Exchange Rate vs Foreign Price Pass-through: Evidence from the European Gasoline Market

Deltas, George and Polemis, Michael

Department of Economics, University of Illinois, Urbana-Champaign, United States, Department of Economics, University of Piraeus, Greece, and Hellenic Competition Commission, Athens, Greece

24 January 2019

Exchange Rate vs Foreign Price Pass-through: Evidence from the European Gasoline Market*

GEORGE DELTAS# AND MICHAEL POLEMIS&

January 2019

Abstract

We show that European retail gasoline prices respond slower to changes in the dollar exchange rate than to changes in the international spot price of wholesale gasoline, which is quoted in dollars. This differential passthrough is not specific to the Euro, and is observed both for Euro-member states and also for those using national currencies. We examine the possibility that this pattern is driven by differences in either the variability and or persistence of exchange rates changes relative to those of the dollar price of gasoline, but find minimal supporting evidence for either. Refinery supply contracts treat changes in the dollar price and the exchange rate symmetrically, and are thus also an unlikely explanation. Other possibilities, such pricing to the market or pricing based on the country of origin are precluded by the nature of the product. There is evidence, however, that exchange rate fluctuations are more strongly correlated with country-specific economic conditions, which reduces the ability of firms to pass-through price increases and lessens their incentive to pass-through price decreases. Moreover, consumers likely draw a more direct link between the crude oil and retail gasoline prices, affecting their price expectations and search intensity, and optimal passthrough.

J.E.L. Codes: L11, L16, F31.

Keywords: Price Adjustment, Inflation, Gasoline Pricing.

---

* Preliminary and incomplete.

Department of Economics, University of Illinois, Urbana-Champaign, United States (deltas@illinois.edu).

& Department of Economics, University of Piraeus, Greece, and Hellenic Competition Commission, Athens, Greece (mpolemis@unipi.gr).

1. Introduction

The import price of a good in local currency depends on the price of that good in the producer's currency and on the importing country's exchange rate. When the good is a commodity, there is often an international price for it, typically in dollars. In that case the cost, of good's import in local currency is a function of the good's dollar price and the importer's dollar exchange rate. A change in either the exchange rate or in the international (foreign currency) price of the good affects its import price expressed in domestic currency. Regardless of the source of the price change, importers typically adjust prices to domestic consumers slowly over time for a number of reasons which the literature on international passthrough has discussed (and to which we return below). One question that has received less attention is whether the passthrough rate from the exchange rate change is equal to the passthrough from a change in the good's foreign currency price. This question is of importance for measuring the transmission of international price shocks, and for measuring the inflationary (or deflationary) effects of a devaluation (or revaluation) of a country's currency. It is also important because it provides insights on the nature of price formation and competition in an industry.

If the exchange rate passthrough is the same as that from the good's international price, then this passthrough rate could be identified from both sources of variation. If, instead, the two rates differ then one must distinguish these two sources of variation when estimating passthrough rates. In that case, for countries with relatively stable exchange rates, we may not be able to credibly identify the exchange rate passthrough even though there is a long series of changes in the good's international price. Thus, for those countries, there will be considerable uncertainty about the impact of a prospective devaluation on domestic prices. Moreover, any difference in the two passthrough rates would merit an explanation, since in a purely neoclassical perfectly competitive framework what is of relevance is the price paid by the firm in domestic currency; whether this is driven by an exchange rate change or a change in the international price should be immaterial.

In this paper, we provide evidence that these two passthrough rates are different in the European gasoline market, a market where one would expect them to be largely the same. Internationally traded bulk wholesale gasoline forms the bulk of the pre-tax price of retail gasoline. The other components of retail gasoline value-added are domestically sourced; changes in the exchange rate do not affect their cost to the firm. Wholesale gasoline is to a first approximation an internationally traded homogeneous product, with a bulk price quoted in dollars. A change in the cost of wholesale gasoline to a domestic firm also depends on the country's exchange rate. A currency appreciation will have the same effect on the domestic price of wholesale gasoline as a proportional reduction in its international dollar-denominated price; a currency depreciation should be equivalent to a proportional increase in the dollar-denominated price. Though a firm can hedge currency fluctuations, it can also hedge the price of oil. Moreover, hedging typically shields a firm's profits from input cost fluctuations; it does not change the marginal cost of the firm, and hence its optimal pricing.

Imperfect passthrough for a foreign produced imported product can be driven by price rigidities, pricing to market (local currency pricing), and pricing at producer prices (producer currency pricing). All of these are relevant to some extent, as shown by Choudhri, Faruquee and Hakura (2005) in the context of an aggregative macroeconomic model. In the gasoline market, the producer price channel is absent, since gasoline is never priced in an exporter's currency. Local currency pricing is also generally not relevant since retail gasoline is typically priced by domestic and not international firms (though in countries with no refineries, this may not be the case).

In other industries, where an internationally traded input is only a small fraction of value-added, the retail product price might respond differently to a change in the exchange rate than to a change in the international price of the input.[1] A change in the exchange rate could affect, for example, the foreign demand for the firm's product, and hence its domestic price; a change in the international price of the input will not have a similar effect. Moreover, exchange rates and the international price of an input do not fluctuate exogenously; they are driven by underlying economic factors. These factors may sway the product's price to an extent that is large compared to the change in marginal cost.[2] Again, none of these conditions apply to the retail gasoline market. The product is sold domestically, its demand is rather unaffected by short-run economic considerations, the bulk of its cost consists of the upstream fuel, and no other internationally-sourced inputs affect marginal costs.

[1] For a comprehensive review of the exchange rate passthrough literature see Goldberg and Knetter (1997).

[2] For example, the firm may also use two internationally traded input whose international prices are uncorrelated with each other. A change in the exchange rate would affect the cost of both inputs simultaneously, while a change in the international price of one input would affect the cost of only that input.

Thus, the main source of incomplete passthrough should be price rigidities driven by demand side considerations.

Despite expectations to the contrary, we show that the price of retail gasoline in the European Union responds slower to changes in the exchange rate than it does to changes in the international (dollar) price of gasoline. This effect is not confined to the countries that use the Euro, is unaffected by the dynamics of exchange rates and fuel prices, and not driven by contractual arrangements between refineries and gasoline retailers. This finding has broader implications of first order importance for forecasting the effect of currency fluctuations and international price shocks in domestic price levels and inflation dynamics.[3] It also suggests a higher elasticity of the retailers' residual demand when costs change due to exchange rate fluctuations than due to changes in the world price. Indeed, we find corroborative evidence for the demand side explanation. Depreciations in EU countries are contemporaneously associated with slower growth at the quarterly frequency, thus reducing the pricing power of gasoline retailers. Moreover, consumers draw a direct link between the international price of oil and the price of gasoline at the pump; with that link being weaker or absent for exchange rate changes, increases in the retail price of gasoline following a currency depreciation trigger increased search, and thus also reduce the pricing power of firms.[4]

2. Literature Review

This paper is on the intersection of the literature on exchange rate pass-through and the literature on gasoline price dynamics. The majority of the empirical studies on exchange rate passthrough (ERPT) use linear econometric models with the importer's price as the dependent variable and a list of explanatory variables the include the exporter's cost and the nominal exchange rate between the importing and the exporting country.[5] The coefficient of the estimated nominal exchange rate variable denotes the elasticity of domestic/importing prices to variations in the exchange rate

[3] As Meyler (2009) points out, energy consumption accounts for 20% of consumer expenditure in the European Union countries. With the volatility of energy prices being approximately an order of magnitude higher than those of other consumer goods, energy price changes account for about half of the volatility of the Consumer Price Index.

