Consumer Choice Between Gasoline and Sugarcane Ethanol

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Abstract

How US motorists might switch from gasoline to an alternative energy source is not known, since the availability of alternatives is currently very limited. To bridge this gap, we exploit recent exogenous variation in ethanol prices at Brazil's pumps and uncover substantial consumer heterogeneity in the choice among century-old gasoline and a less-established—but still widely available and usable—alternative, sugarcane ethanol. Surprisingly, we observe roughly 20% of flexible-fuel motorists choosing gasoline when gasoline is priced 20% above ethanol in energy-adjusted terms ($/mile) and, similarly, 20% of motorists choosing ethanol when ethanol is priced 20% above gasoline. Ceteris paribus, older motorists, heavy commuters, or (in follow-up interviews) motorists voicing engine concerns or "range anxiety", are significantly more likely to choose gasoline over (lower-mileage) ethanol. In contrast, motorists who spontaneously invoke environmental concerns or reside in sugar-producing states exhibit a greater propensity to adopt ethanol. Our findings suggest—and a counterfactual illustrates—that switching away from gasoline *en masse*, should this be desired, would require significant price discounts to boost voluntary adoption, in the US and elsewhere.

JEL classification: D12, D64, L62, L71, Q21, Q41, Q42, R41

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1 Introduction

With the aim to diversify energy sources, curb emissions or sustain growth, policies to wean economies off fossil fuels—and oil in particular—are being pursued by governments around the world. In private road transport, a large and growing sector of the global economy that to date remains heavily dependent on a small number of oil-supplying nations, the established gasoline-powered car engine is set to lose share over the coming decades to alternative energy sources, such as electricity—generated not only from "clean" sources but also coal—and biofuels. Yet research on how motorists might substitute an alternative fuel for century-old gasoline, including the price incentives that may be required at the pump or at the plug, is sparse.[1]

A likely reason for the paucity of research is that most of the world's motorists are currently captive, stuck with an oil derivative, so revealed preference studies cannot be conducted. Most recently, Brazil provides what seems likely to be the first exception. A traditional sugar producer, in the late 1970s Brazil responded to the oil crisis by mandating ubiquitous supply of sugarcane ethanol across the country's fueling stations and the introduction of ethanol-powered cars, thus solving (if at great expense) the "chicken-and-egg" problem. Twenty-five years later, in 2003, carmakers began speedily replacing single-fuel vehicles (either gasoline- or ethanol-dedicated) by dual-fuel "flexible-fuel vehicles" (FFVs), cars that can operate on any combination of gasoline and ethanol. By early 2010, Brazil's 9 million-plus FFVs accounted for one-third of passenger vehicles in circulation.

Watching the world price of sugar rise in late 2009, on the back of a poor sugarcane harvest in India (e.g., Wall Street Journal 2009) and which pushed Brazil's domestic ethanol price up with it, we designed a survey to observe and subsequently interview 2160 FFV motorists choosing at the pump between gasoline and ethanol. We opportunely deployed resources to retail fueling stations in six Brazilian cities at a time in which end consumers were faced with exogenously-varying relative prices.

This paper is the first to provide micro-level evidence on motorists' behavior and preferences over an "established globally-procured fossil-based" fuel and a widely-available "alternative locally-sourced renewable" fuel. We find a surprising amount of consumer heterogeneity, some of which is "observed" and another part "unobserved". In a conventional car engine, a liter of ethanol (retailed as E100) yields a distance approximately 30% shorter than a liter of retailed gasoline (in reality itself a blend containing a small ethanol component), so "energy-adjusted prices", in \$ per kilometer (km) traveled, are equalized when a liter of ethanol at the pump (denote by p_e) amounts to about 70%

[1] Anderson (2009) is a welcome exception, also examining substitution between gasoline and (corn E85) ethanol, but analyzing market-level rather than motorist-level data. Corts (2010) writes that "(w)hat the required discount (of E85) to gas(oline) is remains a debated topic." (p.7)

of the per-liter price of (blended, standard) gasoline (denote by p_g). One might have thought of gasoline and ethanol as perfect, or near-perfect, substitutes since either fuel's primary function is to produce vehicle-kilometers traveled (vkt) and, hidden away in the tank, consumption of fuel type is inconspicuous. Also, Brazil's media—including local radio which urban motorists tune into for traffic updates—regularly reports the mean relative price p_e/p_g vis-à-vis the 70% "parity ratio",[2] and station servicemen, whose role is to fuel vehicles and whom can be thought of as Bayesian updaters, can upon request offer advice to FFV motorists, who tend to be reasonably affluent and educated (i.e., they drive a fairly new car for private use). However, rejecting the "null hypothesis" of perfect substitutes, we observe roughly 20% of (FFV) motorists choosing gasoline when gasoline is priced 20% above ethanol in energy-adjusted terms (i.e., facing a per-liter ratio $p_e/p_g = 70\%/1.2 \simeq 58\%$); similarly, we observe roughly 20% of motorists choosing ethanol when ethanol is priced 20% above gasoline in \$/km terms ($p_e/p_g = 70\% \times 1.2 = 84\%$).

Certainly, part of this heterogeneous response is due to a subset of motorists forming short-run habits, or being inattentive, unwilling or unable to do or ask about the cost conversion (e.g., $p_e \gtrless 0.7p_g$) when refueling. Indeed, we show some evidence of this, for example by observing choices in São Paulo city just one week after ethanol prices had reached their peak, then observing them again a fortnight later during which ethanol prices (fortunately for us) had *remained* at this peak: ethanol adoption did continue falling over the fortnight, though the magnitude of the further reduction in adoption, while statistically significant, is arguably not large. However, the consumer short-run habit persistence/ inattention/ inability story does not satisfactorily explain much of the unobserved heterogeneity. Most of our observations were collected *not* when ethanol prices had just risen sharply, but a couple of weeks after they had begun to taper off, and, subsequently, several weeks after ethanol prices had dropped back to favorable levels.[3] Further, station visits in the two cities of our survey in which ethanol was priced highest (they source from out of state) and, importantly, had been more expensive than gasoline for *at least six weeks*, still revealed solid demand for ethanol: (i) facing mean p_e/p_g of 85%, we observed 20.4% of Belo Horizonte FFV motorists choosing ethanol (this translates to a 22%-dearer 0.294 Brazilian Real per km traveled on ethanol in the city against 0.241 R\$/km on gasoline), and (ii) facing mean p_e/p_g of 91%, we observed 5.4% of Porto Alegre motorists staying with ethanol (paying 0.329 R\$/km against 0.251 R\$/km had they opted for gasoline).

As for observed heterogeneity, on estimating discrete choice models we find that,

[2] Folha de S. Paulo (2009) is one online example among countless others. Certain motorists may also base a price heuristic for ethanol around the per-liter price of gasoline, which has been relatively stable.

[3] Note that the median motorist stops to refuel once a week, and so frequently has the opportunity to directly learn about prices, other than through the radio (media), relatives and colleagues.

ceteris paribus, older motorists are significantly more likely than younger or middle-aged ones to choose the established fuel gasoline over the "entrant" ethanol, which is somewhat surprising given that the biofuel has been around for three decades and car performance issues were largely limited to the early period with single-fuel ethanol-dedicated vehicles, many years prior to FFVs coming on the market. It appears that older people resist a new fuel technology and require an additional price discount to switch. Motorists in the upper quartile of the stated car usage distribution are also significantly more likely to choose gasoline over ethanol, plausibly because of the time cost of stopping to refuel, more highway over city driving, or "range anxiety" (as a tank of ethanol drives a distance 30% less than a tank of gasoline). Such consumer costs, real or perceived, are likely to slow the transition from gasoline to alternative technologies, including electric cars, in mature markets such as the United States.

More directly, our field representatives asked FFV motorists about "the main reason" behind their revealed fuel choice, without showing them a menu or helping them in a way that might have influenced their responses. Motorists who expressed concern over range (and this was credible in the sense that their order filled up a large part of the tank's capacity) were 25% less likely to choose ethanol over gasoline (per the baseline specification, evaluated at mean sample values). In the same direction, the 12% of motorists in the sample who invoked an engine-related reason for their fuel choice were 26% less likely to choose ethanol over gasoline. Intuitively, motorists may perceive the established technology as superior in terms of engine performance, startup or durability, despite statements to the contrary by manufacturers and the specialized press.

On the other hand, 6% of motorists in the sample invoked the environment as the basis for their fuel choice. Whether reality or perception,[4] consumption of the renewable fuel is associated with a less deleterious effect on the environment: spontaneously invoking the environment raises the propensity that ethanol is chosen over gasoline by 44%. ("Greenness", "energy independence" and "local jobs" have been the sugar industry's—and the government's—main advertising themes over decades, e.g., *o álcool é nosso*/"ethanol is ours", Brazil's recent deepwater oil discoveries notwithstanding.) We also find evidence of "home bias": controlling for prices at the pump, propensity to adopt ethanol over gasoline is significantly higher in each of three surveyed ethanol-producing states relative to each of three surveyed ethanol-importing locations.

We illustrate the importance of our results in different ways. We show that switching between gasoline and ethanol by a "median" motorist occurs over a wider range of

[4]For example, the US EPA recently determined, based on lifecycle emissions analysis, that "(e)thanol from sugarcane complies with the applicable 50% reduction threshold (in greenhouse gas emissions) for advanced biofuels (compared to the 2005 gasoline baseline)" (US EPA 2010; parentheses added for clarity). In contrast, when it comes to local pollutants—i.e., urban air quality—rather than global emissions, Jacobson (2007) finds that the use of ethanol is not superior to gasoline and can actually be inferior, particularly due to its contribution to ground-level ozone.

relative price variation than might have been presumed. Controlling for prices, we then contrast the preferences of two extreme hypothetical types of consumer in the population: (i) a "gasoline fan", defined as an older motorist who attained no more than primary education, resides in a remote ethanol-importing state, is a heavy user who drives an expensive model and spontaneously invokes the engine as the basis for his fuel choice; against (ii) an "ethanol fan", defined as a younger college-educated motorist who lives (and was likely brought up) in a sugar-producing state and spontaneously invokes the environment to justify his fuel choice. We compare price elasticity matrices for different subsets of the population, such as sliced by age, and estimate willingness to pay for "greenness" and to relieve "range anxiety". We also illustrate the relevance of our results by conducting a counterfactual: a planner in the remote Amazonian state of Pará is planning the energy mix and wishes to raise the share of ethanol burned in the state's light vehicle stock. Lowering state sales tax on ethanol from the highest level in the nation to that of the state of São Paulo, the main sugar producer, would have only a modest effect on ethanol adoption, at least in the short run, despite undercutting gasoline in energy-adjusted terms. (We do note, however, that even Pará, where ethanol has long been priced above gasoline and is not part of the local landscape, does boast its share of "ethanol fans".)

Our findings speak to literatures beyond energy choice. One line of research examines whether consumers will actually pay more for substitute products perceived to be associated with "good causes" or linked to charity (e.g., see Casadesus-Masanell et al 2009, Elfenbein and McManus 2010, and references therein). We find strong evidence of this: some motorists do pay substantially more $ per km for ethanol and, when asked without judgment, spontaneously respond that they are doing so for the environment's sake (and in our case they are not doing this for others to see[5]). That population groups, older consumers in particular, resist switching away from an established product is consistent with the literature on technology adoption (Rogers 1995). Beyond observed consumer and vehicle characteristics, the residual consumer heterogeneity we find—whether arising from tastes or misconception—seems worth pursuing in future work, and may be relevant to the debate on consumer sophistication (e.g., numeracy) and "rational inattention" that is raging in non-energy markets with frequent interaction and of varying product-attribute complexity (e.g., Clerides and Courty 2010, Miravete 2003, Hastings and Tejeda-Ashton 2008, Lusardi et al 2009, Abaluck and Gruber 2009, Ketcham et al 2010).

The policy challenges posed by Brazilian motorists' perception of (or behavior toward) gasoline and a relatively similar alternative energy source[6] as imperfect substitutes

[5]E.g., "Skin-deep greens" cannot show off a tank of expensive ethanol as they can a Toyota Prius. We thank Meghan Busse for the comment.

[6]For example, both liquid fuels are widely sold at the pump (and often the same one), at linear

should generalize to rich markets such as the United States. For example, we speculate that older motorists in middle America are likely to resist switching away from gasoline to electricity (with quite different technologies—perhaps less so for plug-in hybrids—and pricing structures), or from gasoline to biofuels (perhaps less so in the midwest). Such motorists may demand hefty price discounts (and transparency) to shift.

The paper is structured as follows. Section 2 discusses our survey's setting and design, and presents summary statistics, including empirical demand curves. Section 3 analyzes consumer response by way of binary and multinomial choice models. Section 4 considers the relevance of our demand estimates to energy supply planners and provides a counterfactual. "Salience-raising" policy considerations are briefly made in Section 5.

2 Survey setting, design and summary statistics

An ideal setting in which to infer consumer preferences and behavior over substitute goods, and thus estimate a demand system, is one where large variation in relative prices occurs, and this variation is exogenous to unobserved demand shocks and takes place over a relative short space of time. As Figure 1 suggests, wide fluctuations in the world price of sugar potentially offer one such natural experiment for inferring heterogeneous consumer demand for substitute fuels, namely gasoline and (sugarcane) ethanol at the Brazilian pump. The top panel depicts international sugar (and oil) prices since 2000, the bottom panel reports local ethanol and gasoline prices at retail in the city of São Paulo (all prices are in constant Brazilian Real, R\$). Over this decade, whenever world sugar prices crossed a certain threshold—0.40 R\$/lb, say, and this has happened in early 2003, 2006 and 2010—ethanol prices in São Paulo fueling stations reached 2 R\$/liter. (The exchange rate stood at 1.9 R\$/US\$ in early 2010, so divide by 2 for rough prices in US\$.) Put simply, market forces have been at work in Brazil's vertical sugar/ethanol industry: the opportunity cost of selling ethanol (or sugar) on domestic markets is given by the export price of sugar.[7]

Ethanol has been a fact of life in retail fueling stations across the country since the 1980s, but what made the most recent relative price shift unique as a demand experiment was the large-scale penetration of dual-fuel cars. By early 2010, FFVs already accounted for one-third of the circulating passenger-vehicle stock; in contrast, FFVs had barely

(non-opaque) prices, and are burned in essentially the same combustion engine (and vehicle).

[7]See Salvo and Huse (2010) for a model of this industry, whose supply chain was deregulated in the 1990s. By contrast, fossil fuel prices are still controlled by the central government, by way of the state-controlled oil company Petrobras, a vertical monopolist all the way from exploration to refining. As reflected in Figure 1, the 2003-2010 administration has kept (wholesale) gasoline prices "stable", i.e., rising world oil prices, peaking at 150 US\$/bbl in mid 2008, were not passed through to the gas pump. (The figure shows gasoline prices actually falling gradually, as it adjusts for inflation.)

begun selling in 2003 and their share of the fleet in 2006 was still only 6%, which would have made it significantly more costly for a researcher to observe this subset of consumers choosing among gasoline and ethanol at the pump. Further, institutional aspects make consumer selection among different fuel technologies in the primary car market less of a concern for our research design. Starting in 2003 automakers quickly transitioned their models to the flex-fuel version alone, rather than offering flex alongside the conventional single-fuel versions (i.e., gasoline-only or ethanol-only), and at broadly equivalent prices.[8]

For years, we had been monitoring world sugar and Brazilian fuel markets. Seeing the pump price of ethanol rally over the second half of 2009, we designed a consumer-level survey and put resources on stand-by, ready to be deployed into the field—namely visit retail fueling stations in major cities—when instructed to by us, at informative price points in time. We favored a consumer-level (revealed preference) survey over a market-level demand estimation approach, on two counts. First, our focus is to examine heterogeneity among subsets of the population. Second, while good-quality local price data are available, market-level quantity data are either less reliable or unavailable (e.g., FFV fleet size and usage relative to older single-fuel cars, by state or city).

Survey design[9] In late 2009 we hired a market research firm (CNP) that had field representatives in place, and local market knowledge, in six large cities. All cities are economic, as well as political, state capitals; three states grow sugarcane and thus produce ethanol (as ethanol is less costly to transport than sugarcane), the other three states import ethanol from other states (more below). Our survey would ultimately consist of 9 "city-weeks", with each city-week comprised of 20 station visits; each station visit consisted of observing choices made by (and subsequently interviewing) 12 FFV motorists, thus totaling $9 \times 20 \times 12 = 2160$ consumer-level observations.

Figure 2 reports the weekly evolution of the per-liter ethanol price relative to the per-liter regular gasoline price, denoted by the ratio p_e/p_g, around the week of January 25, 2010, in each of the six cities. Prices were obtained from the National Oil Agency's (ANP) retail price database; they survey a vast cross-section of fueling stations across the country on a weekly basis,[10] and the figure plots moments of the cross-sectional distribution. Two features should be noted, since they determined our deployment of field resources and will inform our demand specification. First, *within-city* price dispersion is low—consider the interquartile range in p_e/p_g, marked by the two inner

[8] For example, conditional on buying any Volkswagen car model as of 2006, a motorist would acquire an FFV (Salvo and Huse 2010). With the collapse in the price of electronics, a carmaker's cost upcharge in equipping a model with a flex engine relative to a single-fuel one is about 100-200 US$ (Corts 2010, Anderson and Sallee 2010), possibly not worth the cost of carrying different engines.

[9] We keep this section brief—see the Appendix for further details and summary statistics.

[10] We used this database to shortlist candidate stations to be visited in our survey. The rich online access to fuel prices, including city-level means, helps local media regularly report them.

curves in each panel—relative to price variation *across cities*. Relative ethanol prices are lower in São Paulo, Curitiba and Recife: the corresponding states of São Paulo (same name as its capital city), Paraná and Pernambuco, respectively located in the Southeast, South and Northeast regions of Brazil, host significant sugarcane plantations and ethanol mills, i.e., some residents of these states might perceive ethanol to be a "home good". Relative ethanol prices are higher (in ascending order) in Rio de Janeiro, Belo Horizonte and Porto Alegre. Located in Brazil's southernmost state, Porto Alegre is 2000km from the nearest sugarcane plantation.[11] [12]

Second, the temporal variation in p_e/p_g follows the same pattern in each city, rising over the weeks leading up to January 25 and falling thereafter; p_e/p_g peaks at about 75% in São Paulo and at about 90% in Porto Alegre. The 9 city-weeks in our survey sample are marked by the thick vertical lines, including multiple city-weeks in São Paulo (three) and Curitiba (two). The first two city-weeks in São Paulo (weeks of January 11 and of January 25) exhibit similar prices but are a fortnight apart (the rise in p_e/p_g petered out at 75%, prior to dropping); we later use these observations in an attempt to gauge short-run habit persistence. In the two surveyed city-weeks at the end of March—in São Paulo and Curitiba—p_e/p_g had dropped to just shy of 60%.

What does this mean in terms of energy-adjusted prices? Consider the fuel economy of a best-selling car, as measured in the laboratory, according to the National Institute for Metrology (Inmetro): a Fiat Palio ELX 1.0 2010 (Flex) operated under a "city driving cycle" (following U.S. EPA guidelines) produces 9.9 km/liter of gasoline and, given ethanol's lower energy content, 6.9 km/liter of ethanol (denote these particular attributes by k_{fi}, with subscripts $f \in \{g, e\}$ denoting the retailed fuel variety and i denoting the car model).[13] Notice that for this particular car (and fuel composition), $k_{ei}/k_{gi} = 6.9/9.9 \simeq 70\%$, equal to the relative price parity ratio that is regularly reported in the media.[14] (The median k_{ei}/k_{gi} in our sample of 2160 motorists, or FFVs, is 69%.) Clearly, a Fiat Palio user who perceives gasoline and ethanol to be *perfect* substitutes

[11] Salvo and Huse (2010) report that gasoline prices vary considerably less across the country, with the central government adopting a "uniform pricing" policy to some degree. Thus, cross-sectional variation in p_e/p_g arises primarily from variation in p_e. Further, some producer states support their local sugar industry (or penalize them less) by way of lower state sales tax on ethanol—see counterfactuals.

[12] Salvo and Huse (2010) show that São Paulo, Paraná and Pernambuco are 3 among only 8 states of Brazil (out of a total of 27) whose share of the national sugarcane harvest exceeds their share of national GDP (e.g., in 2005-07, São Paulo accounted for 61% of the country's harvested sugarcane and 34% of its GDP, suggesting that the state is a "net producer" of ethanol). By contrast, the three other states whose capital cities we surveyed are "net consumers" (or importers) of ethanol.

