0.447)	(0.420)	(0.440)	(0.482)
# of versions		75	72	79	74	89	89	92

[a] 1 lakh=Rs. 100,000.
[1] Version level vehicle characteristics data come from AutoCar India.
[2] The unweighted average across all available versions is presented above with standard deviations in parentheses.

Table 7: Hedonic Price Function Estimation Results

Dependent Variable: Natural Log of Price			
	(both)	(hatchback)	(sedan)
Kerb Weight	1.329***	0.837***	1.497***
	(0.0398)	(0.0471)	(0.0514)
Power Ratio	8.416***	8.544***	7.948***
	(0.406)	(0.679)	(0.499)
Luxury Index	0.0695***	0.0680***	0.0758***
	(0.00378)	(0.00432)	(0.00493)
Safety Index	0.0138*	-0.0147	0.00219
	(0.00810)	(0.00987)	(0.0104)
Automatic	0.218***	0.182***	0.165***
	(0.0199)	(0.0249)	(0.0256)
Diesel	0.177***	0.149***	0.187***
	(0.0173)	(0.0172)	(0.0232)
y2003	-0.00702	-0.0648***	0.0166
	(0.0233)	(0.0208)	(0.0327)
y2004	-0.126***	-0.144***	-0.0976***
	(0.0231)	(0.0208)	(0.0320)
y2005	-0.220***	-0.215***	-0.207***
	(0.0234)	(0.0215)	(0.0322)
y2006	-0.228***	-0.165***	-0.235***
	(0.0230)	(0.0215)	(0.0314)
y2007	-0.290***	-0.275***	-0.269***
	(0.0230)	(0.0217)	(0.0315)
y2008	-0.334***	-0.309***	-0.327***
	(0.0227)	(0.0210)	(0.0312)
Sedan	0.128***		
	(0.0154)		
Constant	-0.391***	0.0842	-0.448***
	(0.0376)	(0.0585)	(0.0561)
# of observations	986	327	659
R^2	0.948	0.868	0.934

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

[1] Table presents hedonic price function estimation results using all available versions for years 2002 to 2008.
[2] Column 1 reports estimation results for hatchabcks and sedans pooled together. Columns 2 and 3 report results of separate estimations for hatchbacks and sedans, respectively.

Table 8: Technical Frontier Estimation Results

Dependent Variable: Natural Log of City Fuel Economy			
	(both)	(hatchback)	(sedan)
Kerb Weight	-0.608***	-0.565***	-0.609***
	(0.0270)	(0.0426)	(0.0360)
Power Ratio	-1.736***	-2.466***	-1.335***
	(0.269)	(0.621)	(0.315)
Luxury Index	0.0103***	0.000213	0.0137***
	(0.00212)	(0.00393)	(0.00257)
Safety Index	0.0193***	0.0279***	0.0130**
	(0.00472)	(0.00907)	(0.00588)
Automatic	-0.0684***	-0.0844***	-0.0769***
	(0.0119)	(0.0290)	(0.0141)
Diesel	0.247***	0.185***	0.278***
	(0.00999)	(0.0158)	(0.0129)
y2003	0.000718	0.00907	-0.00658
	(0.0125)	(0.0186)	(0.0164)
y2004	-0.00341	-0.00269	-0.000705
	(0.0125)	(0.0192)	(0.0160)
y2005	-0.0356***	-0.0213	-0.0438***
	(0.0127)	(0.0191)	(0.0165)
y2006	-0.0237*	-0.0491**	-0.0117
	(0.0125)	(0.0194)	(0.0160)
y2007	0.00285	-0.00301	0.00346
	(0.0125)	(0.0196)	(0.0161)
y2008	0.0169	-0.00266	0.0224
	(0.0126)	(0.0191)	(0.0163)
Sedan	-0.0597***		
	(0.00885)		
Constant	3.029***	3.080***	2.919***
	(0.0282)	(0.0535)	(0.0426)
# of observations	882	311	571
R^2	0.796	0.631	0.783

*** p<0.01, ** p<0.05, * p<0.1

Standard errors in parentheses

[1] Table presents technical frontier estimation results using all available versions for years 2002 to 2008.

[2] Column 1 reports estimation results for hatchabcks and sedans pooled together. Columns 2 and 3 report results of separate estimations for hatchbacks and sedans, respectively.

Table 9: Break Even Period Analysis: Diesel Hatchback Owners

	UNITS	2002	2003	2004	2005	2006
Predicted Petrol Vehicle Price (A)	2008lakhs[a]	4.41	4.30	3.92	3.65	4.19
Predicted Diesel Vehicle Price (B)	2008lakhs	5.12	4.99	4.55	4.23	4.87
Diesel Premium (A-B)	2008lakhs	0.709	0.691	0.630	0.586	0.674
Predicted Petrol Vehicle Fuel Economy	kpl	11.0	11.1	10.9	10.7	10.3
Predicted Diesel Vehicle Fuel Economy	kpl	13.2	13.3	13.2	12.9	12.4
Petrol Minus Diesel Operating Cost	Rs./month	2830	2870	3580	3190	4050
Break Even Period						
10% Discount Rate	years	2.32	2.23	1.58	1.65	1.49
15% Discount Rate	years	2.46	2.36	1.64	1.72	1.54

[a] 1 lakh=Rs. 100,000.
[1] Predicted diesel vehicle price is calculated using the hedonic price function estimation results and the sales weighted average diesel hatchback characteristics. Predicted petrol vehicle price is then calculated using the same bundle of characteristics, but with fuel type switched from diesel to petrol. Predicted fuel economy is similarly calculated.
[2] Petrol minus diesel operating cost is a function of prevailing petrol and diesel fuel price, predicted petrol and diesel fuel economy, and monthly distance driven for the average consumer of diesel hatchbacks.