[4] See Deltas (2008) and Lewis (2011) for discussion linking passthrough speed to consumer search in gasoline markets.

[5] For some early studies, see Woo (1984) and Hooper and Mann (1989).

referred to as the pass-through coefficient.[6] These prices find that ERPT in the US ranges from 50 to 60% (Goldberg and Knetter, 1997). One possible explanation for such incomplete pass-through is that firms adjust their markups to accommodate the local market environment (Krugman, 1986; Helpman and Krugman, 1987). The study of Feenstra, (1989) sheds some light on this explanation of the incomplete ERPT by linking the latter to the presence of imperfect competition.[7] Of some interest to our study, Feenstra finds that for the U.S. imports of Japanese cars, trucks and motorcycles the passthrough to exchange rate changes is the same as the passthrough of import tariffs. Some of the literature focuses on the dynamics of price adjustment, i.e., the speed of the passthrough rate rather than merely the ultimate level. For example, Yang (1997) uses monthly data for 87 manufacturing sectors in the US over the 1980 to 1991 period and finds that the degree of pass-through is positively correlated with product differentiation and negatively correlated with the elasticity of marginal cost.[8]

Much subsequent work explored links between passthrough rates and macroeconomic conditions. Taylor (2000) and Choudhri and Hakura (2006) argue that a low inflation environment results in a low ERPT rate. In an interesting study, Campa and Minquez (2006), investigate the ERPT into the import prices of twelve EMU countries over the 1989 to 2001 period for thirteen different product categories. Short-run passthrough is incomplete, but complete pass-through cannot be rejected for the long-run. This study separately accounts for changes in input prices in the exporting countries and changes in the importing country's exchange rate. However, unlike our work, this paper does not examine the difference in passthrough rates to each of these two types of input cost measures. Bridging the macro and micro literatures, McCarthy (2007) examines the speed of ERPT on producer and consumer prices for nine selected industrialized countries. His results suggest an incomplete ERPT due to market distortions from lack of effective competition.[9] Subsequent work by

---

[6] If the estimated elasticity γ is less than unity then the exchange rate passthrough is incomplete, otherwise it is full or complete (γ=1).

[7] Dornbusch (1987) uses more disaggregated two-digit industry level data to link the incomplete ERPT with micro-economic factors (i.e market concentration, product homogeneity, market shares). The study of Engel (2002) provides a comprehensive review of the possible explanations.

[8] The impact of market structure on the ERPT is also highlighted more recently by Auer and Schonle (2016). The authors use annual firm-level data on standard ERPT regression analysis over the period 1994-2005 for the thirty-four largest trading partners of the US. They argue that market share affects the rate at which firms react to changing competitor prices.

[9] Of more relevance to macroeconomics is the work of Choudhri and Hakura (2006), Hahn (2003), and Campa and Goldberg (2006a and b) who investigate the impact of ERPT on import prices and core inflation in the euro zone. Of interest to the present study is Hahn (2003) who finds that approximately a fifth of the inflation variability in Euro countries is due to

Gopinath et al (2010) investigates the ERPT by developing a dynamic currency choice model. They use monthly time series (at a country level) and panel data (at industry level) on the US import prices for dollar and non-dollar goods over the period 1994-2005 to find that there is a large difference in the pass-through between the two pricing categories. These findings have also been corroborated by the studies of Bhattacharya, Karayalcin, and Thomakos (2008), and Devereux and Yetman (2010).

There are only a few studies focusing on commodities that are priced in the international market, e.g., petroleum products, agricultural products, and metals. Among the few such studies, Yanagisawa (2012) uses weekly data for the Japan over the period January 2012 to February 2013 to investigate the ERPT of petroleum products. He decomposes the pass-through structure of gasoline price into two distinct features comprising of dollar and exchange rate components. It is worth mentioning that this study considers the issue of the "numeraire" currency (dollar) for the ERPT into commodity pricing. He finds an incomplete and symmetric pass-through of the dollar component, but when the pass-through of the exchange rate component is considered.

Most of the above ERPT papers treat the exchange rate as a cost shifter. They have no distinction between the change in the price of the product and change in the exchange rate. The reason is that the product typically does not have an international price denominated in a specific currency. In the gasoline market, however, we are able to separate changes in the domestic cost that arise from changes in the exchange rate from those that arise from changes in the international gasoline price.

3. Econometric Framework

There is a substantial literature studying the dynamics of the retail gasoline price, some using prices in logs, while the rest using prices in levels. Given that by the very nature of our exercise we perform an analysis with prices in different currencies, an analysis is logs, measuring elasticities, is quite natural. Because unit responses, i.e., the price effect of a unit change in input cost, are also intrinsically interesting and robust to differences in the share of other costs in the production of retail gasoline, we also perform the analysis in price levels. However, this analysis requires an approximation in

fluctuations in the price of oil expressed in dollars, and approximately another fifth due to exchange rate fluctuations. Interestingly, the exchange rate effects feed through faster to the inflation rate than changes in the oil price.

decomposing cost changes to an exchange rate component and a world price component, which we explain later below. We also choose to work with price before tax, as does the much of the literature. Doing so is particularly important when prices are in logs. Including excise taxes in this case would not be appropriate, especially since these differ across countries: even if producers' prices have the same elasticity with respect to the input price or the exchange rate across all countries, the tax inclusive prices retail prices will exhibit different elasticities.

We employ the two most prevalent specifications in the retail gasoline price adjustment literature. The simplest and oldest of these is the Distributed Lag model (DL), which when estimated using a panel of countries, takes the form:

$$\Delta\log\left(R_{j,t}\right) = a_j + a_s + \sum_{l=0}^{L} b_l \Delta\log(C_{t-l}) + \varepsilon_{j,t} \tag{1}$$

where $R_{j,t}$ is the retail price (in the *domestic* currency) of gasoline in country *j* and period t, C_t is the upstream input price (in the domestic currency), $\Delta X_{j,t}$ is the change in $X_{j,t}$ from period *t*-1 to period t in country *j*, L is the number of lags in the upstream and downstream prices, a_j is a set of country dummy variables, and a_s is a set of seasonal dummy variables. This regression can also be estimated for a subset of countries or periods, or a subset of the parameters can be allowed to vary across countries or periods (e.g., they may take different values when the domestic currency is the Euro.