[13] We omit other attributes of this car model for brevity. We explain the source of our model-specific fuel economy data in the Appendix. For gasoline, Inmetro publishes the kilometerage per liter for a blend containing a 22% ethanol component, i.e., E22. Since gasoline as retailed in January 2010 was actually an E25 blend in January 2010 and an E20 blend in March (having changed by federal mandate), we linearly (and slightly) adjust k_{gi}. (Retailed ethanol was unblended E100.)

[14] This includes radio which Brazil's urban motorists, often stuck in traffic, spend many hours listening to, and particularly at times when relative ethanol prices are varying, as in 2009 Qtr 4 and 2010 Qtr 1.

would have chosen gasoline when fueling in the January city-weeks of our sample—since $p_e/p_g > k_{ei}/k_{gi}$ or, equivalently, \$/km is lower under gasoline. By March, this motorist would have fueled his car with ethanol (in São Paulo or Curitiba).

Figure 3 indicates the location of retail fueling stations visited by our field representatives in each of the six cities in January and/or March. Of 180 station visits (again, 9 city-weeks and 20 different stations per city-week), 99% were branded (e.g., Shell accounted for 27% of visits), 78% took place on week days (either on rush hours or off-peak) and 22% on Saturdays. Regular gasoline (*gasolina comum*, i.e., g) and ethanol (*álcool*, i.e., e) were available on all station visits, the mean number of nozzles per station being 5 g-nozzles and 4 e-nozzles. (Availability of both standard fuels was by design and is typical in the universe of stations; also, "shelf space" of g and e did not vary between January and March visits). Midgrade gasoline (*gasolina aditivada*, denote by $\bar{g}$) was available on 91% of station visits, at a mean markup of 4% over regular gasoline. And few stations—11% of station visits—carried premium gasoline (*gasolina premium*, denote by $\breve{g}$); among stations which did, $\breve{g}$ retailed at a mean 16% markup over $\bar{g}$.

We instructed the field representative to quietly observe each FFV motorist's choice (among the alternatives available at the station) and only then—once the station's serviceman had begun servicing the vehicle, inside which the motorist was typically sitting idly—approach the motorist to conduct a short interview. The questions included confirming that the car was an FFV and driven for private use (despite these two "filters" being easy to spot in practice); asking about "the main reason" for the motorist's choice of fuel observed on that occasion (without showing a menu of options which might frame the response); and inquiring about the motorist's car usage and age and schooling categories; among other questions. (For brevity, we describe further collected information where relevant to the discussion, and provide summary statistics in the Appendix.) On completing an observation, the representative would move to the next FFV motorist (by order of arrival at the station, typically having to wait for the next FFV to pull up), until a total of 12 observations were completed per station visit, as already mentioned.

In our sample ($N = 2160$), the "median motorist" is male (66% of sample), states being middle-aged (25-40y 46% and 40-65y 40%), states having attained higher education (50% completed a college degree), (spontaneously) invokes "price" as the primary motivation for his choice (68%), and stops to refuel once a week. We inferred the frequency with which a motorist visits stations from the observed fueling amount (the median order is 22 liters, under half the car's tank capacity), stated car usage (the median response is 200 km/week, among the 1835 motorists who were able to provide an estimate), and model-specific fuel economy under city driving. That the amount fueled corresponds to a fraction of a tank, as opposed to a full tank, may be due to cash-in-pocket constraints, or even to a desire to have the oil level or tire pressure checked regularly. 51% (resp., 73%) of the sample stated that on the last three fueling occasions including the present one, they had fueled at that particular station thrice (resp., at least twice), suggesting that “shopping around” does not occur at a substantial rate in these markets, perhaps due partly to moderate within-city (absolute) price dispersion, or to station reputation effects.To the extent that motorists value the familiarity of their local station, an out-of-city trip may raise the odds of choosing gasoline (only in a tank-filling order, presumably).

The interviews also suggest that our station visits were *not* taking place right at the moment in which consumers were beginning to switch between fuels, in which case a large positive mass of less-attentive consumers might still have been unaware of very recent price changes. In the subset of motorists whom we observed purchasing regular gasoline (discussed next), 83% stated having purchased gasoline on both of their two immediately preceding station visits (with the caveat that this particular piece of information is stated, not revealed). Similarly, among motorists whom we observed purchasing ethanol, 78% stated having chosen ethanol on both of their two preceding fueling occasions. Returning to Figure 3, notice that by the week of January 25 (6 city-weeks in our survey) the ethanol price hike had mostly already occurred. Similarly, by the week of March 29 (2 city-weeks in our survey), p_e/p_g had already dipped below the (approximate) 70% distance-equivalent threshold 2 to 3 weeks earlier.[15]

Empirical demand Figure 4 summarizes the choices made by FFV motorists by aggregating these to the station level. We plot the station's per-liter ethanol price relative to regular gasoline, p_e/p_g, against ethanol's overall “share” in the 12 choices we observed in each visit, computing this share in two ways. In the left panel, for each station visit we count the number of FFV motorists who chose ethanol as their dominant energy (kilometerage) source relative to gasoline on that fueling occasion, and divide by 12; that is, we define the ethanol share as

$$s_j^e = \frac{1}{12} \sum_{i \in \mathcal{O}_j} \boldsymbol{\chi} \left[q_{ei} \widehat{\frac{k_e^{city}}{k_g^{city}}}_i > \sum_{f \in \{g, \bar{g}, \breve{g}\}} q_{fi} \right] \tag{1}$$

where $\mathcal{O}_j$ is the set of motorists observed during station visit j, $\boldsymbol{\chi}[x]$ is an indicator function (equal to 1 if condition x holds and 0 otherwise), and the observed quantity in liters of ethanol purchased by motorist i, q_{ei}, is adjusted for ethanol's lower kilometerage per liter (kpl) relative to gasoline liters purchased. The Appendix explains how we

[15] Returning to the two São Paulo-January subsamples that are a fortnight apart but exhibit the same relative prices (p_e/p_g rising then flattening out), it is noteworthy that among motorists observed purchasing gasoline on the week of January 11, 69% stated having fueled with gasoline on their two preceding occasions, to be compared with a higher 85% of motorists observed purchasing gasoline on the week of January 25 who stated having fueled with gasoline on their two preceding occasions.

predict the kpl ratio, under city driving, for every vehicle in our survey sample: the median $\widehat{k_e^{city}/k_g^{city}}_i$ is 69.0%, and the median standard error is 0.5% (that is, the prediction is fairly tight, precise within about 1.0%). Clearly, this "unweighted" ethanol share is discrete-valued, as it is based on a count variable (note that January station visits are marked with circles and March observations are marked with squares).[16]

In the right panel of Figure 4, we alternatively calculate ethanol's share of the aggregate energy purchased by the 12 FFV motorists observed in the station visit, as follows:

$$\tilde{s}_j^e = \left(\sum_{i \in \mathcal{O}_j} q_{ei} \widehat{\frac{k_e^{city}}{k_g^{city}}}_i \right) / \sum_{i \in \mathcal{O}_j} \left(q_{ei} \widehat{\frac{k_e^{city}}{k_g^{city}}}_i + \sum_{f \in \{g, \bar{g}, \breve{g}\}} q_{fi} \right) \tag{2}$$

Like its unweighted counterpart, this "weighted" ethanol share indicates that there is considerable consumer heterogeneity. Eyeballing either panel, Figure 4 shows that facing relative prices p_e/p_g of around 60% (compared to a distance-equivalent ratio of about 70%), about one-fifth of motorists stay with gasoline. Similarly, facing p_e/p_g of around 80%, about one-fifth of motorists choose ethanol.

One may wonder how much of this consumer heterogeneity is explained by variation in the kpl ratio k_{ei}/k_{gi} across FFVs (the interdecile range in the surveyed sample is 3.8%). By controlling for "parity" differences across car models, Figure 5 shows that the answer is "not much". To plot the figure, we compute the difference $p_{ei}/p_{gi} - \widehat{k_e^{city}/k_g^{city}}_i$ for each of the 2160 observations; we then collect observations in 1 percentage point bins and compute the share of motorists who chose ethanol as their dominant energy source relative to gasoline (defined per the condition in the indicator function of (1)). To illustrate by way of a data point, the motorist of a VW Gol 1.0 Flex (another very popular car) fueling at a particular Belo Horizonte station in January faced an ethanol-to-gasoline per-liter price ratio of 88.2% at the pump and a predicted kpl ratio of 69.9% (with s.e. 0.5%); this motorist's choice would enter the $88.2\% - 69.9\% \simeq 18\%$ bin. Figure 5 indicates that the empirical probability that this motorist would have chosen ethanol over gasoline is still no less than a sizable 10-15%, despite facing energy-adjusted fuel prices (i.e., p_f/k_f^{city}) of 0.28 R\$/km on ethanol against a substantially cheaper 0.22 R\$/km on regular gasoline.[17] Computed at the median car usage (200 km/week), this 0.06 R\$/km or 21% discount represents 12 R\$/week, equivalent to 624 R\$ on an annualized basis (again, divide by 2 for approximate US\$ values).

Importantly, the heterogeneous consumer response depicted in Figures 4 and 5 cannot

[16] We do not employ the simpler condition $q_{ei} > 0$ in (1) since 2.5% of motorists in our sample purchased a "combo" of fuels on the same occasion, say 30 R\$ of g and 20 R\$ of e, requiring that the serviceman handle two nozzles (typically by the same pump) to service the order. The simpler condition would, however, yield a similar plot.

[17] Had we instead plotted $p_{ei}/\widehat{k_{ei}^{city}} - p_{gi}/\widehat{k_{gi}^{city}}$ on the vertical axis of Figure 5, the plot would look very similar. In this case, the Belo Horizonte motorist's choice would enter (say) the 0.06 R\$/km bin.

be explained by differences in vehicle condition or average route speed. While these unobserved characteristics impact absolute fuel economy k_g and k_e (see the Appendix), they are unlikely to materially affect the relative fuel economy k_e/k_g as this depends primarily on the relative energy content of the two fuels.

3 Analyzing consumer choice

3.1 Binary choice

We begin by estimating probit models of the following form

$$\boldsymbol{\chi}\left[q_{ei}\widehat{\frac{k_e^{city}}{k_g^{city}}}_i > \sum_{f\in\{g,\bar{g},\breve{g}\}} q_{fi}\right] = \begin{cases} 1 \text{ if } \delta_i + \varepsilon_i > p_{ei}/p_{gi} - \widehat{k_e^{city}/k_g^{city}}_i \\ 0 \text{ otherwise} \end{cases} \tag{3}$$

where, as in (1), we consider the choice of ethanol as the dominant energy source relative to gasoline on the observed fueling occasion (recall note 16 on why we do not employ the indicator function $\boldsymbol{\chi}[q_{ei} > 0]$, though both functions are valued equally for 2133 out of 2160 observations). Observed variables δ_i capture motorist i's relative taste for ethanol—one can interpret these as group-common "fixed effects"—and $\varepsilon_i \sim^{iid} N(0, \sigma^2)$ denotes an unobserved taste shock for (or "mistake" in favor of) ethanol—an individual-specific "random effect". Throughout the paper, we rely on the moderate within-city (within-route) price dispersion, coupled with motorists' professed "station loyalty", and ignore any substitution across stations. To be clear, what we rule out is, e.g., an observed ethanol consumer substituting e at this station for g at another (unobserved) station with lower p_g (and thus the relevant p_e/p_g would be higher), an event that would likely reinforce our results.

Table 1 reports marginal effects (at mean values in sample). We discuss specification I and briefly describe its robustness to variations (standard errors, in parentheses, are clustered at the station visit level). All else equal—and energy-adjusted prices in particular—motorists aged 65y+ are less likely to choose ethanol over gasoline compared to younger motorists, who appear more comfortable with the alternative fuel. Heavy users—defined as motorists whose stated car usage places them in the upper quartile of the surveyed car usage distribution—also display lower propensity to choose ethanol, perhaps because of station stopping time costs or range anxiety. To illustrate, the Fiat Palio 1.0 travels around 520km on a full tank of gasoline (in the city) compared with 360km on a full tank of ethanol. Drivers of expensive car models—defined as those in the upper quartile of the survey's distribution of model prices[18]—are less prone to

[18]See the Appendix on how we matched observed vehicles to estimates of their value.

choosing the renewable fuel. A possible explanation is ethanol's (real or perceived) environmental (or "energy security") credentials relative to the fossil fuel and the fact that expensive (larger, powerful) cars tend to pollute (consume) more than cheaper vehicles;[19] this effect may thus operate through hetergeneous consumer selection over car models, i.e., "resource-concerned" types plausibly favor small cars and locally-grown sugarcane ethanol.

More directly but in a similar vein, motorists who during the on-the-spot interview (conducted after their choice had been made) spontaneously invoked "the environment" as the main driver behind their choice, are way more likely to choose ethanol over gasoline.[20] On the other hand, motorists who (subsequently and spontaneously) invoked an engine-related reason are more likely to choose gasoline. Intuitively, the more traditional fuel—gasoline—may be perceived by motorists as being superior in terms of engine performance or engine startup, despite statements by automakers and the specialized press, to the best of our knowledge, that FFVs are equipped to operate similarly on any blend of gasoline and ethanol.[21] Invoking "range", and conditional on purchasing a volume of fuel equivalent to at least three-quarters of the observed vehicle's tank capacity (to validate our interpretation of the motorist's statement, as explained in the Appendix), is associated with choosing gasoline over ethanol, as one would expect from the higher kpl. Finally, there is indication of home bias: São Paulo, Curitiba and Recife, with higher city fixed effects, are the capitals of sugarcane-producing states, whereas the other three cities (lower effects) are ethanol importers. Each producer's fixed effect is statistically higher (at the 1% significance level) than every importer's effect in all nine pairwise tests (test statistics are not reported for brevity).[22]

In specification II, we add two sets of covariates, noting that the effects just discussed hardly change. First, for cities surveyed on multiple weeks (São Paulo and Curitiba), we replace city fixed effects by city-week fixed effects (in terms of significance, Table 1

[19] In the data, vehicle price correlates tightly (and inversely) with fuel economy, with correlation coefficients of −.64 between price and gasoline kpl (or −.63 between price and ethanol kpl). That is, pricey cars tend to burn more fuel and emit more carbon per km traveled.

[20] In the data, proportionately more "environmentalists" were sampled in Recife (9%), Rio de Janeiro (8%), São Paulo (6%) and Curitiba (5%), and less in Porto Alegre (1%) and Belo Horizonte (3%). Recall that São Paulo and Curitiba were surveyed both when ethanol was dear (in January) and when it was cheap (in March) relative to gasoline. We speculate that "environmentalists" choosing ethanol may feel more strongly that they need to invoke the environment when ethanol is dear and they are going against the flow, than when it is cheap and most other people are also choosing ethanol. Indeed, the proportion of São Paulo and Curitiba motorists invoking the environment rises slightly from 5.8% to 6.5% upon conditioning on higher R$/km ethanol prices relative to gasoline (most January motorists).

[21] Proportionately more motorists expressing concern over the engine were sampled in Rio de Janeiro (24%), Porto Alegre (19%) and Belo Horizonte (14%), and less in São Paulo (7%), Curitiba (11%) and Recife (12%). Suggestive of home bias (more below), the latter three are sugarcane-growing capitals.

[22] Recall note 12. Interestingly, Curitiba, estimated to have the highest relative taste for ethanol, is known for its public transport system, parks and wooded areas, e.g., "In 2007, the city was placed third in a list of "15 Green Cities" in the world, according to U.S. magazine Grist, after Reykjavik in Iceland and Portland, Oregon in the United States." http://en.wikipedia.org/wiki/Curitiba

reports only their levels due to space). The evidence is suggestive of "state dependence" or gradual information diffusion among some motorists. São Paulo motorists on the week of January 11—mean p_e/p_g had only just risen to 74.2% (see Table 3 in the Appendix)—were more likely to stay with ethanol over gasoline than São Paulo motorists two weeks later, when the ethanol price hike had flattened out and was less recent (mean p_e/p_g remained at 74.7%). A pairwise test of equality between São Paulo's early January and late January effects rejects with p-value of 4.3%. (In the raw data, 49% of São Paulo's 240 early January motorists chose gasoline compared with 58% of their 240 counterparts observed two weeks later.)[23] The second set of covariates we add exploits motorists who spontaneously invoked "habit", "custom" or "always use this fuel": we interact a dummy variable indicating such motorists with each of two dummy variables indicating their (stated) prior fueling choices, twice gasoline or twice ethanol. As expected, the "habit-invoked-and-last-choices-g" dummy is strongly negative (21 out of 23 such motorists chose gasoline), while "habit-invoked-and-last-choices-e" predicts outcomes (ethanol) perfectly (with 31 choices being dropped to obtain the reported estimates). (In the data, on facing lower per-km gasoline prices, i.e., $p_{ei}/p_{gi} > \widehat{k_e^{city}/k_g^{city}}_i$, 3% of motorists invoked habit and 63% of these opted for ethanol; similarly, on facing favorable ethanol prices, 2% of motorists invoked habit and 60% of these opted for ethanol.)

To show that the home bias in specification I is not an artifact of our selection of city-weeks in which the survey was conducted, column III restricts the sample to 1440 observations from the week of January 25 (6 city-weeks). Estimated effects are similar. Repeating the nine pairwise equality tests between sugarcane producer and sugarcane importer location effects, all tests but one (São Paulo versus Rio de Janeiro) reject at the 1% significance level.

Specification IV replaces city fixed effects by a set of station visit fixed effects and includes a set of car segment fixed effects. Relative to specification I, the effect of stated educational attainment grows in magnitude and significance, i.e., choosing ethanol over gasoline is more likely among more educated types. Perhaps neighborhood (i.e., very local) fixed effects help control for unobserved quality differences in stated schooling levels. Also, the negative pricey car effect, and our candidate explanation, survive the inclusion of car segment fixed effects (much like engine size predicts fuel economy over and above car segments, as reported in the Appendix).

The two final columns of Table 1 indicate that the above effects are robust to variations in assumed relative energy differences (assumed by motorists or by us). Spec-

[23] An alternative to specification I is to use the price ratio two weeks earlier, $L2\,(p_{ei}/p_{gi})$, in the offset of (3) and to add the two-week price variation leading up to the observation, $p_{ei}/p_{gi} - L2\,(p_{ei}/p_{gi})$, as a predictor variable. The effects just reported are robust, and the marginal effect on recent price variation is +1.70 (s.e. .33), i.e., relative ethanol prices that rose 1% in the past fortnight (rather than earlier) are associated with a 1.7% higher propensity to choose ethanol.

ification V replaces the predicted vehicle-specific kpl ratio in the offset of (3) by the media-reported 70% (approximate) parity threshold. In the sixth column, marked "I [sd]", rather than use the fitted value for the vehicle-specific kpl ratio, we draw this from a normal distribution taking the fitted value as the mean and the prediction's standard error as the standard deviation. The standard deviations of the marginal effects obtained over 1000 replications, shown in square brackets, are 0.000 to 3 decimal places.[24]

3.2 Multinomial response

Now model motorist i as having utility

$$U_{fi} = x_i'\delta_f - \alpha p_{fi}/k_{fi} + \varepsilon_{fi} \tag{4}$$

from choosing fuel $f \in \{g, e, \bar{g}\}$, where p_{fi}/k_{fi} is the fuel-specific price in R$ per km traveled that motorist i faces, vector x_i contains observed motorist (and vehicle) characteristics, and unobserved tastes $\varepsilon := (\varepsilon_g, \varepsilon_e, \varepsilon_{\bar{g}})$ are distributed multivariate normal with mean zero and covariance matrix Ω, i.e., $\varepsilon \sim MVN(0, \Omega)$. To illustrate, the probability that a motorist fuels with ethanol is

$$\begin{aligned} \Pr(i \text{ chooses } e) &= \Pr(U_{gi} - U_{ei} \leq 0 \cap U_{\bar{g}i} - U_{ei} \leq 0) \\ &= \Phi\left(-\left((x_i'\delta_f - \alpha p_{fi}/k_{fi}) - (x_i'\delta_e - \alpha p_{ei}/k_{ei})\right), \Omega_{-e}\right), \qquad f = g, \bar{g} \end{aligned}$$

where Φ is the CDF of the bivariate normal random variable $(\varepsilon_g - \varepsilon_e, \varepsilon_{\bar{g}} - \varepsilon_e)$ with mean zero vector and covariance matrix Ω_{-e}.[25] The baseline multinomial probit we implement: (i) ignores the availability of premium gasoline $\breve{g}$ in the 11% of stations visited (we observed a mere 3 out of 2160 motorists choosing $\breve{g}$, and reclassify these observations as midgrade gasoline $\bar{g}$ choices); and (ii) reclassifies 54 "combo" observations (essentially motorists who ordered positive amounts of both g and e on the same fueling occasion, as per note 16) as choosing a single fuel according to the dominant kilometerage source in the order. The results we report are robust to dropping, rather than reclassifying, these 57 observations (2.6% of sample), or even to modeling combos as a fourth alternative. Energy-adjusted prices in our baseline specification again assume predicted fuel economy

[24] Other robustness tests (not reported) include: (i) replacing city by field representative-week fixed effects; (ii) dropping dummy variables based on the main reason invoked by motorists for their choice (i.e., environment, engine, range); (iii) conditioning the order-volume-adjusted range dummy on a purchase order equivalent to at least two-thirds, rather than three-quarters, of the tank; and (iv) replacing the offset of (3) by $p_{ei}/\widehat{k_{ei}^{city}} - p_{gi}/\widehat{k_{gi}^{city}}$.

