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The cost of fuel economy in the Indian passenger vehicle market ☆

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ABSTRACT

To investigate how fuel economy is valued in the Indian car market, we compute the cost to Indian consumers of purchasing a more fuel-efficient vehicle and compare it to the benefit of lower fuel costs over the life of the vehicle. We estimate hedonic price functions for four market segments (petrol hatchbacks, diesel hatchbacks, petrol sedans, and diesel sedans) to compute 95% confidence intervals for the marginal cost to the consumer for an increase in fuel economy. We find that the associated present value of fuel savings falls within the 95% confidence interval for most specifications, in all market segments, for the years 2002 through 2006. Thus, we fail to consistently reject the hypothesis that consumers appropriately value fuel economy.

1. Introduction

As a result of India's economic boom, the demand for passenger vehicles has grown swiftly over the last decade. In April 2002, passenger vehicle sales were approximately 50,000; by April 2008, monthly sales had tripled to approximately 150,000. To put these figures in perspective, January 2008 monthly sales were approximately 1 million in the United States and approximately 650,000 in China. With such rapid growth, many in India are advocating for strong legislative action to avoid the many economic, security, and environmental concerns that may accompany the expansion of the vehicle fleet.

As fuel consumption is of concern for both energy security and environmental reasons, much of the Indian debate has centered on policies to increase vehicle fuel economy. One argument for fuel economy standards (as opposed to higher fuel taxes) is that consumers undervalue fuel savings; that is, they fail to buy a more fuel-efficient vehicle even though the additional purchase price is less than the present value of fuel savings. This hypothesis has been tested extensively in the United States. Although much of the literature suggests that consumers undervalue fuel savings (Alcott and Wozny, 2010), other studies (Sallee et al., 2010) suggest that consumers are willing to pay an extra dollar when buying a car to reduce the present value of fuel costs by a dollar. This paper examines how car buyers in India value fuel savings.

The approaches that have been used to determine whether consumers undervalue fuel economy include hedonic price methods, studies of the impact of gasoline prices on used car prices, and structural estimates of the parameters of consumers' utility functions (Greene, 2010; Helfand and Wolverton, 2010). Hedonic price methods compare what consumers must pay for additional fuel economy in the market – as estimated by a hedonic price locus – with the associated reduction in fuel expenditures (Espey and Nair, 2005).[1] If the two are equal, when evaluated at chosen vehicle bundles, the null hypothesis that consumers rationally value fuel economy cannot be rejected. The advantage of this approach is that it does not require data on market shares; however, because estimates often rely on cross-sectional variation in vehicle characteristics, multicollinearity can make it difficult to obtain precise estimates of the marginal price of fuel economy, and omitted variable bias is a concern.

The hypothesis that consumers accurately value fuel economy has also been tested using data on used car prices. Because the used car market is competitive, the prices of used cars should adjust to reflect changes in the price of gasoline (Li et al., 2009). Klier and Linn (2009) use a similar approach in the new car

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[1] In an oligopolistic car market, the hedonic price function represents the locus of opportunities facing car buyers, even though it is no longer the envelope of tangencies between marginal bid and marginal offer curves.

market. They examine whether, within a given model year, monthly variation in gasoline prices is reflected in new car prices and market shares. Indeed, if consumers correctly value fuel economy, prices should adjust fully to reflect the change in the present value of fuel expenditures (Sallee et al., 2010). This can be tested by examining variation in car and gasoline prices while holding vehicle characteristics fixed.[2]

A third approach, used by Alcott and Wozny (2010), is to examine how consumers trade off the present value of fuel expenditures against purchase price, holding other vehicle characteristics constant. This requires identifying the parameters of consumers' utility functions. Recognizing that both the demand and supply of new vehicles respond to gasoline prices, Alcott and Wozny (2010) use expected vehicle operating cost at the time when the vehicle was new to instrument for the quantity of used vehicles available on the market.

Unfortunately, approaches that have been used in the literature to examine how consumers value fuel economy are difficult to apply in India because of a lack of data (e.g., on used car prices) and insufficient variation in the price of fuel over time. In this paper, we take a simpler hedonic price approach to examine how Indian car buyers value fuel economy.

1.1. Our approach

We test the hypothesis that consumers accurately value fuel economy by computing the marginal price that consumers face for an improvement in fuel economy and comparing this to the present value of associated fuel savings. For each of four vehicle types (petrol hatchbacks, diesel hatchbacks, petrol sedans, and diesel sedans), we estimate hedonic price functions treating fuel economy as one of several performance characteristics. To account for the possible correlation between fuel economy and unobserved vehicle characteristics, we instrument for the fuel economy of, for example, petrol hatchbacks of a given make using the average fuel economy of petrol sedans of the same make. We use these estimates to compute a 95% confidence interval for the marginal price of fuel economy and ask whether the present value of fuel savings falls within this interval, for the average buyer in each market.[3]

Based on these results, we cannot consistently reject the null hypothesis that the mean consumer equates the marginal price of fuel economy to the present value of fuel savings. In all markets and years, for most specifications of the hedonic price function, the present value of fuel savings falls within the 95% confidence interval of the fuel economy premium. The result is robust to the rate used to discount fuel savings (10% or 15%) and to assumptions about future fuel price expectations (that they will remain constant or increase at historic rates).

We also examine the trade-offs faced by buyers of twins, models that are available in both petrol and diesel form. Diesel versions are generally more expensive than their petrol twins, but cost less to operate because of their greater fuel economy and the fact that diesel fuel is 30% cheaper than petrol. The savings that buyers of diesel twins realize over the life of their vehicles are substantial. Over the expected life of his vehicle, the average diesel hatchback owner saved the equivalent of 50% of the purchase price of his vehicle by selecting it over its petrol twin; the average diesel sedan owner saved 18%. The percentage of twin hatchback owners taking advantage of these savings by buying the diesel twin has risen each year from 46% in 2002 to 74% in 2006. Similarly, 17% of twin sedan owners bought the diesel twin in 2002 and this rose to 59% in 2006.

Does this mean that buyers of petrol twins undervalue fuel economy? Petrol car buyers drive fewer kilometers than buyers of diesel cars, but the fuel savings from buying a diesel twin still outweigh the additional purchase price. Petrol hatchback owners could have saved 24% of the purchase price of their chosen vehicle by buying a diesel; petrol sedan owners could have saved 10%. Diesel cars, however, differ from their petrol twins in other performance characteristics: they are generally heavier and less powerful. It is possible that petrol car buyers accurately value fuel economy but are willing to forgo potential savings to buy a more powerful car. In fact, the fuel savings forgone are a lower bound to the value rational petrol car buyers place on these differences in characteristics.