The changes in upstream prices in domestic currency can be decomposed into changes in the international price of gasoline and changes in the country's exchange rate. Let Γ_t be the international price of the upstream fuel in U.S. dollars (common for every country) and $E_{j,t}$ the exchange rate of country *j* to the dollar (units of domestic currency to one dollar). Then, the domestic currency price of the upstream fuel is $C_{t-l} = E_{j,t}\Gamma_t$. Substituting into equation (1), and allowing for the response to the exchange rate to differ from that of the international price of the input, we obtain the equation

$$\Delta\log\left(R_{j,t}\right) = a_j + a_s + \sum_{l=0}^{L} b_l \Delta\log\left(E_{j,t-l}\right) + \sum_{l=0}^{L} \beta_l \Delta\log(\Gamma_{t-l}) + \varepsilon_{j,t} \tag{2}$$

When the retail price response to the international price of the upstream input is the same as its response to the exchange rate, $b_l = \beta_l$ at all lag lengths. The DL model is sometimes augmented by the use of lags of the dependent variable. This yields the Autoregressive Distributed Lag (ARDL) model that is also common in the literature, and given by

$$\Delta\log(R_{j,t}) = a_j + a_s + \sum_{l=0}^{L} b_l \Delta\log(C_{t-l}) + \sum_{l=1}^{L} c_l \Delta\log(R_{j,t-l}) + \varepsilon_{j,t} \tag{3}$$

After decomposing upstream prices into prices in dollars and the exchange rate, this model yields

$$\Delta\log(R_{j,t}) = a_j + a_s + \sum_{l=0}^{L} b_l \Delta\log(E_{j,t-l}) + \sum_{l=0}^{L} \beta_l \Delta\log(\Gamma_{t-l}) + \sum_{l=1}^{L} c_l \Delta\log(R_{j,t-l}) + \varepsilon_{j,t} \tag{4}$$

The ARDL model does not account for the possibility that the upstream and downstream prices are cointegrated. If that is that case, incorporating the long-run relationship between these prices in the short-term dynamics through an error correction term provides for more efficient estimation and a more accurate representation of the price adjustment process. Let this long run relationship be given by the equation

$$\log(R_{j,t}) = k_j + m\log(C_t) + u_t \tag{5}$$

Then, the Error Correction Model (ECM) estimated from the entire panel of countries is given by:

$$\Delta\log(R_{j,t}) = a_j + a_s + \sum_{l=0}^{L} b_l \Delta\log(C_{t-l}) + \sum_{l=1}^{L} c_l \Delta\log(R_{j,t-l}) + d\left(\log(R_{j,t-1}) - k_j - m\log(C_{t-1})\right) + \varepsilon_{j,t} \tag{6}$$

where the parameter d is the speed at which the retail price returns to its long run equilibrium value. Substituting in for the international price of the upstream input and the country's exchange rate in the short-run dynamics yields the equation

$$\Delta\log(R_{j,t}) = a_j + a_s + \sum_{l=0}^{L} b_l \Delta\log(E_{j,t-l}) + \sum_{l=0}^{L} \beta_l \Delta\log(\Gamma_{t-l}) + \sum_{l=1}^{L} c_l \Delta\log(R_{j,t-l}) + d\left(\log(R_{j,t-1}) - k_j - m\log(C_{t-1})\right) + \varepsilon_{j,t} \tag{7}$$

This specification allows for the retail price in domestic currency to differ with respect to exchange rate fluctuations and fluctuations in the world price in US dollars, but imposes no differences in the long run relationship. We believe this to be reasonable, but in principle one could decompose the domestic price into an exchange rate component and a dollar price component in the cointegrating vector as well, yielding the specification

$$\Delta\log(R_{j,t}) = a_j + a_s + \sum_{l=0}^{L} b_l \Delta\log(E_{j,t-l}) + \sum_{l=0}^{L} \beta_l \Delta\log(\Gamma_{t-l}) + \sum_{l=1}^{L} c_l \Delta\log(R_{j,t-l}) + d\left(\log(R_{j,t-1}) - k_j - m\log(E_{j,t-l}) - \mu\log(\Gamma_{t-l})\right) + \varepsilon_{j,t} \tag{8}$$

It turns out there is minimal difference in the impulse response functions between using (7) and (8). Moreover, the ARDL model is “bracketed” by the DL and ECM models. Therefore, in what follows, we estimate regressions (2) and (7) for the entire panel of European Union countries, and also for subsets of those countries that use the Euro and those that do not.

When expressing changes in levels, the Distributed Lag model becomes

$$\Delta R_{j,t} = a_j + a_s + \sum_{l=0}^{L} b_l \Delta C_{t-l} + \varepsilon_{j,t} \tag{9}$$

To decompose the change of the input price into a foreign exchange and a world price component, we use the product rule, i.e., we write $\Delta C_t \approx \Delta E_{j,t}\Gamma_{t-1} + \Delta\Gamma_{j,t}E_{t-1}$. This expression is exact for infinitesimal changes (that is, using differential notation). For finite changes, the decomposition will be approximate. Using Γ_t and E_t instead of Γ_{t-1} and E_{t-1} yields an alternative approximation. In practice, there is minimal difference between the two expressions, and we report our main results based on the former decomposition. After substituting into equation (9) we obtain

$$\Delta R_{j,t} = a_j + a_s + \sum_{l=0}^{L} b_l \Delta E_{j,t}\Gamma_{t-1} + \sum_{l=0}^{L} \beta_l \Delta\Gamma_{j,t}E_{t-1} + \varepsilon_{j,t} \tag{10}$$

The corresponding error correction model in levels with a common long run response is given by

$$\Delta R_{j,t} = a_j + a_s + \sum_{l=0}^{L} b_l \Delta E_{j,t}\Gamma_{t-1} + \sum_{l=0}^{L} \beta_l \Delta\Gamma_{j,t}E_{t-1} + \sum_{l=1}^{L} c_l \Delta R_{j,t-l} + d\left(R_{j,t-1} - k_j - mC_{t-1}\right) + \varepsilon_{j,t} \tag{11}$$

We estimate specifications (10) and (11). As a robustness exercise, we also estimate threshold models in which the response of the retail price to small changes in the exchange rate or small changes in the upstream price is zero.

4. DATA

Our empirical analysis is based on an unbalanced panel dataset of pre-tax retail gasoline prices comprising of weekly observations spanning the period from 1994 to 2015. The sample includes all

28 European Union countries, but no data are available for a country prior to its accession to the EU.[10] Our measure of upstream price is the New York spot price of wholesale gasoline, obtained from the U.S. Energy Information Administration.[11] The downstream price series contain occasional gaps reflecting weeks when there is no data collection (typically over the Christmas/New Year's holidays). When data is missing for a week, we impute the average value of the adjacent weeks.

For the purpose of this study, retail prices must be in local currency. This is the default for the European data until 2005; starting 2006 figures are in Euros. For both periods, the original source provides the Euro/ECU to local currency exchange rate for the corresponding price quote, so that the entire data series can be conformably converted into local currency and euros as needed. Upstream prices are in U.S. dollars. These are converted to local currency using the Euro/ECU to US dollar exchange rate and the Euro/ECU to local currency exchange rate. For ease of interpretation of the parameter estimates, we convert both upstream and downstream fuels in the same volumetric units and quote prices per 1,000 liters (New York gasoline is originally quoted in US dollars per gallon).

Finally, we pay special attention to the fact that exchange rates are quoted on a daily basis, while fuel prices in a weekly basis. Given that the main interest of the study is the comparison of the passthrough speeds from upstream price changes with that from exchange rate changes, we must ensure that no difference in measured adjustment rates is inadvertently caused by the way the weekly values for these series is computed. The weekly series for the upstream prices is obtained by averaging the daily values for the preceding week. We perform the exact same conversion for the daily US dollar to Euro/ECU exchange rate to arrive at the weekly exchange rate. Moreover, the weekly rate for the exchange rate averages the exact same days as those used to obtain the weekly upstream price, i.e., the two series are exactly in sync. Note that the Euro/ECU to local currency

---

[10] The source of the retail data is the Weekly Oil Bulletin (http://ec.europa.eu/energy/en/data-analysis/weekly-oil-bulletin). Typically, a downstream price quote for a week corresponds to a Monday, and it is based either on an average of quotes obtained over the preceding week, or of reports obtained for that same day. Details of the sampling scheme for each country are contained in the Bulletin.