[25] We place no additional restrictions on Ω beyond those necessary to identify the model, i.e, with $F = 3$ alternatives in the baseline model, Ω has $F(F-1)/2 - 1 = 2$ free terms, say one error variance parameter $\sigma_{\bar{g}}^2$ and one correlation parameter $\rho_{e,\bar{g}} = Corr(\varepsilon_{ie}, \varepsilon_{i\bar{g}})$. Further, in the 9% of station visits in which midgrade gasoline $\bar{g}$ was not available, motorists are modeled as choosing between two alternatives, g or e.

under city driving, i.e., kpl $k_{fi} = \widehat{k_{fi}^{city}}$; estimates are similarly robust to alternative assumptions (more below).

Table 2 reports some marginal effects (again at mean values in the sample) for the baseline specification I and for two variations. (Standard errors in parentheses, now shown to the right of each effect due to space constraints, are again clustered at the station visit level.) Results are very similar to those obtained in the binary response model, both in terms of estimated effects and their precision—to see this, compare specification I in the present table to column I, Table 1, both specifications implementing the same vector of motorist and vehicle characteristics (x_i). For this reason, we do not reproduce our earlier discussion of the strong results obtained. As for responsiveness to fuel prices, choice probability plots and elasticity matrices evaluated for particular subsets of the population are presented below, further highlighting the considerable consumer heterogeneity.

In terms of robustness, specification II confirms that the (positive) number of nozzles dispensing each fuel at the station do not affect our results, price effects in particular. Our empirical strategy relies on each fuel, when modeled as being available at the station (always the case for g and e, mostly the case for $\bar{g}$), being accessible to the consumer. That is, a fuel's "shelf space" is sufficient, conditional on availability at a station, that it does not drive choice. Results are also robust to variations in assumed relative energy differences, as in the binary model. We checked this in three ways: (i) by respecifying the R$/km ethanol price variable in (4) as $p_{ei}/\left(0.7\widehat{k_{gi}^{city}}\right)$, based on the 70% media-reported parity ratio, rather than the "real" $p_{ei}/\widehat{k_{ei}^{city}}$; (ii) also based on the media-reported conversion rate, by replacing the R$/km price variables in (4) by their energy-adjusted per-liter counterparts $0.7p_{gi}$, p_{ei} and $0.7p_{\bar{g}i}$, i.e., irrespective of his FFV, a motorist facing g and e pump prices of, say, 2.729 and 2.199 R$/liter respectively would compare $2.729 \times .7 \simeq 1.910$ to 2.199 (forming a heuristic rule $p_{ei} \gtrless 1.91$, given the stability of gasoline prices); and (iii) rather than using the predicted fuel economy $\widehat{k_{fi}^{city}}$ in (4), drawing k_{fi} from a normal distribution with mean $\widehat{k_{fi}^{city}}$ and standard deviation equal to the prediction's standard error, replicating many times (as in the "bootstrap" reported in the final column of Table 1). For brevity, results are not reported.[26]

Finally, we investigate how estimates change on dropping city fixed effects—which we interpreted as evidence of home bias. Column III shows that price effects grow in

[26] These are available upon request. Price effects under (i) and (ii) are slightly larger than in the baseline specification, offering suggestive evidence that the widely reported (approximate) 70% ratio may be more ingrained than the particular kpl ratio for each FFV (recall that the median prediction in the surveyed sample is 69%). Other robustness tests (not reported) include: (iv) restricting the sample to 1440 observations from the week of January 25 (6 city-weeks), as in specification III of Table 1 (replacing the set of city fixed effects by a constant, to exploit cross-city variation); and (ii) dropping motorists' stated-reason dummies from x_i.

magnitude, and other effects are robust. Intuitively, price sensitivity is now additionally estimated off cross-city variation: sugar-producing locations exhibit low ethanol prices and strong ethanol adoption, and this correlation is now being picked up by a higher price coefficient α. We next show that even under this more price sensitive specification, switching occurs over a wide range of price variation.

3.2.1 Heterogeneous sensitivity to prices: observed and unobserved

What choices does an "average" motorist make at different relative prices? Figure 6 considers a male motorist, with stated age 25-40y, who states having at least some college education, who neither states to use his car heavily nor drives a pricey car model, who invokes neither the environment, the engine nor range as the basis for his fuel choice. Rather than use the baseline multinomial probit estimates for a motorist in a "median" city (i.e., considering say the Rio de Janeiro fixed effect), the figure employs Table 2's specification III estimates, i.e., without city fixed effects: given its higher price sensitivity, our intention is to conservatively reduce the range of price variation over which fuel switching takes place, which we will show to still be surprisingly high. We vary the per-km ethanol price, p_{ei}/k_{ei}^{city}, while holding constant: (i) the per-km regular gasoline price, p_{gi}/k_{gi}^{city}, at 0.246 R\$/km (this is the mean across the entire sample); (ii) its midgrade gasoline counterpart at 0.256 R\$/km (the mean midgrade markup over regular of 1.039 times 0.246 R\$/km); and (iii) the three-alternative choice set $\{g, e, \bar{g}\}$. In the left panel, we plot the simulated choice probabilities. For example, when ethanol is priced at parity to regular gasoline in energy-adjusted terms, i.e., $p_{ei}/k_{ei}^{city} = p_{gi}/k_{gi}^{city} = 0.246$ R\$/km, the probability of choosing ethanol is just over 60%, and the choice probabilities for regular gasoline and midgrade gasoline are just under 35% and 5% respectively.

What is striking is that even for this median motorist, when ethanol is priced at a substantial premium relative to regular gasoline—say $p_{ei}/k_{ei}^{city} = 0.316$ R\$/km, or $0.070/0.246 = 29\%$ above regular gasoline on an energy-adjusted basis, which is equivalent to a per-liter price ratio p_{ei}/p_{gi} of about $1.29 \times 70\% = 90\%$—the choice probability for ethanol is still a sizable 21%! Similarly, when ethanol is priced at a substantial discount relative to regular gasoline—say a 0.070 R\$/km, or 29%, discount, equivalent to a per-liter price ratio p_{ei}/p_{gi} of about $(1 - .29) \times 70\% = 50\%$—the probability that this motorist still chooses gasoline (regular or midgrade) is a non-negligible 8%.

This heterogeneous response to prices among motorists with a given set of observed characteristics is evidence of considerable unobserved consumer heterogeneity. This can also be seen in the right panel of Figure 6, which reports the estimated marginal effect (and 95% confidence interval) of raising the ethanol price on the median motorist's ethanol choice probability: switching occurs over a wide range of relative price variation, not only around parity (where switching occurs at close to the maximal rate). Further raising the price of ethanol starting at a level substantially above parity $p_{ei}/p_{gi} = 90\%$, we still observe significant switching away from ethanol, at a rate of 4.8% (± 0.6%) per +0.01 R$/km. Similarly, departing from cut-priced ethanol $p_{ei}/p_{gi} = 50\%$ and further cutting its level by 0.01 R$/km attracts gasoline users at a rate of about 3%. (Had we plotted Figure 6 using the baseline estimates, i.e., specification I of Table 2, considering a "median" Rio de Janeiro motorist, the larger price range over which switching occurs would be more symmetric about parity—this will be seen in Figure 8 below.)

As for observed characteristics, we illustrate the similarly-extensive consumer heterogeneity in two ways. First, Figure 7 (now employing baseline estimates) plots fuel choice probabilities against ethanol prices for each of two "extreme" hypothetical consumers. The left panel considers an "ethanol fan", defined as a young (male) motorist aged up to 25y, with at least some college education, observed in Curitiba (the capital of a sugarcane-producing state), who spontaneously invokes the environment when asked about the main reason for his fuel choice (other motorist/vehicle characteristics are switched off). His polar opposite is considered in the right panel, a "gasoline fan" defined as an older motorist aged 65y+, with no more than primary education, observed in Porto Alegre (the capital of an ethanol-importing state), a heavy commuter who drives an expensive model and invokes the engine as the reason behind his choice. The difference is stark. Of course these "green and brown" consumers are extreme, but they serve to illustrate the wide range of variation in behavior. For perspective, in the survey sample, all of the 11 young college-educated environment-invoking motorists chose ethanol, whereas ten out of the 11 older engine-invoking motorists chose gasoline.

A second way by which to illustrate observed consumer heterogeneity is through price elasticity matrices. Consider the *effect of age* on the choice of fuel, summarized in the following table (again employing baseline estimates):

São Paulo, January, **Age $\leq$ 65y**			
Increase in	Change in choice probability		
price	e	g	$\bar{g}$
e	-1.77^{***}	2.45^{***}	2.67^{*}
	(0.32)	(0.47)	(1.50)
g	1.49^{***}	-2.51^{***}	2.58
	(0.29)	(0.49)	(2.56)
$\bar{g}$	0.16^{*}	0.25	-5.27
	(0.09)	(0.25)	(3.52)
Median $\widehat{p_{fi}/k_{fi}^{city}}$	0.262	0.243	0.253
Choice probab.	0.58	0.38	0.04

São Paulo, January, **Age > 65y**			
Increase in	Change in choice probability		
price	e	g	$\bar{g}$
e	-3.08^{***}	1.32^{***}	1.31^{*}
	(0.62)	(0.32)	(0.79)
g	2.35^{***}	-1.79^{***}	2.61
	(0.56)	(0.45)	(2.03)
$\bar{g}$	0.53^{*}	0.59	-3.99
	(0.32)	(0.46)	(2.54)
Median $\widehat{p_{fi}/k_{fi}^{city}}$	0.262	0.243	0.253
Choice probab.	0.30	0.58	0.12

Notes: Standard errors in parentheses. * p<.1, ** p<.05, *** p<.01. $\widehat{p_{fi}/k_{fi}^{city}}$ in R$/km

Evaluating regressors (including fuel prices) at their medians in the São Paulo-January subsample, where ethanol was about $0.262/0.243 - 1 \simeq 8\%$ more expensive than regular gasoline on an energy-adjusted basis (recall that the per-liter price ratio stood at about 75% relative to a parity ratio of 70%), notice that a 1% increase in the price of ethanol lowers the demand for this fuel by: (i) 1.77% among under 65-year old motorists, most of whom (58%) have stayed with ethanol thus far; to be compared with (ii) 3.08% among over 65-year old motorists, most of whom (58% + 12%) have already switched to a gasoline variety.[27]

3.2.2 Willingness to pay for "greenness" and to relieve "range anxiety"

Figure 8 plots simulated fuel choice probabilities for "median" motorists (male, 25-40y, some college education, neither a heavy user nor drives a pricey model) in each of three cities with varying degrees of ethanol home bias (recall the baseline estimates): Curitiba, Rio de Janeiro and Porto Alegre. In the left panel, we plot ethanol choice probabilities against ethanol prices (again, holding gasoline prices and the three-alternative choice set constant), switching the environment-invoking main-reason dummy first "on"—marked by the thick lines—and then "off"—marked by the thin lines. (Notice that the Curitiba-environment-off curve happens to be hidden under the thick Porto Alegre-environment-on curve.) The horizontal shifts in the plots, upon turning the environment-invoking main-reason dummy on, provide a natural measure of the willingness to pay for *greenness*: this amounts to a surprisingly large 0.12 R$/km approximately (or 0.10 US$/mile). To see this, notice that an environment-invoking Rio motorist facing an ethanol price of

[27] Under a different institutional setting and research design, Anderson (2009) reports mean demand elasticities in the 2.5-3.0 range.

0.37 R$/km has the same 50% probability of adopting ethanol as a non-environment-invoking Rio motorist facing a substantially lower ethanol price of 0.25 R$/km.

In a similar vein, the right panel plots gasoline choice probabilities (regular or midgrade) against ethanol prices, switching the (order-volume-adjusted) range-invoking reason dummy on and off. (The Porto Alegre-range-off curve is hidden behind the thick Rio de Janeiro-range-on curve.) The horizontal shifts in the corresponding plots, about 0.07 R$/km (0.06 US$/mile), provide a measure of the willingness to pay to *relieve range anxiety*; this also seems surprisingly large. A non-range-invoking Rio motorist facing an ethanol price of 0.25 R$/km has the same 50% probability of adopting gasoline as a range-invoking Rio motorist facing a lower ethanol price of 0.18 R$/km.

4 Predicting market-level fuel shares

The estimated discrete-choice model can be used to predict market-level shares for the substitute fuels. In principle, our survey design accounts for varying rates of car usage in the population, since heavy commuters are more likely to be sampled relative to light users. In practice, we focused our survey dollars on the (fast-rising) one-third of motorists driving FFVs, so one needs additional information, such as from a household-level travel study (e.g., the NHTS in the US), to account for single-fuel car users (essentially gasoline- or ethanol-captive) and predict shares at the market level. In the absence of such information for Brazil, we make some assumptions, as our purpose is to illustrate.

In what follows, we consider the three richest Brazilian states—São Paulo (SP), Minas Gerais (MG) and Rio de Janeiro (RJ), all in the Southeast region—which together account for about 40% of the country's population and over 50% of its GDP. We assume that a state capital's motorists (and cars), whom we surveyed, are fairly representative of motorists in the wider state (the metropolitan areas of Brazilian state capitals are home to a disproportionate share of state populations, e.g., São Paulo metro's population accounts for about half of SP state residents). We base the composition of a state's circulating passenger-vehicle fleet on data on new vehicle registrations (available by state but not by engine type), new car sales (available by engine type) and scrappage rates (see Salvo and Huse 2010 for details). For example, SP state's car fleet in February 2010 by engine type was 56% gasoline-captive (mostly pre-2005), 11% ethanol-captive (pre-2005) and 33% flex-fuel (introduced in 2003). The more "heroic" assumption in this illustration regards relative car usage across engine types (vintage): absent data, one possibility is that the ratio of vehicle kilometers traveled (vkt) to kilometerage per liter (kpl) does not vary significantly between single-fuel car users and FFVs operating on the same fuel. Relative to their single-fuel counterparts, more modern dual-fuel cars have better fuel economy but are plausibly utilized more by (on average) wealthier owners.[28]

We feed the weekly evolution of (mean) state-level pump prices between December 2009 and May 2010 into the estimated baseline multinomial probit, holding constant the distribution of motorist characteristics in the state capital's survey subsample, with the aim to predict fuel choice shares among FFV motorists on a weekly basis. (Choice probabilities are weighted across motorists by the kilometerage embedded in their observed purchases, as in the right panel of Figure 4: recall the denominator of (2).) The table below reports mean per-liter price ratios and market-level shares, both for the subset of FFV motorists and for the population of car commuters, on selected weeks. Given the large variation in pump prices around the 70% distance-equivalent threshold over this period, the limited variation in predicted consumption mix might come as *a surprise to a planner whose understanding is that gasoline and ethanol*—both liquid fuels, distributed through similar infrastructure—*are near-perfect substitutes.*[29]

Selected week (2009/10):	Dec 7	Jan 18	Mar 1	Apr 12	May 24
(Per-liter) p_e/p_g, SP	64%	74%	72%	63%	55%
(Per-liter) p_e/p_g, MG	73%	80%	83%	73%	72%
(Per-liter) p_e/p_g, RJ	71%	79%	80%	70%	69%
Predicted ethanol share of ethanol-plus-gasoline "energy units" consumed:					
FFVs only, SP (2.9m cars)	60%	47%	49%	60%	71%
FFVs only, MG (1.0m cars)	31%	23%	19%	29%	32%
FFVs only, RJ (0.6m cars)	41%	29%	28%	41%	44%
All passenger cars*, SP (8.9m cars)	30%	27%	27%	31%	35%
All passenger cars*, MG (2.6m cars)	22%	19%	18%	22%	23%
All passenger cars*, RJ (2.1m cars)	23%	20%	20%	24%	25%

Notes: Feb-2010 fleet estimates. *Assumes vkt:kpl is equal across flex- and single-fuel

The National Oil Agency (ANP) compiles monthly fuel shipments from distributors to retailers, allegedly by state of destination. As a measure of local fuel consumption, such data might not be comprehensive, or fully capture interstate shipments (e.g., out of ethanol-producing SP state), or account for variation in downstream inventories. It is noteworthy, however, that temporal variation in the Agency's reported ethanol share of ethanol-plus-gasoline shipments, in energy-adjusted "barrels of oil equivalent" (boe), is somewhat consistent with the three last rows of the table. Ethanol's share of shipments

[28] Besides usage, one would need (sparsely available) fuel economy data for early vintage cars, or would require a household-level travel study to collect fuel liters purchased in addition to vehicle kilometers traveled.

[29] Thus wrote U.S. Senator Richard G. Lugar: "Switching to an ethanol-based transportation system, by adapting new cars to run on an ethanol-gasoline blend with inexpensive, off-the-shelf flexible fuel technology and piggy-backing on the existing gas station network, would be both good policy and a great bargain for the American consumer." In addition to other costs, the senator likely did not consider the non-negligible price discount that might be required were U.S. light transportation to voluntarily "switch to an ethanol-based system" (Lugar 2006).

across the three states was 38% in December 2009, bottoming out at 25% in February 2010, and rising to 38% by May 2010. That these reported shares tend to be higher than our predicted shares across all passenger vehicles may also reflect a bias in our "heroic" relative car usage assumption above: unlike what we assumed in these entire-fleet predictions, perhaps newer FFVs burn more liters than single-fuel cars (i.e., the average vkt:kpl ratio for a typical flex-fuel car operation may be higher than for a single-fuel one).

4.1 A counterfactual: Planning the energy mix

Now consider a planner in the Amazonian state of Pará (PA), in the remote north of Brazil, home to 7.6m people, two-thirds of whom live in urban areas (the population of the metropolitan area of Belém, PA's capital city, is 2.1m). Thanks to the federal government's favorable gasoline pricing policy toward remote states, coupled with high state sales tax on ethanol,[30] PA state's FFV motorists are used to less expensive gasoline at the pump relative to market-set ethanol prices: the last time the per-liter price ratio p_e/p_g dipped below the approximate distance-equivalent 70% threshold was in 2002, and since then through May 2010 it has hovered between 75% and 90%, with a mean of 82%. That is, were gasoline and ethanol considered perfect substitutes by Pará's FFV motorists, its fueling stations would already not have been selling ethanol to them, even before the early 2010 rise in ethanol prices. In fact, a glance at state-level distributor shipment data suggests that even this remote location seems to have its share of "ethanol fans": ethanol's share of boe embedded in ethanol-plus-gasoline Pará shipments was 4.0% in December 2009 ($p_e/p_g = 78\%$), falling to 3.1% in March 2010 ($p_e/p_g = 83\%$), and rising to 4.3% in May 2010 ($p_e/p_g = 77\%$). While part of these ethanol shipments may be explained by ethanol-dedicated passenger vehicles, which we estimate at only 1% of the state's circulating stock, the bulk of this level as well as its variation is likely due to FFVs. In February 2010, FFVs already accounted for 45% of Pará's car fleet, thanks to booming new car sales—the overwhelming majority being FFVs—in recent years, from a low base (in part driven by an expansion in federal redistribution policy to northern and northeastern states since 2003).

Suppose the PA state planner is considering a reduction in the state sales tax (known as ICMS) on ethanol, to shift the source of energy powering the state's FFVs to ethanol, away from gasoline, say to meet some carbon emissions target.[31] Pará's nominal ICMS tax rate on ethanol stood at 28% (in May 2010), the highest in the country, to be compared against 12% and 18% in the sugar-producing states of São Paulo and Paraná

[30] Recall note 11. PA and Belém are arguably as distant from sugarcane plantations as they are from oil refineries.

