Integration in Gasoline and Ethanol Markets in Brazil over Time and Space under the Flex-fuel Technology

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Abstract

We employ a pair-wise approach to analyse regional integration in the gasoline and ethanol markets in Brazil. Using weekly price data for these two fuels at the state level over a period of almost 10 years, we find that more than half of the fuel price differentials are stationary, which reveals the importance of allowing for spatial considerations when testing for market integration. We find that the speed at which prices converge to the long-run equilibrium depends upon the distance between states and the similarity between tax regimes. Other demand and supply factors such as population density, number of gas stations and GDP per capita are not statistically significant.

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1. Introduction

In 1973 Brazil, a country heavily dependent on petroleum imports, was severely hit by the first oil crisis. To mitigate the effects of the crisis, the Brazilian government embarked on two ambitious programmes to substitute imported oil with domestic energy sources. The first programme had the objective to increase petroleum reserves mainly through exploration activities initially in offshore shallow waters and subsequently in offshore deep waters. The second programme, established in November 1975 and known as Programa Nacional do Álcool or Pró-Álcool for short, had the purpose of producing large quantities of ethanol from biomass (e.g. sugarcane, cassava and sorghum) as a substitute for gasoline by providing economic incentives to ethanol producers and consumers. For a variety of reasons, including low international prices for sugar and idle capacity for distillation, sugarcane became the sole source of ethanol; for a historical account of the ethanol programme in Brazil see, for instance, Rosillo-Calle & Cortez (1998) and Goldemberg (2006).

According to Goldemberg (2006), Pró-Álcool initially focussed on the production of both anhydrous ethanol and hydrous ethanol. Anhydrous ethanol has remained compulsory as an additive to gasoline in blends of varying proportions that have been increased over the years from 10% to 25%; the use of this fuel requires no modifications in the car engines and the blend mandate is still currently in place. On the other hand, the Brazilian automotive industry developed ethanol-dedicated vehicles that use exclusively 100% hydrous ethanol. According to the Brazilian National Association of Motor Vehicle Manufacturers, ethanol car sales had an initial rapid increase during the 1980s, reaching 93.6% of total sales of new cars in 1987.[1] However, Rosillo-Calle & Cortez (1998) and Salvo and Huse (2011) point out several

[1] See Anúario da Indústria Automobilística Brasileira, available at http://www.anfavea.com.br/anuario.html

reasons why the relative importance of ethanol-dedicated vehicles sales reduced rapidly throughout the 1990s, such as the elimination of subsidies and price supports, the deregulation of the ethanol industry, low international crude oil prices, high sugar prices in world markets, and oil discoveries off the Brazilian coast. Consequently, ethanol production did not increase during those years.

In March 2003 a major technological change took place in the Brazilian automotive industry with the introduction to the market of the flex-fuel vehicles, which are capable of running on any blend of gasoline and hydrous ethanol. Pacini and Silveira (2011) indicate that the rapid acceptance of the flex-fuel technology by Brazilian consumers depended on the fact that they were now able to react to price signals and switch from one fuel to another on a daily basis. This is in sharp contrast with the previous situation in which consumers could only take into account price signals when deciding which type of car to purchase, that is gasoline or ethanol driven. Along with this new technology, both federal and states governments have provided lower tax rates to ethanol relative to those on gasoline, which have boosted domestic ethanol consumption in the last decade, reaching its highest peak in 2010 with 24.4 billion litres in contrast to the 22.8 billion litres of gasoline in the same year.[2] Pacini and Silveira (2011) conclude that the introduction of the flex-fuel technology has opened a major connection between the gasoline and ethanol markets in Brazil.

This paper aims to further our understanding of the extent of spatial integration in the markets for gasoline and ethanol in Brazil, after the introduction of the flex-fuel car technology. According to Fackler and Goodwin (2001), the extent of spatial market integration has often been examined by investigating the validity of the law of one price,

[2] See the Balanço Energético Nacional (BEN) produced by the Empresa de Pesquisa Energética, which is available at https://ben.epe.gov.br/.

either by testing whether the prices of identical products traded in different locations are the same once they are converted to a common currency (that is, the absolute version of the law), or by testing whether price discrepancies are stationary or mean reverting (that is, the relative version of the law).