[11] https://www.eia.gov/dnav/pet/pet_pri_spt_s1_d.htm. The data frequency for these series is weekly, but a daily series is also available and allows us to ascertain how the aggregation to the weekly series is implemented. Using a crude oil price, e.g., that of Brent, is less appropriate because it is further up the supply chain and has a smaller explanatory power in terms of explaining retail gasoline price movements as measured by the R-squared of the price adjustment equations. Moreover, crude is not a homogeneous product, and not all grades move in lock step in terms of price.

exchange rate is already provided on a weekly basis by the European Commission using the same date grid as that used for the reporting of the retail prices.

5. Empirical Findings

The results from the base Distributed Lag and Error Correction specifications in logs, equations (2) and (10), are reported in Table 1. An examination of the parameter estimates reveals a substantial difference between the responses to exchange rate fluctuations and to changes in the world price of gasoline, especially in the first few weeks. Changes in the world price (in dollars) are passed through much faster than changes in the exchange rate. For some, but not all lags, these differences are large when compared with the standard errors, which are clustered at the week level to account for cross-sectional dependence. In part because of somewhat large standard errors for the exchange rate passthrough, the joint test of the differences $b_l \neq \beta_l$ for all nine lags and the contemporaneous term is not statistically significant for either specification.[12] However, the object of primary interest is the cumulative passthrough of a cost change, not the incremental passthrough from one week to the next. Even though the differences in the incremental effects may not be statistically significant, the sum of these differences (which yields the cumulative effect) could be. This is particularly likely since almost all differences are of the same sign. Indeed, the null hypothesis of $\sum_{l=0}^{L} b_l = \sum_{l=0}^{L} \beta_l$ is rejected at the 5% level for the DL model and at the 1% level for the ECM model. Thus, the differences in the cumulative effects are statistically significant. The monthly effects are also statistically significant, but country effects only for the error correction model, suggesting differences in the price level across countries but not in the responses to upstream cost shocks.

Table 2 presents the corresponding results for the specifications in levels, equations (7) and (12). These estimates are consistent with those of Table 1. A change in the wholesale cost of gasoline due to a change in the world dollar price of gasoline is passed through faster to the retail price than an equivalent change in the cost of wholesale gasoline due to a change in the exchange rate. The pattern of differences is somewhat distinct, with a large difference shortly after impact that is partially made

[12] The differences between the parameter estimates are statistically significant when cross-sectional dependence is ignored, but we believe the more conservative standard errors reported here are appropriate.

up in later weeks. This results in rejecting the null of equal coefficients, but not rejecting the null that cumulative effects are the same: under this specification, foreign exchange shocks pass through slower to downstream prices, but cumulative effects are not different. Country dummies are never statistically significant, but monthly dummies are under the Error Correction Model.

Of greater interest than the parameter estimates are the impulse response functions that plot the cumulative change in the retail price from a change in the world price or a change in the exchange rate. These are shown for Figure 1, with each panel corresponding to each of the four specifications in Tables 1 and 2. We obtain and indicate statistical significance based on a non-parametric bootstrap. To account for cross-section dependence, each bootstrap sample takes draws containing the full set of countries in a particular week, i.e., it consists of draws of weeks. This approach is conservative in the sense that it generates larger standard errors. For each week, we also draw the full set of lagged values to account for dynamic effects. Because the residual is generally not serially correlated, we do not need to account for other sources of time-series dependence.[13] The bootstrap consists of 100 replications, and standard errors of the difference are used to assess significance. Statistical significance of the difference between the two impulse responses at the 5% and 1% levels is indicated by large hollow and large solid markers, respectively. Statistical significance at the 10% level is indicated by a small marker; no marker indicates absence of statistical significance.[14]

The top two panels show the response elasticities (corresponding to the parameters in Table 1). Passthrough to exchange rate shocks is slower and smaller. The difference is statistically significant in most weeks, more so using the Error Correction Model. The impulse response profile is almost identical between the DL and ECM sets of estimates. The elasticity response gap between the two series is initially small but grows to over 0.1 by the fifth week. The bottom panels show the responses in currency units, i.e., the change in the retail price divided by the change in the marginal cost (corresponding to the parameters of Table 2). Passthrough to exchange rate driven cost changes is again slower than passthrough to changes in the world price. The response difference is significant

[13] An alternative is to use a Gibbs sampler and perform a parametric bootstrap drawing from the joint distribution of parameters. This is a more demanding approach computationally.

[14] Since the statistical significance refers to the difference between the two impulse response functions, the sets of markers for two series are the same with each other.

from the first period, but statistically significant in later weeks only for the Error Correction Model. This is despite the fact the two series are (by construction) converging under the ECM model, given the imposition of a common cointegrating vector: the standard errors of the impulse response function are sufficiently smaller under ECM, that the reduced difference is more often statistically significant. We do not read too much into the specific time profile of the passthrough, especially given the standard errors associated with the impulse responses of the specifications in Table 2. However, given the similarity between the DL and ECM estimates, and the greater precision of the latter, we limit our subsequent analysis to Error Correction Models. This analysis investigates some possible causes for the more sluggish response of retail prices to exchange rate driven cost changes.

6. Discussion: A Look Into Some Possible Explanations

There are a number of possible explanations. Though we cannot investigate all of them, we examine (and to a large extent reject) some of them. These explanations can be divided to those that originate from the supply side, and to those that originate from the demand side. We discuss each in turn.

6.1 Supply-side explanations

The first supply-side possibility stems from the size of fluctuations of the exchange rates relative to those of the international price of gasoline. Suppose retail prices respond more strongly and fully to large changes in costs than to small changes. If exchange rates exhibit only small fluctuations, but the international price of wholesale gasoline exhibits large fluctuations, then retail prices would be (on average) more responsive to the latter. We verify that indeed the swings in the New York gasoline price are much greater than those of exchange rates: most of the weekly changes in the exchange rate but fewer than a quarter of the weekly changes in the dollar price of gasoline are less than one percent. The time series of the gasoline dollar price is plotted in the top left panel of Figure 2; its fluctuations are large over the long run and often very sharp in the short-run. The top right panel of Figure 2 plots the exchange rate fluctuations of the Euro and British pound relative to the dollar. Both fluctuate around a much narrower band, and their swings are somewhat less sharp in the short-run. Given these observations, we test our conjecture by estimating a simple threshold response model, under which the retail price does not respond at all to changes in the wholesale price or to the exchange rate that are smaller than one percent. This is a large threshold, given the fraction of weekly changes that are smaller than this figure. Moreover, the assumption of no response to cost changes below the threshold is rather extreme. Thus, this specification would be able to ascertain if the relative magnitude of changes were the explanation for the differential response. The resulting impulse response functions are plotted in the bottom two panels of Figure 2. These are similar to our base results; it does not appear that threshold effects explain the slower exchange rate passthrough.

A second possibility is that this phenomenon is limited to the Euro, i.e., it holds for the Euro but not in general. This might be because a major currency, like the Euro, materially affects global demand, and its changes lead to contemporaneous changes in the price of oil. With the countries using the Euro dominating the sample, it might appear that the pattern holds for all European Union countries. To test this possibility, we have re-estimated the price adjustment regressions separately for the countries that have joined the Euro and those that have not. The impulse response functions, plotted in Figure 3, show that the general pattern for the two sets of countries is the same. Though there are some differences in the time profile of the price adjustment between Euro and non-Euro countries, in both cases adjustment to exchange rate changes is slower and smaller than the adjustment to the dollar price of wholesale gasoline, with the difference being statistically significant in about half of the post-shock weeks.[15] One might be concerned that all European currencies are moving in sync (or nearly in sync), and this is certainly true for the period immediately preceding the Euro for the countries were planning to join. But it is not generally true for all non-Euro countries. Looking at the top left panel of Figure 2, we observe that the Euro to US dollar exchange rate does not follow the same pattern as the British pound to US dollar exchange rate. Thus, the non-Euro using countries would provide independent information on the exchange rate passthrough.