[31] We are not advocating any particular policy, just illustrating the planner's problem.

respectively. One might think that lowering the pump price of ethanol to equal that of gasoline on an energy-adjusted basis might suffice. As the table below indicates, our estimated demand system shows otherwise: the column marked "Counterfactual 1" reports that the uptake of ethanol among Pará motorists, were ethanol to be priced at parity in R$/km, would increase slightly from 15% of ethanol-plus-gasoline joules consumed to 21%. (We keep the tax calculation simple—quite unlike the reality of Brazilian taxes—as our purpose is to illustrate. We also ignore a supply response from lower tax—e.g., ethanol producers raising prices—and use the distribution of motorist characteristics and midgrade gasoline availability in our survey, with the expensive-ethanol-and-remote Porto Alegre fixed effect turned on.)

State of **Pará** scenario:	May 2010 "Current"	Counterfactual 1 Pricing parity	Counterfactual 2 12% ICMS tax (SP)	Counterfactual 3 0% ICMS tax
p_g, R$/liter	2.695	2.695	2.695	2.695
p_e, R$/liter	2.075	1.887	1.743	1.494
(Ratio) p_e/p_g	77%	70%	65%	55%
ICMS in p_e, R$/l	0.581	0.393	0.249	0
$p_{\bar{g}}$, R$/l (91% avail.)	2.799	2.799	2.799	2.799
Predicted ethanol share of ethanol-plus-gasoline "energy units" consumed:				
FFVs only, PA	15%	21%	27%	38%

Notes: Pump prices are inclusive of ICMS sales tax

Were Pará's state sales tax on ethanol to be lowered to São Paulo's 12% nominal rate (where there is a strong sugar lobby), our predicted ethanol share would rise to only 27%, despite p_e/p_g falling below the approximate 70% parity threshold. It is striking that even if the tax rate were reduced to zero, with ethanol favorably priced at $p_e/p_g = 55\%$, ethanol's share of the FFV energy mix would not reach 50%.

Of course, the analysis assumes away any changes in consumer preferences, behavior or information. We discuss possible policy prescriptions, not only for the state of Pará but elsewhere, in our concluding remarks.

5 Concluding remarks

This paper has adopted a direct and transparent empirical strategy to uncover substantial consumer heterogeneity in the choice among century-old gasoline and a less-established alternative motor fuel, despite the alternative at hand being similarly distributed (through fueling stations, ubiquitously so, and over several decades), comparably priced (linearly per unit volume, typically at the same pump), and almost identically consumed (burned in a conventional combustion engine, operating essentially the same vehicle). The heterogeneous response we have identified is likely to generalize to other markets—and perhaps even in a magnified way.

Policy considerations for the setting we have examined—which extend naturally to other energy choice contexts—include: (i) educating motorists as to whether FFVs are equally equipped to handle any blend of gasoline and ethanol, in terms of engine power, startup, durability and maintenance costs over the vehicle lifetime, since there is no common perception, despite the extended period in operation;[32] and (ii) mandating that fueling stations display the per-liter ethanol-to-regular-gasoline price ratio by the pump, which should assist motorists in remembering and using the 70% "rule of thumb" regularly reported in the media. Alternatives to reporting this per-liter ratio p_e/p_g at the pump would be to: (iii) report, also at the pump, R$/km prices p_f/k_f^{cycle} for a "representative" car (say the Fiat Palio ELX 1.0) burning $f \in \{g, e\}$ under standard city and highway driving cycles (see the Appendix), much like laundry detergent sellers do on packaging across detergent formats; and (iv) mail cost conversion tables to households paying annual vehicle registration tax—see Figure 9 for a state-specific suggestion. Relative to (ii) and (iii), suggestion (iv) may possibly be less costly to implement for the policymaker but more costly to interpret for the motorist. We are independently beginning to work through the Brazilian Automobile Dealers Association (Fenabrave) to tentatively implement some (modest) form of salience-raising prescriptions (i) and (iv).

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A Appendix

A.1 Survey details and summary statistics

Market research firm CNP was strongly referred to us by a marketing executive at a large established consumer goods firm operating across Brazil. Among many consumer choice environments, CNP had experience conducting fieldwork in retail fueling stations. The agreements we signed with CNP, as well as the station-level and motorist-level forms that were filled out by CNP's field representatives, are available upon request.

Sample of stations In December 2009 we sent CNP a detailed list of candidate retail fueling stations for each city. For logistical reasons (including securing a station manager's authorization to visit, and traffic that can be chaotic), CNP had requested several candidate stations for every station to be visited. We asked that CNP sample at most one station from a given neighborhood (*bairro*), in an attempt to spread stations out in space and raise price dispersion in our sample. We prepared our list of candidate stations from the National Oil Agency's large retail fueling station database, restricting stations to be branded and to have "purchase invoices" on file (exceptions were Belo Horizonte and Porto Alegre, to make the list long enough). Our concern was to control, to the extent possible, for the likelihood of product fraud as perceived by consumers across the stations in our study (i.e., the addition of solvents to gasoline and of water to ethanol). (We flagged any exceptional—e.g., unbranded—stations as such and asked that CNP avoid visiting them, which they did.) In the Agency's data, it is unsurprising that fuel prices are lower at unbranded stations than at branded ones, but what is noteworthy is that ethanol is even cheaper than gasoline at unbranded stations compared to branded ones:[33] might this suggest a higher rate of fraudulent ethanol relative to fraudulent gasoline at unbranded stations? (Finally, the Agency's database, and thus our list of candidate stations, did not inform on the availability of midgrade and premium gasoline varieties.)

The design of a station visit On arrival at a station, our (i.e., CNP's) field representative, wearing a "CNP Research" ("*CNP Pesquisa*") shirt and name tag (ID), would present herself to the station's manager and servicemen (19 out of a total of 21 CNP representatives were women; servicemen, still the norm in Brazil, are typically men). She would emphasize that the "aim of the research was to collect information about FFV motorists, not about the station". On a **station-level form**, to be filled out once, she would enter: (i) her name and company ID, the date and start time of the station visit (subsequently completing the form with the station visit's end time); (ii) the station's name, address, brand, and contact person name and phone number; (iii) per-liter prices of regular gasoline and of ethanol (both fuels g and e were in stock at all visited stations), and of any "upmarket" gasoline varieties carried by the station at that time (midgrade gasoline $\bar{g}$, premium gasoline $\breve{g}$); and (iv) the number of nozzles

[33] E.g., Consider the 5171 observations (station-weeks) in the Agency's database in the six cities over 7 weeks in Dec-2009 and Jan-2010. Regressing the p_e/p_g ratio on a branded station dummy (71% of this sample is branded) and a full set of city-week effects yields a coefficient on the branded dummy of +1.54% (standard error 0.08%).

dispensing each of these fuel varieties. As the station visit progressed, the representative would also record a tally of the motorists she approached who appeared to meet certain FFV-qualifying criteria (detailed next) but who declined to participate in the short (complementary) interview. The proportion of approached motorists who refused participation ranged from 4% in (notoriously friendly northeastern) Recife to 28% in (less friendly southeastern) São Paulo.

FFV-qualifying criteria and sequencing between observations Each station visit would be completed with 12 observations—FFV-qualifying motorists—in sequence. A motorist's car had to meet two qualifying criteria: (i) it was originally manufactured as an FFV (i.e., it was neither a single-fuel car, nor was it subsequently retrofitted[34]); and (ii) the FFV was driven for private use (i.e., the car was not a cab or driven at a company's service)[35]. On completing an observation ($i < 12$), the representative was instructed to move toward what seemed to be the next qualifying FFV pull up alongside *any* of the station's island of pumps (a station typically has more than one island). Though one same island of pumps normally dispenses both regular gasoline and ethanol (via separate nozzles), our concern was to avoid having the representative stand still by an island in which this might not be the case; only observing choices made by FFV motorists who fuel at that particular island would then bias our results. The sequencing rule was "to move to the next FFV motorist by order of arrival *anywhere* in the station". Our data suggests (and casual evidence confirms) that on average no more than one FFV typically fueled at a station at any given moment, providing an incentive for the representative to indeed move around the station (see below). As for the qualifying criteria, verbal confirmation was sought from the motorist during the interview, though in practice spotting an originally-manufactured private-use FFV is not difficult[36], as newer passenger cars are overwhelmingly FFVs, are typically labeled "FLEX" at the rear or on the side, and do not have company logos or taxi signs attached to them.

An observation Each observation consisted of two stages: (i) passively observing the FFV motorist's choice of fuel (in practice discreetly watching as the motorist placed his order with the serviceman), and (ii) actively interviewing the motorist while his car was being serviced. We did not want our survey to influence the consumer's choice, observed in the first stage. On approaching the motorist, in the second stage, the representative would follow a pre-set script and introduce herself, express her research aim and state that she would only take a few minutes of the (typically idly-sitting) motorist's time to "ask his opinion". If the motorist was willing to take some short questions, *and* verbally confirmed that his FFV met the two qualifying criteria, the representative would then start making entries on (the next) one of the station's 12 **motorist-level forms**. Having read two filter questions out loud and entered the motorist's qualifying responses (F1.

[34] Though infrequent, we decided to control for the retrofit possibility by excluding it. Data on the (presumably higher-variance) fuel economy of such modified engines when running on either of the substitute fuels are not available.

[35] We decided to restrict the population of our study to this majority segment, though understanding the fuel preferences of taxi drivers and firms may in themselves be interesting research questions.

[36] We base this statement also on dry runs we personally conducted in stations in São Paulo and in Rio de Janeiro. (In practice, we were impressed by the friendliness of local servicemen who would spontaneously call us in their direction as the next originally-manufactured private-use FFV pulled up.)

"original flex"→continue, and F2. "private use"→continue), the representative would cover the following questions and answers in sequence, reading the questions out loud (except where noted otherwise) and entering the motorist's responses:

M1.,M2. (Revealed) Confirmation of the fuel type and value chosen to fuel the FFV on that occasion, e.g., ethanol, 50 R$. We instructed that the representative cross-check the motorist's response against her observation—at the pump—of his choice.

M3. (Stated) "What is the main reason for your choice of fuel?" ("*Qual o principal motivo de sua escolha do combustível?*") After asking this question, the representative would not read out a menu of options, as dry runs we personally conducted (see note 36) suggested this would take too long and might frame the motorist's response. Instead, relying on some cognitive skill, the representative would tick one of five (pre-set) options that best approximated the motorist's response (e.g., that the consumer was motivated by price), or enter the response verbatim in a sixth option labeled "Other", which we might later reclassify (see below). A seventh option was "I don't know".

M4. (Stated) "On your last two fueling occasions, what were your fuel choices?" If judged helpful, the representative would provide a hint based on the possible responses, such as "Were your choices both ethanol, both gasoline or one of each?"

M5. (Stated) "On your last two fueling occasions, how often did you fuel at this station?" The representative would tick one of three possible responses.

M6. (Stated) "On average, how many kilometers do you drive per week?" The representative would enter the response in a blank cell marked "km/week" or, in view of the relative complexity of this question for the motorist, tick the alternative "I don't know".

Finally, the representative would enter further vehicle and motorist characteristics:

M7. (Revealed, and not cross-checked with the motorist) (i) The vehicle's make and model (including engine size if labeled at the car's rear or on its side): the representative would enter a blank cell, under which four examples were provided, e.g., VW/Polo/1.6; (ii) the motorist's gender: the representative would tick one of two options;

M8. (Stated) (iii) The motorist's age and educational attainment: the representative would tick the corresponding category, such as "Over 65 years" and "College, Complete"; and (iv) the motorist's (first) name and a contact phone number.

Internal controls Market research firm CNP had informed us that requesting consumers' contact details at the close of interviews—characteristic M8, (iv) above—was customary in fieldwork, and they anticipated from the nature of our survey that motorists would likely oblige (i.e., it would be clear that we were only seeking information on preferences, not attempting to sell a product). According to CNP, field representatives were well aware of company policy by which a "verifier" calls at least 20% of consumers who reportedly participated in any survey, to verify that this indeed was the case. That is, down the equilibrium path, a CNP verifier would later talk to at least 17 of Recife rep Leila's 84 motorist observations (among those motorists who truthfully provided contact numbers, and noting that Leila visited $84/12 = 7$ stations over the week). It was also common knowledge that during the course of station visits each representative would receive at least one surprise audit from their local CNP supervisor.

In our data, only 8% of the 2160 motorist observations have missing phone numbers. The distribution of missing phone numbers across representatives within a city appears reasonable. Across cities, variation in missing phone numbers also seems plausible, e.g., a lower 2% of (friendly) Recife motorists have missing contact numbers. Our ideal scenario was one in which the representative would on average have some, but not too much, idle time between motorist observations. Too frequent FFV arrivals might provide an incentive for the representative to rush the data collection, as well as stand by the same island of pumps rather than follow the sequencing rule discussed above. Too sparse FFV arrivals could lead to motivational issues (CNP typically pays its representatives a piece rate, in our case per station visit). The mean duration of a station visit turned out to be 2.5 hours (minimum and maximum durations were respectively 50 minutes and 5hrs25mins): given 12 observations per station visit and an expected interview length of under 5 minutes (informed by CNP and supported by our personal dry runs), it appears that our ideal scenario prevailed during the course of the survey.[37]

Descriptive statistics of the sample[38] Table 3 summarizes station-level data collected in our survey. Variable names (or descriptions) are self-explanatory, hence our comments are selective. The first rows describe per-liter regular gasoline prices p_g, per-liter ethanol prices p_e, and the price ratio p_e/p_g, at all 180 stations visited (recall that both these fuels were in stock in the entire sample). Notice the considerable cross-sectional and time-series variation in p_e/p_g, as discussed earlier (the table summarizes this price ratio in each of the surveyed 9 city-weeks). Among 180 visited stations, midgrade gasoline $\bar{g}$ was available at 164 stations (at a mean $p_{\bar{g}}/p_g$ of 4%, as mentioned), and only 20 of these stations carried premium gasoline $\breve{g}$ (at a mean $p_{\breve{g}}/p_{\bar{g}}$ of 16%). "Shelf space" allocated to regular gasoline g and to ethanol e hardly changed from January to March (as measured by the mean number of nozzles dispensing each fuel, for the two cities surveyed in both months). Compared to the 2.5-hour mean duration of a station visit, a representative's mean time traveling between stations on the same day was (where applicable) an equally plausible 1.8 hours (stuck in traffic or taking time off before returning to work that same day). On average, less than 3 motorists per station visit refused to take questions (their choices were not recorded).

Table 4 summarizes data that varies across motorists. 45% of the 2160 FFV motorists in our sample ordered (only) g at the pump whereas 44% chose (only) e. 9% of motorists chose (only) $\bar{g}$ (and this share rises slightly to 10% if we condition on the midgrade variety being available at the station). ($\breve{g}$ was chosen by a mere 0.1% of sampled motorists, which

[37] In terms of execution, CNP reported that: (i) heavy rainfall delayed fieldwork in Curitiba, prompting their local supervisor to increase the number of field representatives (to 6, compared to 3 or 4 elsewhere); (ii) one representative "gave up" while on the job and her observations were discarded and replaced; and (iii) one station manager's authorization was overruled by the station owner while a visit was in session and observations were discarded and replaced (by observations at another station).

[38] We have audited the data to ensure that it is "procedurally" consistent (some comments follow, e.g., on a given representative's time traveling from one station visit to the next). We have also checked that prices recorded by our representatives are plausible in light of the National Oil Agency's database (which contains a representative sample of retail fueling stations at the city-and-week level).

corresponds to a still low 2% of choices in the 20 stations where $\breve{g}$ was available.) 2% of motorists purchased a "combo" of g and e, i.e., for which the serviceman needs to handle two nozzles.[39] Other combos were negligible. The mean fueling ticket was 47 R$ (24 R$ of g, 17 R$ of e, 6 R$ of $\bar{g}$, averaged over all choices). The mean spend among motorists who chose e-only was 37 R$ whereas the mean spend among motorists who chose g-only was (a statistically significantly higher) 52 R$.

On the dummy variables indicating "the main reason" invoked spontaneously by a motorist for his (revealed) choice of fuel, a few comments are in order. First, the sum of the means for the five precoded-reason dummies, the "Other" dummy and the "I don't know" dummy listed in Table 4 exceeds 1 since 17% of motorists were recorded by representatives as volunteering more that one reason (despite the question's wording, we instructed the representative to record as many reasons as stated by the motorist). Second, with the wisdom of hindsight, it is now clear to us that the wording of the second most-marked reason—see the table below—is *not* distinct from the notion of price: while "*tem mais autonomia*" translates into the distinct notion of **Range**, the component "*roda mais*" which loosely translates into "travels further" could be confused with the top-cited price motivation. (To support this, three-quarters of motorists for whom this reason was ticked purchased less than 28 liters, or a volume lower than 54% of their vehicle's tank capacity: otherwise, why would a motorist concerned with maximizing range, and thus prone to choosing g thanks to its higher energy content, not fill the tank?) Third, upon inspection we have reclassified 74 of the 172 statements originally marked under "Other" by representatives (who, if unsure as to how to categorize a motorist's statement, were also instructed to enter this "other" reason verbatim). For example, we have interpreted statements such as "more economical", "I drive more km per liter" and "ethanol is expensive" as being motivated primarily by a **Price characteristic**, rather than non-price price characteristics, and reclassified these statements accordingly. Statements remaining in **Other** in the table below are either orthogonal to the precoded menu of five reasons (over half, or 56 to be precise, were motorists invoking "habit", "accustomed" or a similar reason), or ambiguous or uninformative (e.g., "cost benefit", "family recommendation" and "my option"):[40]

Main reason(s) behind fuel choice as stated by motorist (and subject to representative's and our interpretation)	Number of reasons Raw data	 Post reclassification
1 **Price characteristic** "*O preço está mais em conta*"	1454	1475
2 **Range (or Price)** "*Tem mais autonomia/roda mais*"	566	567
3 **Environment** "*É melhor para o meio-ambiente*"	121	121
4 **Engine performance** "*Quero limpar o motor*"	72	101
5 **Engine startup** "*O motor pega melhor*"	175	179
Other (enter verbatim) "*Outro 1 (descrever) _ _ _ _ _ _ _*"	172	98
I don't know "*Não Sei*"	7	7
Total number of reasons:	2567	2548

[39]Recall that gasoline varieties retailed in Brazil already contain a 20% to 25% proportion of pure ethanol by volume (this was mandated at 25% between Jul-2007 and Jan-2010, and at 20% from Feb-2010). The average combo consisted of 24 R$ of (blended) g and 32 R$ of e. (We instructed representatives to ignore any gasoline used to fill up the 1-liter auxiliary gasoline startup tank that older FFVs came equipped with, which comes into use when starting the engine on ethanol in cold weather, notably around July in the south. Since the value of g recorded on combos was at least 10 R$, or about 4 liters, combo observations cannot be attributed to the 1-liter startup tank.)

[40]The total number of reasons drops from 2567 to 2548 since some statements that were entered as "Other" merely reinforce another reason that was already recorded for the same motorist.

Further validating collected data Vehicle model and engine size—for brevity Table 4 shows only vehicle make—required a small amount of cleaning and imputing. (Full details are available upon request.) The recorded vehicle characteristics reassure us that the qualifying criterion "originally-manufactured FFV" was met, since in the raw data there was only a single observation (among 2160) for which the recorded model had been discontinued by the automaker prior to FFVs being introduced in 2003 (namely, we changed a Ford Escort record to the currently-marketed Ford Ecosport, since Ford discontinued the Escort in 1995). Also, there was a single observation for which by 2010 Qtr 1 the recorded model had not yet been originally equipped with a flex engine (namely, a Toyota Hilux; one possibility is that the observed vehicle was a retrofit and should have been, but was not, filtered).

We obtained detailed data on the nationwide car fleet circulating at the end of 2009 from the autoparts industry trade association (Sindipeças). This is available by make, model (including year) and fuel type but, unfortunately, not at the regional level. We then compared the proportion of car models in our six-city survey sample to those in the nationwide stock of FFVs (only passenger cars, including SUVs and small/medium pickup trucks). Compared to the nationwide stock, of three leading models, our (unweighted) survey records oversample the Fiat Palio (13.3% of our observations vs. 11.5% of the stock, in all its flex versions), undersample the VW Gol (10.1% vs. 13.2%), and sample the GM Corsa at the nationally representative rate (7.7% vs 7.8%). With hypothetical data on cars circulating in each of the surveyed cities (or neighborhoods) by time of day, one could formally test the distribution of car models in our survey records. In the absence of such data, we did not detect any anomaly.[41] At the more aggregate automaker level, our survey oversamples GM (25% of our observations vs. 23% of the nationwide stock) and Ford (10% vs. 9%), and undersamples Fiat (28% vs 29%) and VW (23% vs. 27%).