Table 10: Break Even Period Analysis: Diesel Sedan Owners

	UNITS	2002	2003	2004	2005	2006
Predicted Petrol Vehicle Price (A)	2008lakhs[a]	8.62	7.24	6.71	6.00	6.37
Predicted Diesel Vehicle Price (B)	2008lakhs	10.4	8.72	8.10	7.23	7.68
Diesel Premium (A-B)	2008lakhs	1.77	1.49	1.38	1.23	1.31
Predicted Petrol Vehicle Fuel Economy	kpl	9.01	9.24	9.22	8.82	9.10
Predicted Diesel Vehicle Fuel Economy	kpl	11.9	12.2	12.2	11.7	12.0
Petrol Minus Diesel Operating Cost	Rs./month	3980	4200	4070	4550	4860
Break Even Period						
10% Discount Rate	years	4.58	3.47	3.29	2.54	2.53
15% Discount Rate	years	5.23	3.81	3.60	2.71	2.69

[a] 1 lakh=Rs. 100,000.
[1] Predicted diesel vehicle price is calculated using the hedonic price function estimation results and the sales weighted average diesel sedan characteristics. Predicted petrol vehicle price is then calculated using the same bundle of characteristics, but with fuel type switched from diesel to petrol. Predicted fuel economy is similarly calculated.
[2] Petrol minus diesel operating cost is a function of prevailing petrol and diesel fuel price, predicted petrol and diesel fuel economy, and monthly distance driven for the average consumer of diesel sedans.

Table 11: Break Even Period Analysis: Petrol Hatchback Owners

	UNITS	2002	2003	2004	2005	2006
Predicted Petrol Vehicle Price (A)	2008lakhs[a]	4.43	4.07	3.78	3.68	3.84
Predicted Diesel Vehicle Price (B)	2008lakhs	5.15	4.72	4.39	4.27	4.45
Diesel Premium (A-B)	2008lakhs	0.713	0.653	0.607	0.591	0.617
Predicted Petrol Vehicle Fuel Economy	kpl	12.0	11.8	11.8	11.3	11.3
Predicted Diesel Vehicle Fuel Economy	kpl	14.5	14.2	14.2	13.6	13.6
Petrol Minus Diesel Operating Cost	Rs./month	1510	1680	1630	1810	2060
Break Even Period						
10% Discount Rate	years	4.94	3.86	3.69	3.14	2.84
15% Discount Rate	years	5.72	4.30	4.08	3.42	3.06
Distance Driven For $T = \hat{T}$						
10% Discount Rate	km/month	596	512	452	435	416
15% Discount Rate	km/month	723	621	549	528	505
Discount Rate For $T = \hat{T}$		0.265	0.347	0.365	0.435	0.487

[a] 1 lakh=Rs. 100,000.
[1] Predicted petrol vehicle price is calculated using the hedonic price function estimation results and the sales weighted average petrol hatchback characteristics. Predicted diesel vehicle price is then calculated using the same bundle of characteristics, but with fuel type switched from petrol to diesel. Predicted fuel economy is similarly calculated.
[2] Petrol minus diesel operating cost is a function of prevailing petrol and diesel fuel price, predicted petrol and diesel fuel economy, and monthly distance driven for the average consumer of petrol hatchbacks.
[3] Distance driven for $T = \hat{T}$ is the distance a petrol hatchback owner would have to drive each month for the diesel premium to equal the present discounted value of fuel savings from switching from a petrol hatchback to an otherwise identical diesel hatchback accumulated over the assumed life of the vehicle (11 years for a hatchback).
[4] Discount rate for $T = \hat{T}$ is the discount rate that must be used by the average petrol hatchback owner (in terms of monthly driving distance) for diesel premium to equal the present discounted value of fuel savings from switching from a petrol hatchback to an otherwise identical diesel hatchback accumulated over the assumed life of the vehicle (11 years for a hatchback).

Table 12: Break Even Period Analysis: Petrol Sedan Owners

	UNITS	2002	2003	2004	2005	2006
Predicted Petrol Vehicle Price (A)	2008lakhs[a]	8.27	9.17	8.45	7.23	7.51
Predicted Diesel Vehicle Price (B)	2008lakhs	9.98	11.1	10.2	8.72	9.06
Diesel Premium (A-B)	2008lakhs	1.70	1.89	1.74	1.49	1.54
Predicted Petrol Vehicle Fuel Economy	kpl	9.46	9.27	9.22	8.87	9.27
Predicted Diesel Vehicle Fuel Economy	kpl	12.5	12.2	12.2	11.7	12.2
Petrol Minus Diesel Operating Cost	Rs./month	2600	3150	2880	2850	3350
Break Even Period						
10% Discount Rate	years	7.71	6.76	6.85	5.61	4.79
15% Discount Rate	years	10.3	8.53	8.69	6.68	5.52
Distance Driven For $T = \hat{T}$						
10% Discount Rate	km/month	975	1010	871	726	726
15% Discount Rate	km/month	1200	1240	1070	890	890
Discount Rate For $T = \hat{T}$		0.167	0.193	0.190	0.237	0.280

[a] 1 lakh=Rs. 100,000.
[1] Predicted petrol vehicle price is calculated using the hedonic price function estimation results and the sales weighted average petrol sedan characteristics. Predicted diesel vehicle price is then calculated using the same bundle of characteristics, but with fuel type switched from petrol to diesel. Predicted fuel economy is similarly calculated.
[2] Petrol minus diesel operating cost is a function of prevailing petrol and diesel fuel price, predicted petrol and diesel fuel economy, and monthly distance driven for the average consumer of petrol sedans.
[3] Distance driven for $T = \hat{T}$ is the distance a petrol sedan owner would have to drive each month for the diesel premium to equal the present discounted value of fuel savings from switching from a petrol sedan to an otherwise identical diesel sedan accumulated over the assumed life of the vehicle (12 years for a sedan).
[4] Discount rate for $T = \hat{T}$ is the discount rate that must be used by the average petrol sedan owner (in terms of monthly driving distance) for diesel premium to equal the present discounted value of fuel savings from switching from a petrol sedan to an otherwise identical diesel sedan accumulated over the assumed life of the vehicle (12 years for a sedan).