The econometric modelling strategy that we propose in this paper offers two distinguishing features with respect to the existing literature. First, we study the interaction between gasoline and ethanol prices at the state level by adapting the Pesaran (2007) pairwise procedure to the study of market integration. The idea underlying the pairwise procedure is that given a sample of N prices, unit root tests are conducted on all $(N(N-1)/2)$ price differentials, so that the total number of stationary price differentials can be determined. The use of the pairwise procedure offers the advantage that, by calculating all possible price differentials, it does not involve the choice (in some cases arbitrary) of a base or benchmark price with respect to which all other prices ought to be measured. Bearing in mind that Brazil is a federation that consists of 27 states, a pairwise analysis of 27 gasoline price series and 27 ethanol price series, that is 54 price series, yields a total of 1,431 possible price differentials that can be computed. Consequently, the application of this modelling strategy not only allows us to study the possibility of spatial integration within the gasoline and ethanol markets, but also between them. To the best of our knowledge, this is perhaps the most comprehensive analysis of integration in the Brazilian gasoline and ethanol markets available in the literature.

The second novelty of our modelling strategy is that once the number of stationary price differentials is determined, in a subsequent stage of the analysis we employ information from geographical and economic variables to explain differences in the speed of convergence towards long-run equilibrium across the pairwise price differentials. More specifically, in the event of regional shocks to gasoline or ethanol prices, we investigate whether the speed of adjustment towards long-run equilibrium is fastest between contiguous as opposed to more distant or non-contiguous states, by relying on the distance between states as an explanatory variable. However, we also evaluate the role played by variables such as population density, real per-capita GDP, number of gas stations, and gasoline and ethanol tax regimes at the state level in influencing the speed of adjustment of price differentials.

The paper proceeds as follows. Section 2 presents a brief review of the literature. Section 3 outlines the econometric modelling strategy. Section 4 describes the data and presents the results of the empirical analysis. Section 5 offers concluding remarks.

2. A Brief Review of the Literature

Numerous studies have addressed the existence of integration in gasoline markets including, inter alia, Stigler and Sherwin (1985), Spiller and Huang (1986), Paul, Miljkovic, and Ipe (2001) and Holmes, Otero, and Panagiotidis (2013) for the United States, and Suvankulov, Lau, and Ogucu (2012) for Canada.[3] In spite of the extensive literature, the above studies leave scope for further research and analysis. Indeed, the study of the Brazilian experience with gasoline and ethanol is interesting because it offers the possibility of investigating two highly connected markets. As indicated in the previous section, prior to the introduction of the flex-fuel car technology, adapting car engines from gasoline-fuel to alcohol-fuel was expensive and therefore substitution between these fuels was limited. This fact is confirmed by the long-run own-price elasticities of demand for gasoline in Brazil estimated in several studies, where low values indicate low substitutability, and vice versa. For the period before

[3] A different strand of the literature has studied the transmission of shocks between wholesale and retail prices. For example, see A. S. da Silva et al. (2014) for a recent analysis using prices of regular gasoline at the gas stations and at the distributors in 134 municipalities throughout Brazil.

flex-fuel era, own-price elasticity of demand estimates for gasoline include -0.2 by Assis and de Barros Rodrigues Lopes (1980), -0.31 by Burnquist and Bacchi (2002), -0.46 by Alves and Bueno (2003), -0.49 by Gately and Streifel (1997), -0.63 by Roppa (2005), and -0.98 by Rogat and Sterner (1998).

Studies which provide estimates of the own-price elasticity of demand for gasoline in the flex-fuel era (i.e. after 2003) include Schünemann (2007), with a value of -0.29, and Silva, Tiryaki, and Pontes (2009), with -0.57. Much larger values (in absolute value) are obtained by Santos (2013) and de Freitas and Kaneko (2011) with estimates of -1.2 and -1.8, respectively. Alves and Bueno (2003) obtain a value of the cross-price elasticity of gasoline demand with respect to ethanol equal to 0.48 with annual data from 1974 to 1999.[4] Using similar information, Roppa (2005) finds a value of 0.40, but when adding information up to 2003, the estimate reduces to -0.15. More recent econometric estimations by de Freitas and Kaneko (2011) and Santos (2013) yield higher values of cross-price elasticities of gasoline and ethanol demands, which provide support for the view that the flex-fuel car technology, by eliminating switching costs, has increased consumer choices and stimulated competition between fuels. Introducing a regional perspective in the ethanol demand analysis, de Freitas and Kaneko (2011b) divide the country in two regions, namely the center-south (CS) and the north-northeast (NN). The distinguishing feature between the two regions is that the economic and social development indicators in the CS region are higher than in the NN region. The results show that ethanol demand in the CS region is characterised by higher price elasticities compared to the lower values that are obtained for the NN region.