The rest of the paper is organized as follows. Section 2 presents stylized facts about the Indian car market. Section 3 presents our hedonic analysis, and Section 4 compares the cost and fuel economy of petrol and diesel twins. Section 5 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. The market is highly concentrated, with the top five manufacturers accounting for nearly 90% of the market between 2002 and 2006. Maruti Suzuki accounted for 48% of sales, Tata Motors 18 percent, and Hyundai 15%. Mahindra and Toyota each accounted for 4%. Fig. 1 shows average market shares by body type and fuel type for the same period. The majority of passenger vehicles sold in India are small cars: hatchbacks constitute approximately 65% of the market, sedans about 17%, sport utility vehicles (SUVs) 12%, and vans 5%. The remainder of the market is composed of multi-use vehicles (MUVs), wagons, and coupes.

Averaged over the years 2002 through 2006, 73% of passenger vehicles ran on petrol and 27% on diesel, but the fuel breakdown varied significantly by body type. Approximately 85% of

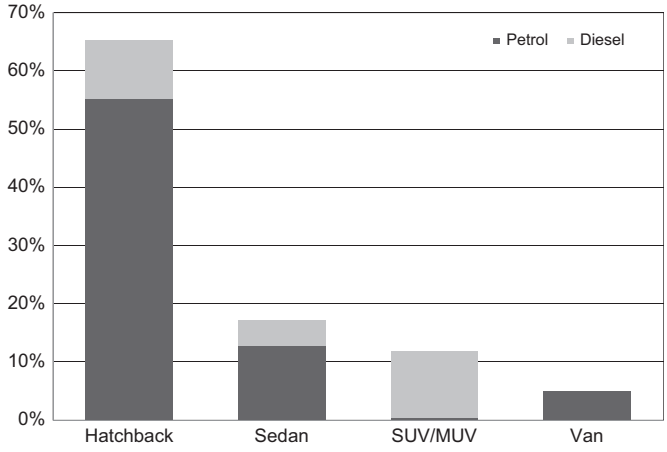

Fig. 1. Market shares by body and fuel type, averaged over 2002–2006.
Source: Annual vehicle sales data come from the J.D. Power APEAL survey.

[2] This test rests on assumptions about future gasoline prices. Sallee et al. (2010) assume that gasoline prices follow a random walk; hence today's price is the best estimate of tomorrow's price. According to Anderson et al. (2011) consumer forecasts of gasoline prices agree with this assumption.

[3] Our hedonic analysis indicates that the new car market is segmented by vehicle size (hatchback vs. sedan) and fuel type (petrol vs. diesel). So, the cost of buying additional fuel economy is conditional on market segment. Average kilometers driven also vary by market segment. We judge rationality conditional on market segment. We thus compute the fuel savings that diesel car buyers would realize if they were to buy a more fuel-efficient diesel car, rather than the fuel savings a person in the petrol hatchback market would realize if they were to buy a more fuel-efficient diesel car.

Table 1
Sales-weighted model-level summary statistics.

Variables	Units	Petrol hatchback	Diesel hatchback	Petrol sedan	Diesel sedan
Price	10^5 Rs. 2008	4.09	4.63	8.76	8.62
	(USD 2008)	(10,400)	(11,800)	(22,200)	(21,900)
Kerb weight	1000 kg	0.773	0.976	1.04	1.13
	(pound)	(1700)	(2150)	(2300)	(2490)
Power ratio	hp/kg	0.0707	0.0559	0.0892	0.0607
	(hp/pound)	(0.0321)	(0.0254)	(0.0405)	(0.0275)
Engine size	cm^3	972	1420	1540	1570
Torque	kg m	7.89	9.00	13.0	14.9
	(ft pound)	(57.0)	(65.1)	(94.1)	(108)
City fuel economy	km/l	12.1	13.0	9.60	12.3
	(mile/gal)	(28.5)	(30.7)	(22.6)	(29.0)
Luxury index[a]	0–10	2.04	2.16	4.71	4.11
Safety index[b]	0–4	0.427	0.221	0.889	0.978
Automatic transmission		0.131	0.000	0.124	0.005
Distance driven	km/month	1070	1870	1300	1870
	(mile/month)	(663)	(1160)	(808)	(1160)
# of models		43	12	72	31

Version level vehicle characteristics data come from AutoCar India. Model level market share data come from the JD Power.
Each model is available in multiple versions. For each year, and for each vehicle category, model/fuel-type level vehicle characteristics are constructed as the unweighted average across all available versions of each model for each fuel type. The within year sales weighted average of these models is calculated for each vehicle category. The resulting year representative vehicles are averaged across years 2002–2006 and presented above.

[a] Luxury index is defined as the sum of www.Carwale.com luxury rating (0-none, 1-luxury, or 2-super luxury) and the dummy variables for air conditioning, power steering, central locking, power windows, alloy wheels, leather seats, power mirrors, and cd player.

[b] Safety index is defined as the sum of the dummy variables for airbags, rear seat belts, antilock braking system, and traction control.

hatchbacks and 75% of sedans ran on petrol, whereas virtually all SUVs ran on diesel (only 3% used petrol). Because we examine the petrol/diesel fuel choice, the remainder of the paper focuses on hatchbacks and sedans. For hatchbacks, diesel market share has remained constant at around 15% between 2002 and 2006. For sedans, a trend of increasing diesel market share (i.e., dieselization) has taken place, from 11% in 2002 to 32% in 2006.

During the period of our study fuel prices were set by the Indian government and varied little across cities.[4] In our analysis, we use fuel prices in Delhi. In 2008 petrol in Delhi sold at 45 Rs. per liter ($4.20 per gallon) and diesel at 31 Rs. per liter ($2.90 per gallon). Diesel fuel in India is priced below petrol because of its uses in the agricultural sector. The gap between the two fuel prices has remained constant in percentage terms since around 2002, but the historic percentage gap is even greater. Between 2002 and 2008, the price of diesel and petrol (in real terms) rose by about 2 Rs. per year.

Tables 1 and 2 describe the characteristics of petrol and diesel hatchbacks and sedans. Table 1 describes vehicle characteristics at the model level (e.g., Honda Accord) for the period 2002–2006, weighted by market share. Table 2 summarizes the same variables at the version level (e.g., Honda Accord LX), not weighted by market share, for the period 2002 through 2008. These are the data used to estimate our hedonic price functions. Because our market share data only cover the 2002–2006 period, we cannot extend Table 1 to cover years 2007 and 2008.

Vehicle characteristics data, which cover the period 2002–2008, come from *AutoCar India*, an Indian car industry magazine, and Segment Y, a private market research firm. Additional data on body type classification and fuel type come from Carwale, a website that provides information for car buyers (www.Carwale.com). All market share data come from the 2002 to 2006 waves of the J.D. Power Asia Pacific APEAL study, an annual survey of approximately 4000 new car buyers in India.