Table 13: Willingness To Pay Analysis: Petrol Hatchback Owners

	UNITS	2002	2003	2004	2005	2006
Predicted Petrol Vehicle Price (A)	2008lakhs[a]	4.43	4.07	3.78	3.68	3.84
Predicted Diesel Vehicle Price (B)	2008lakhs	5.12	4.99	4.55	4.23	4.87
Diesel Premium (A-B)	2008lakhs	0.684	0.929	0.776	0.552	1.03
Predicted Petrol Vehicle Fuel Economy	kpl	12.0	11.8	11.8	11.3	11.3
Predicted Diesel Vehicle Fuel Economy	kpl	13.2	13.3	13.2	12.9	12.4
Petrol Minus Diesel Operating Cost	Rs./month	1350	1560	1470	1660	1790
Money Forgone						
10% Discount Rate	Rs.	42100	34500	42900	81000	43400
15% Discount Rate	Rs.	22700	12100	21700	57100	17700

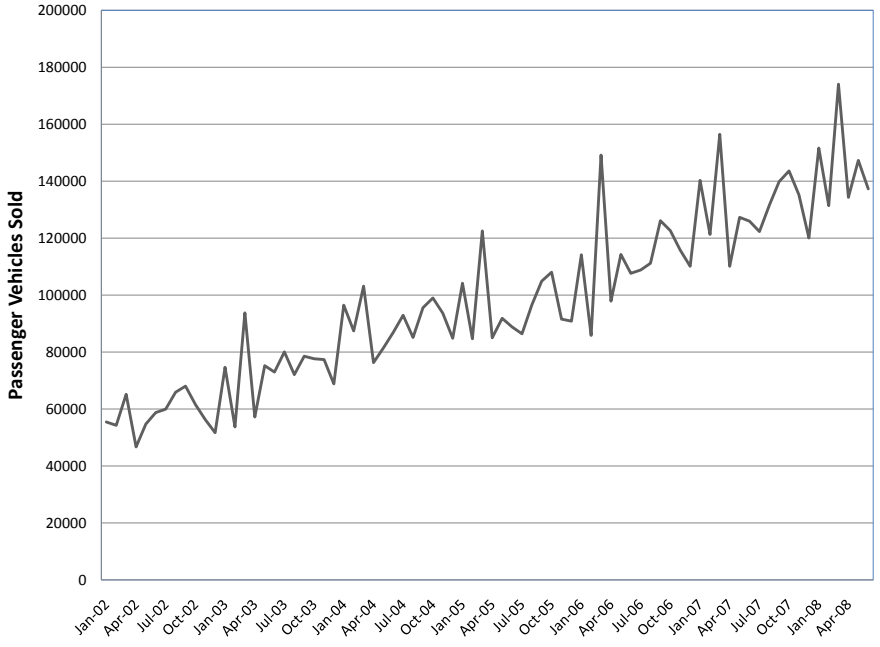
[a] 1 lakh=Rs. 100,000.
[1] Predicted petrol vehicle price is calculated using the hedonic price function estimation results and the sales weighted average petrol hatchback characteristics. Predicted diesel vehicle price is then calculated using the same bundle of characteristics, but with fuel type switched from petrol to diesel. Predicted fuel economy is similarly calculated.
[2] Petrol minus diesel operating cost is a function of prevailing petrol and diesel fuel price, predicted petrol and diesel fuel economy, and monthly distance driven for the average consumer of petrol hatchbacks.
[3] Money forgone is calculated as the difference in purchase plus operating cost of the average petrol hatchback and the puchase plus operating cost of the average diesel hatchback.

Table 14: Willingness To Pay Analysis: Petrol Sedan Owners

	Units	2002	2003	2004	2005	2006
Predicted Petrol Vehicle Price (A)	2008lakhs[a]	8.27	9.17	8.45	7.23	7.51
Predicted Diesel Vehicle Price (B)	2008lakhs	10.4	8.72	8.10	7.23	7.68
Diesel Premium (A-B)	2008lakhs	2.12	-0.450	-0.358	-0.973	0.162
Predicted Petrol Vehicle Fuel Economy	kpl	9.46	9.27	9.22	8.87	9.27
Predicted Diesel Vehicle Fuel Economy	kpl	11.9	12.2	12.2	11.7	12.0
Petrol Minus Diesel Operating Cost	Rs./month	2480	3140	2880	2840	3280
Money Forgone						
10% Discount Rate	Rs.	1080	315000	283000	243000	265000
15% Discount Rate	Rs.	-38600	265000	237000	198000	213000

