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How Large and Persistent is the Response of Inflation to
Changes in Retail Energy Prices?

by Chadi Abdallah and Kangni Kpodar

I N T E R N A T I O N A L M O N E T A R Y F U N D

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Fiscal Affairs Department

How Large and Persistent is the Response of Inflation to Changes in Retail Energy Prices?

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Authorized for distribution by David Coady

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Abstract

We estimate the dynamic effects of changes in retail energy prices on inflation using a novel monthly database, covering 110 countries over 2000:M1 to 2016:M6. We find that (i) inflation responds positively to retail energy price shocks, with effects being, on average, modest and transitory. However, our results suggest significant heterogeneity in the response of inflation to these shocks owing to differences in factors related to labor market flexibility, energy intensity, and monetary policy credibility. We also find compelling evidence of asymmetric effects—under sufficiently large shocks—in the case of high-income and low-income countries, with increases in retail fuel prices inducing larger effects on inflation than decreases in fuel prices.

JEL Classification Numbers: E30,E31,H23

Keywords: Retail fuel prices, Oil prices, inflation, local projections, asymmetries, non-linearity

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I. INTRODUCTION

The macroeconomic effects of changes in energy prices continue to generate much interest, especially in light of the increasing recognition of the broader environmental, fiscal, macroeconomic consequences of underpricing energy products (Clements et al., 2013, and Coady, Parry, Sears, and Shang, 2015). Fuel pricing continues to be at the center of an ongoing policy debate that has gained prominence in 2009 with the world's largest economies (G20) agreeing to mitigate emissions of carbon dioxide and other greenhouse gases, as part of a concerted effort to combat global warming (Parry et al., 2014). Such commitment has been reaffirmed in 2012, and more recently, in the context of the 2015 Paris Climate Agreement.

Nevertheless, concerns related to the potential adverse macroeconomic effects of increases in energy prices constitute an important impediment to reforming their prices. For instance, one challenge is the impact of changes in energy prices on inflation which has direct implications for the real purchasing power of households. The perception that increases in energy prices lead to large and persistent inflationary impact is due to several major past episodes of high inflation, including during the mid to late 1970s, and more recently during the period that preceded the financial crisis and recession of 2008–09.

How do changes in retail energy price changes affect consumer price inflation? For simplicity, suppose that there is a one-time increase in the retail price of gasoline, while everything else is unchanged. Economic theory suggests that, since households consume gasoline, any increase in the price of this fuel would lead to a reduction in the purchasing power of households—with the magnitude of the impact being proportional to the share of gasoline consumption in the consumer basket of a typical household. This is referred to as the *direct* effect. While such effect should, at least in principle, be small and is expected to fade away due to consumers adjusting *downwards* their consumption in response to the price increase, estimates suggest that the demand by households for energy is, on average, relatively inelastic in the short-run (Labandeira, Labeaga, and López-Otero, 2017). Hence, there is no reason to believe that *direct* effects are necessarily small and insignificant in the short-run. In fact, in countries where switching to more energy efficient cars and other household equipment can be challenging due to issues related to affordability, direct effects are expected to be more persistent, possibly spilling over into the medium-term. The same argument applies to countries where the appropriate infrastructure is lacking and the absence of adequate public transportation systems makes it challenging for households to decrease their consumption of the more expensive fuel or substitute away from driving energy inefficient cars for the purpose of commuting to work or school. Another impact on inflation, referred to as the *indirect* effect, results from the fact that some energy products—such as diesel—are often used directly by industries as inputs in the production process of other (non-energy) goods and services. Similarly, the *indirect* effects on inflation can also be induced by the extent to which higher diesel or natural gas prices impact electricity prices faced by industries, thus affecting their cost of production. The indirect impact tends to be more worrisome for policymakers, especially in countries that are relatively more energy intensive. We can cast these two types of effects into two main channels of transmission of fuel price shocks, with the indirect effect exhibiting the impact of an aggregate supply shock, while the direct effect being akin to an aggregate demand shock. Recent empirical evidence suggests that while the former channel's quantitative importance remains an open issue (Kilian, 2008), there is a

consensus in the literature that the latter channel dominates in practice. From this perspective, a key mechanism whereby fuel price shocks affect the economy is through a disruption in consumers' and firms' spending on goods and services other than energy (Kilian 2008; Hamilton 2008).² Nevertheless, even if both channels of transmission respond to increases in fuel prices—leading to shifts in both the aggregate supply and demand curves to the left—the net effect on domestic inflation may likely be small and transitory. Nevertheless, under certain conditions, the impact of fuel price shocks on inflation can be amplified. For instance, less flexible labor markets—for example, when the wage setting mechanism is centralized in the presence of powerful unions—an upward pressure on wages could well induce wage-price spiral effects that can magnify the effects of fuel price shocks.