Throughout the paper, we focus on city fuel economy rather than highway fuel economy. *AutoCar India* reports both city and highway fuel economy data; however, city fuel economy data correlate much better with fuel economy data reported by respondents in the APEAL survey. A regression through the origin of buyers' estimates of fuel economy on published estimates of city fuel economy yields a coefficient of 1.14 (s.e.=0.010); when highway fuel economy is added to the equation, the coefficient on city fuel economy equals 1.09 (s.e.=0.099) and the coefficient on highway fuel economy is 0.034 (s.e.=0.071).[5]

How do diesel and petrol cars compare in terms of fuel economy and other performance characteristics? Diesel hatchbacks are heavier and less powerful than petrol hatchbacks (see Table 1) but have better fuel economy in city driving. The fact that diesel hatchbacks weigh more reflects their larger engine size: no diesel hatchbacks are produced with engines smaller than 1250 cm^3, which is larger than the mean petrol hatchback engine. On average, diesel hatchbacks have more torque than petrol hatchbacks, but their ratio of torque to weight is lower. Diesel hatchbacks have about 1 kilometer-per-liter (kpl) greater fuel economy than petrol hatchbacks (sales weighted). The difference in fuel economy is much greater between diesel and petrol sedans: diesel sedans have about 2.7 kpl greater fuel economy than petrol sedans. Diesel sedans have a horsepower-to-weight ratio that is only 70% of that of a petrol sedan, but have 15% more torque and a 5% higher torque-to-weight ratio.

To put our study in perspective, we note that Indian cars are lighter and less powerful than cars in the United States (US Environmental Protection Agency (EPA), 2008). Between 2002 and 2006, the average weight of an Indian petrol hatchback (sales

[4] In 2006 the average price of petrol (in 2008 Rs. per liter) based on 25 Indian cities was 51.6, with a standard deviation of 2.34. (The corresponding diesel figures are Rs. 36.2 with a standard deviation of 2.01.) Since 2010 the Indian government has not controlled the price of petrol; however, as of this writing, it controls the price of diesel.

[5] We do not use self-reported fuel economy data from the APEAL survey because it is reported at the model, but not the version, level.

Table 2
Version-level summary statistics (standard deviations in parentheses).

Variables	Units	Petrol hatchback	Diesel hatchback	Petrol sedan	Diesel sedan
Price	10^5 Rs 2008	4.71 (1.42)	4.84 (0.758)	14.3 (15.8)	13.0 (9.24)
Kerb weight	1000 kg	0.907 (0.155)	0.991 (0.095)	1.19 (0.219)	1.22 (0.170)
Power ratio	hp/kg	0.0749 (0.00906)	0.0603 (0.00900)	0.0946 (0.0191)	0.0666 (0.0175)
Engine size	cm^3	1160 (244)	1570 (220)	1810 (580)	1810 (317)
Torque	kg m	9.81 (2.32)	10.8 (2.85)	16.1 (6.04)	18.4 (8.47)
City fuel economy	km/l	11.0 (1.42)	13.1 (1.12)	8.70 (1.37)	11.6 (1.67)
Luxury index[a]	0–10	2.91 (1.73)	2.48 (1.47)	5.82 (2.56)	5.50 (2.62)
Safety index[b]	0–4	0.775 (0.727)	0.781 (0.766)	1.71 (1.41)	1.61 (1.46)
Automatic transmission		0.041 (0.199)	0.000 0.000	0.212 (0.409)	0.146 (0.354)
# of versions		244	64	411	158

Version level vehicle characteristics data come from AutoCar India.
For each vehicle category, the unweighted average across all available versions from years 2002–2008 is presented above with standard deviations in parentheses.

[a] Luxury index is defined as the sum of www.Carwale.com luxury rating (0-none, 1-luxury, or 2-super luxury) and the dummy variables for air conditioning, power steering, central locking, power windows, alloy wheels, leather seats, power mirrors, and cd player.

[b] Safety index is defined as the sum of the dummy variables for airbags, rear seat belts, antilock braking system, and traction control.

weighted) was about 1700 pounds; for an Indian petrol sedan it was 2300 pounds. In the United States in 2006, the average car weighed approximately 3500 pounds.[6] The average horsepower-to-weight ratio (in horsepower per pound) was 0.032 for the Indian petrol hatchback, 0.041 for the Indian petrol sedan, and 0.054 for an average car in the United States. In view of their lighter weight and lower horsepower ratio, it is not surprising that the average fuel economy of the Indian petrol hatchback and sedan (28.5 and 22.6 mile/gal in city driving, respectively) was greater than that of the average US car (19.4 mile/gal).[7] Estimates of fuel economy technical frontiers, which show how fuel economy varies with vehicle characteristics, suggest that Indian cars are not necessarily as fuel efficient as US cars, holding weight and horsepower constant.[8]

3. Hedonic price approach

The hedonic approach to evaluating how buyers value fuel economy asks whether consumers equate the marginal cost of buying a more fuel-efficient vehicle to the present value of fuel savings. Such a comparison tests the null hypothesis that new car buyers are willing to pay an extra rupee in purchase price to decrease the present value of fuel costs by a rupee. Formally, new car buyers face a function that describes vehicle price (P) as a function of fuel economy (kpl) and other vehicle characteristics (Z), such as weight, horsepower, and type of transmission (automatic or manual). We assume quasilinear preferences over consumption of an outside good (x) and vehicle subutility (u), which depends on Z and driving distance, but not directly on fuel economy. $\boldsymbol{K}$ denotes the vector of distances driven each year over the car's lifetime. Each buyer chooses the (Z,$\boldsymbol{K}$,kpl) bundle that maximizes his utility (U),

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

If the buyer is sufficiently forward looking, he considers the impact of fuel economy on the present value of fuel costs over the life of the vehicle, and thus faces the budget constraint

$$y = x + P(kpl,Z) + \sum_{t=0}^{T} \frac{1}{(1+r)^t} K(t) \frac{p_f(t)}{kpl} \pi(t). \tag{2}$$

In Eq. (2), y is wealth, T is the maximum life of the vehicle, r is the buyer's discount rate, $K(t)$ is the number of kilometers driven in year t, $p_f(t)$ is the (expected) price of fuel in year t, and $\pi(t)$ is the probability that the vehicle survives to year t. The first-order conditions for this problem imply that, at the chosen level of fuel economy, the marginal cost of an additional unit of fuel economy must equal the resulting reduction in fuel costs

$$\frac{\partial P}{\partial kpl} = \sum_{t=0}^{T} \frac{1}{(1+r)^t} K(t) \frac{p_f(t)}{kpl^2} \pi(t). \tag{3}$$

To test whether this condition is satisfied, we estimate hedonic price functions facing consumers in four vehicle markets – petrol hatchbacks, diesel hatchbacks, petrol sedans, and diesel sedans – and compute the 95% confidence intervals for the cost of a 1 kpl increase in fuel economy, evaluated at the sales-weighted mean (Z,kpl) vector for each vehicle type. We compute the associated reduction in fuel costs over the life of the vehicle based on the sales-weighted mean driving distance in each market.

Because we focus on sales-weighted mean vehicle characteristics and driving distances, ours is a test of whether car buyers choose fuel economy optimally, on average. Note also that Eq. (2) treats the new car buyer as the sole owner of the vehicle. A

[6] The EPA car category is comparable to our hatchbacks and sedans, as it excludes SUVs, wagons, vans, and pickup trucks.

