



STATISTICAL MODELLING OF FUEL DEMAND DYNAMICS PRICE ELASTICITIES

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Abstract

This study analyzed fuel-demand dynamics across Brazilian states, combining spatial dependence, temporal effects, economic determinants, and price elasticities in a single panel econometric model. The data analysed included a balanced sample of 27 Brazilian states and 432 state-year observations, spanning 16 years from 2006 to 2021, and were analysed with descriptive statistics, correlation analysis, multicollinearity diagnostics, generalized least squares with alternative structures of serial correlation, and spatial dependence measures. The results indicated that gasoline demand is negatively related to current and one-year-lagged gasoline prices and the two-year-lagged gasoline prices, as evidenced by the elasticities -0.994 , -0.366 , and -0.548 , respectively. Positive cross-price effects of 0.669 , 0.311 , and 0.184 were observed for ethanol, which is consistent with substitution between gasoline and ethanol. Gasoline demand was found to be positively correlated with GDP per capita and negatively correlated with both alternative motorization and spatially weighted motorization, while conventional motorization was found to show positive results. The spatial analysis showed that gasoline demand at the state level had significant long-run clustering, with Moran's $I=0.409$ and permutation $p=0.005$. However, the long-run clustering is insignificant after multivariable adjustment. Overall, the results confirm that Brazilian gasoline demand is affected by both the price and the combined effects of the economic, temporal and regional factors, justifying the use of panel and spatial methods in transport-energy planning, gasoline taxation and alternative-fuel policy.

Keywords: Fuel demand; Price elasticity; Panel data; Spatial dependence; Brazil

1. Introduction

Fuel demand is a core factor in transportation planning, energy security, taxation, and environmental policy since any changes in fuel consumption impact government revenues, household transport costs, emissions and national energy strategies. The need for fossil fuel reduction, developing energy efficiency and enhancing the speed of energy transition in the transport sector has been a constant focus in international energy assessments [1]. This is particularly relevant in Brazil, where the transport-energy system has both traditional petroleum-based fuels and a well-developed biofuel sector. This trend of using ethanol or biofuels has reinforced the relationship between the growth of transportation demand, diversification of energy supplies, and economic transformation [2,3]. Biofuels also feature prominently in national planning processes for energy security and long-term stability of the fuel market [4,5].

The price elasticity gives an important statistical indicator of the responsiveness of fuel consumption to variations in fuel prices. The own-price elasticity is the percentage change in gasoline demand caused by a one percent change in gasoline prices, and the cross-price elasticity is the percentage change in gasoline demand caused by a one percent change in the price of an alternative fuel, like ethanol. The evidence from Brazil shows that the pricing dynamics, biofuel policies, and alternative-fuel technologies (AFT) availability affect fuel demand [6,7]. The price relationships between crude oil, gasoline and ethanol are also interdependent, with a price change in one market impacting the other markets' pricing behaviour [8]. Regional variation in ethanol prices also indicates regional variations in consumer substitution between gas and ethanol [9]. Furthermore, the elasticity can vary over time, especially if consumers are exposed to frequent price fluctuations or significant policy measures [10,11]. Fuel taxation continues to play a key role in both demand management and transport decarbonisation, provided that consumers are responsive to price changes [12].

Prices, but also the general economic situation, affect how much fuel is used. GDP can lead to an increase in mobility, vehicle use and travel demand, whereas structural changes in vehicle ownership and motorization can lead to structural changes in fuel consumption. Therefore, using an income, economic activity and motorisation fuel demand estimation approach may lead to imperfect elasticity estimates. The nature of these connections may also vary significantly between regions due to the spatial inequality of economic development and energy use [13]. Panel-data methods are thus helpful since they can analyze both cross-sectional variation and time variation, accounting for unobserved regional variation.

Spatial dependence in fuel demand patterns may be present due to the fact that neighboring states may have shared transport corridors, economic links, market conditions, infrastructure, and other factors that lead to similar consumer behavior. There also be a regional correlation between fuel prices and energy use, which is not captured by the geographic dimension. The geographic dimension may therefore be linked to fuel prices and energy use regionally, too. When economic and/or energy indicators exhibit spatial clustering or 'spillover effects' the use of spatial analysis is especially useful [13]. The use of spatial relationships can then enhance the statistical inference over standard non-spatial regression. While fuel-price elasticity, ethanol substitution, biofuel policy, taxation and regional energy behavior have been individually explored in separate studies, few studies combine current and lagged responses to fuel prices, economic determinants, panel data heterogeneity and spatial dependence in a single modelling framework. This is particularly important for Brazil, as it is a regionally diverse country with a unique market for gasoline ethanol.