Finally, the way in which monetary policy reacts to the domestic fuel price shocks—for example by accommodating or not accommodating such shocks—may potentially matter for how domestic inflation responds to them. For example, if domestic fuel price shocks coincide with the cycle of wage negotiations (e.g., in a centralized wage bargaining system) or if the central bank generally fails to anchor inflation expectations in the face of these shocks, it may be very likely that what ought to be a transitory domestic supply side shock (i.e., the fuel price shock) becomes a demand side shock that has a permanent impact on the general price level in the economy and thus may necessitate the undertaking of contractionary monetary policy with unintended negative consequences on short-term growth. This, for example, begs the important question of whether coordination between monetary and fiscal authorities is necessary when governments embark on energy subsidy reforms—with respect to both, the timing and the sequencing or size of ensuing fuel price increases. These are questions that matter for many areas of study, including for the sustainability of energy price increases under energy subsidy reforms—which has very relevant macroeconomic, environmental and fiscal policy implications (Clements et al., 2013; Davis, 2014; and Coady et al., 2015). Overall, improving our understanding of the inflationary effects of domestic fuel price increases is very relevant for policymaking going forward.

II. LITERATURE REVIEW

There are at least two shortcomings with much of the work that attempts to sort out the potential impact of fuel price shocks on inflation. The first is that much of the literature has focused on the price of crude oil as the variable of interest in studying the effects of fuel price shocks on macroeconomic variables (De Gregorio et al., 2007; Blanchard and Galí, 2007; Chen, 2009; Habermeier et al., 2009; Caceres and Medina, 2012; Gelos and Ustyugova, 2017; and Choi et al., 2018). While undoubtedly relevant for analysis, shocks to the international price of crude oil are generally not very informative in answering the question at hand, mainly because crude oil is not consumed directly by consumers and is not used—at least not directly—as an input to production by firms outside of the refining industry.³ And while it is reasonable to assume that

² The demand channel may be amplified by increased precautionary savings and by the increased operating cost of energy-using durables (Edelstein and Kilian, 2009).

³ For example, in advanced countries, the magnitude of fuel price shocks faced by firms can be much smaller than the corresponding shocks to international crude oil prices due to the large share of electric power available at stable prices (Kilian, 2008).

shocks to international crude oil prices are eventually transmitted one-to-one to retail domestic fuel prices, this is only true for a handful of countries where prices are fully liberalized. Furthermore, global crude oil price shocks are not the only major source of shocks to retail fuel prices across countries. Differences in fuel pricing policies, taxation, fluctuations in exchange rates, and other important domestic factors also matter and may distort analyses that focus solely on the effect of international crude oil price shocks. To reinforce the importance of domestic factors and country-specific shocks (other than energy subsidy reform scenarios), the weather events of Hurricane Katrina in the Gulf Coast of the United States in 2005 provide a very good illustration, in the sense that they have shown that country-specific shocks—and even regional within-country shocks—can explain a large component of the fluctuations in domestic retail fuel prices that is not necessarily reflected (at least not meaningfully) in the dynamics of international crude oil prices. Therefore, from the perspective of households and firms, retail fuel prices—such as the retail price of fuel or diesel—are most relevant than measures of international crude oil prices, since they are ultimately the basis on which these agents make their economic decisions (Kilian, 2008). And while reliable high frequency data on retail fuel prices in advanced countries are readily available, the public availability of such data tend to be generally very acute across emerging, developing and low-income countries. The lack of availability of a consistent dataset on high frequency retail domestic fuel prices worldwide, has often hindered empirical research on the macroeconomic impact of fuel price shocks. In the context of the ongoing debate on the potential macroeconomic impact of energy price increases under energy subsidy reform, this can hamper reform efforts by increasing the uncertainty about the potential impact of such price reforms on inflation (and growth). For example, the need to increase energy prices to achieve full-cost recovery in some countries—most notably across countries in the Middle East and North Africa region—or to address the negative externalities of low fuel prices through corrective Pigouvian taxation across all countries in general, has often been faced with great resistance from policymakers and other stakeholders—at least partly, as a result of such uncertainty in the potential macroeconomic impact of the required energy price increases under the reforms.