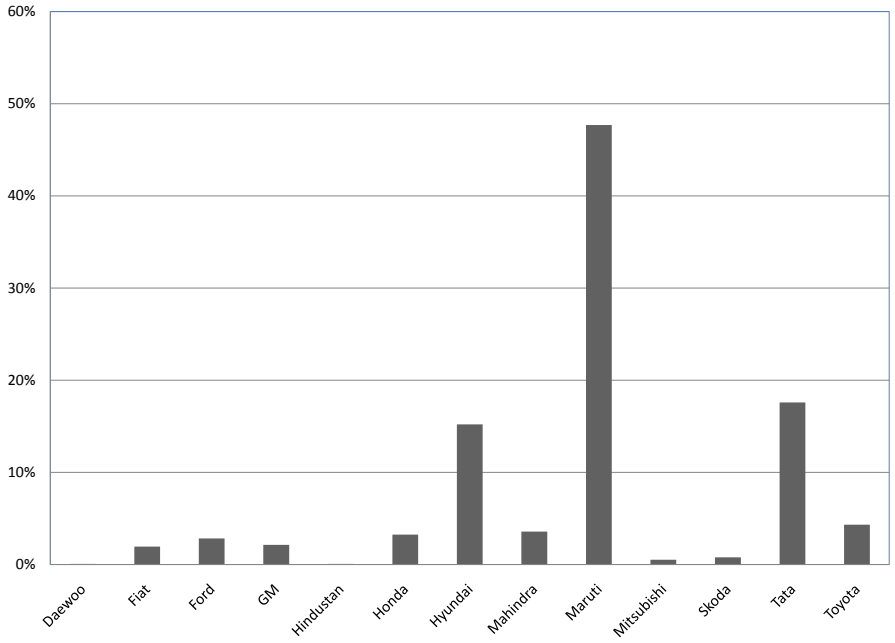
[a] 1 lakh=Rs. 100,000.
[1] Predicted petrol vehicle price is calculated using the hedonic price function estimation results and the sales weighted average petrol sedan characteristics. Predicted diesel vehicle price is then calculated using the same bundle of characteristics, but with fuel type switched from petrol to diesel. Predicted fuel economy is similarly calculated.
[2] Petrol minus diesel operating cost is a function of prevailing petrol and diesel fuel price, predicted petrol and diesel fuel economy, and monthly distance driven for the average consumer of petrol sedans.
[3] Money forgone is calculated as the difference in purchase plus operating cost of the average petrol sedan and the puchase plus operating cost of the average diesel sedan.

Figure 1: Monthly Passenger Vehicle Sales, 2002 to 2008



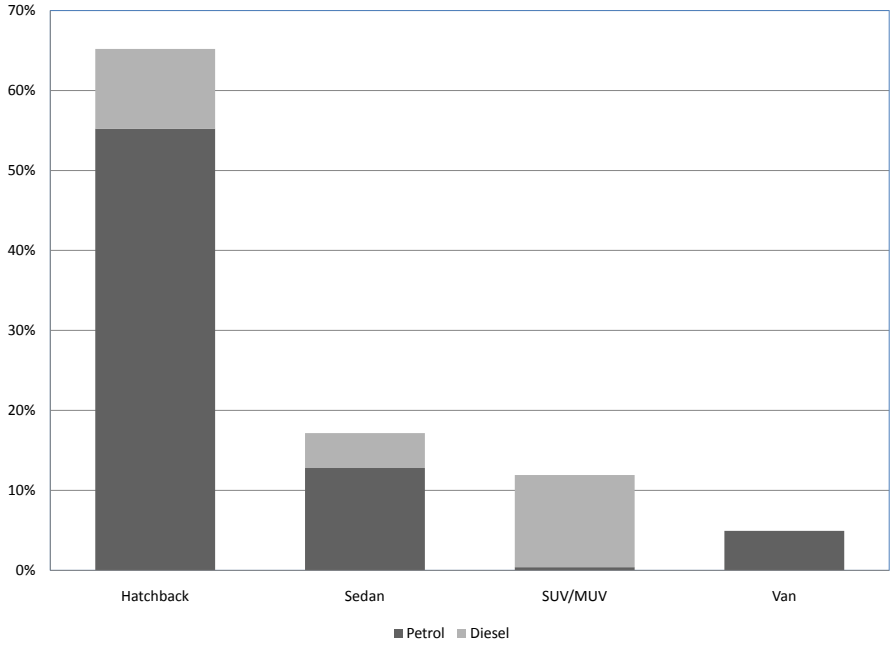
Source: Monthly vehicle sales data come from Society of Indian Automobile Manufacturers.

Figure 2: Market Shares by Vehicle Make, Averaged Over 2002 to 2006



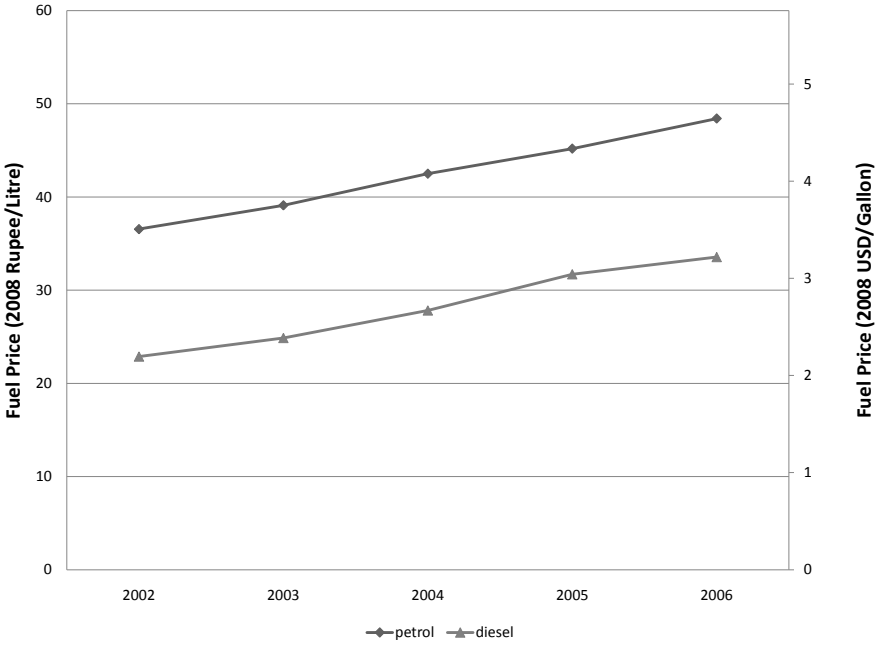
Source: Annual vehicle sales data come from the J.D. Power APEAL survey.