The purpose of this study is thus to estimate the Price Elasticity of Gasoline, analyse the current and lagged price effects, analyse the effect of the price of ethanol and other fuels, analyse the influence of GDP per capita and motorization and compare the performance of different statistical models that explain the dynamics of fuel demand in Brazil, taking into account the existence of spatial dependence between the States.

2. Materials and Methods

2.1 Research Design

A quantitative longitudinal study with state-level panel data was used to analyze the dynamics of gasoline demand in Brazil. The analytical approach involved econometric modelling of the price panels, along with spatial analysis, in order to estimate the elasticities of fuel prices, the economic effects and their geographic dependence over time.

2.2 Data Source and Panel Structure

The Brazilian fuel-demand data were used for analysis [14]. The dataset consisted of 432 observations from 27 Brazilian states over the years 2006-2021, with 16 yearly observations per state. i and t indicated the state and year, respectively, for each. The spatial relationship structure among neighboring states was obtained from the adjacency.csv file. Complete observations were available for the variables analyzed.

2.3 Study Variables

The dependent variable is the natural log of per-capita gasoline demand ($\ln_Sg_pc$). The current price ($\ln_Pg$), first lag ($\ln_l1_Pg$), and second lag ($\ln_l2_Pg$) of gasoline were considered. To account for the cross-price and substitution effects of ethanol, $\ln_Pe$, $\ln_l1_Pe$ and $\ln_l2_Pe$ were used. This was measured by GDP per capita ($\ln_gdp_pc$) and by two factors related to motorization: $\ln_Mi_e$ and $\ln_Mi_c$. Spatial effects were captured in the form of a spatially weighted motorization variable, $\ln_W_adj_Mi_e$, based on the relationships between nearby states.

2.4 Data Preparation and Descriptive Analysis

The data were checked for completeness, for duplicated state-year observations that were duplicated, for missing observations, and for consistency of the panel structure. All the study variables were subjected to descriptive statistics such as mean, standard deviation, minimum, and maximum. Analyzing the temporal variation in gasoline consumption, fuel prices, GDP per capita and motorization also helped to assess the change in these measures among the states and years.

2.5 Correlation and Multicollinearity Assessment

Relationships between gasoline demand and gasoline prices, ethanol prices, motorization variables and GDP per capita

were evaluated using Pearson correlation analysis. To determine whether there is multicollinearity among the variables for regression estimation, variance inflation factors were investigated.

2.6 Panel Econometric Modelling

Generalized least squares was the main estimation method employed, since state-level observations were repeated, which may lead to heteroskedasticity and serial correlation. Three models were explored; heteroskedastic panels with independent errors, a common AR(1) error structure, and panel-specific AR(1) errors in accordance with the analytical specification provided. A 2020 year indicator and a regional indicator were added to adjust for geographic heterogeneity and exceptional temporal effects. The general model was given as:

$$\ln S_{it} = \beta_0 + \beta_1 \ln P_{g,it} + \beta_2 \ln P_{g,i,t-1} + \beta_3 \ln P_{g,i,t-2} + \beta_4 \ln P_{e,it} + \beta_5 \ln GDP_{it} + \beta_6 M_{it} + \beta_7 WM_{it} + \varepsilon_{it}.$$

2.7 Price Elasticity and Economic Effects

The contemporaneous own-price elasticity of gasoline demand was interpreted as the coefficient of $\ln_Pg$, given that the variables were in logarithms. The gasoline-price variables included a lag to reflect delayed responses, and the ethanol-price variables represented the cross-price effect of ethanol and gasoline prices. The coefficient of $\ln_gdp_pc$ reflected economic conditions and gasoline demand; motorization variables reflected structural differences in gasoline use resulting from vehicles.

2.8 Spatial Dependence Analysis

The adjacency structure (in the file adjacency.csv) was used to examine spatial relationships. In a neighborhood state space model, the spatially weighted variable $\ln_W_adj_Mi_e$ was used to account for neighboring state influences. Spatial autocorrelation in gasoline demand was assessed and model residuals were tested using Global Moran's I. Robustness extensions were considered in the case of residual spatial dependence: spatial lag specification, spatial error specification, and the Spatial Durbin specification.