The second issue is that insufficient attention has been paid in the literature to the potential non-linearity and asymmetry in the effects of fuel price shocks on domestic inflation.⁴ For instance, there is no reason to expect a large increase in fuel prices to have a similar effect on inflation than an increase of a much smaller magnitude. This is because economic agents are unlikely to change their behavior in response to small fluctuations in fuel prices. Therefore, output and prices may respond differently to oil price shocks of different magnitudes (Hamilton 1996, 2003). Another important aspect is the potential asymmetry in the effects of changes in retail fuel prices on domestic inflation. Such asymmetry (e.g., increases versus decreases in prices) may have important implications for our understanding of the transmission mechanism of these shocks and for the debate about the appropriate design of automatic fuel pricing mechanisms in countries that still regulate domestic fuel prices, and the debate about the appropriate monetary policy response to fuel price shocks. From that perspective, while central banks— especially in countries with existing initial high levels of inflation—should not accommodate transitory supply side fuel price increases when secondary effects on inflation are likely, should they

⁴ Existing studies mostly focused on the case of advanced countries.

accommodate, for example, supply side fuel price decreases even when such secondary round effects materialize?

In this study, we use and update the large novel monthly dataset of domestic retail fuel prices compiled in Kpodar and Abdallah (2017), to estimate the effects of retail fuel price changes on inflation for different country groups. When devising country groups, we focus on country-specific factors—including the income level, energy intensity, labor market flexibility, and central bank credibility—as candidate features that can help explain the heterogeneity in the spillovers from retail domestic fuel price shocks to inflation across countries.

The empirical approach, detailed in the next section of the paper, relies on a multivariate model that accounts for the dynamic relations among the variables, and allows for non-linearity in the effects. Within this framework, we identify shocks to retail domestic fuel prices by relying on the common assumption (in the literature) that innovations to the domestic fuel price series—measured in local currency units—are predetermined with respect to macroeconomic variables. To the best of our knowledge, this study involves the first attempt to use the most comprehensive monthly data on retail domestic fuel prices across a broad set of 110 countries over 2010 to 2016—including advanced, emerging, and developing countries—to: (i) undertake a detailed and careful empirical analysis of their dynamic effects on inflation; and (ii) explain the heterogeneity in such effects across countries using country-specific factors such as energy intensity, labor market flexibility, and central bank credibility. The main results of our study can be summarized as follows:

- i. The dynamic response of inflation to a retail domestic fuel price shock is generally modest and transitory. For the full sample, a 1 percent shock to retail fuel prices leads to an increase of about 0.04 percent in the level of consumer prices, one year after the shock, and then decreases thereafter. However, the responses vary significantly across country groups, with low income countries exhibiting the largest response (around 0.06 percent), followed by emerging countries (around 0.036 percent) and advanced countries (around 0.025 percent), over the same horizon.
- ii. Aside from the income level, other structural factors seem to largely explain the heterogeneity in the response of inflation to the shocks across countries. For example, the variation in the response of inflation to fuel price shocks across country groups can be explained by differences in the extent of wage flexibility, energy intensity, and monetary policy credibility. Specifically, our results suggest that larger responses of inflation to domestic retail fuel price shocks are exhibited by economies with less flexible wages, less credible monetary policy regimes, and higher energy intensity.
- iii. There is an asymmetry in the responses of inflation to fuel prices shocks—especially in the case of advanced and low-income countries—whereby positive domestic fuel price shocks tend to exhibit larger and more persistent impacts on inflation than negative domestic fuel price shocks. Such asymmetry in the inflationary response tends to be more pronounced under sufficiently large domestic fuel price shocks, and essentially vanishes when shocks become small.