[7] The figures for the United States are the adjusted city miles per gallon as reported in EPA (2008, Table 1), rather than laboratory results.

[8] When a fuel economy technical frontier model estimated using Indian data is used to predict the fuel economy of an average US car, predicted fuel economy is less than 16 miles per gallon (Chugh et al., 2010).

Table 3
Explanatory variables.

Variable	Description
Price	Price of vehicle in Delhi inclusive of taxes and fees in 2008 rupees
Kerb weight	Weight of vehicle in thousands of kilograms
Power ratio	Ratio of horsepower to vehicle weight (hp/kg)
Engine size	Measured in cm^3
Torque	Engine torque, measured in kg m
Luxury index	The sum of www.Carwale.com luxury rating (0-none, 1-luxury, or 2-super luxury) and the dummy variables for air conditioning, power steering, central locking, power windows, alloy wheels, leather seats, power mirrors, and cd player
Safety index	The sum of the dummy variables for airbags, rear seat belts, antilock braking system, and traction control
Automatic	A dummy variable for transmission type (0-manual or 1-automatic)
City fuel economy	Fuel economy measured under urban driving conditions in km/l

rational new car buyer who keeps a car until it is scrapped is equivalent to a rational new car buyer who can sell the vehicle to another rational (used) car buyer before it is scrapped. Thus our null hypothesis 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.

3.1. Estimation of the hedonic price function

The problems involved in estimating the marginal price of fuel economy using hedonic price functions are well known. Correlation between fuel economy and vehicle characteristics, such as weight and horsepower, make precise estimation of the marginal price difficult, and correlation between fuel economy and unobserved vehicle characteristics (such as acceleration) leads to omitted variable bias, which renders estimates inconsistent (Atkinson and Halvorsen, 1984; Espey and Nair, 2005). To deal with these issues, we estimate different specifications of the hedonic price function and instrument for fuel economy. For comparison purposes, we also present ordinary least squares (OLS) results.

In each specification, the logarithm of vehicle price is expressed as a function of subsets of vehicle characteristics described in Table 3 (Cropper et al., 1988),[9]

$$\log P(Z_j) = \sum_{i=1}^{n} \beta_i z_i + \epsilon_j. \quad (4)$$

The vehicle characteristics that are most highly correlated with fuel economy, but which are valued in their own right, are vehicle weight and engine performance. Engine performance is usually measured by torque (or horsepower) and by engine size.[10] Horsepower (or torque) relative to vehicle weight determines how much "pickup" a car has (i.e., how well it accelerates). We use different combinations of engine size, torque, and the ratio of horsepower to weight to measure performance. All 4 specifications of the hedonic price function include fuel economy, weight, indices that measure a vehicle's luxury and safety features, and whether the car has an automatic transmission. Specification 1 uses the ratio of horsepower to weight to measure performance; specification 2 adds engine size to specification 1. Specification 3 measures performance by torque, and specification 4 adds engine size to specification 3. The data used to estimate hedonic price functions (summarized in Table 2) include all versions available in each market over the period 2002–2008, unweighted by sales.

We separate the market into sedans and hatchbacks as vehicles of very different sizes and price ranges are unlikely to be close substitutes. We also segment the market according to fuel type as the marginal price of fuel economy is likely to differ by fuel type as a result of the diesel–petrol price differential. Wald tests allow us to reject the null hypothesis that these market segments should be combined.

We instrument for fuel economy because gains in fuel economy are often achieved by sacrifices in weight, horsepower, and other desirable characteristics. Although we control for observable characteristics in our model, failure to account for correlation between higher fuel economy and unobservable attributes may bias our fuel economy coefficients downward. We instrument for the fuel economy of petrol hatchbacks of a given make using the average fuel economy of petrol sedans of the same make. We instrument for the fuel economy for each petrol sedan of a given make using the average fuel economy of petrol hatchbacks of the same make. Instruments for diesel vehicles are constructed analogously. For example, the 2002 Fiat petrol hatchbacks, the Palio (which comes in 11 versions) and the Uno (which comes in 2 versions), all have the same value of the instrument, which is constructed as the average fuel economy of all 7 versions of the 2002 Fiat petrol sedan (the Siena). The 2002 Fiat Siena (all 7 versions) share the same IV value, which is equal to the average fuel economy of all 13 2002 Fiat petrol hatchbacks.

Our instrument is constructed to reflect the fuel economy technology available to manufacturers at the time of vehicle design. Sedan fuel economy should be correlated with hatchback fuel economy, but not with unmeasured hatchback design characteristics, provided manufacturers' design decisions are made separately for each vehicle segment. Even if this last assumption is violated, we believe that sedan fuel economy will certainly be less correlated with unmeasured hatchback design features than the hatchback's own fuel economy.

3.2. Hedonic price function results

Instrumental variable (IV) estimates of specification 4 of the hedonic price function are presented in Table 4.[11] Ordinary Least Squares (OLS) estimates and IV estimates of the fuel economy coefficients are presented for all 4 specifications in Table 5. Specification 4 fits well in all market segments: most coefficients are statistically significant, with expected signs. Vehicle price varies positively with weight, torque, engine size, luxury index, and automatic transmission (relative to manual). For all vehicle categories, quality-adjusted prices are approximately 20–40% lower in 2008 than in 2002. Holding vehicle characteristics constant, petrol car prices have fallen more than diesel car prices.

What is the marginal cost to consumers of buying a car with greater fuel economy? IV estimates from Table 5 suggest that the cost of fuel economy ranges from 1% to 10% of vehicle price. As expected, this is higher than the marginal cost in the OLS models, suggesting that fuel economy is negatively correlated with desirable, but unmeasured, vehicle characteristics.

We compute 95% confidence intervals for the cost of a 1 kpl increase in fuel economy holding all other vehicle characteristics

[9] Cropper et al. (1988) find that hedonic price functions that are linear in the explanatory variables perform better than functions using quadratic forms of the explanatory variables when some variables are measured with error or missing from the equation.

[10] Holding engine speed constant, horsepower is a multiple of torque.

[11] The first-stage results for our IV estimates are presented in Appendix A. Second-stage IV results for specifications 1–3 are presented in Chugh et al. (2011).

Table 4
Hedonic price function instrumental variable estimation results.