2.9 Model Diagnostics and Evaluation

The tests of the model's adequacy were performed for heteroskedasticity, serial correlation, multicollinearity and spatial autocorrelation. Coefficient stability, statistical significance, log-likelihood based, AIC, BIC, RMSE and MAE (where appropriate) were used to compare alternative specifications. The concluding interpretation highlighted the statistical significance of the estimated price and income effects as well as the economic size of the estimated motorization and spatial effects.

3. Results

3.1 Descriptive Characteristics of the Panel Dataset

The balanced panel contained 432 observations representing 27 Brazilian states over 2006–2021. The balanced panel was composed of 432 observations from 27 Brazilian states between 2006 and 2021. The key study variables are summarized in Table 1. The demand for gasoline per capita was considerably different from year to year and state to state, as evidenced by the large range of values from -3.005 to -0.876 for mean log per-capita gasoline demand. The mean log gasoline and ethanol prices were 0.780 and 0.512 , respectively. The level of economic heterogeneity was large with respect to GDP per capita and other motorization variables were also quite diverse across the panel. The mean for the spatially weighted motorization term was 0.160 ; this demonstrated the need to include neighboring-state conditions in subsequent analysis. The gasoline demand and GDP dispersion, as well as the motorization variables, are sufficient to provide a sufficient range of values within each panel to estimate the price, economic, and spatial effects.

Table 1. Descriptive statistics of the principal study variables

Variable	Mean	SD	Minimum	Median	Maximum
$\ln_Sg_pc$	-1.809	0.415	-3.005	-1.829	-0.876
$\ln_Pg$	0.780	0.101	0.507	0.761	1.082
$\ln_Pe$	0.512	0.129	0.138	0.506	0.895
$\ln_gdp_pc$	2.528	0.471	1.453	2.461	3.818
$\ln_Mi_e$	-4.988	2.831	-10.623	-4.916	1.200
$\ln_Mi_c$	-1.447	0.502	-2.988	-1.394	-0.565
$\ln_W_adj_Mi_e$	0.160	0.626	-0.993	0.005	1.546

3.2 Temporal and Regional Fuel-Demand Patterns

Average log per-capita gasoline demand increased steadily from -2.243 in 2006 to approximately -1.578 in 2014, followed by a period of relative stabilization and moderate fluctuations. A decrease was seen in 2020 with the annual mean dropping to -1.736 and then seeing a recovery in 2021 to -1.686 . Variations were also seen between regions. The Southeast region had the lowest average gasoline demand, while the Center-West and South regions had the next lowest gasoline demand. Figure 1 illustrates that the long-term increase in gasoline demand occurred across all broad regions, although the absolute levels and trajectories differed. The temporary decline around 2020 was visible across several regional series, supporting the inclusion of the 2020 indicator in the regression specification.

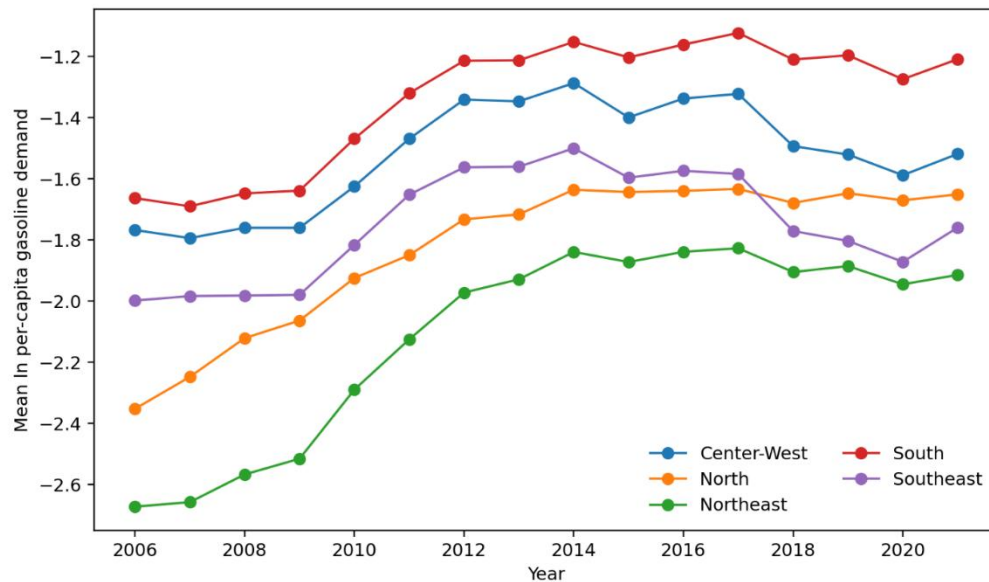


Figure 1. Temporal and regional trends in log per-capita gasoline demand, 2006–2021

3.3 Correlation and Multicollinearity Results

The main bivariate correlations and variance inflation factors of the explanatory variables are provided in Table 2. The gasoline price ($r = -0.450$) and the GDP per capita ($r = 0.732$) and conventional motorization ($r = 0.851$) had negative and positive relationships with gasoline demand, respectively. There was a moderate correlation between the price of ethanol and gasoline ($r = 0.510$). Most of the regressors had low correlations with the spatially weighted motorization measure.