Figure 3: Market Shares by Body- and Fuel-Type, Averaged Over 2002 to 2006



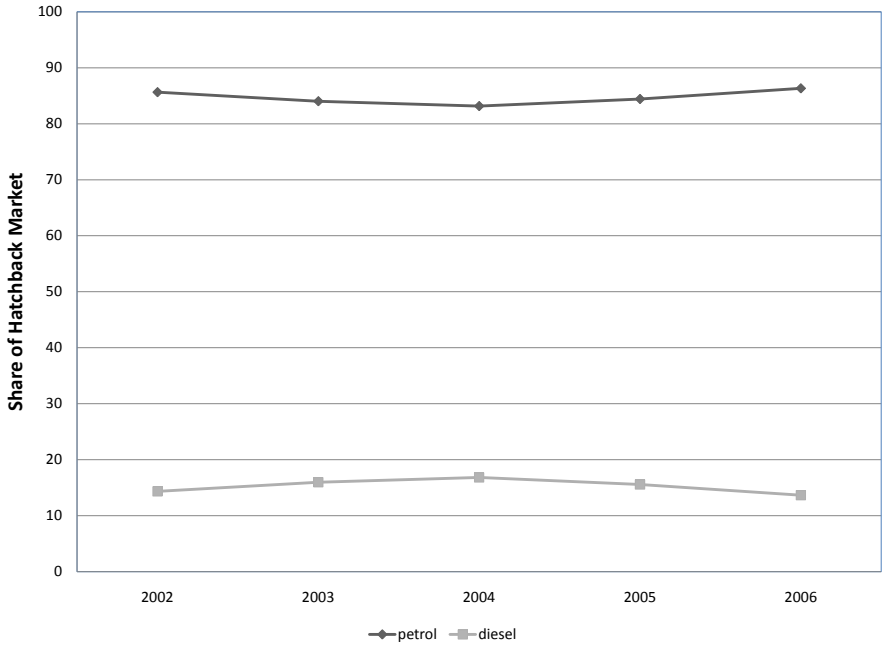
Source: Annual vehicle sales data come from the J.D. Power APEAL survey.

Figure 4: Average Diesel and Petrol Fuel Price in Delhi, 2002 to 2006



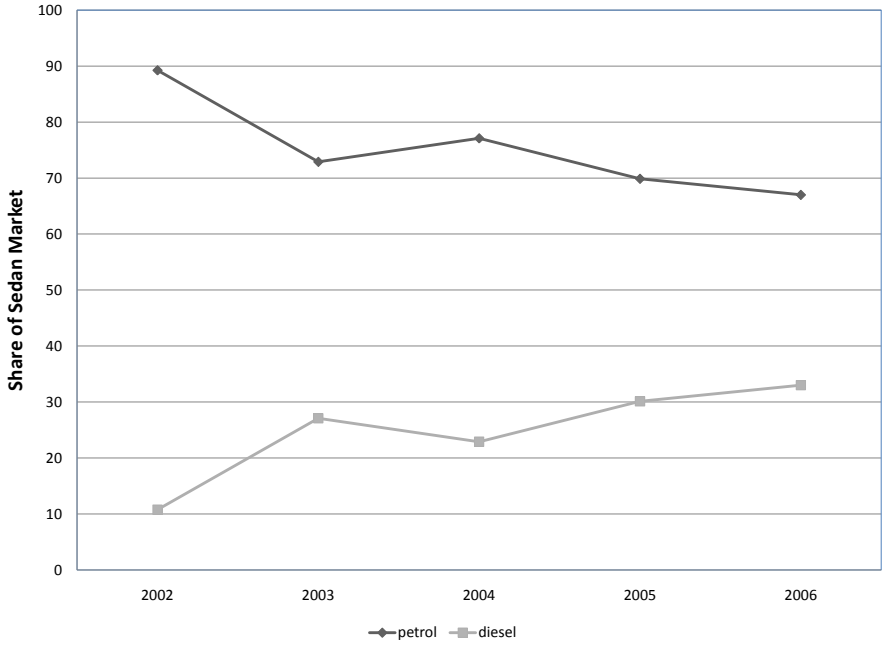
Source: Monthly Delhi fuel price data come from IndiaStat. Annual average prices are constructed by weighting monthly prices by fraction of annual vehicle sales sold in each month.

Figure 5: Hatchback Market Share By Fuel Type, 2002 to 2006



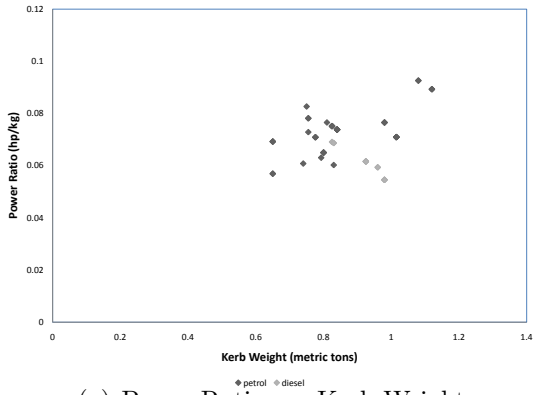
Source: Annual vehicle sales data come from the J.D. Power APEAL survey.