[4] This coefficient, however, is statistically different from zero at the 10% level based on a one-sided t-test.

Ferreira, de Almeida Prado, and da Silveira (2009) and Salvo and Huse (2011) build theoretical models to accommodate the presence of the flex-fuel technology in the Brazilian fuel market. These models indicate that the possibility of substituting gasoline and ethanol as alternative fuels implies the existence of a long-run cointegration relationship between the prices of these two fuels. Moreover, given the lower energy content (or fuel economy) of ethanol relative to gasoline, pricing parity occurs when the price of ethanol is approximately equal to 70% of the price of gasoline.

Empirical support for the existence of cointegration between gasoline and ethanol prices is somewhat mixed. Using data for the country as a whole, Ferreira, de Almeida Prado, and da Silveira (2009) and Du and Carriquiry (2013) find that the differential between the ethanol and gasoline price series is stationary. Ferreira, de Almeida Prado, and da Silveira (2009) further report that causality (in the Granger sense) between gasoline and ethanol runs from the former to the later, but not vice versa. Tello-Gamarra (2009) carries out cointegration tests between ethanol and gasoline markets in Brazil using monthly prices from 2003 to 2008. This author finds evidence of cointegration in the long-run, causality in both directions, and that the intensity of price transmission from gasoline to ethanol is 1 to 2.74. In turn, Serra, Zilberman, and Gil (2011), employing data on weekly international crude oil prices, and Brazilian ethanol and sugar prices, find that in the long run an increase in crude oil prices leads the system to a new equilibrium characterised by higher ethanol prices. Moreover, ethanol prices respond to departures from the long-run equilibrium relationship, while crude oil and sugar prices do not. Barros, Gil-Alana, and Wanke (2014) use fractional integration techniques to study the degree of persistence in the ethanol to gasoline price ratio, and find that it is not stationary.

Within a regional framework, Salvo and Huse (2011) test for the existence of cointegration between gasoline and ethanol prices using state-level price data, and find that support for the hypothesis occurs in 7 out of 27 states. In 6 additional cases the gasoline and ethanol price series are found to be stationary in levels, so that the difference between the two is, by definition, also a stationary series. Although Salvo and Huse (2011) recognise in their theoretical model that distance may play a role as a factor that determines the speed at which gasoline and ethanol prices adjust to their pricing parity, spatial considerations are not present in their empirical analysis. Indeed, they only examine the time-series properties of $(p_i^g - p_i^e)$, where p_i^g and p_i^e denote the prices of gasoline and ethanol in state *i*, respectively. However, if one allows for spatial considerations, then it is necessary to examine the time-series properties not only of $(p_i^g - p_i^e)$, but also of $(p_i^g - p_j^e)$, $(p_i^e - p_j^e)$ and $(p_i^g - p_j^g)$. This extended approach is the one that we follow in our empirical analysis.

3. Econometric Modelling Strategy

The econometric modelling strategy that we follow in this paper starts employing tools from time-series analysis, but in a way that subsequently uses techniques from cross-section analysis. Commencing with time-series analysis, we apply the Pesaran (2007) pairwise approach to the study of gasoline and ethanol price differentials. More specifically, and using the notation introduced earlier, let us denote as the set that comprises the prices of gasoline and ethanol in all 27 Brazilian states at time *t* in energy equivalents, that is $p_{i,t} = (p_1^g, p_2^g, \dots, p_{27}^g, p_1^e, p_2^e, \dots, p_{27}^e)$. Overall, $p_{i,t}$ consists of *N*=54 price series. Then, let us define all possible price differentials as $p_{ij,t} = p_{i,t} - p_{j,t}$, where *i* = 1, ..., *N*−1 and *j* = *i*+1, ..., *N*. It ought to be noticed that $p_{ij,t}$ permits the computation of all arbitrage opportunities that could exist, that is $(p_i^g - p_i^e)$, $(p_i^g - p_j^e)$, $(p_i^e - p_j^e)$ and $(p_i^g - p_j^g)$. The idea underlying the pairwise approach is to investigate the order of integration of all $(N(N-1)/2)$ price differentials. For this, we employ the Dickey and Fuller (1979) and Leybourne (1995) unit root tests, where the latter is based on the maximum statistic that results from applying the ADF test to both the forward and reversed realisations of the data. The nominal size of the underlying unit root test statistic is denoted α.