Table 2. Correlations with gasoline demand and variance inflation factors

Variable	Correlation with $\ln_Sg_pc$	VIF
$\ln_Pg$	-0.450	5.32
$\ln_l1_Pg$	—	10.13
$\ln_l2_Pg$	—	6.86
$\ln_Pe$	-0.098	5.36
$\ln_l1_Pe$	—	7.21
$\ln_l2_Pe$	—	4.68
$\ln_gdp_pc$	0.732	2.74
$\ln_Mi_e$	0.503	2.83
$\ln_Mi_c$	0.851	4.34
$\ln_W_adj_Mi_e$	-0.163	1.08

The first gasoline-price lag produced the largest VIF (10.13), indicating expected collinearity among temporally adjacent price measures. Nevertheless, the remaining VIF values were generally moderate, and the lagged terms were retained because they were theoretically necessary for identifying delayed price responses.

3.4 Gasoline Price Elasticity Estimates

Elasticities of gasoline prices obtained from the common AR(1) panel specification were always negative and significant at the 5% level. The gasoline-price coefficient was -0.994 ($p < 0.001$), meaning that a 1% increase in the gasoline price was estimated to be associated with a 0.99% decrease in the gasoline demand per capita, for all other factors held constant.

The one-period lag elasticity was -0.366 ($p < 0.001$), while the two-period lag coefficient was -0.548 ($p < 0.001$). All three gasoline-price effects were negative and none of their confidence intervals intersected with zero as shown in Figure 2. The total coefficient of the current and two lagged prices was about -1.91 , which implies that the demand response did not stop after the initial price change.

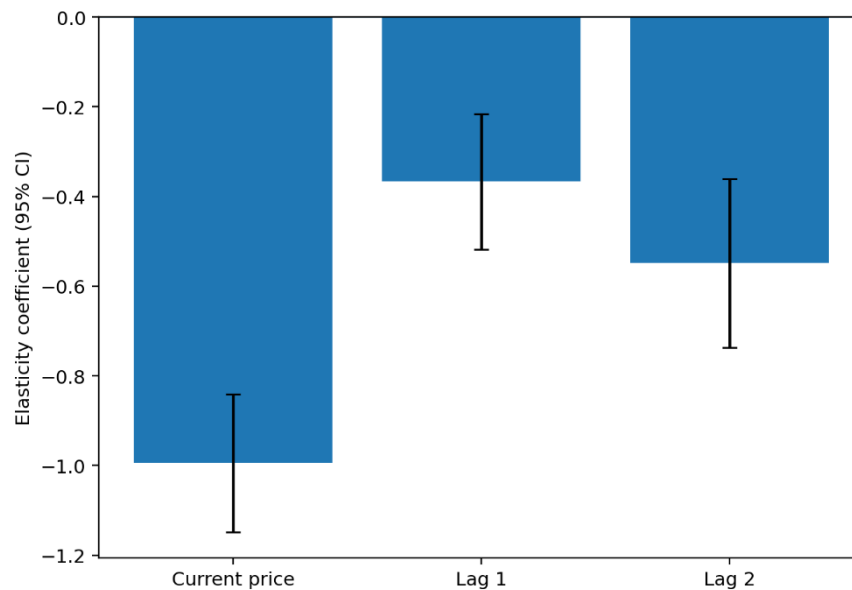


Figure 2. Estimated contemporaneous and lagged gasoline-price elasticities with 95% confidence intervals

3.5 Economic and Motorization Effects on Fuel Demand

Economic and structural factors were significant even when current and lagged fuel prices were controlled. Table 3 shows the major coefficients of AR(1)-adjusted specification. The coefficient of GDP per capita was 0.144 ($p < 0.001$), which means that better economic conditions were linked to higher demand for gasoline per capita. The largest positive structural impact was on conventional motorization ($\ln_Mi_c$) but the $\ln_Mi_e$ and the spatially weighted motorization term were negative.