As for the recorded demographic composition of motorists—see the bottom rows of Table 4, recalling that the median motorist is male and middle-aged—an old survey by São Paulo city's traffic authority (CET 1987) found that 84% of the city's weekday motorists were men; 13% of motorists were under 25 years, 52% were 25-40y, 31% were 40-60y, and 4% were 60y+. That half of our sample declared having completed college education could owe in part to cultural factors, but one should note that subjects belong to Brazil's better-off households, as they had a relatively new car at their personal disposal (the average age of FFVs in circulation was 2.6 years according to the Sindipeças data). Also, quality varies significantly in the country's provision of higher education.

A.2 Other data sources

Vehicle-specific fuel economy As mentioned, we use laboratory measurements endorsed by Inmetro to predict the fuel economy of the FFVs in our sample. Following U.S. EPA guidelines, Inmetro reports the kilometerage per liter (kpl) for retailed fuels g (E22) and e (E100) under separate driving cycles—city and highway—for a selection of new FFVs. (The higher octane rating or "cleaning" additives in upmarket retailed gasoline varieties $\bar{g}$ and $\breve{g}$ do not materially affect their kpl relative to the regular variety g; retailed ethanol already considers a residual water content, thus known as "hydrated"

[41] The distribution of car models does vary significantly across cities in our survey sample. Unsurprisingly, a χ^2 goodness of fit test indicates that car model composition in our (unweighted, six-city) sample differs significantly from that in the nationwide stock.

ethanol.) Specifically, lab measures are available on 23 2009 models (such measures were first published in April 2009) and on 44 2010 models. Since measures are not available for several FFVs in our survey sample, we take an indirect route. Using the available lab data, we first project kpl on other vehicle characteristics; the fitted regression is then used to predict kpl for each vehicle in our survey sample based on its observed characteristics. Unlike those tested in the lab, surveyed cars were not necessarily new, but, important for our purpose of analyzing fuel choice, one can plausibly assume that the *ratio* of kpl for the two fuels, k_{ei}/k_{gi}, hardly varies with car use, condition or age (recalling that surveyed cars were manufactured no earlier than 2003).

Table 5 presents these auxiliary regressions. We predict six vehicle-specific fuel economy variables, respectively labeled in columns I to VI k_e^{city}/k_g^{city} (i.e., city driving), $k_e^{highway}/k_g^{highway}$, k_g^{city}, k_e^{city}, $k_g^{highway}$ and $k_e^{highway}$. When subsequently examining consumer behavior, we take city driving as our baseline. Each dependent variable is projected on two sets of explanatory variables: specification "a" in the upper part of the table or specification "b" in the lower part of the table. Specification "a", which includes car model fixed effects, is subsequently used to predict fuel economy for those car models in our survey sample which were tested in the lab (i.e., for which there is a model fixed effect, e.g., the GM Celta 1.0 liter)—this is the case for 66% of FFVs in our survey sample. Specification "b", which includes carmaker fixed effects and car segment fixed effects, is subsequently used to predict fuel economy for those car models in our survey sample which were not tested in the lab. In this latter case, we need to use lab data on similar car models (e.g., the compact VW Fox 1.6 came up in our survey but was not tested in the lab, so we use the estimated VW and compact segment fixed effects)—this is the case for 34% of our survey sample.

The rest of the table is self-explanatory, but it is worth pointing out that the R^2 are quite high, in the $75\% - 89\%$ range for specification "a" under city driving. The fitted value for the kpl ratio, k_e^{city}/k_g^{city}, evaluated at the mean of the regressors (in the lab sample) is 67.7% (and 68.1% excluding Renault models, see below), with robust standard error of 0.1% or 0.2%. The kpl ratio is similar across FFVs: the interdecile (p90-p10) is 3.3% (i.e., $69.4\% - 66.1\%$). This indicates that the 70% relative price parity threshold that is repeatedly reported in the media is not wide off the mark.[42] (Renault is an outlier: the firm produces all 5 models with kpl ratio below 65%, i.e., low ethanol economy relative to gasoline in comparison to other makes. Renault entered Brazil only a decade ago and has less than 5% market share.)

Vehicle-specific prices and tank capacities We matched the vehicles in our survey to an external dataset on used car prices.[43] Based on observed make and model (we do not observe the surveyed car's age), we took the price in the secondary market in February 2010 for the most recent year-version ("model year") of that make and model. For example, Fiat was still producing its Palio 1.0 (liter) in early 2010 so we took the price of a 2010 Fiat Palio 1.0 in the February 2010 secondary market. On the other hand, GM stopped producing its Meriva 1.8 in 2008 so we took the price of a 2008 GM

[42] The mean predicted value for surveyed vehicles (adjusting for slightly varying blended gasoline composition between Jan-2010 and Mar-2010—recall note 13) is 68.7% (standard deviation 1.6%), not shown in Table 5.

[43] We accessed the QuatroRodas/Molicar/Fipe price tables on March 9-11, 2010; these are available at http://quatrorodas.abril.com.br/compre-seu-carro/tabela-de-precos. Further details are available upon request.

Meriva 1.8 in February 2010. Since in practice automakers discontinue models slowly, we were able to match nine-tenths of our observations with 2009 or 2010 model prices. The mean price across the 2160 FFVs in our sample is 33,602 R$ (minimum price is 21,216 R$, maximum price is 90,732 R$).

It is reassuring that surveyed cars fueling at stations that carried midgrade gasoline on top of regular (presumably located in wealthier neighborhoods) have a higher mean price than cars observed in stations carrying only the regular gasoline variety; the p-value of a test of the equality of means is 0.031 (a mean car price of 33,780 R$ in stations where $\bar{g}$ was available against 31,784 R$ in the fewer stations where it was not). Similarly, surveyed cars fueling at stations that carried the even more upmarket $\breve{g}$ (besides $\bar{g}$ and g) have a higher mean price than cars at stations carrying only $\bar{g}$ and g (the equality test has p-value of 0.034).

As might be expected, cars surveyed in relatively less affluent Recife, in the country's Northeast region, have a lower mean price (30,834 R$) than cars surveyed in the five southern/southeastern cities (a mean price of 33,948 R$; an equality test yields a p-value of 0.000).

Similarly, we obtained vehicle-specific tank capacities from Carrosnaweb. The mean tank capacity in our survey sample is 51 liters (minimum capacity is 42 liters, maximum capacity is 80 liters).

Specification (probit, e):	**I**	**II**	**III**	**IV**	**V**	**I [sd]**
dv_female	−0.005	−0.011	−0.001	0.037	−0.005	−0.005
mean = .342	(0.027)	(0.027)	(0.030)	(0.033)	(0.027)	[0.000]
dv_age_25to40y	−0.048	−0.059	−0.023	−0.091*	−0.049	−0.048
mean = .463	(0.039)	(0.040)	(0.045)	(0.047)	(0.040)	[0.000]
dv_age_40to65y	−0.043	−0.061	−0.059	−0.072	−0.044	−0.043
mean = .395	(0.039)	(0.038)	(0.043)	(0.045)	(0.039)	[0.000]
dv_age_morethan65y	−0.238***	−0.234***	−0.180***	−0.275***	−0.239***	−0.238***
mean = .037	(0.054)	(0.056)	(0.056)	(0.061)	(0.054)	[0.000]
dv_school_some_secondary	0.060	0.059	0.087	0.120***	0.059	0.060
mean = .310	(0.052)	(0.051)	(0.062)	(0.056)	(0.052)	[0.000]
dv_school_some_college	0.037	0.039	0.014	0.085	0.035	0.037
mean = .618	(0.048)	(0.047)	(0.059)	(0.054)	(0.048)	[0.000]
dv_heavy_user	−0.078***	−0.086***	−0.081***	−0.105***	−0.079***	−0.078***
mean = .229	(0.025)	(0.026)	(0.029)	(0.033)	(0.025)	[0.000]
dv_pricey_car_model	−0.054**	−0.062**	−0.042	−0.065*	−0.056**	−0.054**
mean = .262	(0.027)	(0.027)	(0.032)	(0.038)	(0.026)	[0.000]
dv_reason_environment	0.431***	0.446***	0.480***	0.471***	0.432***	0.431***
mean = .056	(0.041)	(0.041)	(0.058)	(0.038)	(0.041)	[0.000]
dv_reason_engine	−0.255***	−0.253***	−0.176***	−0.295***	−0.256***	−0.255***
mean = .122	(0.032)	(0.033)	(0.032)	(0.040)	(0.033)	[0.000]
dv_reason_range_75%tank	−0.239***	−0.244***	−0.109	−0.330***	−0.241***	−0.239***
mean = .035	(0.053)	(0.055)	(0.070)	(0.057)	(0.052)	[0.000]
dv_sao_paulo (Producer)	0.095		−0.033		0.091	0.095
mean = .333	(0.067)		(0.082)		(0.067)	[0.000]
dv_curitiba (Producer)	0.234***		0.113		0.229***	0.234***
mean = .222	(0.064)		(0.076)		(0.064)	[0.000]
dv_recife (Producer)	0.065	0.086	0.056		0.064	0.065
mean = .111	(0.072)	(0.071)	(0.085)		(0.072)	[0.000]
dv_rio_de_janeiro (Importer)	−0.095	−0.076	−0.092		−0.096	−0.095
mean = .111	(0.064)	(0.063)	(0.067)		(0.063)	[0.000]
dv_belo_horizonte (Importer)	−0.194***	−0.181***	−0.174***		−0.195***	−0.194***
mean = .111	(0.059)	(0.059)	(0.058)		(0.059)	[0.000]
dv_porto_alegre (Importer)	−0.372***	−0.357***	−0.314***		−0.373***	−0.372***
mean = .111	(0.044)	(0.046)	(0.041)		(0.044)	[0.000]
dv_sao_paulo_wkofjan11		0.082				
dv_sao_paulo_wkofjan25		−0.040				
dv_sao_paulo_wkofmar29		0.267***				
dv_curitiba_wkofjan25		0.148***				
dv_curitiba_wkofmar29		0.352***				
dv_reason_habit_last2g		−0.317***				
dv_reason_habit_last2e		(perfect)				
Station visit FEs	N	N	N	Y	N	N
Car segment FEs	N	N	N	Y	N	N
Number of observations	2160	2129	1440	1992	2160	2160
Log likelihood	−1185.8	−1135.1	−755.2	−1028.1	−1184.1	−1185.8

Table 1: Probit estimated marginal effects (at the sample mean, N=2160). Success is "Ethanol is chosen over gasoline". An observation is an FFV-qualifying motorist. "dv" denotes dummy variable. Station visit-clustered standard errors in parentheses, except for the last column which shows standard deviations over 1000 replications. * p<.1, ** p<.05, *** p<.01

Specification (multinomial probit):	**I: m.e.**	**(s.e.)**	**II: m.e.**	**(s.e.)**	**III: m.e.**	**(s.e.)**
Pr (**Motorist** i **chooses fuel** e)						
Price of e per km (mean = .268)	−3.961***	(0.689)	−3.933***	(0.714)	−6.345***	(0.507)
Price of g per km (mean = .246)	3.463***	(0.654)	3.424***	(0.686)	4.804***	(0.531)
Price of $\bar{g}$ per km (mean = .257)	0.499**	(0.240)	0.509**	(0.234)	1.541***	(0.316)
dv_female (mean = .342)	−0.009	(0.027)	−0.009	(0.028)	−0.010	(0.027)
dv_age_25to40y (mean = .463)	−0.057	(0.040)	−0.056	(0.041)	−0.064	(0.040)
dv_age_40to65y (mean = .395)	−0.054	(0.039)	−0.053	(0.040)	−0.075*	(0.038)
dv_age_morethan65y (mean = .037)	−0.255***	(0.055)	−0.254***	(0.058)	−0.276***	(0.057)
dv_school_some_secondary (mean=.310)	0.060	(0.053)	0.060	(0.053)	0.059	(0.054)
dv_school_some_college (mean = .618)	0.042	(0.049)	0.042	(0.049)	0.040	(0.051)
dv_heavy_user (mean = .229)	−0.086***	(0.026)	−0.086***	(0.027)	−0.092***	(0.027)
dv_pricey_car_model (mean = .262)	−0.049*	(0.027)	−0.050*	(0.027)	−0.046*	(0.028)
dv_reason_environment (mean = .056)	0.435***	(0.041)	0.436***	(0.044)	0.432***	(0.039)
dv_reason_engine (mean = .122)	−0.261***	(0.035)	−0.261***	(0.038)	−0.259***	(0.036)
dv_reason_range_75%tank (mean= .035)	−0.245***	(0.058)	−0.246***	(0.059)	−0.242***	(0.067)
dv_sao_paulo (Producer, mean = .333)	0.182**	(0.074)	0.169*	(0.095)		
dv_curitiba (Producer, mean = .222)	0.288***	(0.065)	0.276***	(0.085)		
dv_recife (Producer, mean = .111)	0.173**	(0.075)	0.163*	(0.088)		
dv_rio_de_janeiro (Importer, mean= .111)	0.086	(0.079)	0.073	(0.094)		
dv_belo_horizonte (Importer, mean= .111)	−0.022	(0.079)	−0.038	(0.097)		
dv_porto_alegre (Importer, mean = .111)	−0.133	(0.101)	−0.155	(0.112)		
Number of nozzles of e (mean = 3.900)			−0.005	(0.007)		
Number of nozzles of g (mean = 5.044)			0.004	(0.006)		
Number of nozzles of $\bar{g}$ (mean = 3.677)			0.001	(0.001)		
Pr (**Motorist** i **chooses fuel** g)						
Price of e per km (mean = .268)	3.463***	(0.654)	3.424***	(0.686)	4.804***	(0.531)
Price of g per km (mean = .246)	−4.222***	(0.859)	−4.370***	(1.015)	−5.826***	(0.785)
Price of $\bar{g}$ per km (mean = .257)	0.759	(0.614)	0.946	(0.898)	1.022	(0.721)
(...other marginal effects omitted)						
Pr (**Motorist** i **chooses fuel** $\bar{g}$)						
Price of e per km (mean = .268)	0.499**	(0.240)	0.509**	(0.234)	1.540***	(0.316)
Price of g per km (mean = .246)	0.759	(0.614)	0.946	(0.898)	1.022	(0.721)
Price of $\bar{g}$ per km (mean = .257)	−1.258*	(0.725)	−1.455	(0.966)	−2.563***	(0.821)
(...other marginal effects omitted)						
Log likelihood	−1618.8		−1618.5		−1683.7	
$\sigma_{\bar{g}}$	1.135	(1.250)	0.786	(1.599)	1.085	(0.780)
$\rho_{e,\bar{g}}$	−0.272	(0.887)	−0.586	(1.981)	0.378	(0.385)

Table 2: Multinomial probit estimated marginal effects (at the mean). Some effects are not reported due to space constraints. Alternatives per FFV-qualifying motorist (N=2160) are regular gasoline (the base alternative, always available), ethanol (the scale alternative, always available) and midgrade gasoline (if available at the station). "dv" denotes dummy variable. Station visit-clustered standard errors in parentheses. * p<.1, ** p<.05, *** p<.01

Variable	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max.**
(Per-liter) p_g...	180	2.515	.146	2.199	2.989
...for city-weeks in January	140	2.550	.125	2.199	2.989
...for city-weeks in March	40	2.391	.148	2.229	2.989
(Per-liter) p_e...	180	1.879	.316	1.239	2.549
...for city-weeks in January	140	2.017	.196	1.690	2.549
...for city-weeks in March	40	1.399	.129	1.239	1.899
(Ratio) p_e/p_g...	180	.745	.105	.520	1.050
...for São Paulo, week of Jan 11	20	.742	.027	.692	.800
...for São Paulo, week of Jan 25	20	.747	.032	.692	.833
...for Curitiba, week of Jan 25	20	.747	.021	.692	.775
...for Recife, week of Jan 25	20	.745	.022	.698	.784
...for Rio de Janeiro, week of Jan 25	20	.805	.037	.739	.873
...for Belo Horizonte, week of Jan 25	20	.846	.026	.800	.885
...for Porto Alegre, week of Jan 25	20	.905	.041	.858	1.050
...for São Paulo, week of Mar 29	20	.591	.038	.520	.667
...for Curitiba, week of Mar 29	20	.578	.021	.541	.609
(Per-liter) $p_{\bar{g}}$	164	2.618	.185	2.25	3.499
(Ratio) $p_{\bar{g}}/p_g$	164	1.039	.030	1	1.171
(Per-liter) $p_{\breve{g}}$	20	3.213	.240	2.799	3.699
(Ratio) $p_{\breve{g}}/p_{\bar{g}}$	20	1.162	.093	1.034	1.375
(Ratio) $p_{\breve{g}}/p_g$	20	1.223	.095	1.071	1.435
Number of nozzles, all ethanol and gasoline fuels	180	12.522	6.386	3	48
Number of nozzles, g...	180	5.044	2.422	1	16
...for São Paulo or Curitiba, week of Jan 25	40	4.875	2.053	2	12
...for São Paulo or Curitiba, week of Mar 29	40	5.175	2.591	2	16
Number of nozzles, e...	180	3.900	2.302	1	16
...for São Paulo or Curitiba, week of Jan 25	40	3.950	2.183	1	10
...for São Paulo or Curitiba, week of Mar 29	40	4.500	2.792	1	16
Number of nozzles, $\bar{g}$ if $\bar{g}$ is available	164	3.677	2.419	1	16
Number of nozzles, $\breve{g}$ if $\breve{g}$ is available	20	2.050	.510	1	4
dv_branded_station	180	.989	.105	0	1
dv_brand_BR	180	.294	.457	0	1
dv_brand_Shell	180	.267	.443	0	1
dv_brand_Ipiranga	180	.189	.393	0	1
dv_weekday_startpeakhour	180	.317	.466	0	1
dv_weekday_startoffpeak	180	.467	.500	0	1
dv_Saturday	180	.217	.413	0	1
Duration of station visit	180	2.543	.971	.833	5.417
Representative's travel time between stations	100	1.804	1.448	.133	7.75
Number of motorists who refused to participate	180	2.844	4.026	0	22

Table 3: Summary statistics: Data directly collected in, or constructed from, station-level forms. An observation is a station visit. "dv" denotes dummy variable. Prices are in Brazilian Real per liter. Times are in hours.

Variable	Obs	Mean	Std. Dev.	Min	Max.
Purchased (only) g...	2160	.451	.498	0	1
...for city-weeks in January	1680	.520	.500	0	1
Purchased (only) e...	2160	.435	.496	0	1
...for city-weeks in March	480	.719	.450	0	1
Purchased (only) $\bar{g}$	2160	.087	.282	0	1
Purchased (only) $\breve{g}$	2160	.001	.037	0	1
Purchased a "combo" of g and e	2160	.024	.152	0	1
Purchased any other "combo"	2160	.001	.037	0	1
Value of fuel purchased	2160	46.973	29.601	10	158
Value of g purchased...	2160	24.052	33.354	0	150
...if purchasing (only) g	975	51.932	31.659	10	150
Value of e purchased...	2160	17.081	23.877	0	140
...if purchasing (only) e	940	37.459	22.401	10	140
Value of $\bar{g}$ purchased...	2160	5.752	21.126	0	150
...if purchasing (only) $\bar{g}$	188	65.477	34.472	10	150
dv_reason_1_price_characteristic	2160	.683	.465	0	1
dv_reason_2_range_or_price	2160	.263	.440	0	1
dv_reason_3_environment	2160	.056	.230	0	1
dv_reason_4_engine_performance	2160	.047	.211	0	1
dv_reason_5_engine_startup	2160	.083	.276	0	1
dv_reason_other_enter_verbatim	2160	.045	.208	0	1
dv_reason_does_not_know	2160	.003	.057	0	1
Last two occasions both chose g...	2160	.479	.500	0	1
...if (now) purchasing (only) g	975	.825	.380	0	1
Last two occasions both chose e...	2160	.372	.484	0	1
...if (now) purchasing (only) e	940	.778	.416	0	1
Last two occasions alternated e, g	2160	.149	.356	0	1
Last two occasions chose this station 2X	2160	.513	.500	0	1
Last two occasions chose this station 1X	2160	.219	.413	0	1
Last two occasions chose this station 0X	2160	.269	.444	0	1
Car usage	1835	296.094	319.930	5	3500
dv_fiat	2160	.281	.449	0	1
dv_general_motors	2160	.248	.432	0	1
dv_volkswagen	2160	.231	.422	0	1
dv_ford	2160	.102	.303	0	1
dv_male	2160	.658	.475	0	1
dv_age_25to40y	2160	.463	.499	0	1
dv_age_40to65y	2160	.395	.489	0	1
dv_age_morethan65y	2160	.037	.188	0	1
dv_school_primary_complete	2160	.059	.235	0	1
dv_school_secondary_incomplete	2160	.026	.160	0	1
dv_school_secondary_complete	2160	.284	.451	0	1
dv_school_college_incomplete	2160	.121	.326	0	1
dv_school_college_complete	2160	.497	.500	0	1
dv_provided_a_phone_number	2160	.922	.269	0	1

Table 4: Summary statistics: Data directly collected in, or constructed from, motorist-level forms. An observation is an FFV-qualifying motorist. "dv" denotes dummy variable. Values are in Real. Car usage is in kilometers per week.