Variables	Petrol hatchback: ln(price)	Diesel hatchback: ln(price)	Petrol sedan: ln(price)	Diesel sedan: ln(price)
City fuel economy (IV)	0.0899*** (0.0285)	0.0830*** (0.0193)	0.0843*** (0.0304)	0.0447** (0.0177)
Kerb weight	0.548*** (0.130)	0.753*** (0.188)	0.742*** (0.137)	0.677** (0.338)
Engine size	0.000473 (0.000290)	0.000156*** (5.99e−05)	0.000461*** (8.95e−05)	0.000201*** (5.24e−05)
Torque	0.0274 (0.0229)	0.0161*** (0.00444)	0.0176** (0.00830)	0.0228*** (0.00555)
Luxury index	0.0845*** (0.00646)	0.0399*** (0.00713)	0.0437*** (0.00508)	0.0411*** (0.00751)
Safety index	−0.0286* (0.0166)	−0.0158 (0.0154)	0.0264** (0.0110)	−0.0255 (0.0189)
Automatic	0.173*** (0.0511)	N/A	0.0614 (0.0479)	N/A
Y2003	−0.0293 (0.0336)	−0.0700** (0.0310)	−0.00107 (0.0332)	−0.0190 (0.0672)
Y2004	−0.0927*** (0.0353)	−0.147*** (0.0302)	−0.149*** (0.0298)	−0.140** (0.0677)
Y2005	−0.163*** (0.0346)	−0.0682* (0.0408)	−0.191*** (0.0413)	−0.128* (0.0767)
Y2006	−0.115*** (0.0363)	0.0384 (0.0459)	−0.258*** (0.0303)	−0.0976 (0.0820)
Y2007	−0.278*** (0.0355)	−0.0978** (0.0445)	−0.276*** (0.0297)	−0.164** (0.0818)
Y2008	−0.289*** (0.0381)	−0.168*** (0.0517)	−0.362*** (0.0315)	−0.228*** (0.0859)
Constant	−0.894* (0.519)	−0.695* (0.390)	−0.529 (0.418)	0.0221 (0.527)
Observations	236	64	216	42
R-squared	0.794	0.839	0.899	0.947

Standard errors in parentheses.
This table presents IV estimation results for hedonic price function specification 4. There are no diesel hatchbacks or diesel sedans with automatic transmission for which the instrumental variable can be constructed.

* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

Table 5
OLS and IV estimates of city fuel economy coefficient.

	Specifications				Observations
	(1)	(2)	(3)	(4)	
Petrol hatchback					
OLS	0.0144** (0.00673)	0.000870 (0.00739)	0.0128 (0.00776)	0.00381 (0.00860)	244
IV	0.0316* (0.0179)	0.0155 (0.0302)	0.0935*** (0.0314)	0.0899*** (0.0285)	236
Diesel hatchback					
OLS	0.0358*** (0.0107)	0.0363*** (0.0103)	0.0281** (0.0110)	0.0292*** (0.0104)	64
IV	0.0734*** (0.0182)	0.0873*** (0.0181)	0.0633*** (0.0192)	0.0830*** (0.0193)	64
Petrol sedan					
OLS	0.0472*** (0.0114)	0.0442*** (0.0114)	0.0264** (0.0107)	0.0260** (0.0106)	411
IV	0.0484** (0.0220)	0.0597*** (0.0197)	0.0699** (0.0306)	0.0843*** (0.0304)	216
Diesel sedan					
OLS	0.0137 (0.0103)	0.0273*** (0.00983)	0.00866 (0.0112)	0.0239** (0.0107)	158
IV	0.0973** (0.0383)	0.0398* (0.0210)	0.103*** (0.0272)	0.0447** (0.0177)	42

Standard errors in parentheses.
This table presents OLS and IV fuel economy coefficient estimates for all 4 hedonic price function specifications.

* $p < 0.1$
** $p < 0.05$
*** $p < 0.01$

at their sales-weighted means for each year. Table 6 presents these cost calculations for years 2002–2006 for each market segment based on the IV results shown in Table 4. The marginal price of fuel economy is generally falling between 2002 and 2005. This reflects the fact that, holding vehicle characteristics constant, the real price of a car is falling in each market over this period.

3.3. The savings from improved fuel economy

We compute the savings from a 1 kpl increase in fuel economy using the discrete counterpart to Eq. (3)

$$\sum_{t=0}^{T} \frac{1}{(1+r)^t} K(t)\left(\frac{p_f(t)}{kpl} - \frac{p_f(t)}{kpl+1}\right)\pi(t). \quad (5)$$

Savings are evaluated in each market segment based on the mean monthly driving distance by buyers in that segment, averaged over the years 2002 through 2006. These monthly driving distances are 1070 kilometers (petrol hatchback owners), 1870 kilometers (diesel hatchback owners), 1300 kilometers (petrol sedan owners), and 1870 kilometers (diesel sedan owners). We use these driving distances to estimate $K(0)$ (km driven during the first year of ownership) and then allow $K(t)$ to decline at a rate of 2.5% per year as the car ages. This is the rate at which distance driven declines in the US (Lu, 2006). Barth et al. (2007) suggest that km driven may decline more rapidly in India, suggesting that our estimates may overstate fuel cost savings.[12]

To calculate fuel savings, we must also make assumptions about vehicle life, interest rates, and future fuel prices. The probability of a car surviving to each future age, $\pi(t)$, is based on a survival curve for Indian cars estimated by Arora et al. (2011). Their survival curve sets T equal to 20 and implies an expected vehicle life of 18 years. In contrast, the expected life of a car in the United States is 13 years (Lu, 2006). Interest rates are also higher in India than in the United States. We use a discount rate of 15% for car buyers, based on interest rates charged on new car loans in India and note that about 80% of new car purchases are financed with such loans (Shankar, 2007; Carazoo, n.d.; Seth, 2009). As a sensitivity analysis we also use a discount rate of 10% (the return on certificates of deposits in India in 2011).[13] Following Anderson et al. (2011), we assume that consumers expect future fuel prices to follow a random walk. This allows us to replace $p_f(t)$ in Eq. (5) with $p_f(0)$, the price of fuel at the time of vehicle purchase.[14] As a sensitivity analysis we allow $p(t)$ to increase at the rate of 2 Rs. per year, approximately the average rate of increase for both diesel and petrol over the 2002–2008 period.

[12] Barth et al. (2007) report that km driven decrease with vehicle age at the rate of 794 km per year, based on data from Pune. Unfortunately this is based on vehicles aged 13 years or younger, so that km driven fall to zero at age 13. Since our expected vehicle life is 18 years, km driven cannot decrease this rapidly.

[13] http://articles.economictimes.indiatimes.com/2011-02-03/news/28427857_1_cd-rates-short-term-rates-policy-rates.

[14] For each model year, we construct a sales-weighted average petrol price and a sales-weighted average diesel price. We weight monthly fuel price, reported in www.Indiastat.com, by monthly vehicle sales.

Table 6
Fuel economy premium vs. present discounted value of fuel savings.