Figure 6: Sedan Market Share By Fuel Type, 2002 to 2006

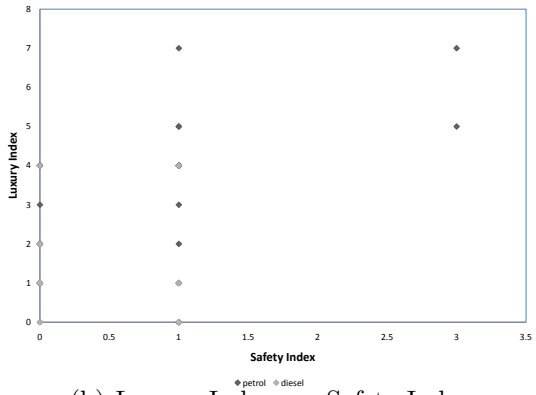


Source: Annual vehicle sales data come from the J.D. Power APEAL survey.

Figure 7: Availability of Vehicle Characteristics - 2002 Hatchback



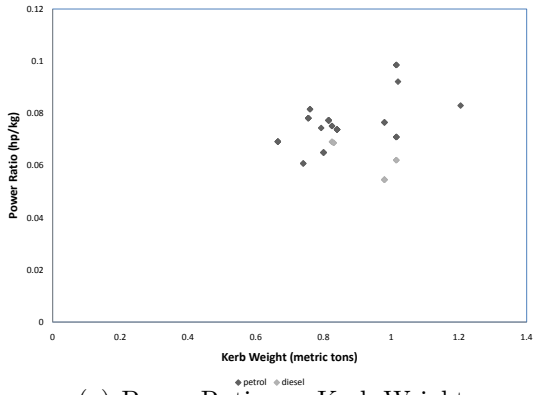
(a) Power Ratio vs. Kerb Weight



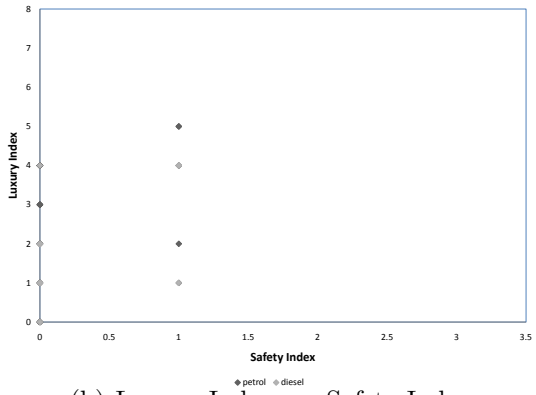
(b) Luxury Index vs. Safety Index

Source: Vehicle characteristics data come from AutoCar India.

Figure 8: Availability of Vehicle Characteristics - 2003 Hatchback



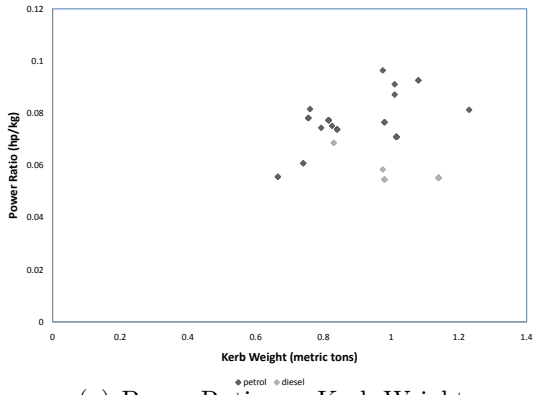
(a) Power Ratio vs. Kerb Weight



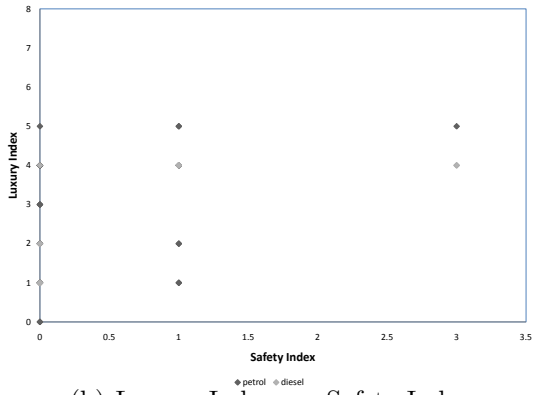
(b) Luxury Index vs. Safety Index

Source: Vehicle characteristics data come from AutoCar India.

Figure 9: Availability of Vehicle Characteristics - 2004 Hatchback



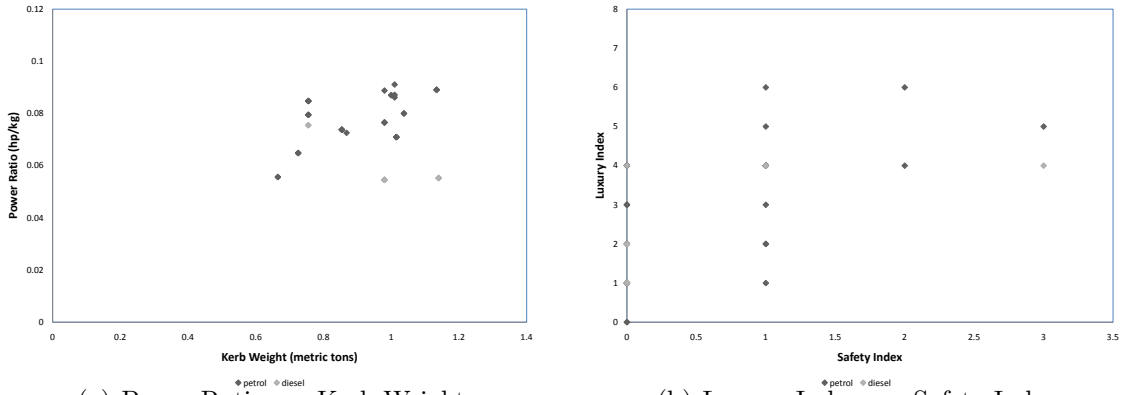
(a) Power Ratio vs. Kerb Weight



(b) Luxury Index vs. Safety Index

Source: Vehicle characteristics data come from AutoCar India.