The rest of the paper is structured as follows. Section II lays out the empirical approach and presents the data along with some stylized facts. Section III presents and discusses the empirical results from the baseline model and attempts to explain the heterogeneity in the response of inflation to fuel price shocks across country groups, focusing on the role of economic fundamentals. This section also presents the results from the non-linear model. Section VI summarizes the findings and concludes.

III. EMPIRICAL FRAMEWORK: ESTIMATION AND IDENTIFICATION

Our aim is to estimate the dynamic responses of consumer price inflation to domestic retail fuel price shocks. Let y_t be the k -dimensional vector stochastic process for the following set of variables: retail fuel prices—measured in local currency—the nominal effective exchange rate (NEER), the consumer price index, and a measure of the short-term interest rate (the lending rate).⁵ We postulate that y_t can be approximated by a vector autoregression of finite order p :

$$B_0 y_{it} = B_1 y_{it-1} + \dots + B_p y_{it-p} + u_{it} \quad (1a)$$

where u_{it} contains country-specific structural shocks—with their variance-covariance matrix being normalized to be the identity matrix. To allow estimation of the structural model in (1a), one first needs to derive its reduced-form representation. This simply involves expressing y_t as a function of lagged y_{it} . A typical variation of (1a) allows for an intercept, a vector of conditioning exogenous variables and country fixed effects. For expository purposes, we abstract here from these, although we will use them in the estimation throughout this paper. To derive the reduced-form representation, we pre-multiply both sides of the structural model representation in (1a) by B_0^{-1} :

$$B_0^{-1} B_0 y_{it} = B_0^{-1} B_1 y_{it-1} + \dots + B_0^{-1} B_p y_{it-p} + B_0^{-1} u_{it}$$

Consequently, the reduced-form counterpart of the structural model in (1a) is as follows:

$$y_{it} = A_1 y_{it-1} + \dots + A_p y_{it-p} + \varepsilon_{it} \quad (1b)$$

By construction, the reduced-form error terms ε_{it} in (1b) are a transformed version of the structural errors u_{it} in (1a), where $\varepsilon_{it} = B_0^{-1} u_{it}$. This implies that the variance-covariance matrix Σ_ε of ε_{it} is:

$$\Sigma_\varepsilon = B_0^{-1} B_0^{-1'}$$

By using this multivariate specification, one could determine the response of domestic inflation to fuel price shocks conventionally as follows: (i) in a first step, estimate the reduced form representation in (1b); (ii) in a second step, invert the resulting estimated coefficient (i.e., the coefficients on the lagged variables in the vector y_{it}) to obtain the moving average coefficients—which constitute the reduced-form impulse response functions; and (iii) in a final step, impose sufficient identifying restrictions on B_0^{-1} to form the structural impulse response functions of

⁵ We use the local currency price of fuel rather than the dollar price to avoid dividing by an endogenous variable (Blanchard and Galí, 2007).

interest—part of which are the dynamic impulse responses of inflation to the orthogonalized domestic retail fuel price shocks.

While such approach is standard, it presupposes that the data is generated by a Vector Autoregression (VAR) model—which is clearly only correct if the model coincides with the data generating process. Studies have argued that the dynamics of some basic models often follow VARMA representations that are often incompatible with VARs (Cooley and Dwyer, 1998). Consequently, and under such conditions, it follows that specifying a VAR may well introduce significant misspecification, with potentially serious implications for the estimation of—and inference from—impulse response functions, since misspecification errors are compounded with the forecast horizon (Jordà, 2005).⁶ To address this issue, we take an alternative approach to estimating the impulse responses by fitting the following linear projection for each equation in our multivariate model (Jordà 2005, 2009):

$$y_{it+h} = G_1 y_{it} + G_2 y_{it-1} + \dots + G_p y_{it-p} + D_1 z_t + F_i + \varepsilon_{it+h} \quad h = 1, \dots, H \quad (2)$$

