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Biofuel Substitution and Carbon Dioxide Emission: Implication for Biofuel Mandate

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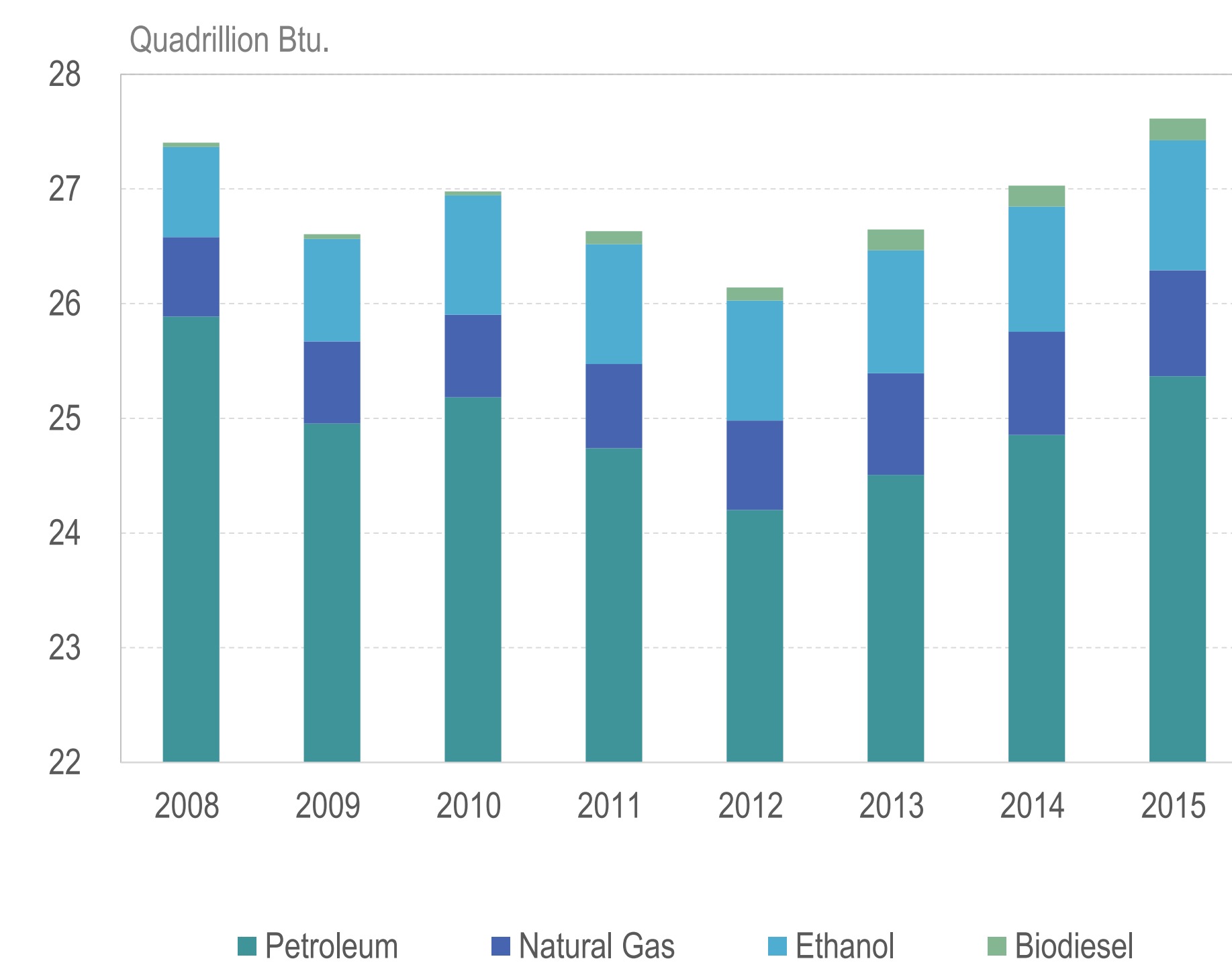
Introduction