Table 3. Selected estimates from the AR(1)-adjusted panel model

Predictor	Coefficient	SE	p-value
$\ln_gdp_pc$	0.144	0.029	<0.001
$\ln_Mi_c$	0.649	0.030	<0.001
$\ln_Mi_e$	-0.036	0.004	<0.001
$\ln_W_adj_Mi_e$	-0.095	0.012	<0.001
$\ln_Pg$	-0.994	0.078	<0.001
$\ln_l1_Pg$	-0.366	0.077	<0.001
$\ln_l2_Pg$	-0.548	0.096	<0.001
$\ln_Pe$	0.669	0.058	<0.001
$\ln_l1_Pe$	0.311	0.055	<0.001
$\ln_l2_Pe$	0.184	0.052	<0.001

These results indicate that economic growth and conventional motorization increased gasoline demand, whereas the alternative motorization and neighboring-state motorization terms were associated with lower demand after controlling for other determinants.

3.6 Cross-Price Effects of Ethanol

The coefficients of the price of ethanol were estimated to be positive in the three time periods. The contemporaneous cross-price elasticity was 0.669 ($p < 0.001$), the one-period lag was 0.311 ($p < 0.001$), and the two-period lag was 0.184 ($p < 0.001$). Positive coefficients also suggest that a rise in the price of ethanol was linked with a rise in gasoline demand, which is expected in substitution between the two fuels. Figure 3 shows that the effect of substitution was the highest in the current period and decreased in the lags. The overall reaction of ethanol prices was about 1.16 , indicating that the

relative fuel-price conditions had short- and long-term effects on gasoline consumption.

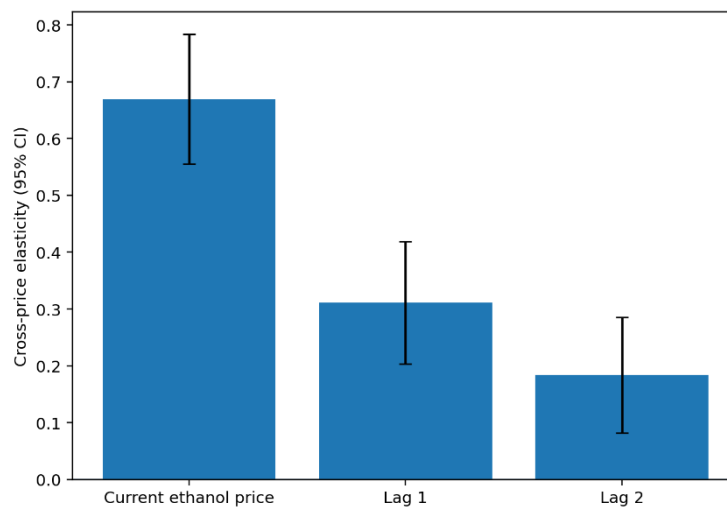


Figure 3. Estimated contemporaneous and lagged ethanol cross-price elasticities with 95% confidence intervals

3.7 Spatial Dependence and Model Comparison

There were important geographical patterns found in average state-level gasoline demand from the spatial analysis. The Moran's I for mean state demand was positive across the entire study period (0.409) and was significant with a $p=0.005$ based on permutations. The 2021 value was smaller and not statistically significant, however ($I=0.226$, $p=0.136$). The conventional multivariable model accounted for the majority of the observed spatial clustering as the residual Moran's I from this model was -0.059 ($p=0.692$).

Table 4. Spatial diagnostics and comparative model performance

Indicator / Model	Estimate
Moran's I, long-run state mean	0.409
Permutation p-value	0.005
Moran's I, 2021	0.226
2021 permutation p-value	0.136
Spatial-lag coefficient	0.013
Spatial-lag p-value	0.887
Residual Moran's I, spatial model	-0.063
Residual Moran p-value	0.706
Conventional model RMSE	0.101
Common AR(1) RMSE	0.102
Spatial-augmented model RMSE	0.101
Conventional model R^2	0.941
Common AR(1) R^2	0.940
Spatial-augmented model R^2	0.941

The explicit spatial-lag coefficient was not statistically significant once the full covariate structure was introduced. Model fit was therefore very similar across conventional and spatially augmented specifications, while the AR(1) model mainly improved the treatment of serial dependence rather than materially changing predictive accuracy.

3.8 Spatial Distribution of Fuel Demand

The Moran scatterplot in Figure 4 further illustrates the spatial distribution of long-run state-average gasoline demand. States in the upper-right quadrant had gasoline demand that was above average with surrounding states also above average, while states in the lower-left quadrant were low-demand spatial clusters.