	2002	2003	2004	2005	2006
Petrol hatchback					
FE premium	42,600	38,600	36,800	35,300	37,500
	[14,400, 70,800]	[13,400, 63,700]	[13,500, 60,000]	[12,800, 57,800]	[13,500, 61,500]
PDV of fuel savings					
r=0.15, constant fuel price	16,675	17,980	21,022	21,850	23,087
r=0.15, increasing fuel price	20,972	22,310	25,680	26,404	27,579
r=0.10, constant fuel price	21,278	22,943	26,824	27,881	29,460
r=0.10, increasing fuel price	27,779	29,495	33,873	34,772	36,256
Diesel hatchback					
FE premium	40,800	41,400	38,100	35,300	42,500
	[22,200, 59,400]	[21,500, 61,300]	[19,800, 56,400]	[20,800, 51,700]	[24,800, 60,300]
PDV of fuel savings					
r=0.15, constant fuel price	16,405	16,050	17,918	25,691	27,174
r=0.15, increasing fuel price	23,160	22,129	23,984	33,322	34,801
r=0.10, constant fuel price	20,933	20,480	22,864	32,782	34,674
r=0.10, increasing fuel price	31,155	29,678	32,042	44,328	46,215
Petrol sedan					
FE premium	77,100	79,400	74,700	65,300	68,500
	[19,900, 134,000]	[21,600, 137,000]	[19,300, 130,000]	[19,000, 112,000]	[18,000, 114,000]
PDV of fuel savings					
r=0.15, constant fuel price	30,863	34,722	37,241	43,735	45,093
r=0.15, increasing fuel price	38,816	43,085	45,494	52,851	53,866
r=0.10, constant fuel price	39,382	44,306	47,520	55,807	57,540
r=0.10, increasing fuel price	51,415	56,960	60,008	69,600	70,814
Diesel sedan					
FE premium	45,500	35,400	33,200	31,600	35,400
	[11,600, 79,500]	[11,000, 59,800]	[9590, 56,800]	[10,300, 53,000]	[10,700, 60,000]
PDV of fuel savings					
r=0.15, constant fuel price	16,393	21,130	21,259	28,381	27,294
r=0.15, increasing fuel price	23,143	29,133	28,456	36,812	34,954
r=0.10, constant fuel price	20,918	26,962	27,127	36,215	34,827
r=0.10, increasing fuel price	31,132	39,072	38,017	48,971	46,418

FE *premium* results are based on hedonic price function IV estimates presented in Table 4 (specification 4), delta method 95% confidence intervals are presented in brackets. All values are in 2008 Rupees.
Present discounted value of fuel savings is calculated using vehicle survival probability and declining annual driving distances discussed in text. Calculations are presented for interest rates of 15% and 10% as well as constant fuel price and increasing fuel price.

In addition to the 95% confidence intervals of the cost of a 1 kpl increase in fuel economy, Table 6 presents point estimates of the present value of corresponding fuel savings. Fuel savings calculations are presented for both discount rate assumptions and both fuel price expectations assumptions. Fuel savings are increasing in absolute terms over the 2002–2006 period as a result of increases in the real prices of both diesel and petrol. In all years fuel savings are sensitive to discount rate and fuel price expectations assumptions. To illustrate, 2006 fuel savings are 57% higher for petrol vehicles and 70% higher for diesel vehicles using a discount rate of 10% and allowing prices to increase by 2 Rs. per year, compared to a discount rate of 15% and an assumption of constant real fuel prices.

3.4. Comparison of the marginal price of fuel economy and fuel savings

To test the null hypothesis that consumers equate the marginal price of fuel economy to the present value of fuel savings, we subtract the fuel savings reported in Table 6 from the marginal price of fuel economy (based on Table 4) to construct 95% confidence intervals of the net costs of purchasing additional fuel economy. If zero lies within this interval, we cannot reject the null hypothesis. Fig. 2 presents results based on a discount rate of 15% and the assumption that fuel prices are expected to remain constant. Fig. 3 uses a discount rate of 10% and assumes that fuel prices are expected to increase at 2 Rs. per year

The results presented in Figs. 2 and 3, based on hedonic price function specification 4, show that for all four segments in all years we find no evidence of fuel economy undervaluation. In fact, in Fig. 2 consumers in the diesel hatchback market appear to be overvaluing

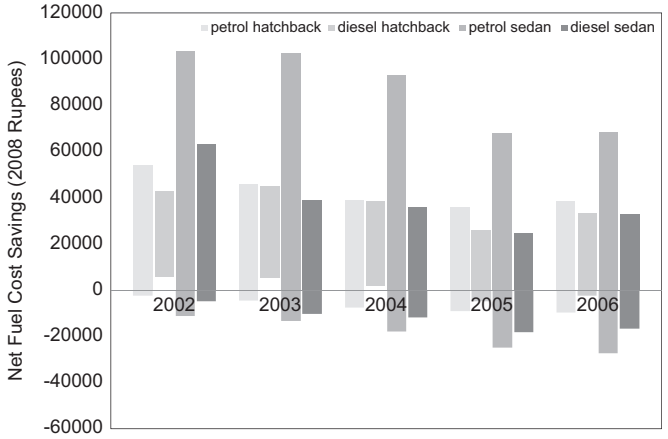

Fig. 2. 95% Confidence intervals of fuel economy premium minus present discounted value of fuel savings (r=15%; constant fuel prices). *Notes:* The graph presents 95% confidence intervals of hedonic price function specification 4 estimates of the price of a 1 kpl improvement in fuel economy minus the associated present discounted value of fuel savings, calculated using a 15% discount rate. Fuel prices are expected to remain constant over the life of the vehicle.

fuel economy in 2002 to 2004. Using other specifications of the hedonic price function (see Table 5) we generally fail to reject the hypothesis that consumers equate the cost of additional fuel economy to the present value of fuel savings. The only cases in which consumers undervalue fuel economy occur in the 2005 and 2006 markets for petrol hatchbacks when results from specifications

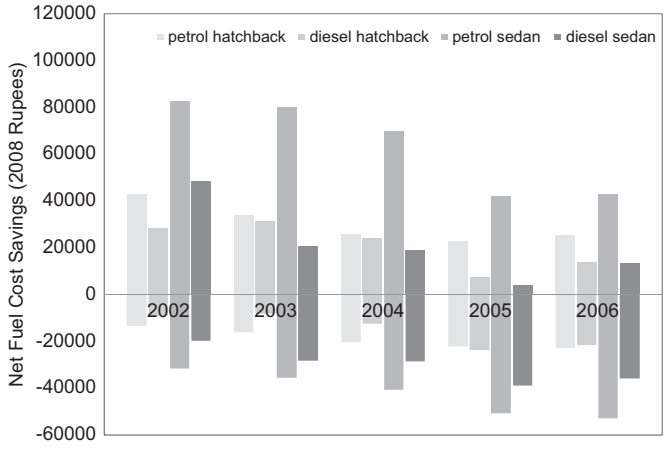

Fig. 3. 95% confidence intervals of fuel economy premium minus present discounted value of fuel savings ($r=10\%$; increasing fuel prices). *Notes:* The graph presents 95% confidence intervals of hedonic price function specification 4 estimates of the price of a 1 kpl improvement in fuel economy minus the associated present discounted value of fuel savings, calculated using a 10% discount rate. Fuel prices are expected to increase by 2 Rs. per year over the life of the vehicle.

1 or 2 are combined with the 10% discount rate and increasing fuel price assumptions. Overall, our results provide little support for the argument that fuel economy standards in India are justified because consumers undervalue fuel economy.