Dependent variable:	$\frac{k_e^{city}}{k_g^{city}}$	$\frac{k_e^{highway}}{k_g^{highway}}$	k_g^{city}	k_e^{city}	$k_g^{highway}$	$k_e^{highway}$
Specification:	**Ia**	**IIa**	**IIIa**	**IVa**	**Va**	**VIa**
engine_size_liters	−0.011**	−0.004	−1.036***	−0.814***	−0.576*	−0.430**
	(0.005)	(0.009)	(0.233)	(0.158)	(0.312)	(0.184)
dv_nonmanual_transmission	−0.013	−0.007	−0.015	−0.147	0.251	0.072
	(0.008)	(0.009)	(0.167)	(0.104)	(0.216)	(0.142)
Intercept	0.709***	0.684***	11.250***	7.940***	12.156***	8.302***
	(0.009)	(0.013)	(0.388)	(0.282)	(0.438)	(0.257)
Car model fixed effects	Y	Y	Y	Y	Y	Y
R^2	0.750	0.629	0.883	0.893	0.914	0.938
Fitted value at covariate mean	0.677	0.674	10.393	7.036	12.652	8.528
(in lab data)	(0.002)	(0.002)	(0.043)	(0.028)	(0.057)	(0.033)
Specification:	**Ib**	**IIb**	**IIIb**	**IVb**	**Vb**	**VIb**
engine_size_liters	−0.012**	−0.003	−1.530***	−1.170***	−0.956**	−0.685**
	(0.005)	(0.008)	(0.330)	(0.239)	(0.463)	(0.337)
dv_nonmanual_transmission	−0.013**	−0.006	0.013	−0.122	0.145	0.016
	(0.006)	(0.007)	(0.147)	(0.098)	(0.222)	(0.148)
dv_segment_compact	−0.007*	−0.006	−0.553*	−0.454**	−0.536	−0.431
	(0.004)	(0.006)	(0.295)	(0.208)	(0.380)	(0.262)
dv_segment_midsize	−0.007	−0.004	−0.263	−0.257	−0.447	−0.350
	(0.004)	(0.007)	(0.295)	(0.216)	(0.421)	(0.293)
dv_segment_fullsize	0.002	−0.003	−0.925**	−0.594**	0.138	0.064
	(0.015)	(0.015)	(0.371)	(0.253)	(0.534)	(0.372)
dv_segment_smalltruck	−0.011**	−0.004	−0.659	−0.571*	−1.656**	−1.174**
	(0.005)	(0.008)	(0.455)	(0.307)	(0.737)	(0.542)
Intercept	0.710***	0.689***	12.685***	8.945***	13.636***	9.369***
	(0.008)	(0.011)	(0.580)	(0.416)	(0.759)	(0.529)
Carmaker fixed effects	Y	Y	Y	Y	Y	Y
R^2	0.674	0.468	0.553	0.562	0.556	0.519
Fitted value at covariate mean	0.677	0.674	10.393	7.036	12.652	8.528
(in lab data)	(0.001)	(0.002)	(0.070)	(0.048)	(0.110)	(0.078)
Number of observations	67	67	67	67	67	67

Table 5: Auxiliary OLS regressions for predicting vehicle-specific fuel economy based on laboratory test data reported by Inmetro. An observation is a car model in the selected test sample. In "a" specifications, car model fixed effects are included (the Fiat Palio subcompact dummy variable is omitted). In "b" specifications, carmaker fixed effects and car segment fixed effects are included (the Fiat and the subcompact dummy variables are omitted). Heteroscedasticity-robust standard errors in parentheses. * p<.1, ** p<.05, *** p<.01

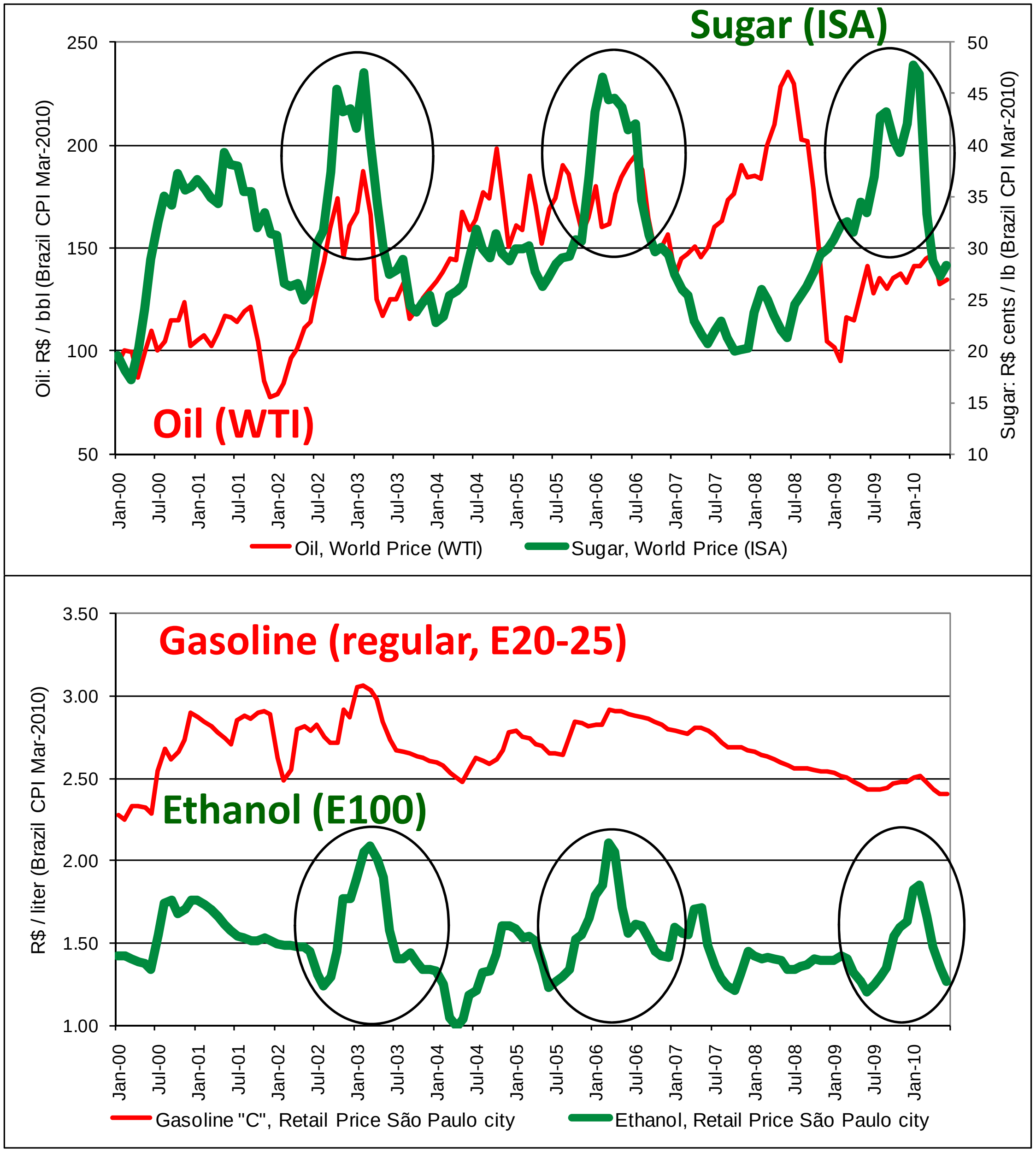

Figure 1: The pump price of ethanol peaks when the world price of sugar peaks. Upper panel: World sugar price (ISA, R$ cents per pound) and World oil price (WTI, R$ per barrel). Lower panel: Ethanol (E100) and Gasoline (regular, E20-25) prices at the pump in the city of São Paulo (R$ per liter). All 2000-2010 prices are in constant Brazilian Real, R$, Brazil CPI base Mar-2010. Source: IBGE, EIA, ISO, BCB.

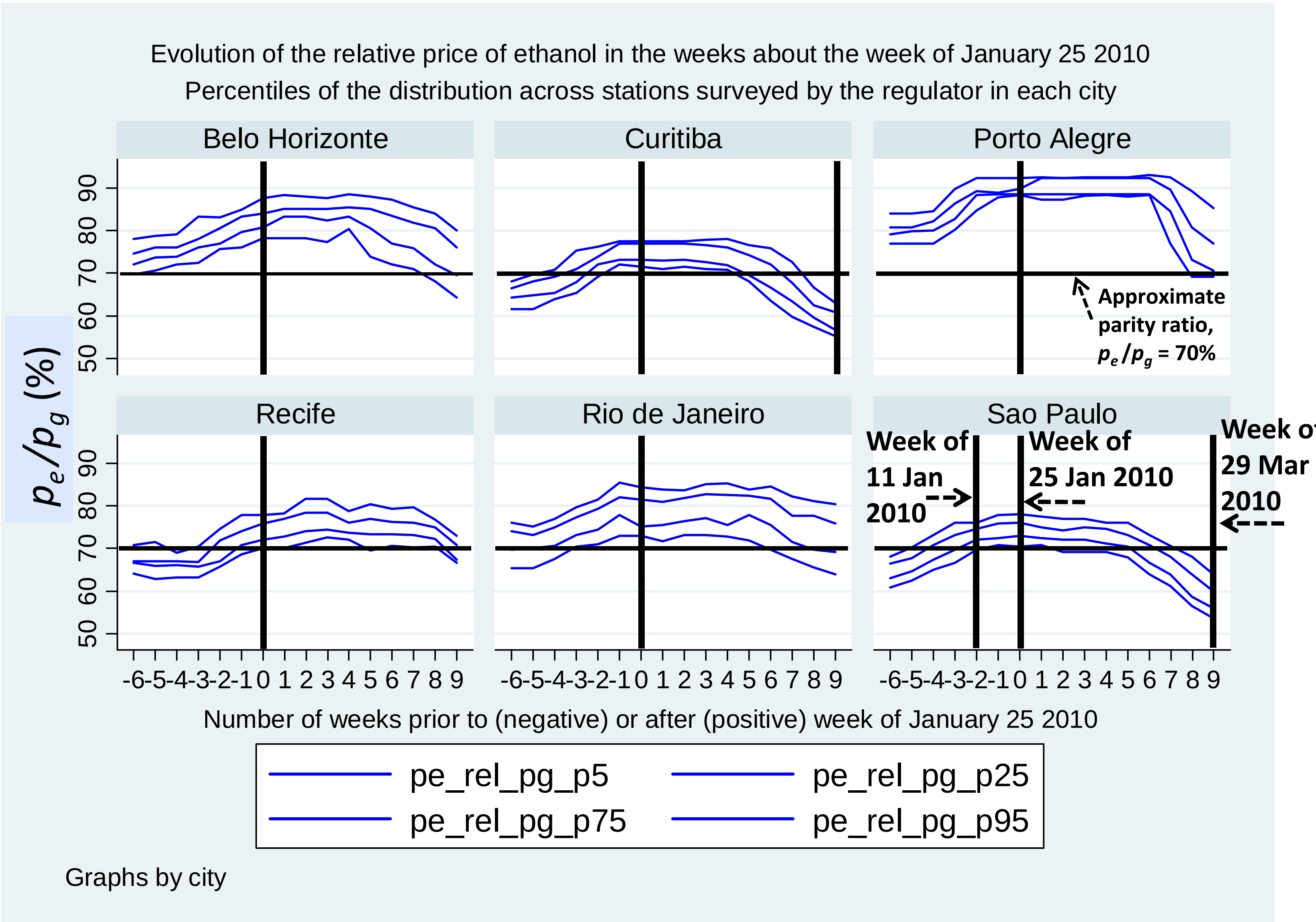

Figure 2: Opportune price variation in the 1st Quarter of 2010. Percentiles of the distribution across stations of the ethanol-to-regular-gasoline per-liter price ratio, in six cities in each of several weeks running up to and following the week of January 25, 2010. The 5th, 25th, 75th and 95th percentiles of the price ratio are shown. Source: ANP's retail price database. City-weeks in our survey are marked with vertical lines.

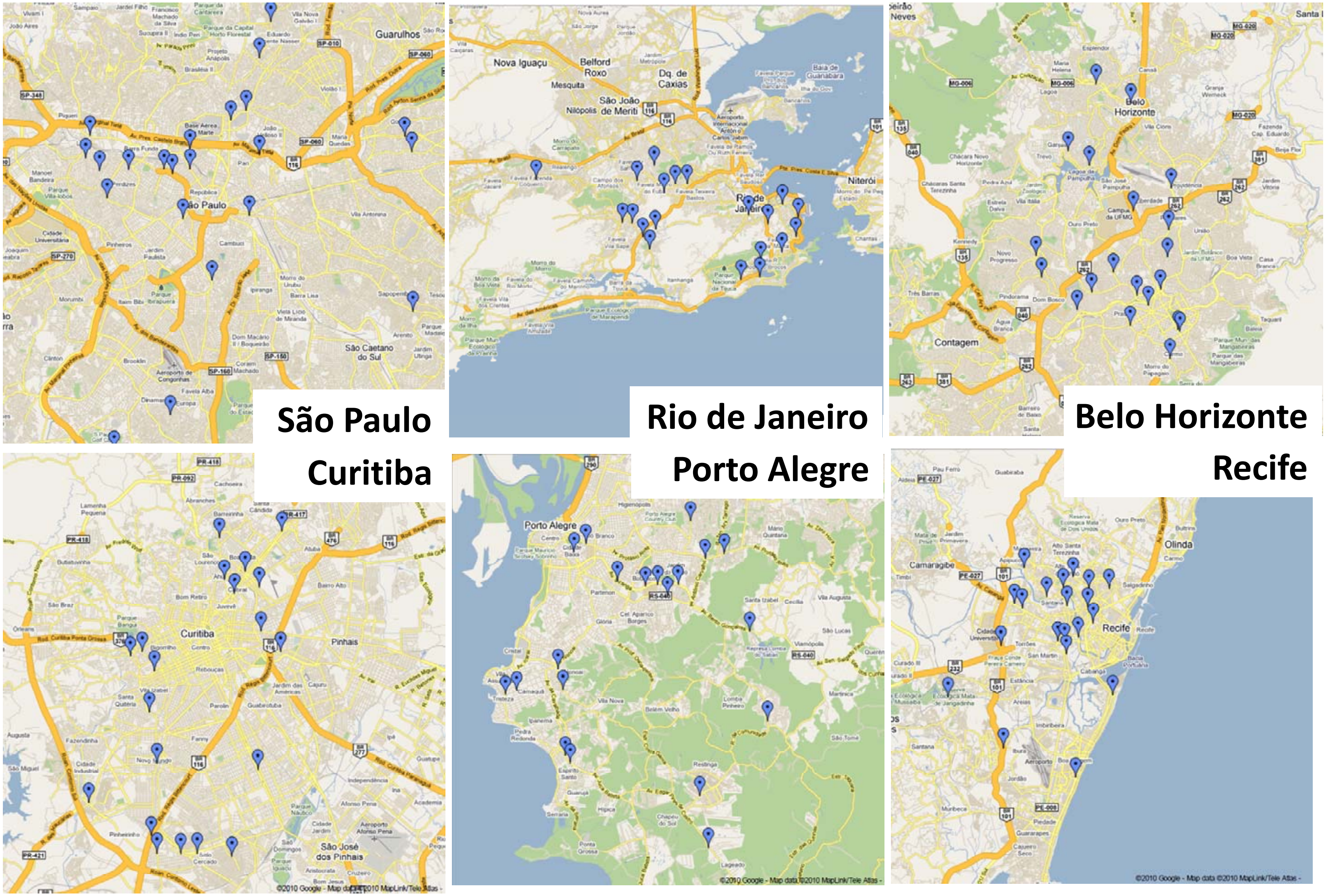

Figure 3: Location of retail fueling stations in our sample. From top to bottom, from left to right: cities of (in southeast) São Paulo, Rio de Janeiro, Belo Horizonte, (in south) Curitiba, Porto Alegre and (in northeast) Recife.

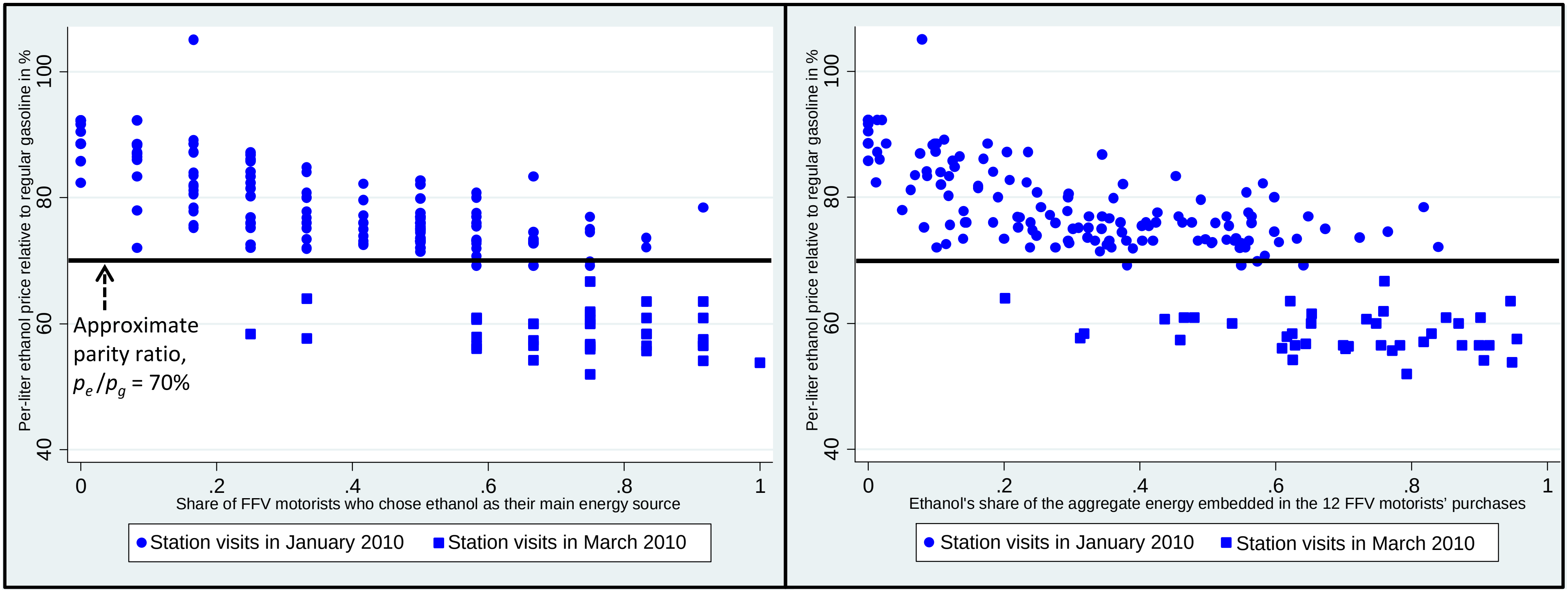

Figure 4: Empirical demand by FFV motorists at the station level. Per-liter ethanol price relative to regular gasoline (p_e/p_g) plotted against ethanol's overall "share" in the 12 choices observed in each station visit. The left and right panels respectively plot the "unweighted" and "weighted" ethanol shares, as defined in the text. An observation is a station visit (January visits are marked with circles and March visits with squares). Source: Own survey.