where ε_{it} is serially correlated or heteroscedastic, z_t is a vector of conditioning exogenous variables, and F_i denote country fixed effects. By construction, the slope G_1 is interpreted as the response of y_{it+h} to a reduced-form disturbance in period t . This approach is essentially akin to generating multi-step predictions using direct forecasting equations that are re-estimated for each forecast horizon. As argued in Jordà (2005), such approach is robust to misspecification because impulse responses can be defined without any reference to the unknown data generating process—and even when the Wold decomposition does not exist (Koop et al., 1996; Potter, 2000; and Jordà, 2005).⁷ Consequently, the impulse responses can be defined as follows:

$$\Phi_h = G_1 = E(y_{it+h} | \varepsilon_t = 1; y_{it}, \dots, y_{it-p}) - E(y_{it+h} | \varepsilon_t = 0; y_{it}, \dots, y_{it-p}) \quad (3)$$

Nevertheless, while the local projection approach allows us to more accurately estimate the impulse responses of interest, it doesn't address the issue of correct inference—which is related to identifying the causal effects of domestic retail fuel price shocks. Here, it is important to note that strict exogeneity is not required for estimating such causal effects. A much weaker—and more defensible—assumption is that changes in fuel prices are predetermined with respect to macroeconomic variables (Davis and Haltiwanger, 2001; Lee and Ni, 2002; Kilian, 2008; Blanchard and Galí, 2007). In other words, the retail price of fuel is assumed to respond, with a delay, to changes in macroeconomic conditions—an assumption that is standard in the literature. The study by (Kilian and Vega, 2011) lends credence to such exclusion restrictions in monthly retail fuel price models—ruling out instantaneous feedback from domestic macroeconomic aggregates to the retail price of fuel. This reinforces confidence in our identification strategy and makes it

⁶ Misspecification problems are potentially even more relevant in the context of our study, since we use panel data consisting of a wide range of countries, which makes it more difficult to specify the estimation equations from the viewpoint of economic theory.

⁷ This modelling approach has its roots in the direct multi-step versus iterated forecasting approaches (see, for example, Stock and Watson, 1999).

more robust, especially in the context of our monthly data (Kilian, 2008).⁸ Consequently, the corresponding dynamic structural impulse responses of interest ψ_h can be written as follows:

$$\psi_h = \Phi_h B_0^{-1} \quad h = 1, \dots, H \quad (4)$$

where B_0^{-1} is assumed to be a lower-triangular matrix and is obtained based on recursively identifying the VAR model in (1b), with fuel prices ordered first. And while the analysis in Jordà (2005) does not explicitly discuss the distinction between structural and reduced form impulse responses derived from local projections, the impulse responses in his study are obtained using a similar identification approach (Jordà 2005, pp. 175).

Since our study is investigating hypotheses related to the sign and size of the fuel price shocks, an alternative specification to the one in (2) is clearly needed to account for the non-linearity. In a traditional multivariate setting, the investigation of nonlinearities can be complex due to: (i) the limited ability to jointly estimate a nonlinear system of equations with its inherent computational difficulties; (ii) the difficulty in generating multiple-step ahead forecasts from a multivariate non-linear model since it requires simulation methods; and (iii) the challenge in computing appropriate standard errors for the impulse responses.

Broadly speaking, there have been several approaches in the literature that allow for non-linearity in the effects of energy prices. One approach relies on linear models involving censored repressors (Mork, 1989) or on asymmetric model specifications that combine asymmetries with additional nonlinearities—with the net oil price variable of Hamilton (1996, 2003, 2009, 2011) being an example. However, recent studies have argued that estimates from such models can be inconsistent and mis-specified, regardless of whether the data generating process is symmetric or asymmetric. More specifically, any inference based on linear impulse responses—that are independent of the magnitude and the history of shocks—can be misleading for studying the hypotheses of symmetry. From this perspective, Kilian and Vigfusson (2011) specify an econometric model that can capture asymmetric responses to positive and negative oil price shocks, building on Mork (1989). The approach that we take in this study is to extend the local projections approach (Jordà, 2005) as specified in (2). More specifically, we modify the set of local projection equations in (2)—consistent with the flexible local projections of Jordà (2005, 2009)—as follows:

$$y_{it+h} = G_1 y_{it} + G_2 y_{it-1} + \dots + G_p y_{it-p} + H_1 y_{it}^2 + H_2 y_{it}^3 + D_1 z_t + F_i + \varepsilon_{it+h} \quad (5)$$