- In the United States, biofuels such as ethanol and biodiesel are primary renewable energy sources, constituting 99% of all biofuels produced in the U.S. (Farrell et al., 2006).
- While the use of biofuels targets to reduce dependence on fossil fuels and to mitigate greenhouse gas (GHG) emissions (Khanna et al., 2008; Liu et al., 2014), the empirical analyses on the use of biofuels have presented mixed results with respect to the roles of biofuels.
- Examining the substitution possibilities and their environmental consequences in the transportation sector are of great importance to policy makers because understanding the extent to which biofuels contribute to interfuel substitution and carbon dioxide (CO₂) emissions is requisite to formulate energy and environmental policies.
- That is, it is an empirical question how much biofuels substitute for fossil fuels, and how biofuel substitution is closely associated with CO₂ emissions.
- Thus, this study aims to explore interfuel substitution possibilities in the U.S. transportation sector with a focus on the roles of ethanol and biodiesel.
- This study also quantifies how much the changes in the demand for ethanol and biodiesel contribute to CO₂ emissions in response to the changes in the relative prices.

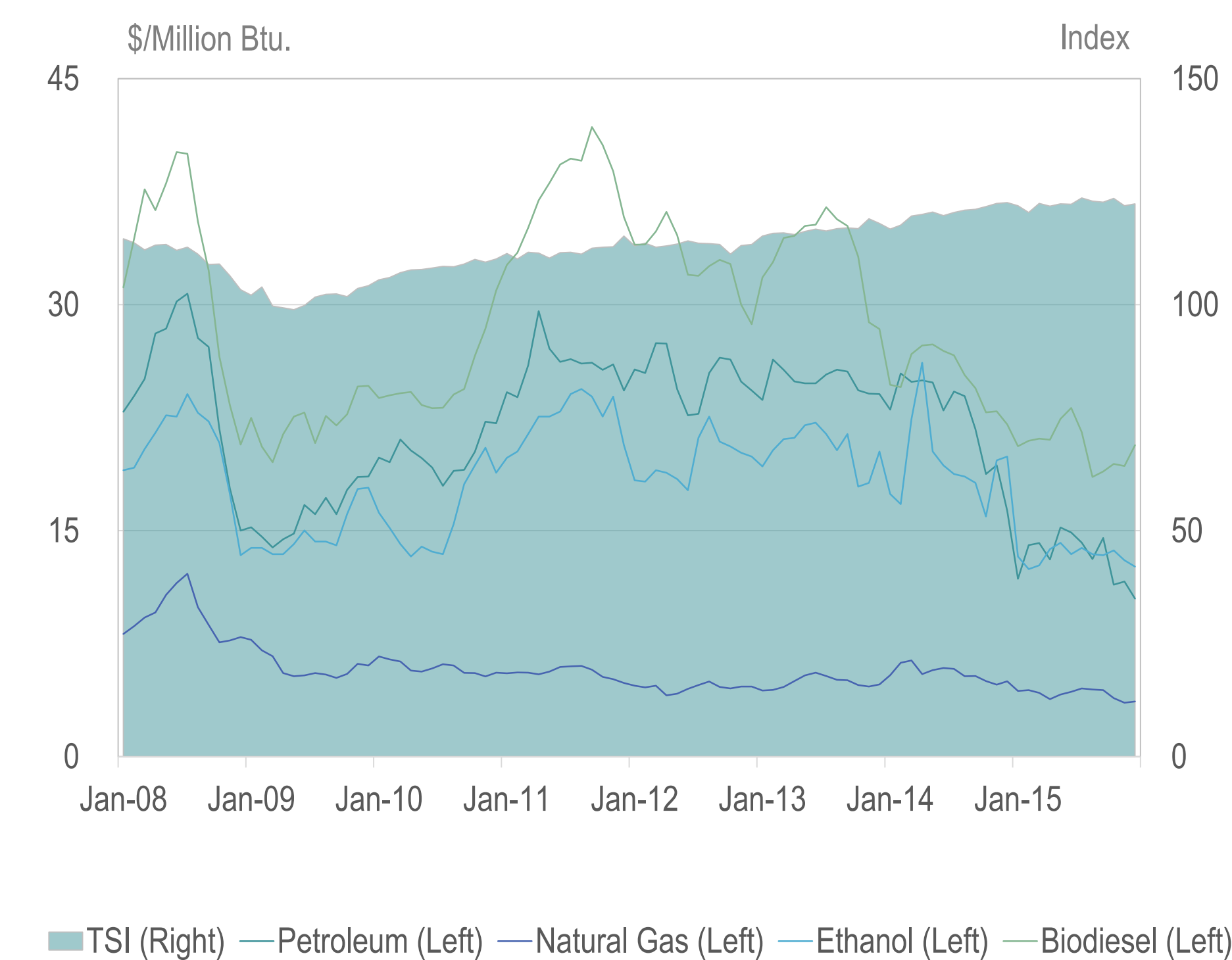
Data

- The major fuels consumed in the transportation sector are considered: petroleum, natural gas, ethanol, and biodiesel.
- Monthly fuel data are obtained from the Energy Information Administration of the Environmental Protection Agency (EPA-EIA) and the U.S. Bioenergy Statistics of the U.S. Department of Agriculture (USDA).
- The monthly quantities and prices of fuels are measured in quadrillion Btu. and dollars per million Btu., respectively.
- The Transportation Services Index (TSI) is obtained from the Bureau of Transportation Statistics of the U.S. Department of Transportation (DOT).
- The data cover the period from January 2008 to December 2015.