4. Lowering fuel costs by purchasing a diesel vehicle

Another way in which consumers can reduce their fuel costs is to purchase a diesel rather than a petrol car. In this section, we compare the additional cost of buying a diesel vehicle with the savings in fuel costs using data on twins—models that are available in both diesel and petrol form. More sedans than hatchbacks are available in diesel form. Of the 34 petrol sedan models available in 2006, 12 of them had diesel twins, whereas only 2 of 11 petrol hatchback models available in 2006 had a diesel twin. A similar pattern is reflected in market shares: in 2002, twins accounted for 62% of sedan sales and 31% of hatchback sales. In 2006, twins accounted for 54% of sedan and 19% of hatchback sales.

On average, diesel twins cost more, but have better fuel economy. Table 7 shows results of regressing the log of vehicle price and the log of fuel economy on a diesel dummy variable and model-year dummy variables for the hatchback and sedan markets. On average, diesel hatchbacks cost 9.9% more than their petrol twins; diesel sedans cost 8.0% more. The difference in fuel economy is large: diesel hatchbacks are on average 31%, and diesel sedans 35%, more fuel efficient than their petrol twins. On average, a diesel car travels 3 km farther on a liter of fuel than its petrol twin.

4.1. The cost savings from buying a diesel twin

The cost advantage of a diesel twin is the difference between the purchase price of the petrol and diesel versions of the vehicle plus the present value of savings in fuel costs over the life of the vehicle,[15]

$$P_p - P_d + \sum_{t=0}^{T} \frac{1}{(1+r)^t} K(t) \left(\frac{p_p(t)}{kpl_p} - \frac{p_d(t)}{kpl_d} \right) \pi(t), \quad (6)$$

[15] This ignores differences in maintenance costs for the two types of vehicle and also assumes that survival curves are the same for diesel and petrol vehicles. Unfortunately, we have no data on either point.

Table 7
Differences between petrol and diesel twins in price and fuel economy.

Variables	Hatchback		Sedan	
	ln(price)	ln(city FE)	ln(price)	ln(city FE)
Diesel	0.0945***	0.271***	0.0767***	0.301***
	(0.0210)	(0.00921)	(0.00988)	(0.00853)
Constant	1.51***	2.37***	2.47***	2.15***
	(0.00819)	(0.00361)	(0.00475)	(0.00390)
Model-year dummies	Yes	Yes	Yes	Yes
Observations	343	314	689	579
R-squared	0.815	0.895	0.989	0.909
Adj *R*-squared	0.761	0.861	0.984	0.871

Standard errors in parentheses.
*$p < 0.1$.
**$p < 0.05$.
*** $p < 0.01$.

where the p and d subscripts refer to petrol and diesel, respectively.

The fuel savings of a diesel are substantial: the fuel cost per kilometer of a diesel car is about half that of its petrol twin. To illustrate, a petrol sedan that achieves average fuel economy (9 kpl) costs 5 Rs. per kilometer to operate at a petrol price of 45 Rs. per liter. Its diesel twin, with a fuel economy of 12 kpl, costs only 2.5 Rs. per kilometer because diesel fuel is one-third cheaper (30 Rs. per liter). The corresponding figures for hatchbacks are 4.5 Rs. per kilometer for petrol hatchbacks vs. 2.3 Rs. per kilometer for their petrol twins.[16] In both cases, two-thirds of the reduction in fuel costs is due to the lower price of diesel fuel and one-third to the better fuel economy of diesel vehicles.[17]

Total fuel savings from buying the diesel twin increase with driving distance. For buyers who drive 2000 km per month, the present value of fuel savings is about 240,000 Rs. over the life of a hatchback and 320,000 Rs. over the life of a sedan. For buyers who drive 1000 km per month, the savings are still substantial: about 98,800 Rs. for a hatchback and 139,000 Rs. for a sedan. To obtain net savings, the difference in purchase price of the diesel and petrol vehicles (41,400 Rs. for hatchbacks and 86,600 Rs. for sedans) must be subtracted from the fuel savings.

We have calculated the net fuel savings from buying a diesel for 21 hatchback and 70 sedan models for which a twin was available over the period 2002–2006. In these computations, fuel savings are based on mean monthly driving distances for each vehicle type, using a 15% discount rate and constant fuel price expectations. Expressed as a percentage of the price of its petrol twin, the average net fuel savings realized by buyers of diesel hatchbacks was 46%. The corresponding figure for diesel sedan owners was 17%. At the same time, buyers of petrol hatchbacks gave up savings equal to 24% of the price of their cars, and buyers of petrol sedans gave up savings equal to 10% of the price of their cars.

What percentage of twin buyers realized these savings? In 2006, 74% of hatchback twin buyers bought a diesel hatchback, and 59% of sedan twin buyers bought a diesel sedan; these percentages have risen steadily since 2002. Clearly, the majority of twin buyers realized significant savings. Does this mean that the buyers of petrol twins undervalued fuel savings? As Table 8 shows, diesel and petrol twins differ noticeably in weight and in

[16] This is based on 10 kpl for a petrol hatchback and 13 kpl for a diesel hatchback.

[17] At 9 kpl, the petrol sedan would cost 30/9=3.33 Rs. per kilometer if petrol cost the same per liter as diesel. Increasing fuel economy from 9 to 12 kpl reduces the cost per kilometer from 3.33 to 2.5 Rs. So 1.67 Rs. of the 2.5 Rs. reduction in cost comes from the lower cost of diesel fuel.

Table 8
Twins-only version-level summary statistics.

Variables	Units	Petrol hatchback	Diesel hatchback	Petrol sedan	Diesel sedan
Price	10^5 Rs 2008	4.61 (0.94)	4.84 (0.758)	12.0 (10.9)	12.7 (9.35)
Kerb weight	1000 kg	0.957 (0.101)	0.991 (0.095)	1.15 (0.198)	1.22 (0.170)
Power ratio	hp/kg	0.0761 (0.00755)	0.0603 (0.00900)	0.0896 (0.0168)	0.0658 (0.0175)
Engine size	cm^3	1280 (169)	1570 (220)	1680 (370)	1800 (320)
Torque	kg m	10.70 (1.67)	10.8 (2.85)	15.0 (4.65)	18.0 (8.40)
City fuel economy	km/l	10.1 (1.00)	13.1 (1.12)	8.75 (1.22)	11.6 (1.69)
Luxury index	0–10	2.82 (1.53)	2.48 (1.47)	5.04 (2.55)	5.33 (2.57)
Safety index	0–4	0.730 (0.647)	0.781 (0.766)	1.40 (1.41)	1.49 (1.38)
Automatic transmission		0.000 (0.000)	0.000 (0.000)	0.133 (0.341)	0.127 (0.334)
# of versions		74	64	210	150

Version level vehicle characteristics data come from AutoCar India.
The unweighted average across all available twin hatchback versions is presented above with standard deviations in parentheses.

performance: diesel twins are generally heavier and less powerful than their petrol counterparts. It could be that buyers of petrol twins value these characteristics enough to forgo the fuel savings from buying a diesel.