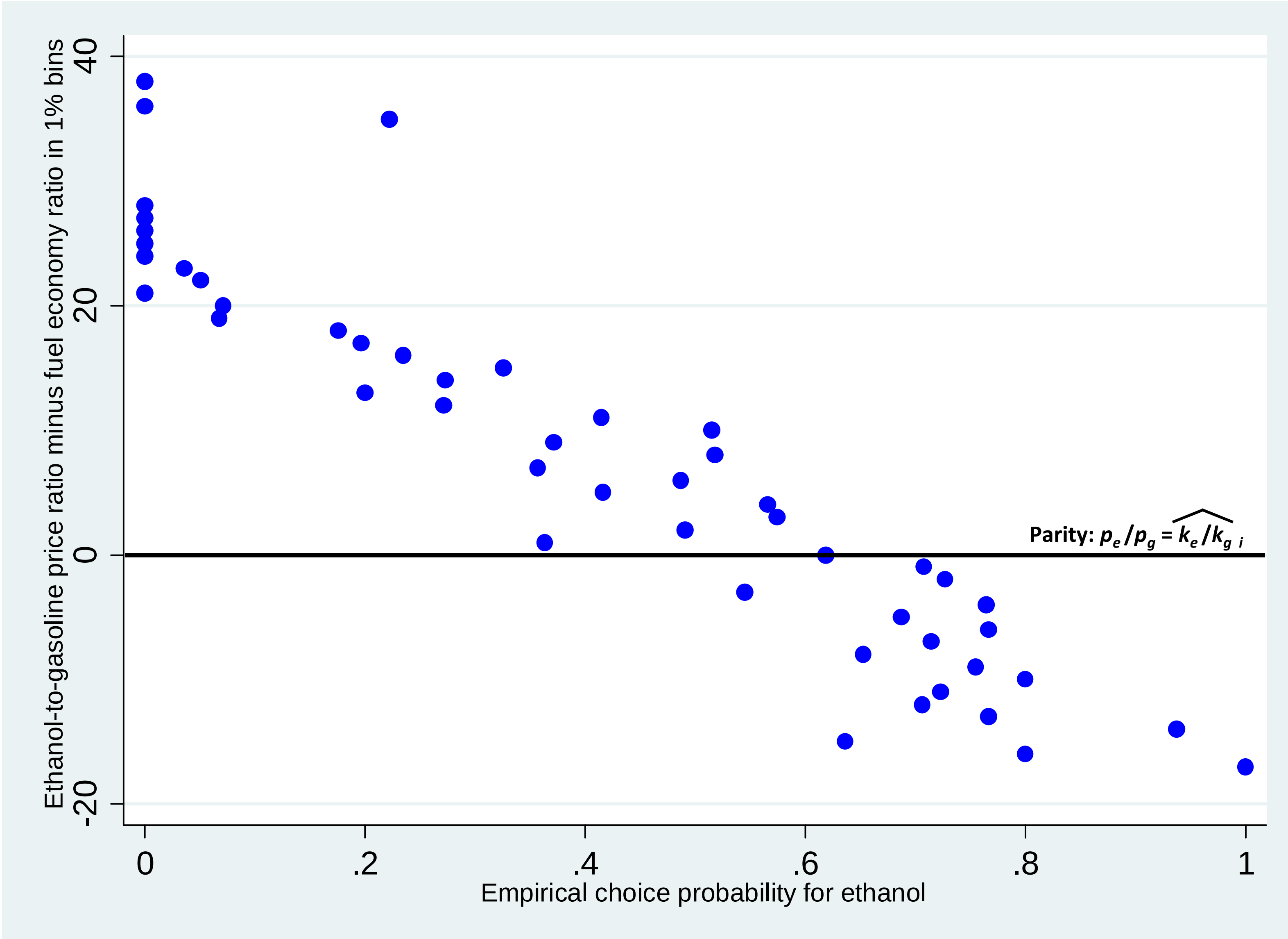

Figure 5: Empirical choice probability for ethanol controlling for energy-adjusted relative prices. An observation is an integer category defined over 2160 choices. The vertical axis shows 1 ppt "bins" for the difference between the ethanol-to-regular-gasoline per-liter price ratio the motorist faced at the station and the predicted ethanol-to-gasoline kpl ratio for his FFV. The horizontal axis reports the proportion of motorists in that bin who chose ethanol as their dominant energy source. (See text.) Source: Own survey.

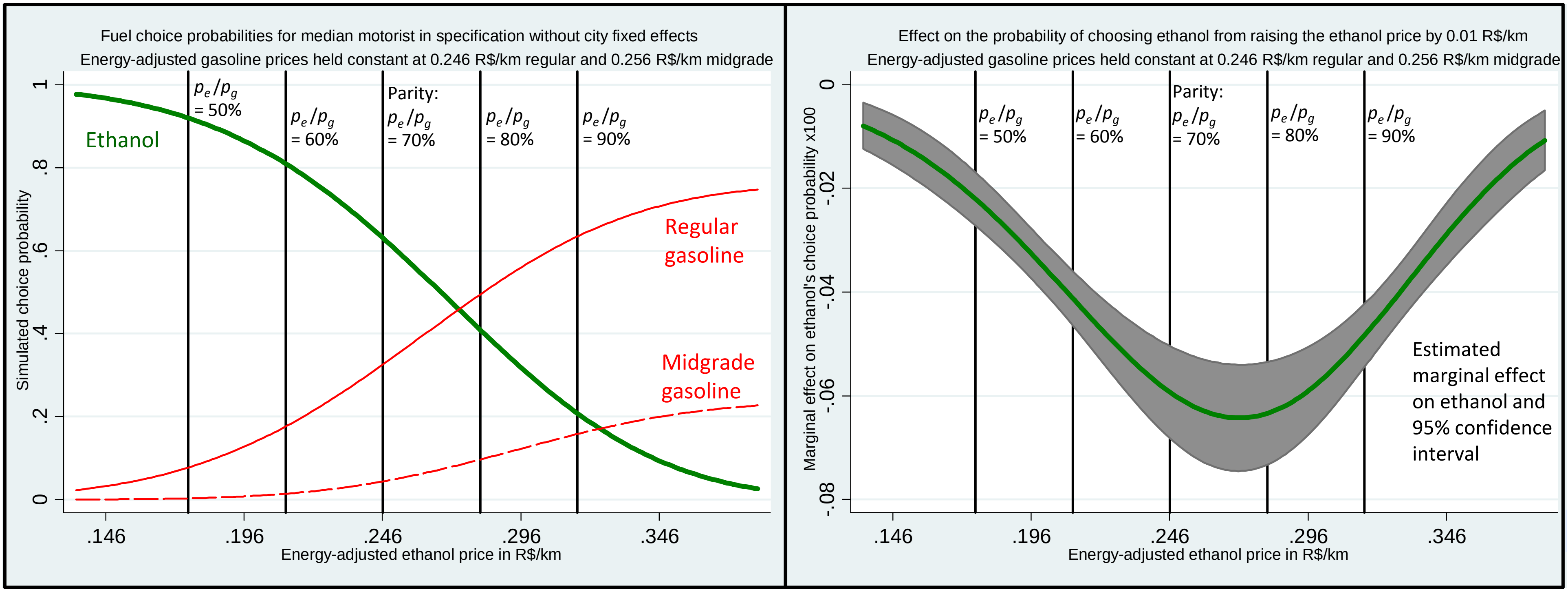

Figure 6: "Median" motorist's simulated fuel choice probabilities (left panel) and estimated ethanol choice marginal effect (right panel) from varying the energy-adjusted price of ethanol, in R$/km, holding gasoline prices constant at the sample means (regular 0.246 R$/km, midgrade 0.256 R$/km). See text for definition of a median motorist. Considers three fuels in motorist's choice set. Equivalence scale in terms of ethanol-to-regular-gasoline per-liter price ratio is indicated by the vertical lines (for an ethanol-to-gasoline kpl ratio of 70%). The marginal effect in the right panel is rescaled by 1/100 to reflect a +0.01 R$/km price increment. Source: Multinomial probit estimates, specification III (baseline without city fixed effects, to conservatively reduce the range)

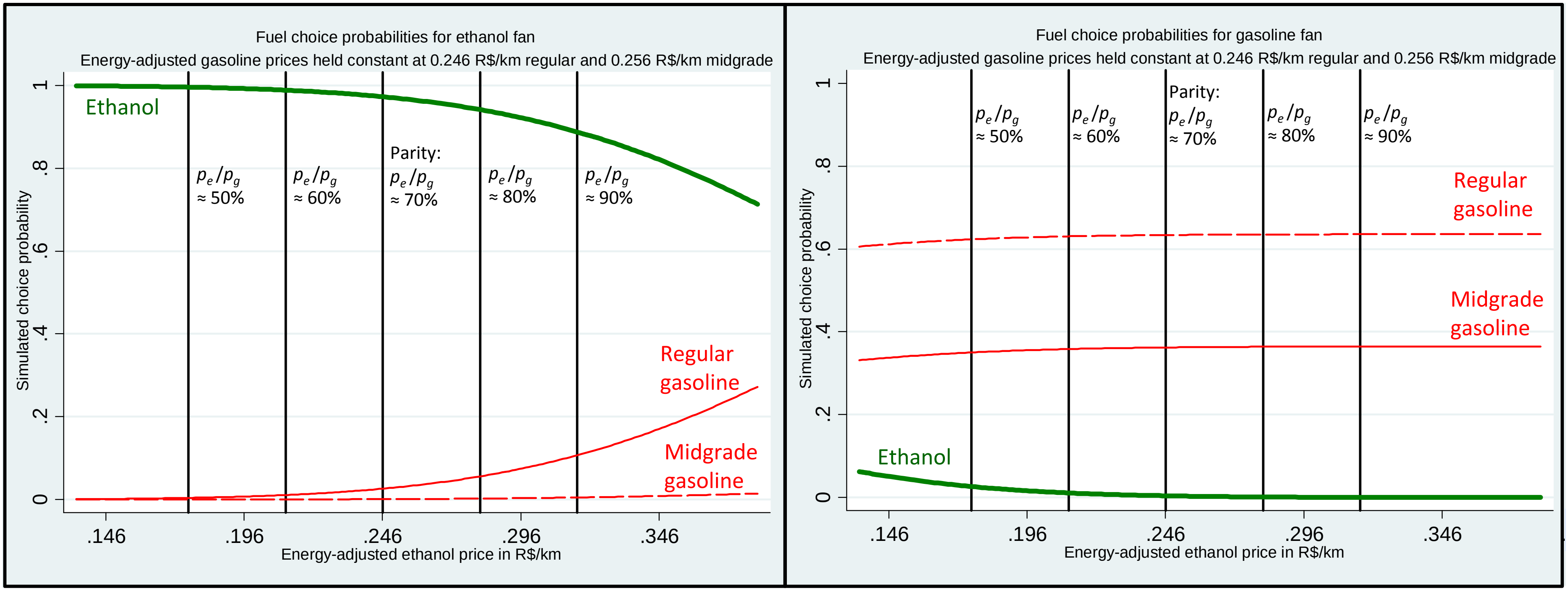

Figure 7: "Green and Brown" consumers. Simulated fuel choice probabilities for two "extreme" hypothetical consumers. See text for definitions of an "ethanol fan" (left panel) and a "gasoline fan" (right panel). The energy-adjusted price of ethanol, in R$/km, is varied holding gasoline prices constant at the sample means (regular 0.246 R$/km, midgrade 0.256 R$/km). Considers three fuels in both motorists' choice set. Equivalence scale in terms of ethanol-to-regular-gasoline per-liter price ratio is indicated by the vertical lines (for an ethanol-to-gasoline kpl ratio of 70%). Source: Baseline multinomial probit estimates.

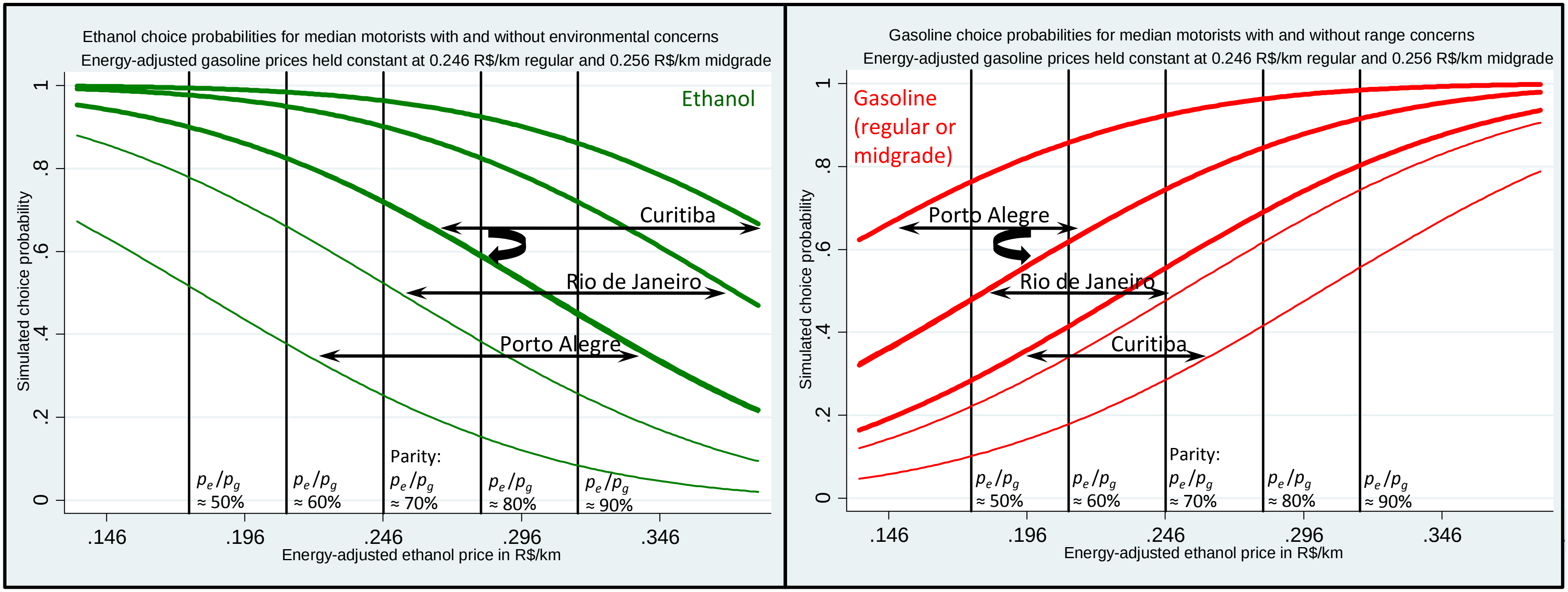

Figure 8: Willingness to pay for "greenness" and to avoid "range anxiety". Simulated fuel choice probabilities (for ethanol in the left panel, for both gasoline varieties in the right panel) for "median" motorists in each of three cities. See text for definition of a median motorist. In the left panel, the environment-reason dummy is switched on (marked by thick lines) or off (thin lines). In the right panel, the (order-volume-adjusted) range-reason is switched on (thick lines) or off (thin lines). The energy-adjusted price of ethanol, in R$/km, is varied holding gasoline prices constant at the sample means (regular 0.246 R$/km, midgrade 0.256 R$/km). Considers three fuels in motorists' choice set. Equivalence scale in terms of ethanol-to-regular-gasoline per-liter price ratio is indicated by the vertical lines (for an ethanol-to-gasoline kpl ratio of 70%). Source: Baseline multinomial probit estimates.