A third supply-side possibility centers around the persistence of changes in the exchange rates relative to that of the world price of gasoline. Firms are less likely to respond to a cost change that

[15] In this analysis, a country that has eventually used the Euro is considered a Euro-adopter even prior to its switch to that currency. This is done because the exchange rates of Euro-adopters fluctuated only around small bands prior to them joining the common currency. However, the same results are obtained if we divided the same in the countries and observations based on whether they were using the Euro on each specific point in time.

will likely reverse itself within a week (or possibly two). They are more likely to respond to a change that will be followed by one of the same sign. Thus, the serial correlation of changes in the exchange rate and the world price of gasoline could be of relevance. We computed the serial correlation in changes in the logs of the exchange rate and the dollar price of wholesale gasoline. The former is higher than the latter (0.191 versus 0.155). The exchange rate persistence is even higher when we limit it to the euro rate. At the two-week frequency, the exchange rate change persistence is smaller, but still in the same ballpark as that of the dollar price of gasoline (0.119 versus 0.155). The correlations become smaller at the three-week frequency (0.091 versus 0.145) with the difference somewhat widening. However, it is noteworthy that all these correlations are positive, i.e., there is no reversion in the short-run for either series. To better ascertain whether the somewhat stronger persistence of changes for the wholesale gasoline price might contribute to a stronger retail price response, we examined the exchange rate persistence for each currency separately. The only currency with negative correlation between changes in successive weeks is the British pound. We re-estimated our price adjustment models for the United Kingdom, and found that, if anything, the retail response to exchange rates is faster and closer to the response to the dollar price of wholesale gasoline. Therefore, there is no evidence that the slower response of retail prices to exchange rates is driven by expectations that these rates will revert to their prior values.

A fourth supply-side explanation is that refinery contracts to retailers treat exchange rates and the world price of gasoline differentially. This, however, is not the case in European countries during this period. The contractual ex-refinery price in the countries where transactions are "arms-length" is based on the international price of gasoline converted in domestic currency. It responds symmetrically to changes in either component. Though typically time averages of these prices are used, they are defined symmetrically. For example, in Greece, both the exchange rate and the international price of gasoline as used in the calculation of the ex-refinery price corresponds to averages taken over the same four days. Similar pricing mechanisms prevails in other EU countries, such as Italy, France, Spain and Portugal. However, in many EU countries there is extensive vertical integration between the refineries, wholesalers and retailers. As a consequence, in these countries, the ex-refinery price is just an internal transfer price (see Polemis, 2012). In sum, there is little to no evidence that the slower passthrough to exchange rates changes is driven by the retailer cost side.

6.2 Demand Side Explanations

We consider two explanations that originate from the demand side. The first possible explanation is that a currency depreciation relative to the US dollar is associated with weaker growth for the EU countries (and conversely for currency appreciation). If that were the case, then an increase in the ex-refinery price driven by a depreciation would meet weaker demand; the passthrough rate would, therefore, be tempered by the demand reduction. Conversely, a decrease in the ex-refinery price driven by a currency appreciation would meet stronger demand, and the passthrough rate would again be tempered, i.e., retail prices would decline by less, because of the demand increase. We have investigated this possibility, by obtaining data on nominal GDP for European Union countries at quarterly rates (the highest frequency available), and deflating them using the harmonized price index (HCPI).[16] We then computed quarterly rates for the changes in a country's exchange rate to the US dollar and the change in the international price of gasoline. A regression of changes in the log of real GDP on changes in the log exchange rate and changes in the log international price of gasoline would yield the partial correlations between these variables. To account for trends in the real GDP, we also estimated this regression with a linear and with a quadratic time trend. In all specifications, a depreciation is contemporaneously related to weaker growth (the point estimate of the associated elasticity is 0.03 and statistically significant). There is no statistically significant association between growth and changes in the gasoline's dollar price. Note that these regressions are only used to obtain partial statistical associations and that for the demand explanation made above, only the contemporaneous association between prices changes and economic growth is relevant. Therefore, one possible explanation for the divergence in the pass-through profiles is that gasoline retailers face weaker demand when their input costs increase due to a depreciation.

The second demand side explanation stems from the relative salience of the international price of oil versus that of the exchange rate for consumer purchase decisions. Consumers decide whether to

[16] The data for nominal GDP are available from the Quarterly National Accounts of the Eurostat, while data on the HCPI are available on a monthly basis also from Eurostat (https://ec.europa.eu/eurostat/data/database). The HCPI measures the change over time of the prices of consumer goods and services acquired by households and gives comparable measures of inflation for the EU countries. In other words, it is a set of consumer price indices (CPI) calculated according to a harmonized approach. In addition, the HCPI provides the official measure of consumer price inflation in the euro area for the purposes of monetary policy and the assessment of inflation convergence as required under the Maastricht criteria.

purchase gasoline from a particular station or keep searching elsewhere for a lower price based on their expectations of the retail price distribution. When consumers learn from news outlets that the price of oil goes up, they become conditioned to expect higher prices at the pump, and conversely when news outlets report oil price declines. Currency depreciations and appreciations likely have a far smaller conditioning effect for two reasons. First, there are many exchange rates, and the one against the dollar may not move in sync with the others. Because of this multiplicity of exchange rates, a consumer's perception of how the local currency appreciates or depreciates will generally be some composite of all these rates. Second, consumers may be less likely to draw a direct link between the USD to local currency rate and the price at the pump, being unware of how exchange rates affect the refinery price and also being less cognizant of that specific exchange rate. Because consumers are less likely to incorporate exchange rate fluctuations into their expectations of retail prices, price increases due to exchange rates are associated with higher consumer search and gasoline retailers will pass them through slower to avoid losing sales to their competitors. Similarly, price decreases due to exchange rates are associated with lower consumer search and gasoline retailers have a smaller incentive to pass them through. These effects will be less pronounced for price changes that are driven by the dollar price of gasoline.

7. Concluding Remarks

Transmission of input price shocks in gasoline is faster when it is driven by changes in the international price of gasoline than by changes in a country's exchange rate. We investigate a number of possibilities for this regularity, and conclude that demand side factors are the most likely explanation. These explanations are likely to hold more generally beyond EU countries. The question is to what extent they might be operative for other products. The demand channel that operates through consumer search is only applicable for consumer products for which the foreign input price is salient in the minds of consumers. This is unlikely to be the case for most imported goods. However, the demand channel that operates through the correlation of exchange rate changes and aggregate domestic demand should be relevant for most products. Therefore, the possibility exists that this divergence in pass-through rates holds more broadly beyond the market for liquid fuels.

References

Auer, P., and P. Schoenle (2016). "Market Structure and Exchange Rate Pass-through," *Journal of International Economics*, vol. 98, pages 60-77.

Bhattacharya, P.S., C.A. Karayalcin, and D. Thomakos (2008). "Exchange Rate Pass-through and Relative Prices: An Industry-level Empirical Investigation," *Journal of International Money and Finance,* vol. 27, pages 1135–1160.