Up to this point, our empirical analysis has relied on the examination of the time-series properties of the gasoline and ethanol prices under consideration. Next, we turn to the cross-section part of the analysis to understand the drivers that explain the speed of adjustment of the price differentials. To do this, we focus on the differentials that are stationary, and estimate the associated half-life of a shock, which we denote hl_{ij}.[5] Notice that in the notation used for hl_{ij} we drop the subindex t since we focus on the price differentials that are stationary, and for these the mean and variance are constant through time. For the purposes of the cross-section analysis that follows, hl_{ij} is considered in logarithms and denoted lhl_{ij}.

To specify the cross-section model for lhl_{ij} we follow Holmes, Otero, and Panagiotidis (2013), who consider cost or supply-side variables, demand-side variables and geographical variables as possible drivers. Cost or supply-side variables include the absolute value of the tax differential between states *i* and *j*, denoted $dtax_{ij}$.[6] The variable $dtax_{ij}$ aims to capture the effect of differentiated levels of taxation across products and/or states. The second cost or supply-side variable that we consider is the absolute differential in the logarithm of the number of gas stations, $dlg_{ij} = |lgs_i - lgs_j|$, where lgs_i and lgs_j denote the logarithms of

[5] The half-life is approximated using the formula $-\ln(2/(1+\hat{\delta}))$, where $\hat{\delta}$ denotes the autoregressive coefficient in the corresponding ADF test regression; see Goldberg and Verboven (2005).

[6] The variable $dtax_{ij}$ includes all possible tax differentials, that is $(tax_i^g - tax_i^e)$, $(tax_i^g - tax_j^e)$, $(tax_i^e - tax_j^e)$ and $(tax_i^g - tax_j^g)$, where tax_k^g and tax_k^e denote the tax rates applicable to gasoline and ethanol in state k=i, j, respectively.

the number of gas stations in states *i* and j, respectively.[7] The estimated coefficients on $dtax_{ij}$ and dlg_{ij} are expected to be positive, indicating lower speed of adjustment (that is, higher half-life) when the differentials in tax rates and in the number of gas stations are higher.

To account for demand-side variables we include the absolute difference in the logarithm of the population density, denoted $dlpd_{ij} = |lpd_i - lpd_j|$, where lpd_i and lpd_j are the logarithms of the population densities in states *i* and *j*, respectively. Another variable is the absolute differential in the logarithm of real per-capita GDP in states *i* and *j*, which we denote $dlgdp_{ij} = |lgdp_i - lgdp_j|$. The coefficients associated to $dlpd_{ij}$ and $dlgdp_{ij}$ are expected to be positive supporting the view of lower speed of adjustment (that is, higher half-life) when the differentials in population densities and real per-capita output are higher.

Regarding geographical variables, we consider the logarithm of the distance between states *i* and j, which is denoted $ldist_{ij}$. The hypothesis of interest here is whether a longer distance is associated with a higher half-life and therefore a slower speed of adjustment back to equilibrium. Therefore, the coefficient associated to this variable is expected to be positive. Finally, we also include the dummy variable dug_{ij} which takes the value of one when the two prices in a differential refer to gasoline (and zero otherwise), and the dummy variable due_{ij} when they refer to ethanol (and zero otherwise). The role of these two dummy variables is to capture differentiated speeds of adjustment when prices correspond to the same fuel. The resulting cross-section regression model is:

$$\begin{aligned} lhl_{ij} = \beta_1 + \beta_2 ldist_{ij} + \beta_3 dtax_{ij} + \beta_4 dlgs_{ij} + \beta_5 dlpd_{ij} + \beta_6 dlgdp_{ij} + \beta_7 dug_{ij} \\ + \beta_8 due_{ij} + \epsilon_{ij} \end{aligned} \tag{1}$$

[7] In Brazil the overwhelming majority of gas stations are dual fuel, and so we assume that this variable is the same for both gasoline and ethanol.

where, in addition to the variables already defined, ϵ_{ij} is the equation error term.

4. Data and Empirical Analysis

The database consists of the weekly average prices (measured in R$ per litre) of gasoline (gasolina comun) and hydrous ethanol (etanol hidratado) in each of the 27 Brazilian states over the period 2004w19 to 2014w16, for a total of T=514 time observations.[8] All the price series data are obtained from the Agência Nacional do Petróleo, Gás Natural e Biocombustíveis (ANP), which gathers the information from fuel stations in 411 Brazilian municipalities. Prices are analysed after applying the logarithmic transformation.