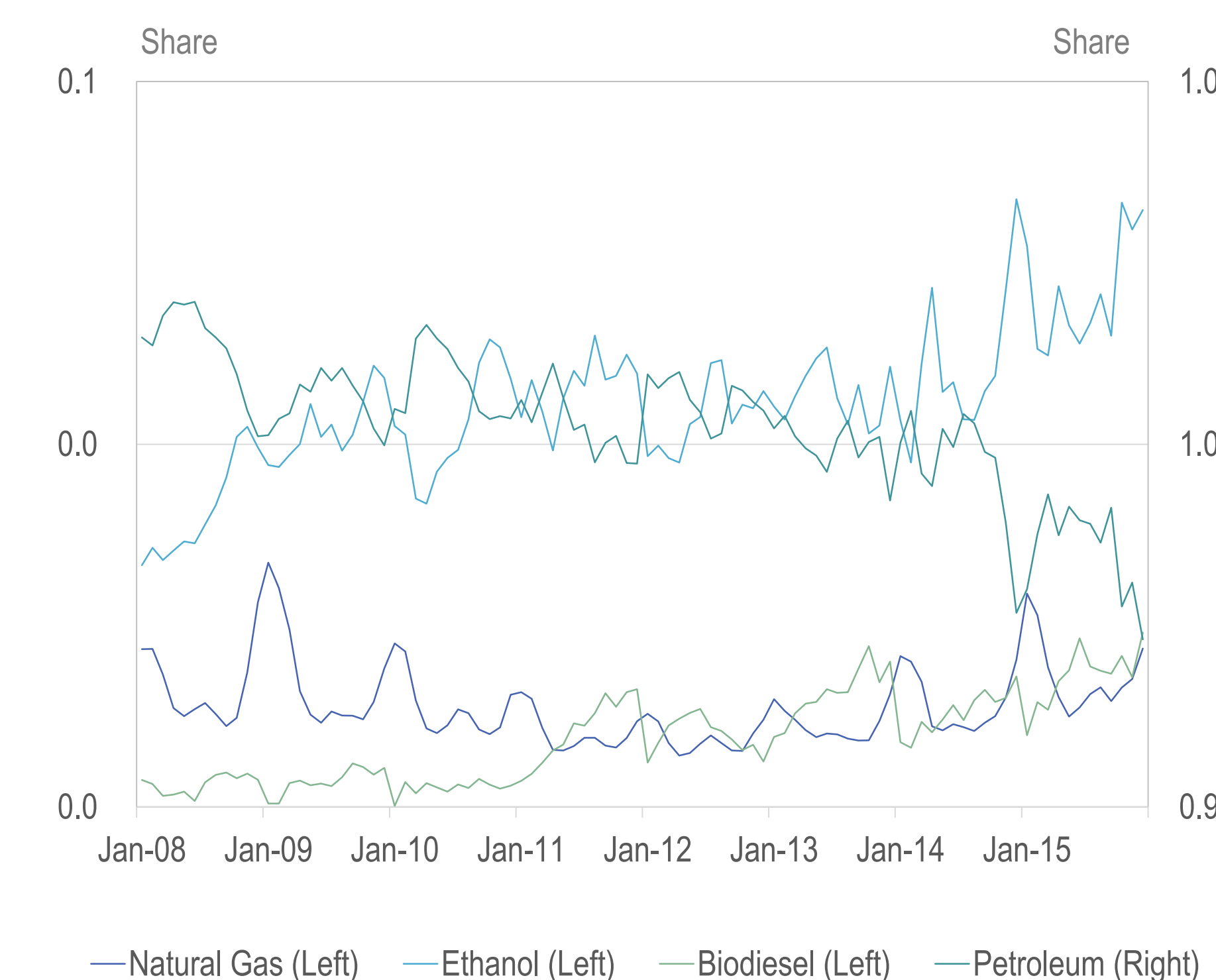
Fuel Consumption



Fuel Price



Cost Share



Methodology

- Translog Cost Function

$$\ln C = \beta_0 + \sum_{i=1} \beta_i \ln P_i + \frac{1}{2} \sum_{i=1} \sum_{j=1} \beta_{ij} \ln P_i \ln P_j + \beta_Y \ln Y + \frac{1}{2} \beta_{YY} (\ln Y)^2 + \sum_{i=1} \beta_{iY} \ln P_i \ln Y$$

- Share Equation

$$S_i = \beta_i + \sum_{j=1} \beta_{ij} \ln P_j + \beta_{iY} \ln Y$$

- Own-Price Elasticities

$$\varepsilon_{ii} = \frac{\beta_{ii}}{S_i} + S_i - 1$$

- Cross-price Elasticities

$$\varepsilon_{ij} = \frac{\beta_{ij}}{S_i} + S_j$$

Price Elasticities

Variable	Coefficient	Standard Error
Own-Price Elasticities		
Ethanol	-0.224***	0.051
Biodiesel	-0.198	0.136
Natural Gas	-0.142***	0.037
Petroleum	-0.021***	0.002
Cross-Price Elasticities		
Ethanol - Biodiesel	-0.023	0.033
Ethanol - Natural Gas	-0.047***	0.017
Ethanol - Petroleum	0.294***	0.034
Biodiesel - Ethanol	-0.090	0.129
Biodiesel - Natural Gas	-0.029	0.050
Biodiesel - Petroleum	0.316***	0.113
Natural Gas - Ethanol	-0.183***	0.067
Natural Gas - Biodiesel	-0.029	0.050
Natural Gas - Petroleum	0.354***	0.055
Petroleum - Ethanol	0.013***	0.002
Petroleum - Biodiesel	0.004***	0.001
Petroleum - Natural Gas	0.004***	0.001

- While ethanol demand is more elastic than the other fuels, petroleum demand is the most inelastic.
- Ethanol is a complement for natural gas but a substitute for petroleum.
- Biodiesel is a substitute for petroleum.

Carbon Dioxide Emissions

- The carbon dioxide emissions coefficients are obtained from the EPA-EIA, which are used to examine the extent to which interfuel substitution contributes to CO₂ emissions in response to the changes in the relative prices.
- Monthly Changes in CO₂ Emissions (million metric tons)



Conclusions

- While ethanol is a complement for natural gas but a substitute for petroleum, biodiesel is a substitute for petroleum in the transportation sector.
- Ethanol demand contributes to a rise in CO₂ emission in response to a decrease in the natural gas price or an increase in the petroleum price.
- Biodiesel demand contributes to a rise in CO₂ emissions in response to an increase in the petroleum price.

References

- Farrell, A.E., Plevin, R.J., Turner, B.T., Jones, A.D., O'hare, M., Kammen, D.M., 2006. Ethanol can contribute to energy and environmental goals. Science 311(5760), 506-508.
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