Campa, J. M. and L. Goldberg (2006a). "Distribution Margins, Imported Inputs, and the Sensitivity of the CPI to Exchange Rates, NBER Working Papers, no. 12121.

Campa, J. M. and L. Goldberg (2006b). "Pass Through of Exchange Rates to Consumption Prices: What has Changed and Why?," NBER Working Papers, no. 12547.

Campa, J.M., G. Minquez (2006). "Differences in Exchange Rate Pass-through in the Euro Area," *European Economic Review*, vol. 50, pages 121-145.

Choudhri, E. U. and D. S. Hakura (2002). "Exchange Rate Pass-Through to Domestic Prices: Does the Inflationary Environment Matter?," *European Economic Review*, vol. 25, pages 614-639.

Choudhri E.U., H. Faruqee, D.S. Hakura (2005). "Explaining the Exchange Rate pass-through in Different Prices," *Journal of International Economics*, vol. 65, pages 349– 374.

Deltas, G. (2008). "Retail Gasoline Price Dynamics and Local Market Power," *Journal of Industrial Economics*, vol. 61, pages 613-628.

Devereux, M., and J. Yetman (2010). "Price Adjustment and Exchange Rate Pass-through," *Journal of International Money and Finance*, vol. 29, pages 181–200.

Dornbusch, R., (1987). "Exchange Rates and Prices," *American Economic Review*, vol. 77, pages 93–106.

Feenstra, R.C. (1989). "Symmetric Pass-Through of Tariffs and Exchange Rates Under Imperfect Competition: An Empirical Test," *Journal of International Economics*, vol. 27, pages 25-45.

Goldberg, P., M. Knetter (1997) Goods Prices and Exchange Rates: What Have We Learned? *Journal of Economic Literature*, vol. 35, pages 1243-1272.

Hahn, E. (2003). "Pass-Through of External Shocks to Euro Area Inflation," ECB Working Paper Series, No. 243.

Helpman, E., and P. Krugman (1987). *Market Structure and Foreign Trade: Increasing Returns, Imperfect Competition, and the International Economy*. The MIT Press: Cambridge, MA.

Hooper, P. and C. Mann (1989). "Ex-change Rate Pass-Through in the 1980s: The Case of U.S. Imports of Manufactures," *Brookings Papers of Economic Activity*, vol. 1, pages 297-337.

Krugman, P. (1986). "Pricing to Market when the Exchange Rate Changes," NBER Working Paper no. 1926.

Lewis, M.S., (2011). "Asymmetric price adjustment and consumer search: an examination of retail gasoline market," *Journal of Economics and Management Strategy*, vol. 20, pages 409–449.

Meyler, A. (2009). "The Pass Through of Oil Prices into Euro Area Consumer Liquid Fuel Prices in an Environment of High and Volatile Oil Prices," *Energy Economics*, vol. 31, pages 867-881.

McCarthy, J., (2007). "Pass-through of Exchange Rates and Import Prices to Domestic Inflation in Some Industrialized Economies," *Eastern Economic Journal*, vol. 33, pages 511-537.

Polemis, Michael, (2012). "Competition and price asymmetries in the Greek oil sector: an empirical analysis on gasoline market," *Empirical Economics*, vol. 43, pages 789-817.

Taylor, J., (2000). "Low Inflation, Pass-through and the Pricing Power of Firms," *European Economic Review*, vol. 44, pages 1389–1408.

Woo, W (1984). "Exchange Rates and the Prices of Nonfood, Nonfuel Products," *Brookings Papers of Economic Activity*, vol. 2, pages 511-530.

Yanagisawa, A. (2012). "Structure for Pass-through of Oil Price to Gasoline Price in Japan," *IEEJ Energy Journal*, vol. 7 (August), pages 1-12.

Yang, J., (1997). "Exchange Rate Pass-through in U.S. Manufacturing Industries," *The Review of Economics and Statistics*, vol. 79, pages 95–104.

Table 1. Retail Price Elasticity with Respect to Changes in the World Price and the Exchange Rate.

	Distributed Lag Model		Error Correction Model	
	Parameter Estimate	Standard Error	Parameter Estimate	Standard Error
Δlog(New York Price in Dollars)	0.192	*0.008*	0.197	*0.008*
Δlog(New York Price in Dollars)_{t-1}	0.154	*0.007*	0.152	*0.007*
Δlog(New York Price in Dollars)_{t-2}	0.066	*0.007*	0.077	*0.008*
Δlog(New York Price in Dollars)_{t-3}	0.052	*0.006*	0.061	*0.007*
Δlog(New York Price in Dollars)_{t-4}	0.036	*0.006*	0.047	*0.007*
Δlog(New York Price in Dollars)_{t-5}	0.021	*0.006*	0.034	*0.007*
Δlog(New York Price in Dollars)_{t-6}	0.023	*0.006*	0.032	*0.007*
Δlog(New York Price in Dollars)_{t-7}	0.007	*0.006*	0.019	*0.007*
Δlog(New York Price in Dollars)_{t-8}	0.025	*0.006*	0.035	*0.007*
Δlog(New York Price in Dollars)_{t-9}	0.005	*0.006*	0.014	*0.007*
Δlog(Exchange Rate)	0.204	*0.024*	0.207	*0.025*
Δlog(Exchange Rate)_{t-1}	0.094	*0.024*	0.095	*0.025*
Δlog(Exchange Rate)_{t-2}	0.048	*0.028*	0.051	*0.028*
Δlog(Exchange Rate)_{t-3}	0.040	*0.029*	0.044	*0.029*
Δlog(Exchange Rate)_{t-4}	0.020	*0.022*	0.027	*0.023*
Δlog(Exchange Rate)_{t-5}	0.035	*0.024*	0.041	*0.025*
Δlog(Exchange Rate)_{t-6}	0.005	*0.021*	0.012	*0.022*
Δlog(Exchange Rate)_{t-7}	-0.022	*0.022*	-0.015	*0.023*
Δlog(Exchange Rate)_{t-8}	0.040	*0.022*	0.042	*0.023*
Δlog(Exchange Rate)_{t-9}	-0.022	*0.024*	-0.018	*0.025*
Δlog(Retail Price in Local Currency)_{t-1}			-0.090	*0.013*
Δlog(Retail Price in Local Currency)_{t-2}			-0.048	*0.013*
Δlog(Retail Price in Local Currency)_{t-3}			-0.032	*0.012*
Δlog(Retail Price in Local Currency)_{t-4}			-0.035	*0.013*
Δlog(Retail Price in Local Currency)_{t-5}			-0.031	*0.012*
Δlog(Retail Price in Local Currency)_{t-6}			-0.014	*0.013*
Δlog(Retail Price in Local Currency)_{t-7}			-0.024	*0.010*
Δlog(Retail Price in Local Currency)_{t-8}			-0.014	*0.010*
Δlog(Retail Price in Local Currency)_{t-9}			-0.002	*0.011*
log(Retail Price in Local Currency)_{t-1}			-0.042	*0.004*
log(New York Price in Dollars)_{t-1}			0.030	*0.003*
Monthly Dummies (p-value)	0.0042		0.0000	
Country Dummies (p-value)	1.0000		0.0000	
Equality of NY price and XR (p-value)	0.3430		0.3102	
Cumulative NY and XR effects	0.1412	*0.0678*	0.1846	*0.0706*
Disturbance autocorelation	-0.1014	*0.0067*	-0.0011	*0.0067*
R-squared	0.2524		0.2799	

Notes: Standard errors are heteroskedasticity consistent, clustered at the week level. N=22,342 for DL specification; N=22,337 for ECM specification. See text for details.