In addition to the price series, to perform the subsequent cross-section analysis stated in equation (1), we consider the following information. First, to construct $dtax_{ij}$ we employ the latest regulation of each state on gasoline and ethanol tax rates. The information was gathered from each state's Department of Finance. The mode of gasoline taxes is 25% and is applied by 16 out of the 27 states, including Sao Paulo, which is state with the largest fuel consumption. In the case of ethanol taxes, the mode is 25% too, but Sao Paulo state applies a rate of 12%. It is important to point out that these rates have changed very little during the last eight years. Second, for $dlgs_{ij}$ we use the ratio between the average number of gas stations in each state over the period 2004-2013, which was calculated using data from the Anuário Estatístico Brasileiro do Petróleo, Gás Natural e Biocombustíveis of the ANP, and the corresponding total number of vehicles during the same period, where information on the latter variable is taken from Anuário of the Departamento Nacional de Trânsito. Third, for $dlpd_{ij}$ we use average population in the years 2000, 2007 and 2010 and area in each state,

[8] The states of the Brazilian federation are: Acre, Alagoas, Amapá, Amazonas, Bahia, Ceará, Distrito Federal, Espírito Santo, Goiás, Maranháo, Mato Grosso, Mato Grosso do Sul, Minas Gerais, Pará, Paraíba, Paraná, Pernambuco, Piauí, Rio de Janeiro, Rio Grande do Norte, Rio Grande do Sul, Rondônia, Roraima, Santa Catarina, São Paulo, Sergipe and Tocantins.

both taken from the Instituto Brasileiro de Geografia e Estatística. For real per-capita GDP at the state level, nominal values over the period 2004-2011 are deflated using the consumer price index, averaged over time, and divided by the population figures described earlier. Finally, for the geographical distance between states i and j, $dist_{ij}$, we calculate the shortest great-circle distance in kilometres between centroids of any pair of states, where information on centroids is obtained through a Geographical Information System. To assess the robustness of the results to alternative measures of distance, we also consider the shortest road distance between the main cities of any pair of states. The results obtained using the two measures of distance are qualitatively the same.

Table 1 reports the percentage of rejections of both the ADF and ADF_{max} unit root tests based on all 1,431 price differentials, which we denote $\bar{Z}$. The unit root test regressions include an intercept, and the order of augmentation is determined using the Akaike information criterion (AIC), with $p_{\max} = 6$ lags (results were very similar when $p_{\max}$ was set at 4 and 8 lags). Inference is performed at the α=0.05, 0.10 significance levels. In all cases the percentage of rejections exceeds the underlying size of the unit root test statistics. For instance, the ADF test yields a rejection frequency of $\frac{994}{1{,}431} = 69.5\%$ at the α=0.10 significance level. When α is reduced to 5% the percentage of rejection falls to 56.9%. When using the ADF_{max} test the percentages of rejection are smaller, that is, 61.1% when α=0.10 and 51.4% when α=0.05. In short, the previous findings indicate that more than half of the price differentials are stationary. This reflects the importance of allowing for spatial effects when analysing fuel prices in Brazil.

Computation of the half-life for the price differentials that turn out to be stationary, based on the ADF test at the 5% significance levels, reveals that the average half-life for gasoline price differentials is 6.4 weeks, compared to 8.5 weeks for ethanol price differentials. The quicker speed of adjustment in gasoline can be explained by the larger pipeline network and infrastructure to transport it, whereas ethanol is mostly dependent on road transportation.

Next, we attempt to understand the factors that explain the speed of adjustment of gasoline and ethanol price differentials in Brazil. To do this, we focus on the cases where the null of non-stationarity is rejected using the ADF test at the 5% significance level (qualitatively similar results are obtained when using a 10% significance level). Ordinary least squares estimation of equation (1) yields the results reported in Table 2 as model 1. As can be seen, in model 1 the estimated coefficients on $ldist_{ij}, dtax_{ij}, dlgs_{ij}, dlpd_{ij}$ and $dlgdp_{ij}$ are positive, as expected, although those for the last three variables are not statistically different from zero.

Excluding the insignificant regressors results in model 2 in Table 2. For this model, significance, magnitude and sign of all coefficients remain almost unchanged relative to those reported in model 1. Overall the diagnostic statistics are adequate. The Jarque-Bera test for normality is $\chi_2^2 = 2.2$ (p-value=0.333) and the Ramsey regression specification error test is $F_{1,808} = 1.552$ (p-value=0.213). However, the White test for heteroskedasticity is $F_{11,802} = 2.026$ (p-value=0.024), and so it seems prudent to perform inference based on White's heteroskedasticity consistent standard errors, which are reported in parentheses next to each regression coefficient. Both the estimated coefficients on $ldist_{ij}$ and $dtax_{ij}$ have the expected positive sign and are statistically different from zero. These coefficients indicate that the half-life of shocks is higher (i.e. the speed of adjustment is slower) for states that are farther apart, and for states that are more dissimilar in terms of fuel taxation, respectively.