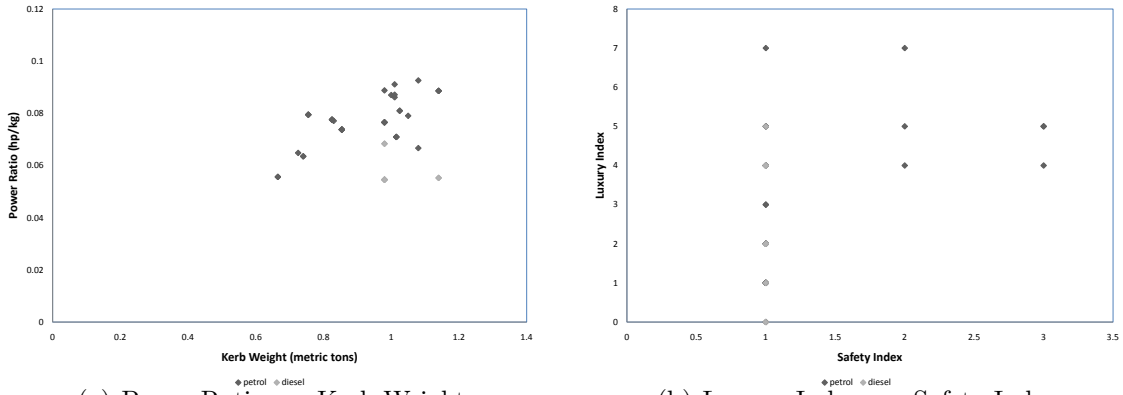
Figure 10: Availability of Vehicle Characteristics - 2005 Hatchback



(a) Power Ratio vs. Kerb Weight (b) Luxury Index vs. Safety Index

Source: Vehicle characteristics data come from AutoCar India.

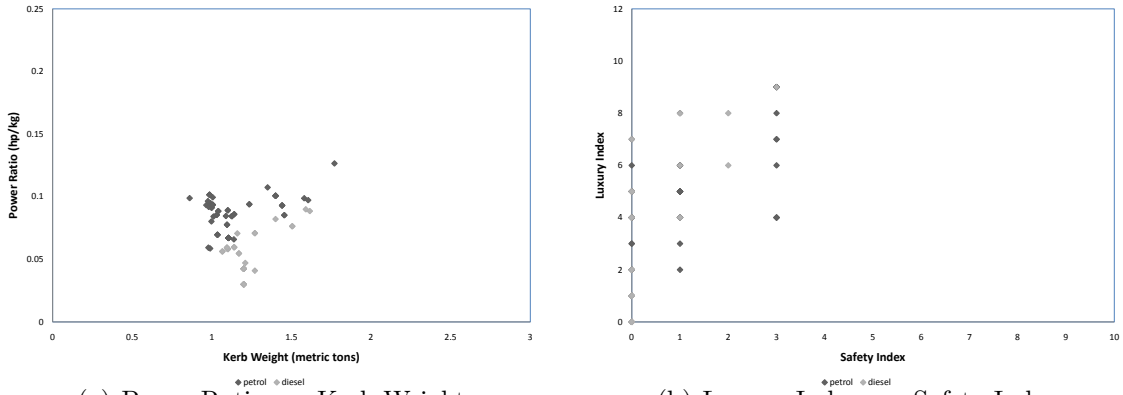
Figure 11: Availability of Vehicle Characteristics - 2006 Hatchback



(a) Power Ratio vs. Kerb Weight (b) Luxury Index vs. Safety Index

Source: Vehicle characteristics data come from AutoCar India.

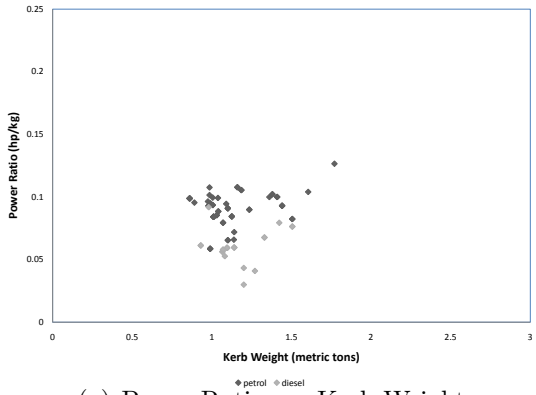
Figure 12: Availability of Vehicle Characteristics - 2002 Sedan



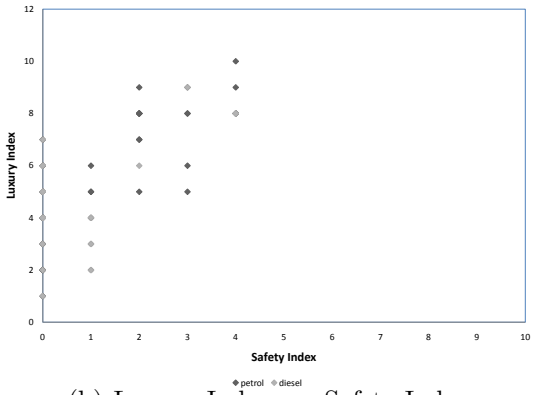
(a) Power Ratio vs. Kerb Weight (b) Luxury Index vs. Safety Index

Source: Vehicle characteristics data come from AutoCar India.