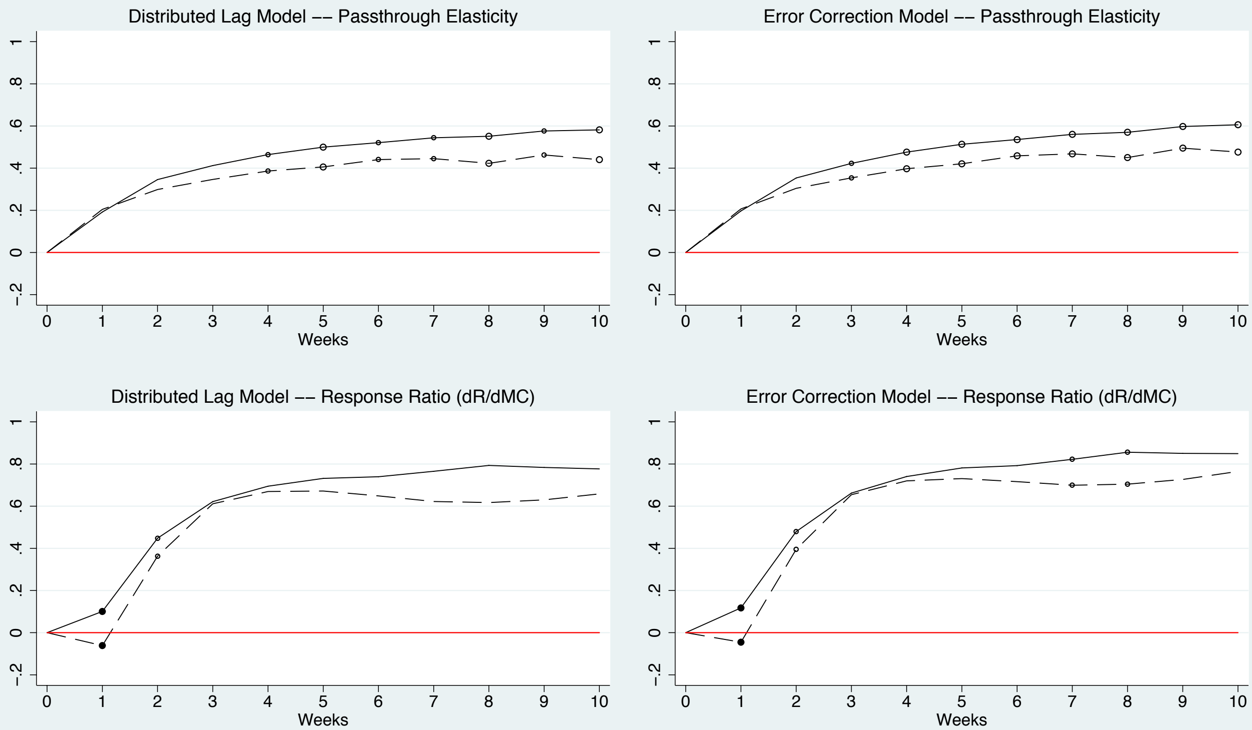
Table 2. Retail Price Response to Changes in the World Price and the Exchange Rate.

	Distributed Lag Model		Error Correction Model	
	Parameter Estimate	Standard Error	Parameter Estimate	Standard Error
Δ(NY Price in Dollars) * (XChange Rate)_{t-1}	0.101	*0.025*	0.118	*0.027*
Δ(NY Price in Dollars)_{t-1} * (XChange Rate)_{t-1}	0.347	*0.024*	0.316	*0.030*
Δ(NY Price in Dollars)_{t-2} * (XChange Rate)_{t-1}	0.173	*0.018*	0.146	*0.027*
Δ(NY Price in Dollars)_{t-3} * (XChange Rate)_{t-1}	0.073	*0.018*	0.098	*0.029*
Δ(NY Price in Dollars)_{t-4} * (XChange Rate)_{t-1}	0.037	*0.018*	0.093	*0.029*
Δ(NY Price in Dollars)_{t-5} * (XChange Rate)_{t-1}	0.008	*0.018*	0.043	*0.028*
Δ(NY Price in Dollars)_{t-6} * (XChange Rate)_{t-1}	0.026	*0.020*	0.060	*0.026*
Δ(NY Price in Dollars)_{t-7} * (XChange Rate)_{t-1}	0.028	*0.020*	0.046	*0.026*
Δ(NY Price in Dollars)_{t-8} * (XChange Rate)_{t-1}	-0.010	*0.017*	-0.008	*0.025*
Δ(NY Price in Dollars)_{t-9} * (XChange Rate)_{t-1}	-0.007	*0.017*	-0.001	*0.023*
Δ(Exchange Rate) * (NY Price in Dollars)_{t-1}	-0.061	*0.043*	-0.045	*0.042*
Δ(Exchange Rate)_{t-1} * (NY Price in Dollars)_{t-1}	0.424	*0.045*	0.397	*0.047*
Δ(Exchange Rate)_{t-2} * (NY Price in Dollars)_{t-1}	0.249	*0.041*	0.201	*0.049*
Δ(Exchange Rate)_{t-3} * (NY Price in Dollars)_{t-1}	0.058	*0.048*	0.063	*0.054*
Δ(Exchange Rate)_{t-4} * (NY Price in Dollars)_{t-1}	0.002	*0.041*	0.079	*0.046*
Δ(Exchange Rate)_{t-5} * (NY Price in Dollars)_{t-1}	-0.023	*0.045*	0.018	*0.047*
Δ(Exchange Rate)_{t-6} * (NY Price in Dollars)_{t-1}	-0.027	*0.042*	0.011	*0.046*
Δ(Exchange Rate)_{t-7} * (NY Price in Dollars)_{t-1}	-0.005	*0.045*	0.016	*0.051*
Δ(Exchange Rate)_{t-8} * (NY Price in Dollars)_{t-1}	0.013	*0.043*	0.006	*0.046*
Δ(Exchange Rate)_{t-9} * (NY Price in Dollars)_{t-1}	0.028	*0.037*	0.021	*0.041*
Δ(Retail Price in Local Currency)_{t-1}			0.059	*0.050*
Δ(Retail Price in Local Currency)_{t-2}			-0.083	*0.044*
Δ(Retail Price in Local Currency)_{t-3}			-0.150	*0.048*
Δ(Retail Price in Local Currency)_{t-4}			-0.013	*0.047*
Δ(Retail Price in Local Currency)_{t-5}			-0.064	*0.044*
Δ(Retail Price in Local Currency)_{t-6}			-0.016	*0.044*
Δ(Retail Price in Local Currency)_{t-7}			0.012	*0.043*
Δ(Retail Price in Local Currency)_{t-8}			-0.005	*0.042*
Δ(Retail Price in Local Currency)_{t-9}			0.009	*0.031*
Retail Price in Local Currency_{t-1}			-0.041	*0.019*
New York Price in Dollars_{t-1}			0.044	*0.021*
Monthly Dummies (p-value)	0.2842		0.0551	
Country Dummies (p-value)	1.0000		0.9999	
Equality of NY price and XR (p-value)	0.0026		0.0102	
Cumulative NY and XR effects	0.1184	*0.1236*	0.1441	*0.1178*
Disturbance autocorelation	0.0504	*0.0067*	0.0004	*0.0067*
R-squared	0.5872		0.6102	

Notes: Standard errors are heteroskedasticity consistent, clustered at the week level. N=22,342 for DL specification; N=22,337 for ECM specification. See text for details.