		P	R	E	Ç	O		G	A	S	O	L	I	N	A																																					
	R$/litro	2.00	2.02	2.04	2.06	2.08	2.10	2.12	2.14	2.16	2.18	2.20	2.22	2.24	2.26	2.28	2.30	2.32	2.34	2.36	2.38	2.40	2.42	2.44	2.46	2.48	2.50	2.52	2.54	2.56	2.58	2.60	2.62	2.64	2.66	2.68	2.70	2.72	2.74	2.76	2.78	2.80	2.82	2.84	2.86	2.88	2.90	2.92	2.94	2.96	2.98	3.00
P	1.20	0.60	0.59	0.59	0.58	0.58	0.57	0.57	0.56	0.56	0.55	0.55	0.54	0.54	0.53	0.53	0.52	0.52	0.51	0.51	0.50	0.50	0.50	0.49	0.49	0.48	0.48	0.48	0.47	0.47	0.47	0.46	0.46	0.45	0.45	0.45	0.44	0.44	0.44	0.43	0.43	0.43	0.43	0.42	0.42	0.42	0.41	0.41	0.41	0.41	0.40	0.40
R	1.22	0.61	0.60	0.60	0.59	0.59	0.58	0.58	0.57	0.56	0.56	0.55	0.55	0.54	0.54	0.54	0.53	0.53	0.52	0.52	0.51	0.51	0.50	0.50	0.50	0.49	0.49	0.48	0.48	0.48	0.47	0.47	0.47	0.46	0.46	0.46	0.45	0.45	0.45	0.44	0.44	0.44	0.43	0.43	0.43	0.42	0.42	0.42	0.41	0.41	0.41	0.41
E	1.24	0.62	0.61	0.61	0.60	0.60	0.59	0.58	0.58	0.57	0.57	0.56	0.56	0.55	0.55	0.54	0.54	0.53	0.53	0.53	0.52	0.52	0.51	0.51	0.50	0.50	0.50	0.49	0.49	0.48	0.48	0.48	0.47	0.47	0.47	0.46	0.46	0.46	0.45	0.45	0.45	0.44	0.44	0.44	0.43	0.43	0.43	0.42	0.42	0.42	0.42	0.41
Ç	1.26	0.63	0.62	0.62	0.61	0.61	0.60	0.59	0.59	0.58	0.58	0.57	0.57	0.56	0.56	0.55	0.55	0.54	0.54	0.53	0.53	0.53	0.52	0.52	0.51	0.51	0.50	0.50	0.50	0.49	0.49	0.48	0.48	0.48	0.47	0.47	0.47	0.46	0.46	0.46	0.45	0.45	0.45	0.44	0.44	0.44	0.43	0.43	0.43	0.43	0.42	0.42
O	1.28	0.64	0.63	0.63	0.62	0.62	0.61	0.60	0.60	0.59	0.59	0.58	0.58	0.57	0.57	0.56	0.56	0.55	0.55	0.54	0.54	0.53	0.53	0.52	0.52	0.52	0.51	0.51	0.50	0.50	0.50	0.49	0.49	0.48	0.48	0.48	0.47	0.47	0.47	0.46	0.46	0.46	0.45	0.45	0.45	0.44	0.44	0.44	0.44	0.43	0.43	0.43
	1.30	0.65	0.64	0.64	0.63	0.63	0.62	0.61	0.61	0.60	0.60	0.59	0.59	0.58	0.58	0.57	0.57	0.56	0.56	0.55	0.55	0.54	0.54	0.53	0.53	0.52	0.52	0.52	0.51	0.51	0.50	0.50	0.50	0.49	0.49	0.49	0.48	0.48	0.47	0.47	0.47	0.46	0.46	0.46	0.45	0.45	0.45	0.45	0.44	0.44	0.44	0.43
E	1.32	0.66	0.65	0.65	0.64	0.63	0.63	0.62	0.62	0.61	0.61	0.60	0.59	0.59	0.58	0.58	0.57	0.57	0.56	0.56	0.55	0.55	0.55	0.54	0.54	0.53	0.53	0.52	0.52	0.52	0.51	0.51	0.50	0.50	0.50	0.49	0.49	0.49	0.48	0.48	0.47	0.47	0.47	0.46	0.46	0.46	0.46	0.45	0.45	0.45	0.44	0.44
T	1.34	0.67	0.66	0.66	0.65	0.64	0.64	0.63	0.63	0.62	0.61	0.61	0.60	0.60	0.59	0.59	0.58	0.58	0.57	0.57	0.56	0.56	0.55	0.55	0.54	0.54	0.54	0.53	0.53	0.52	0.52	0.52	0.51	0.51	0.50	0.50	0.50	0.49	0.49	0.49	0.48	0.48	0.48	0.47	0.47	0.47	0.46	0.46	0.46	0.45	0.45	0.45
A	1.36	0.68	0.67	0.67	0.66	0.65	0.65	0.64	0.64	0.63	0.62	0.62	0.61	0.61	0.60	0.60	0.59	0.59	0.58	0.58	0.57	0.57	0.56	0.56	0.55	0.55	0.54	0.54	0.54	0.53	0.53	0.52	0.52	0.52	0.51	0.51	0.50	0.50	0.50	0.49	0.49	0.49	0.48	0.48	0.48	0.47	0.47	0.47	0.46	0.46	0.46	0.45
N	1.38	0.69	0.68	0.68	0.67	0.66	0.66	0.65	0.64	0.64	0.63	0.63	0.62	0.62	0.61	0.61	0.60	0.59	0.59	0.58	0.58	0.58	0.57	0.57	0.56	0.56	0.55	0.55	0.54	0.54	0.53	0.53	0.53	0.52	0.52	0.51	0.51	0.51	0.50	0.50	0.50	0.49	0.49	0.49	0.48	0.48	0.48	0.47	0.47	0.47	0.46	0.46
O	1.40	0.70	0.69	0.69	0.68	0.67	0.67	0.66	0.65	0.65	0.64	0.64	0.63	0.63	0.62	0.61	0.61	0.60	0.60	0.59	0.59	0.58	0.58	0.57	0.57	0.56	0.56	0.56	0.55	0.55	0.54	0.54	0.53	0.53	0.53	0.52	0.52	0.51	0.51	0.51	0.50	0.50	0.50	0.49	0.49	0.49	0.48	0.48	0.48	0.47	0.47	0.47
L	1.42	0.71	0.70	0.70	0.69	0.68	0.68	0.67	0.66	0.66	0.65	0.65	0.64	0.63	0.63	0.62	0.62	0.61	0.61	0.60	0.60	0.59	0.59	0.58	0.58	0.57	0.57	0.56	0.56	0.55	0.55	0.55	0.54	0.54	0.53	0.53	0.53	0.52	0.52	0.51	0.51	0.51	0.50	0.50	0.50	0.49	0.49	0.49	0.48	0.48	0.48	0.47
	1.44	0.72	0.71	0.71	0.70	0.69	0.69	0.68	0.67	0.67	0.66	0.65	0.65	0.64	0.64	0.63	0.63	0.62	0.62	0.61	0.61	0.60	0.60	0.59	0.59	0.58	0.58	0.57	0.57	0.56	0.56	0.55	0.55	0.55	0.54	0.54	0.53	0.53	0.53	0.52	0.52	0.51	0.51	0.51	0.50	0.50	0.50	0.49	0.49	0.49	0.48	0.48
	1.46	0.73	0.72	0.72	0.71	0.70	0.70	0.69	0.68	0.68	0.67	0.66	0.66	0.65	0.65	0.64	0.63	0.63	0.62	0.62	0.61	0.61	0.60	0.60	0.59	0.59	0.58	0.58	0.57	0.57	0.57	0.56	0.56	0.55	0.55	0.54	0.54	0.54	0.53	0.53	0.53	0.52	0.52	0.51	0.51	0.51	0.50	0.50	0.50	0.49	0.49	0.49
	1.48	0.74	0.73	0.73	0.72	0.71	0.70	0.70	0.69	0.69	0.68	0.67	0.67	0.66	0.65	0.65	0.64	0.64	0.63	0.63	0.62	0.62	0.61	0.61	0.60	0.60	0.59	0.59	0.58	0.58	0.57	0.57	0.56	0.56	0.56	0.55	0.55	0.54	0.54	0.54	0.53	0.53	0.52	0.52	0.52	0.51	0.51	0.51	0.50	0.50	0.50	0.49
	1.50	0.75	0.74	0.74	0.73	0.72	0.71	0.71	0.70	0.69	0.69	0.68	0.68	0.67	0.66	0.66	0.65	0.65	0.64	0.64	0.63	0.63	0.62	0.61	0.61	0.60	0.60	0.60	0.59	0.59	0.58	0.58	0.57	0.57	0.56	0.56	0.56	0.55	0.55	0.54	0.54	0.54	0.53	0.53	0.52	0.52	0.52	0.51	0.51	0.51	0.50	0.50
	1.52	0.76	0.75	0.75	0.74	0.73	0.72	0.72	0.71	0.70	0.70	0.69	0.68	0.68	0.67	0.67	0.66	0.66	0.65	0.64	0.64	0.63	0.63	0.62	0.62	0.61	0.61	0.60	0.60	0.59	0.59	0.58	0.58	0.58	0.57	0.57	0.56	0.56	0.55	0.55	0.55	0.54	0.54	0.54	0.53	0.53	0.52	0.52	0.52	0.51	0.51	0.51
	1.54	0.77	0.76	0.75	0.75	0.74	0.73	0.73	0.72	0.71	0.71	0.70	0.69	0.69	0.68	0.68	0.67	0.66	0.66	0.65	0.65	0.64	0.64	0.63	0.63	0.62	0.62	0.61	0.61	0.60	0.60	0.59	0.59	0.58	0.58	0.57	0.57	0.57	0.56	0.56	0.55	0.55	0.55	0.54	0.54	0.53	0.53	0.53	0.52	0.52	0.52	0.51
	1.56	0.78	0.77	0.76	0.76	0.75	0.74	0.74	0.73	0.72	0.72	0.71	0.70	0.70	0.69	0.68	0.68	0.67	0.67	0.66	0.66	0.65	0.64	0.64	0.63	0.63	0.62	0.62	0.61	0.61	0.60	0.60	0.60	0.59	0.59	0.58	0.58	0.57	0.57	0.57	0.56	0.56	0.55	0.55	0.55	0.54	0.54	0.53	0.53	0.53	0.52	0.52
	1.58	0.79	0.78	0.77	0.77	0.76	0.75	0.75	0.74	0.73	0.72	0.72	0.71	0.71	0.70	0.69	0.69	0.68	0.68	0.67	0.66	0.66	0.65	0.65	0.64	0.64	0.63	0.63	0.62	0.62	0.61	0.61	0.60	0.60	0.59	0.59	0.59	0.58	0.58	0.57	0.57	0.56	0.56	0.56	0.55	0.55	0.54	0.54	0.54	0.53	0.53	0.53
	1.60	0.80	0.79	0.78	0.78	0.77	0.76	0.75	0.75	0.74	0.73	0.73	0.72	0.71	0.71	0.70	0.70	0.69	0.68	0.68	0.67	0.67	0.66	0.66	0.65	0.65	0.64	0.63	0.63	0.63	0.62	0.62	0.61	0.61	0.60	0.60	0.59	0.59	0.58	0.58	0.58	0.57	0.57	0.56	0.56	0.56	0.55	0.55	0.54	0.54	0.54	0.53
	1.62	0.81	0.80	0.79	0.79	0.78	0.77	0.76	0.76	0.75	0.74	0.74	0.73	0.72	0.72	0.71	0.70	0.70	0.69	0.69	0.68	0.68	0.67	0.66	0.66	0.65	0.65	0.64	0.64	0.63	0.63	0.62	0.62	0.61	0.61	0.60	0.60	0.60	0.59	0.59	0.58	0.58	0.57	0.57	0.57	0.56	0.56	0.55	0.55	0.55	0.54	0.54
	1.64	0.82	0.81	0.80	0.80	0.79	0.78	0.77	0.77	0.76	0.75	0.75	0.74	0.73	0.73	0.72	0.71	0.71	0.70	0.69	0.69	0.68	0.68	0.67	0.67	0.66	0.66	0.65	0.65	0.64	0.64	0.63	0.63	0.62	0.62	0.61	0.61	0.60	0.60	0.59	0.59	0.59	0.58	0.58	0.57	0.57	0.57	0.56	0.56	0.55	0.55	0.55
	1.66	0.83	0.82	0.81	0.81	0.80	0.79	0.78	0.78	0.77	0.76	0.75	0.75	0.74	0.73	0.73	0.72	0.72	0.71	0.70	0.70	0.69	0.69	0.68	0.67	0.67	0.66	0.66	0.65	0.65	0.64	0.64	0.63	0.63	0.62	0.62	0.61	0.61	0.61	0.60	0.60	0.59	0.59	0.58	0.58	0.58	0.57	0.57	0.56	0.56	0.56	0.55
	1.68	0.84	0.83	0.82	0.82	0.81	0.80	0.79	0.79	0.78	0.77	0.76	0.76	0.75	0.74	0.74	0.73	0.72	0.72	0.71	0.71	0.70	0.69	0.69	0.68	0.68	0.67	0.67	0.66	0.66	0.65	0.65	0.64	0.64	0.63	0.63	0.62	0.62	0.61	0.61	0.60	0.60	0.60	0.59	0.59	0.58	0.58	0.58	0.57	0.57	0.56	0.56
	1.70	0.85	0.84	0.83	0.83	0.82	0.81	0.80	0.79	0.79	0.78	0.77	0.77	0.76	0.75	0.75	0.74	0.73	0.73	0.72	0.71	0.71	0.70	0.70	0.69	0.69	0.68	0.67	0.67	0.66	0.66	0.65	0.65	0.64	0.64	0.63	0.63	0.63	0.62	0.62	0.61	0.61	0.60	0.60	0.59	0.59	0.59	0.58	0.58	0.57	0.57	0.57
	1.72	0.86	0.85	0.84	0.83	0.83	0.82	0.81	0.80	0.80	0.79	0.78	0.77	0.77	0.76	0.75	0.75	0.74	0.74	0.73	0.72	0.72	0.71	0.70	0.70	0.69	0.69	0.68	0.68	0.67	0.67	0.66	0.66	0.65	0.65	0.64	0.64	0.63	0.63	0.62	0.62	0.61	0.61	0.61	0.60	0.60	0.59	0.59	0.59	0.58	0.58	0.57
	1.74	0.87	0.86	0.85	0.84	0.84	0.83	0.82	0.81	0.81	0.80	0.79	0.78	0.78	0.77	0.76	0.76	0.75	0.74	0.74	0.73	0.73	0.72	0.71	0.71	0.70	0.70	0.69	0.69	0.68	0.67	0.67	0.66	0.66	0.65	0.65	0.64	0.64	0.63	0.63	0.63	0.62	0.62	0.61	0.61	0.60	0.60	0.60	0.59	0.59	0.58	0.58
	1.76	0.88	0.87	0.86	0.85	0.85	0.84	0.83	0.82	0.81	0.81	0.80	0.79	0.79	0.78	0.77	0.77	0.76	0.75	0.75	0.74	0.73	0.73	0.72	0.72	0.71	0.70	0.70	0.69	0.69	0.68	0.68	0.67	0.67	0.66	0.66	0.65	0.65	0.64	0.64	0.63	0.63	0.62	0.62	0.62	0.61	0.61	0.60	0.60	0.59	0.59	0.59
	1.78	0.89	0.88	0.87	0.86	0.86	0.85	0.84	0.83	0.82	0.82	0.81	0.80	0.79	0.79	0.78	0.77	0.77	0.76	0.75	0.75	0.74	0.74	0.73	0.72	0.72	0.71	0.71	0.70	0.70	0.69	0.68	0.68	0.67	0.67	0.66	0.66	0.65	0.65	0.64	0.64	0.64	0.63	0.63	0.62	0.62	0.61	0.61	0.61	0.60	0.60	0.59
	1.80	0.90	0.89	0.88	0.87	0.87	0.86	0.85	0.84	0.83	0.83	0.82	0.81	0.80	0.80	0.79	0.78	0.78	0.77	0.76	0.76	0.75	0.74	0.74	0.73	0.73	0.72	0.71	0.71	0.70	0.70	0.69	0.69	0.68	0.68	0.67	0.67	0.66	0.66	0.65	0.65	0.64	0.64	0.63	0.63	0.63	0.62	0.62	0.61	0.61	0.60	0.60
	1.82	0.91	0.90	0.89	0.88	0.88	0.87	0.86	0.85	0.84	0.83	0.83	0.82	0.81	0.81	0.80	0.79	0.78	0.78	0.77	0.76	0.76	0.75	0.75	0.74	0.73	0.73	0.72	0.72	0.71	0.71	0.70	0.69	0.69	0.68	0.68	0.67	0.67	0.66	0.66	0.65	0.65	0.65	0.64	0.64	0.63	0.63	0.62	0.62	0.61	0.61	0.61
	1.84	0.92	0.91	0.90	0.89	0.88	0.88	0.87	0.86	0.85	0.84	0.84	0.83	0.82	0.81	0.81	0.80	0.79	0.79	0.78	0.77	0.77	0.76	0.75	0.75	0.74	0.74	0.73	0.72	0.72	0.71	0.71	0.70	0.70	0.69	0.69	0.68	0.68	0.67	0.67	0.66	0.66	0.65	0.65	0.64	0.64	0.63	0.63	0.63	0.62	0.62	0.61
	1.86	0.93	0.92	0.91	0.90	0.89	0.89	0.88	0.87	0.86	0.85	0.85	0.84	0.83	0.82	0.82	0.81	0.80	0.79	0.79	0.78	0.78	0.77	0.76	0.76	0.75	0.74	0.74	0.73	0.73	0.72	0.72	0.71	0.70	0.70	0.69	0.69	0.68	0.68	0.67	0.67	0.66	0.66	0.65	0.65	0.65	0.64	0.64	0.63	0.63	0.62	0.62
	1.88	0.94	0.93	0.92	0.91	0.90	0.90	0.89	0.88	0.87	0.86	0.85	0.85	0.84	0.83	0.82	0.82	0.81	0.80	0.80	0.79	0.78	0.78	0.77	0.76	0.76	0.75	0.75	0.74	0.73	0.73	0.72	0.72	0.71	0.71	0.70	0.70	0.69	0.69	0.68	0.68	0.67	0.67	0.66	0.66	0.65	0.65	0.64	0.64	0.64	0.63	0.63
	1.90	0.95	0.94	0.93	0.92	0.91	0.90	0.90	0.89	0.88	0.87	0.86	0.86	0.85	0.84	0.83	0.83	0.82	0.81	0.81	0.80	0.79	0.79	0.78	0.77	0.77	0.76	0.75	0.75	0.74	0.74	0.73	0.73	0.72	0.71	0.71	0.70	0.70	0.69	0.69	0.68	0.68	0.67	0.67	0.66	0.66	0.66	0.65	0.65	0.64	0.64	0.63
	1.92	0.96	0.95	0.94	0.93	0.92	0.91	0.91	0.90	0.89	0.88	0.87	0.86	0.86	0.85	0.84	0.83	0.83	0.82	0.81	0.81	0.80	0.79	0.79	0.78	0.77	0.77	0.76	0.76	0.75	0.74	0.74	0.73	0.73	0.72	0.72	0.71	0.71	0.70	0.70	0.69	0.69	0.68	0.68	0.67	0.67	0.66	0.66	0.65	0.65	0.64	0.64
	1.94	0.97	0.96	0.95	0.94	0.93	0.92	0.92	0.91	0.90	0.89	0.88	0.87	0.87	0.86	0.85	0.84	0.84	0.83	0.82	0.82	0.81	0.80	0.80	0.79	0.78	0.78	0.77	0.76	0.76	0.75	0.75	0.74	0.73	0.73	0.72	0.72	0.71	0.71	0.70	0.70	0.69	0.69	0.68	0.68	0.67	0.67	0.66	0.66	0.66	0.65	0.65
	1.96	0.98	0.97	0.96	0.95	0.94	0.93	0.92	0.92	0.91	0.90	0.89	0.88	0.88	0.87	0.86	0.85	0.84	0.84	0.83	0.82	0.82	0.81	0.80	0.80	0.79	0.78	0.78	0.77	0.77	0.76	0.75	0.75	0.74	0.74	0.73	0.73	0.72	0.72	0.71	0.71	0.70	0.70	0.69	0.69	0.68	0.68	0.67	0.67	0.66	0.66	0.65
	1.98	0.99	0.98	0.97	0.96	0.95	0.94	0.93	0.93	0.92	0.91	0.90	0.89	0.88	0.88	0.87	0.86	0.85	0.85	0.84	0.83	0.83	0.82	0.81	0.80	0.80	0.79	0.79	0.78	0.77	0.77	0.76	0.76	0.75	0.74	0.74	0.73	0.73	0.72	0.72	0.71	0.71	0.70	0.70	0.69	0.69	0.68	0.68	0.67	0.67	0.66	0.66
	2.00	1.00	0.99	0.98	0.97	0.96	0.95	0.94	0.93	0.93	0.92	0.91	0.90	0.89	0.88	0.88	0.87	0.86	0.85	0.85	0.84	0.83	0.83	0.82	0.81	0.81	0.80	0.79	0.79	0.78	0.78	0.77	0.76	0.76	0.75	0.75	0.74	0.74	0.73	0.72	0.72	0.71	0.71	0.70	0.70	0.69	0.69	0.68	0.68	0.68	0.67	0.67
	2.02	1.01	1.00	0.99	0.98	0.97	0.96	0.95	0.94	0.94	0.93	0.92	0.91	0.90	0.89	0.89	0.88	0.87	0.86	0.86	0.85	0.84	0.83	0.83	0.82	0.81	0.81	0.80	0.80	0.79	0.78	0.78	0.77	0.77	0.76	0.75	0.75	0.74	0.74	0.73	0.73	0.72	0.72	0.71	0.71	0.70	0.70	0.69	0.69	0.68	0.68	0.67
	2.04	1.02	1.01	1.00	0.99	0.98	0.97	0.96	0.95	0.94	0.94	0.93	0.92	0.91	0.90	0.89	0.89	0.88	0.87	0.86	0.86	0.85	0.84	0.84	0.83	0.82	0.82	0.81	0.80	0.80	0.79	0.78	0.78	0.77	0.77	0.76	0.76	0.75	0.74	0.74	0.73	0.73	0.72	0.72	0.71	0.71	0.70	0.70	0.69	0.69	0.68	0.68
	2.06	1.03	1.02	1.01	1.00	0.99	0.98	0.97	0.96	0.95	0.94	0.94	0.93	0.92	0.91	0.90	0.90	0.89	0.88	0.87	0.87	0.86	0.85	0.84	0.84	0.83	0.82	0.82	0.81	0.80	0.80	0.79	0.79	0.78	0.77	0.77	0.76	0.76	0.75	0.75	0.74	0.74	0.73	0.73	0.72	0.72	0.71	0.71	0.70	0.70	0.69	0.69
	2.08	1.04	1.03	1.02	1.01	1.00	0.99	0.98	0.97	0.96	0.95	0.95	0.94	0.93	0.92	0.91	0.90	0.90	0.89	0.88	0.87	0.87	0.86	0.85	0.85	0.84	0.83	0.83	0.82	0.81	0.81	0.80	0.79	0.79	0.78	0.78	0.77	0.76	0.76	0.75	0.75	0.74	0.74	0.73	0.73	0.72	0.72	0.71	0.71	0.70	0.70	0.69
	2.10	1.05	1.04	1.03	1.02	1.01	1.00	0.99	0.98	0.97	0.96	0.95	0.95	0.94	0.93	0.92	0.91	0.91	0.90	0.89	0.88	0.88	0.87	0.86	0.85	0.85	0.84	0.83	0.83	0.82	0.81	0.81	0.80	0.80	0.79	0.78	0.78	0.77	0.77	0.76	0.76	0.75	0.74	0.74	0.73	0.73	0.72	0.72	0.71	0.71	0.70	0.70
	2.12	1.06	1.05	1.04	1.03	1.02	1.01	1.00	0.99	0.98	0.97	0.96	0.95	0.95	0.94	0.93	0.92	0.91	0.91	0.90	0.89	0.88	0.88	0.87	0.86	0.85	0.85	0.84	0.83	0.83	0.82	0.82	0.81	0.80	0.80	0.79	0.79	0.78	0.77	0.77	0.76	0.76	0.75	0.75	0.74	0.74	0.73	0.73	0.72	0.72	0.71	0.71
	2.14	1.07	1.06	1.05	1.04	1.03	1.02	1.01	1.00	0.99	0.98	0.97	0.96	0.96	0.95	0.94	0.93	0.92	0.91	0.91	0.90	0.89	0.88	0.88	0.87	0.86	0.86	0.85	0.84	0.84	0.83	0.82	0.82	0.81	0.80	0.80	0.79	0.79	0.78	0.78	0.77	0.76	0.76	0.75	0.75	0.74	0.74	0.73	0.73	0.72	0.72	0.71
	2.16	1.08	1.07	1.06	1.05	1.04	1.03	1.02	1.01	1.00	0.99	0.98	0.97	0.96	0.96	0.95	0.94	0.93	0.92	0.92	0.91	0.90	0.89	0.89	0.88	0.87	0.86	0.86	0.85	0.84	0.84	0.83	0.82	0.82	0.81	0.81	0.80	0.79	0.79	0.78	0.78	0.77	0.77	0.76	0.76	0.75	0.74	0.74	0.73	0.73	0.72	0.72
	2.18	1.09	1.08	1.07	1.06	1.05	1.04	1.03	1.02	1.01	1.00	0.99	0.98	0.97	0.96	0.96	0.95	0.94	0.93	0.92	0.92	0.91	0.90	0.89	0.89	0.88	0.87	0.87	0.86	0.85	0.84	0.84	0.83	0.83	0.82	0.81	0.81	0.80	0.80	0.79	0.78	0.78	0.77	0.77	0.76	0.76	0.75	0.75	0.74	0.74	0.73	0.73
	2.20	1.10	1.09	1.08	1.07	1.06	1.05	1.04	1.03	1.02	1.01	1.00	0.99	0.98	0.97	0.96	0.96	0.95	0.94	0.93	0.92	0.92	0.91	0.90	0.89	0.89	0.88	0.87	0.87	0.86	0.85	0.85	0.84	0.83	0.83	0.82	0.81	0.81	0.80	0.80	0.79	0.79	0.78	0.77	0.77	0.76	0.76	0.75	0.75	0.74	0.74	0.73

Figure 9: Suggested cost conversion table for the state of São Paulo in 2010. Per-liter regular gasoline prices are indicated across columns and per-liter ethanol prices are indicated down rows. Cells contain the p_e/p_g ratio. The white "diagonal" indicates the approximate price parity ratio.