Figure 13: Availability of Vehicle Characteristics - 2003 Sedan



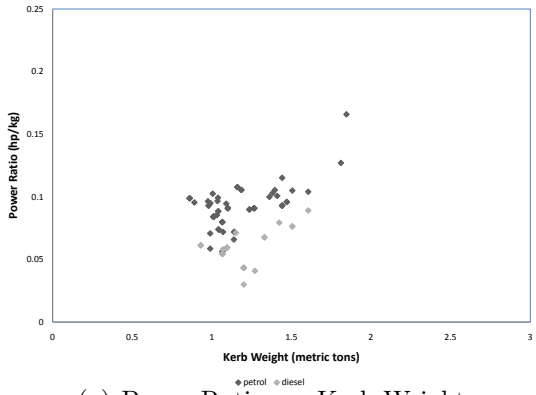
(a) Power Ratio vs. Kerb Weight



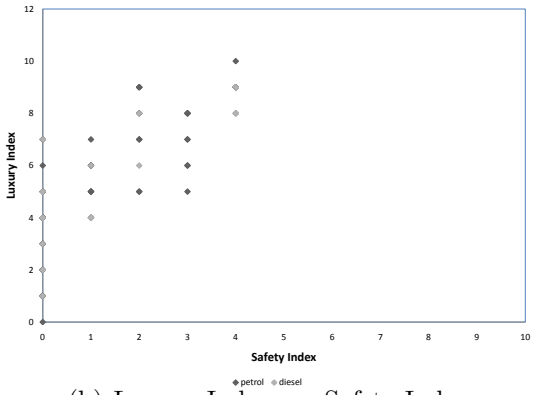
(b) Luxury Index vs. Safety Index

Source: Vehicle characteristics data come from AutoCar India.

Figure 14: Availability of Vehicle Characteristics - 2004 Sedan



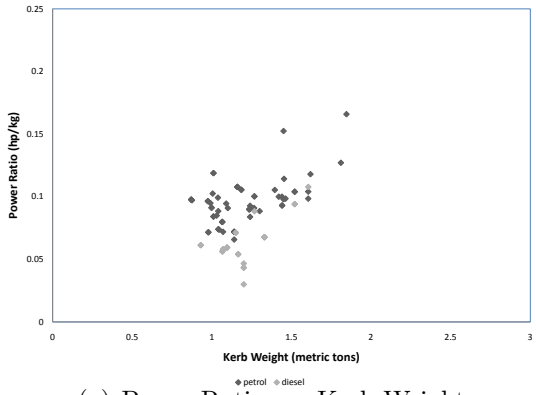
(a) Power Ratio vs. Kerb Weight



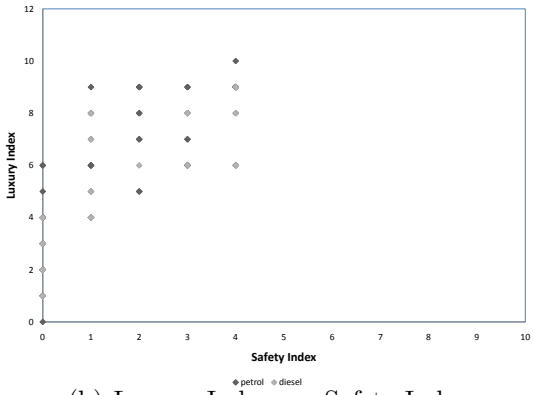
(b) Luxury Index vs. Safety Index

Source: Vehicle characteristics data come from AutoCar India.

Figure 15: Availability of Vehicle Characteristics - 2005 Sedan



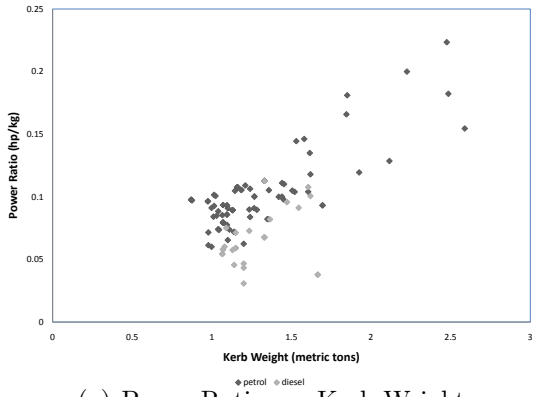
(a) Power Ratio vs. Kerb Weight



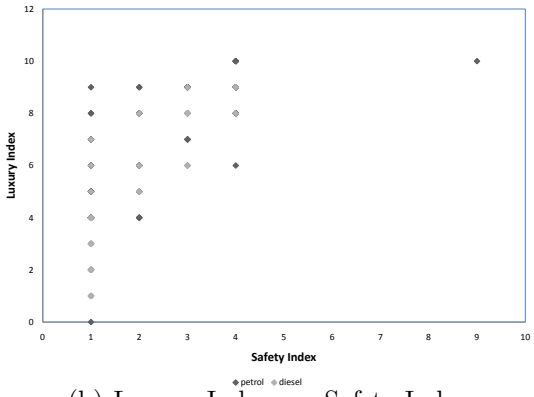
(b) Luxury Index vs. Safety Index

Source: Vehicle characteristics data come from AutoCar India.

Figure 16: Availability of Vehicle Characteristics - 2006 Sedan



(a) Power Ratio vs. Kerb Weight



(b) Luxury Index vs. Safety Index

Source: Vehicle characteristics data come from AutoCar India.