Because of the presence of due_{ij} and dug_{ij} the intercept term must be interpreted as the half-life for the group against which comparisons are made, namely price differentials that involve prices of different fuels. Given that the estimated coefficients on due_{ij} and dug_{ij} are negative and statistically different from zero, with the former being smaller (in absolute value) than the latter, adjustment is quicker for price differentials that involve ethanol prices than it is for prices of different fuels, and even quicker for those that involve gasoline prices.

5. Concluding Remarks

This paper studies integration in the gasoline and ethanol markets in Brazil, a large country with an established biofuel market, where currently most of the light-duty vehicles can use indifferently either ethanol or gasoline at any proportion. The distinguishing feature of the paper is that we explicitly incorporate spatial considerations into the analysis. We consider that these are very relevant in a country such as Brazil, where geographical conditions are complex and where tax regimes vary considerably across states. To test for spatial integration we adopt a time-series pairwise approach, but we also employ information from a cross-section approach. The pairwise view allows us to determine the proportion of stationary price differentials out of all the possible price differentials that can be constructed both within and between ethanol and gasoline for all 27 Brazilian states.

We present several important findings. Firstly, more than half of the fuel price differentials are stationary, which reveals the importance of accounting for spatial effects in the analysis. Second, the average half-life for gasoline price differentials is shorter than that for hydrous ethanol, which can be due to the larger pipeline network and infrastructure to transport gasoline, while ethanol is mostly dependent on road transportation. Thirdly, distance and tax differentials play a role in determining the speed of adjustment of price differentials. Regarding distance, there is evidence that the longer the distance between two states, the slower the speed of adjustment back to equilibrium. As to taxes, the larger the existing differential between tax rates, that is between states and/or between ethanol and gasoline, the slower the speed of adjustment. Lastly, compared to price differentials that involve gasoline and ethanol prices, adjustment is quicker for price differentials that only involve ethanol prices, and even quicker for those that involve gasoline prices alone.

From the point of view of economic policy, our findings illustrate the role played by factors additional to pure market forces that do not allow fuel prices to adjust quickly and homogenously within the country. Hence, federal and state governments can help to reduce price gaps between type of fuels and across regions by investing in better fuel transportation infrastructure and by unifying tax regimes across states.

6. References

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Table 1: Proportion of stationary gasoline and ethanol price differentials

Unit root test	α	$\bar{Z}$
ADF	5%	56.9%
ADF	10%	69.5%
ADF_{max}	5%	51.4%
ADF_{max}	10%	61.1%

Note: The underlying unit-root test regressions include a constant, and the number of lags of the dependent variable that are included in the test regression is selected using the Akaike information criterion with $p_{\max} = 6$ lags. Both the ADF and ADF tests are performed at significance level α. The critical values of ADF and ADF tests are calculated using the response surfaces estimated by Cheung and Lai (1995) and Otero and Smith (2012), respectively.

Table 2: Determinants of the half-life of fuel price differentials

	Model 1		Model 2	
Variable	Coefficient	(s.e.)	Coefficient	(s.e.)
Intercept	2.187	(0.042)	2.187	(0.024)
$ldist_{ij}$	0.064	(0.022)	0.071	(0.021)
$dtax_{ij}$	0.760	(0.362)	0.750	(0.365)
$dlgdp_{ij}$	0.012	(0.036)		
$dlpd_{ij}$	0.010	(0.012)		
$dlgs_{ij}$	-0.009	(0.014)		
due_{ij}	-0.315	(0.030)	-0.318	(0.030)
dug_{ij}	-0.451	(0.037)	-0.454	(0.037)
Obs.	814		814	
R-squared	0.206		0.206	
Normality	2.515	[0.284]	2.200	[0.333]
Hetero	1.639	[0.015]	2.026	[0.024]
RESET	1.117	[0.264]	1.552	[0.213]

Note: The dependent variable is measured in logarithms. Standard errors (in parentheses) are heteroskedasticity consistent. Normality is the Jarque-Bera test for normality, which is distributed as χ_2^2. Hetero is the (F-version of the) White test for heteroskedasticity (including cross products). Numbers in squared brackets indicate the probability values of the test statistics.