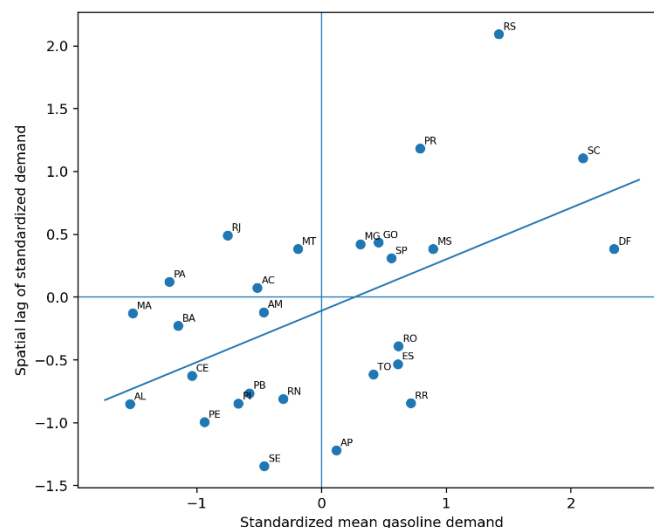


Figure 4. Moran scatterplot of long-run average gasoline demand across Brazilian states

A positive overall slope as shown in Figure 4 is in line with the Moran I statistic in Table 4. Nonetheless, the fact that the residual spatial dependence is much less than when multivariate-adjusted means that the major geographic trend could be mostly attributed to regional economic factors, fuel prices, motorization features, and corresponding structural variations instead of a strong independent spatial-lag effect.

4. Discussion

Fuel prices, economic conditions, motorization, temporal dynamics and spatial relationships were found as factors relevant in gasoline demand in different Brazilian states. The contemporaneous and lagged effects of gasoline were consistently negative, whereas the cross-price coefficients of ethanol were positive, reflecting substitution between the two fuels. Both gasoline demand and GDP per capita were positively correlated, while conventional motorization was negatively correlated, and spatial analysis showed strong long-run clustering among neighboring states. The results highlight the need to account for temporal and regional heterogeneities when modelling transport-fuel consumption [15,16].

The negative own-price elasticity indicates that when gasoline prices go up, demand for gasoline goes down. The contemporaneous elasticity was greater than the individual lagged elasticities but there was lagged elasticity suggesting that consumers take time to adjust to the initial price change. Delayed responses can be attributed to slow changes in travel behavior, vehicle usage, or fuel choice. Previously, it has been demonstrated that road-fuel elasticities can change over time and across market and economic conditions [17,18]. Current prices may also be compared with earlier prices, which affect the response to current prices [19].

Positive ethanol-price coefficients suggest a substitution relationship between ethanol and gasoline, as higher ethanol prices lead to greater gasoline demand. This is especially true in Brazil, where flex-fuel vehicles enable consumers to use gasoline or ethanol based on the price differential. Data from Brazilian capitals also show the effect of ethanol-gasoline price ratio on consumer fuel selection and regional market conditions [20]. The result thus reinforces the notion that the gasoline market should not be considered on its own terms.

Overall, gasoline demand exhibited positive association with GDP per capita, reflecting that increased economic activity leads to increased mobility and transport-energy use. The availability of vehicles had a large positive impact as well, typical of conventional motorization. This result is aligned with international evidence that indicates that income, vehicle ownership and other transport activity are all factors that influence fuel demand [15]. In Brazil, research has also highlighted the importance of structural demand trends, in addition to fuel prices [21].

The spatial autocorrelation is fairly high, as indicated by the high value of Moran's I, suggesting spatial clustering in gasoline-demand patterns in neighbouring Brazilian states. This clustering can be caused by common transport corridors, regional economic integration, similar vehicle-use patterns, and a common fuel market. Adjustment of the weak residual spatial dependence, however, suggests that much of the geographical pattern was accounted for by the observed economic, regional and motorization variables.

The negative gasoline-price response reported in this study is in line with previous Brazilian panel data-based findings that show that gasoline demand is price sensitive [16]. The result is also consistent with international research that shows that road-fuel elasticities have been stable but varied over time and across countries [17]. The cross-price elasticity of ethanol is positive, which reflects its unique market structure in Brazil, where the relative price of fuels influences consumption patterns [20].