4.2. The value petrol car buyers place on the petrol twin

It is straightforward to show that the net fuel savings forgone by petrol car buyers (Eq. (6)) is a lower bound to the money these buyers would have to receive to keep their utility constant if they were forced to buy the diesel twin. Let x^* denote the income remaining after the petrol car buyer purchases a petrol car (Z_p) and drives $\boldsymbol{K}^*$ kilometers. Let x' denote the income remaining if he drives $\boldsymbol{K}^*$ kilometers but buys the diesel twin (Z_d). If the buyer is rational, he prefers $(x^*,Z_p,\boldsymbol{K}^*)$ to $(x',Z_d,\boldsymbol{K}^*)$; that is

$$U(x^*,Z_p,\boldsymbol{K}^*) > U(x',Z_d,\boldsymbol{K}^*). \quad (7)$$

There is, however, some amount of money, $\hat{x}$, that will make him as happy as with the petrol twin, implicitly defined by

$$U(x^*,Z_p,\boldsymbol{K}^*) = U(\hat{x},Z_d,\boldsymbol{K}^*). \quad (8)$$

To keep his utility constant, the amount the petrol buyer would have to be given (his compensating variation) if forced to buy a diesel car is $\hat{x}-x^*$. Because $\hat{x} > x'$, $x'-x^*$ is a lower bound to this value. From Eq. (2), $x'-x^*$ equals the net value of fuel savings from buying a diesel; that is, Eq. (6) evaluated at $\boldsymbol{K}^*$.

This implies that the lower bound to the value placed on characteristics Z_p (vs. Z_d) is approximately 110,000 Rs. for buyers of petrol hatchbacks and 153,000 Rs. for buyers of petrol sedans. It is, of course, impossible to say whether this is rational. To judge how these car buyers valued fuel economy requires estimating a model of the demand for vehicle characteristics (see, e.g., Alcott and Wozny, 2010).

5. Conclusion

The debate over mitigating the environmental impact of India's rapidly expanding vehicle fleet has centered on reducing fuel consumption. One commonly cited justification for fuel economy standards, as opposed to higher fuel taxes, is the belief that consumers undervalue fuel economy when making purchasing decisions. We have addressed this concern by comparing the cost to consumers of increased fuel economy to the associated fuel savings. Based on our IV estimates of hedonic price functions, we cannot consistently reject the hypothesis that the mean consumer equates the marginal price of fuel economy to the present value of fuel savings To test this hypothesis, we have estimated the marginal cost of fuel economy to consumers in 4 market segments using 4 specifications of the hedonic price function for 5 model years. By comparing these results to fuel price savings calculated under 2 sets of alternate assumptions about the discount rate and future fuel price expectations, we put consumer rationality to the test a total of 160 times. Of the 31 instances in which we reject the hypothesis, only 9 provide any evidence of fuel economy undervaluation while the remaining 22 indicate that consumers may, in fact, be overvaluing fuel economy.

To further understand the trade-offs faced by consumers, we considered the choices faced by potential buyers of twins. Diesel versions of twins are, in general, more expensive than their petrol counterparts but have sufficiently lower operating costs as to more than offset the difference in purchase price. Net savings from purchasing a diesel twin are substantial. By choosing their vehicle over its petrol twin, diesel hatchback owners save the equivalent of 50% of the purchase price of their chosen vehicle; diesel sedan owners save 18%. In 2006, 74% of twin hatchback owners and 59% of twin sedan owners realized these savings by buying the diesel twin. Because of their lower monthly driving distance, forgone savings by owners of petrol twins are lower, but still substantial: petrol hatchback owners could have saved 24% of the purchase price of their chosen vehicles, and sedan owners 10%, by buying a diesel. This does not mean that buyers of petrol twins were irrational; they may have been willing to forgo these savings to drive a more powerful petrol vehicle.

There are limits to what can be said using the data on vehicle characteristics and prices used in this paper. The next step in our analysis is to estimate models of vehicle demand and miles driven

Table A.1
Instrumenting for fuel economy: first stage results.

Variables	Petrol hatchbacks: city fuel economy	Diesel hatchbacks: city fuel economy	Petrol sedans: city fuel economy	Diesel sedans: city fuel economy
IV	0.490***	0.441***	0.285***	1.22***
	(0.0862)	(0.0839)	(0.0640)	(0.292)
Kerb weight	−2.34***	−1.79	−1.73**	−5.03
	(0.705)	(1.63)	(0.789)	(3.60)
Torque	0.636***	0.0294	−0.0725	0.180***
	(0.110)	(0.0413)	(0.0632)	(0.0458)
Engine size	−0.00865***	0.00104	−0.00000368	−0.00230**
	(0.00100)	(0.000635)	(0.000662)	(0.000990)
Luxury index	−0.0285	0.0696	0.0283	0.0179
	(0.0399)	(0.0674)	(0.0362)	(0.101)
Safety index	0.0317	0.270	−0.251***	0.0552
	(0.101)	(0.146)	(0.0723)	(0.259)
Automatic	−0.707***	N/A	−0.970***	N/A
	(0.270)		(0.293)	
Y2003	−0.235	−0.166	−0.704***	−2.20***
	(0.205)	(0.301)	(0.200)	(0.681)
Y2004	−0.343	−0.316	−0.534***	−2.23***
	(0.211)	(0.303)	(0.197)	(0.685)
Y2005	−0.427**	−1.50	−1.137***	−3.19***
	(0.203)	(0.322)	(0.211)	(0.623)
Y2006	−0.502**	−1.72***	−0.504**	−3.11***
	(0.202)	(0.344)	(0.201)	(0.650)
Y2007	−0.210	−1.58***	−0.488**	−3.14***
	(0.214)	(0.322)	(0.209)	(0.636)
Y2008	−0.448**	−1.59***	−0.366	−3.41***
	(0.213)	(0.409)	(0.233)	(0.685)
Constant	12.8***	8.52***	9.66***	5.40
	(0.998)	(2.33)	(1.04)	(5.93)
Observations	236	64	216	42
R-squared	0.699	0.699	0.546	0.843

Standard errors in parentheses.
This table presents first stage results of IV estimation of hedonic price function specification 4.
There are no diesel hatchbacks or diesel sedans with automatic transmission for which the instrumental variable can be constructed.
*Significant at 10% level.

** Significant at 5% level.
*** Significant at 1% level.

using individual household data on vehicle purchases. These models can be used to compute the welfare effects of changes in fuel taxes (e.g., the impact of equalizing the cost of diesel and petrol) and of imposing fuel economy standards. If, for example, auto manufacturers in India were to meet fuel economy standards by reducing vehicle weight and horsepower, as was done in the United States (Klier and Linn, 2008), this could result in a welfare loss to Indian consumers. To justify such an intervention, these losses should be compared to the welfare gains from reduced pollution, congestion, and dependence on foreign oil. Such a comparison of costs and benefits cannot be accomplished without first quantifying both.

Appendix A

See Table A.1.

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