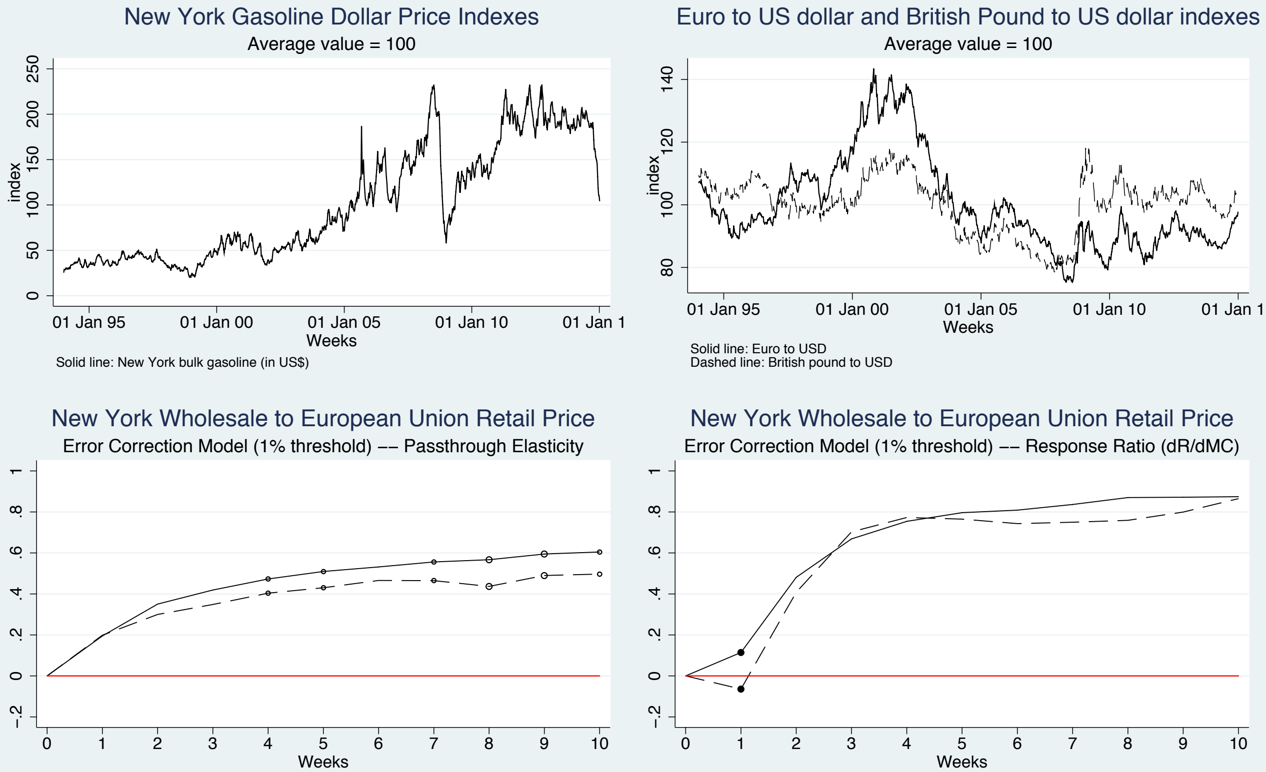
Figure 1. Retail Passthrough from Changes in Wholesale Cost Components

New York Wholesale to European Union Retail Price



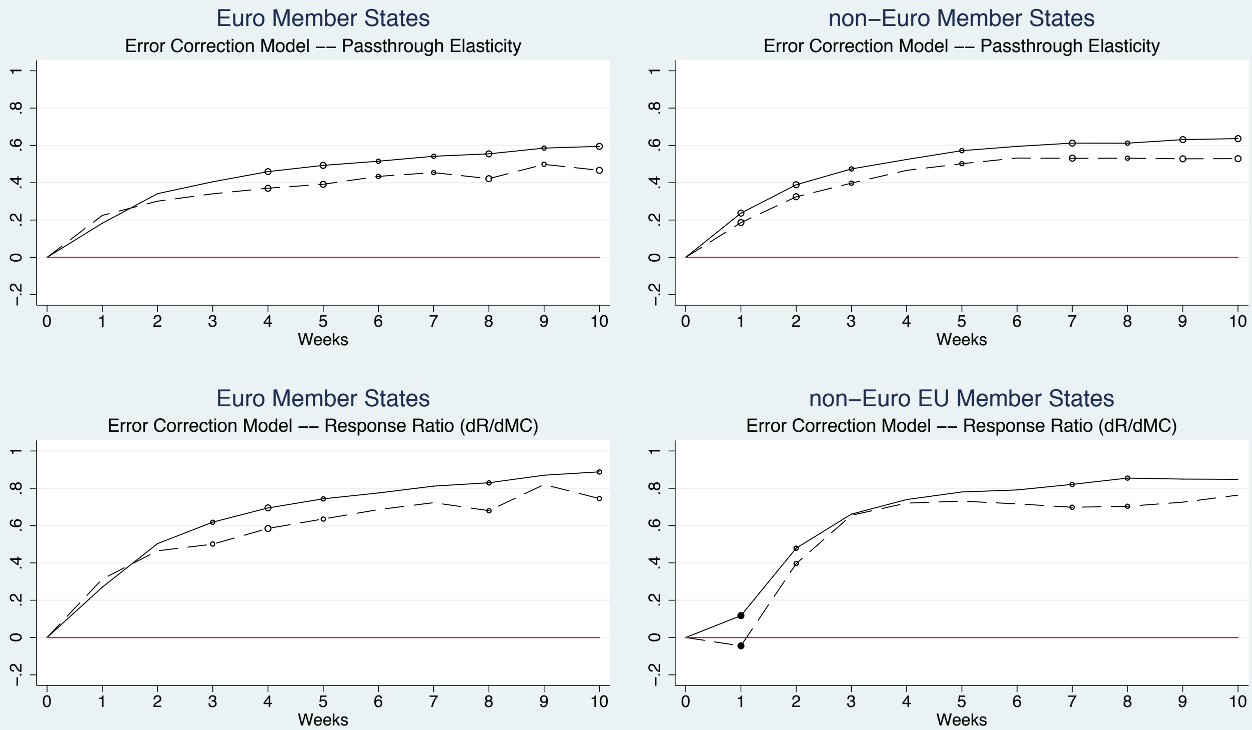
Solid line: passthrough from world wholesale price in US$, dashed line: exchange rate passthrough.
Solid marker: statistically significant difference at 1%; hollow marker: signif. at 5%; small marker: signif. at 10%

Figure 2. Exchange Rate vs Gasoline Price Variability, and Minimum Thresholds



Solid line: passthrough from world wholesale price in US$, dashed line: exchange rate passthrough.
Solid marker: statistically significant difference at 1%; hollow marker: signif. at 5%; small marker: signif. at 10%

Figure 3. Retail Passthrough from Changes in Wholesale Cost Components
New York Wholesale to E.U. Retail Price by Euro Membership



Solid line: passthrough from world wholesale price in US$, dashed line: exchange rate passthrough.
Solid marker: statistically significant difference at 1%; hollow marker: signif. at 5%; small marker: signif. at 10%