The results suggest that the adjustment period in fuel-pricing and taxation policies should not be ignored when assessing their effectiveness. Relative-price effects also change gasoline demand as a result of policies that support ethanol and other alternative fuels. Therefore, broader transport approaches should integrate pricing measures with alternative fuel facilities and regional planning [22]. Finally, long-term transport policy should account for changing mobility demand and overall transport-system evolution [23,24].

The panel modelling and spatial analysis approach was able to give a more comprehensive picture of the gasoline-demand

dynamics than either cross-sectional or time-series analysis alone. The log-linear format allowed for a direct interpretation of elasticity, and the lagged price terms allowed for delayed behavioural responses. The use of spatial diagnostics also allowed for exclusion of geographic clusters that could be attributable to observed covariates.

Future research should include more comprehensive socioeconomic variables, household travel data, and dynamic spatial panel models. One potential extension would be to explore structural breaks, policy changes, and varying levels of fuel price responsiveness over different periods of the economy. The framework could be extended to cover forecasting and alternative fuel transition, which would increase its relevance for transport and energy planning.

5. Conclusion

This study analyzed the dynamics of gasoline demand in 27 Brazilian states between 2006 and 2021, using a panel econometric model that considers price elasticities, economic determinants, time-invariant effects and spatial dependence. Results indicated that gasoline demand was sensitive to both the current and lagged gasoline price, supporting the notion that price changes have both an immediate and delayed effect on gasoline demand. Ethanol prices, on the other hand, showed positive cross-price effects, consistent with a substitution between gasoline and ethanol in the Brazilian fuel market. Gasoline demand was positively related to GDP per capita and conventional motorization, reflecting their role in influencing transport-energy demand. Spatial analysis also showed that state-level gasoline demand exhibited strong long-term spatial clustering, but much of this spatial dependence was incorporated in the set of observed economic, regional, and motorization factors. Results show that gasoline demand is not fully determined by current gasoline prices; lagged gasoline prices and interactions among regions also play a significant role in explaining the demand for gasoline. Methodologically, panel generalized least squares and lagged price variables with spatial diagnostics were a solid approach to capture heterogeneous and persistent demand responses. The results are relevant for fuel-pricing policies and for taxation, ethanol policy, regional transport planning, and long-term energy-demand forecasting in Brazil.

References

1. IEA P. World energy outlook 2022. Paris, France: International Energy Agency (IEA) [Internet]. 2022 [cited 2026 Sep 23];17. Available from: https://uploads.iasscore.in/pdf/CAA_WEEK-2_NOVEMBER--2022.pdf
2. da Costa MG, Gonçalves DNS, Marcio de Almeida D. From commodities to high-value exports: biofuels as a catalyst for Brazil's energy transition and economic transformation. *Sustainable Energy Technologies and Assessments*. 2025;81:104416.
3. Neves Filho AO, de Oliveira AS, Marques RF de PV, Alcantra E. Bioenergy in Brazil: the current scenario of the energy matrix and the biofuel production. *Revista Ibero-Americana de Ciências Ambientais*. 2021;12(5):478–91.
4. Coordination E, da Costa AO, Henriques RM, Araujo RB, Graça BSL, Perecin D, et al. TECHNICAL NOTE EPE/DPG/SDB/2024/09 [Internet]. 2024 [cited 2026 Sep 23]. Available from: https://www.epe.gov.br/sites-en/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-191/topico-208/NT-EPE-DPG-SDB-2024-09_Scenarios%20of%20ethanol%20supply%20and%20Otto%20cycle%20demand%202025-2034.pdf
5. de Oliveira Gonçalves F, Firmani Perna R, Savioli Lopes E, Plazas Tovar L, Maciel Filho R, Savioli Lopes M. Strategies to ensure fuel security in Brazil considering a forecast of ethanol production. *Biomass*. 2023;3(1):1–17.
6. Brito TLF, Islam T, Mouette D, Meade N, dos Santos EM. Fuel price elasticities of market shares of alternative fuel vehicles in Brazil. *Transportation Research Part D: Transport and Environment*. 2020;89:102643.
7. Cardoso LC, Bittencourt MV, Litt WH, Irwin EG. Biofuels policies and fuel demand elasticities in Brazil. *Energy policy*. 2019;128:296–305.
8. Hallack LN, Kaufmann R, Szklo AS. Price discovery in Brazil: causal relations among prices for crude oil, ethanol, and gasoline. *Energy Sources, Part B: Economics, Planning, and Policy*. 2020 Apr 2;15(4):230–51. doi:10.1080/15567249.2020.1780346
9. Hoeckel PH, Alvim A. The ethanol market in Brazil: price behavior and regional differences. *Biofuels Bioprod Bioref*. 2023 Jul;17(4):884–903. doi:10.1002/bbb.2479
10. Eleyan MIA, Çatik AN, Balçılar M, Ballı E. Are long-run income and price elasticities of oil demand time-varying? New evidence from BRICS countries. *Energy*. 2021;229:120710.
11. Ghoddusi H, Morovati M, Rafizadeh N. Dynamics of fuel demand elasticity: Evidence from Iranian subsidy reforms. *Energy Economics*. 2022;110:106009.
12. Bardazzi R, Paziencia MG. Decarbonising transport: Can we rely on fuel taxes? *Transportation Research Part D: Transport and Environment*. 2024;136:104391.
13. Chica-Olmo J, Sari-Hassoun S, Moya-Fernandez P. Spatial relationship between economic growth and renewable energy consumption in 26 European countries. *Energy Economics*. 2020;92:104962.
14. Prolo S. Panel dataset on Brazilian fuel demand [Internet]. Vol. 1. 2024 Oct 7;1. doi:10.17632/hzpwbp7j22.1
15. Liddle B, Huntington H. 'On the Road Again': A 118 country panel analysis of gasoline and diesel demand. *Transportation Research Part A: Policy and Practice*. 2020;142:151–67.
16. Uchôa F, Jesus CS de, Cardoso LCB. Fuel demand elasticities in Brazil: a panel data analysis with instrumental variables. *International Journal of Energy Economics and Policy*. 2020;10(2):450–7.
17. Liddle B, Hasanov FJ, Parker S. Your mileage may vary: Have road-fuel demand elasticities changed over time in middle-income countries? *Transportation Research Part A: Policy and Practice*. 2022;165:38–53.
18. Mikayilov JI, Mukhtarov S, Mammadov J. Gasoline demand elasticities at the backdrop of lower oil prices: Fuel-subsidizing country case. *Energies*. 2020;13(24):6752.
19. Levin L, Lewis MS, Wolak FA. Reference dependence in the demand for gasoline. *Journal of Economic Behavior & Volume-12 | Issue-01 | January 2026*

- Organization. 2022;197:561–78.
20. Quintino DD, Burnquist HL, Ferreira P. Relative prices of ethanol-gasoline in the major Brazilian capitals: an analysis to support public policies. *Energies*. 2022;15(13):4795.
 21. Rodrigues N, Losekann L, Silveira Filho G. Demand of automotive fuels in Brazil: Underlying energy demand trend and asymmetric price response. *Energy Economics*. 2018;74:644–55.
 22. Teixeira ACR, Machado PG, Borges RR, Mouette D. Public policies to implement alternative fuels in the road transport sector. *Transport Policy*. 2020;99:345–61.
 23. Forum IT. ITF Research Reports Liberalisation of Air Transport [Internet]. OECD Publishing; 2019 [cited 2026 Sep 23]. Available from: [https://books.google.com/books?hl=en&lr=&id=AQ2iDwAAQBAJ&oi=fnd&pg=PP1&dq=International+Transport+Forum.+\(2019\).+ITF+transport+outlook+2019.+OECD+Publishing.&ots=9BZ0M4J1gj&sig=lig3AXtdt0Atag6eeKgTgSt39CU](https://books.google.com/books?hl=en&lr=&id=AQ2iDwAAQBAJ&oi=fnd&pg=PP1&dq=International+Transport+Forum.+(2019).+ITF+transport+outlook+2019.+OECD+Publishing.&ots=9BZ0M4J1gj&sig=lig3AXtdt0Atag6eeKgTgSt39CU)
 24. Forum IT. ITF transport outlook 2021 [Internet]. OECD Publishing; 2021 [cited 2026 Sep 23]. Available from: [https://books.google.com/books?hl=en&lr=&id=xdEwEAAAQBAJ&oi=fnd&pg=PA3&dq=International+Transport+Forum.+\(2021\).+ITF+transport+outlook+2021.+OECD+Publishing.&ots=Iqxe0HxqVR&sig=8DcjeA1PqyqmpKZNS50lCiGA5nA](https://books.google.com/books?hl=en&lr=&id=xdEwEAAAQBAJ&oi=fnd&pg=PA3&dq=International+Transport+Forum.+(2021).+ITF+transport+outlook+2021.+OECD+Publishing.&ots=Iqxe0HxqVR&sig=8DcjeA1PqyqmpKZNS50lCiGA5nA)

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