Note that the polynomial terms in (5) imply that the impulse responses will now vary according to both, the sign and the size of the fuel price shock. In addition, the impulse responses now also inherently depend on the local history of the shock (we evaluate them, as in Jordà (2005), at the sample mean). Monte Carlo simulations presented in Jordà (2005) show that flexible projections with polynomial terms perform well with respect to approximating the inherent nonlinearities of a dynamic model. Note that both, the approach by Kilian and Vigfusson (2011) and the flexible local projection approach of Jordà (2005, 2009) both provide a semi-parametric approximation to

⁸ The assumption that changes in fuel prices are *predetermined* with respect to macroeconomic variables is typically inappropriate when working with annual data. The literature supports its use when working with high frequency data in general—and with monthly data in particular (Kilian, 2008).

potentially asymmetric and non-linear responses generated by a variety of models. We choose the latter because it allows the use of more parametric structure which helps improve the precision of the estimates and the power of tests of symmetry and non-linearity. Recently, there has been a growing interest in the literature in estimating impulse responses using local projections, including studies on the fuel pass-through from international oil price shocks to retail fuel prices (Kpodar and Abdallah, 2017), the effects of fiscal policy shocks (Auerbach and Gorodnichenko, 2013; Ramey and Zubairy, 2014), the effects of exchange rate shocks (Caselli and Roitman, 2016), and shocks to excess credit (Jordà et al., 2013).

Finally, we include in each equation 12 lags of each of the four endogenous variables, country fixed-effects, an intercept, and a binary variable indicating the period of the great recession of 2008–09. Prior to estimation, we transform all data to log first-differences (except for the interest rate variable, which we first-difference only). We estimate each equation, for each horizon, by least squares regression.⁹ Finally, for hypothesis testing, we use standard errors that are clustered at the country level, robust to heteroscedasticity and autocorrelation, and based on a non-parametric block bootstrap procedure with 2000 replications (Bertrand et al, 2004; and Kilian and Kim, 2009). We report confidence intervals based on selected percentiles from the resulting empirical density.

IV. DATA AND STYLIZED FACTS

In this study, we extract from the database compiled in Kpodar and Abdallah (2017) monthly domestic retail fuel prices over the period 2000:1 to 2014:6 for a sample of 110 countries, of which 31 are high income countries, 42 are emerging countries and 37 are low income countries.¹⁰ We use the retail gasoline price as the fuel price variable in all specifications, throughout our study. Using the retail diesel price produces similar results.

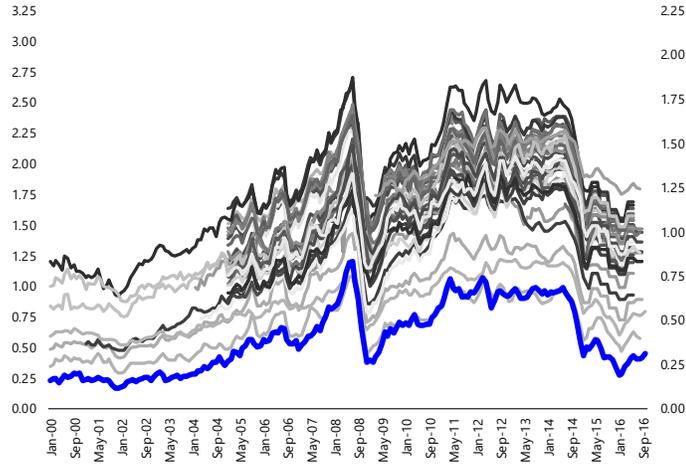
The unbalanced panel data in this study contains around 12600 observations—an order of magnitude greater than has been used in most studies on the macroeconomic effects of fuel price shocks to date. We divide the sample into a number of country-observation groupings (according to income levels, and economic fundamentals), estimate and compare the effects across groups. The remaining variables are obtained from the IMF's International Finance Statistics (IFS) database and Haver Analytics.

⁹ While the presence of a lagged dependent variable and country fixed effects may in principle bias the estimation of β_1 in small samples (Nickell, 1981), the length of our time dimension mitigates this concern. The finite sample bias is in the order of $1/T$, where T in our sample is large.

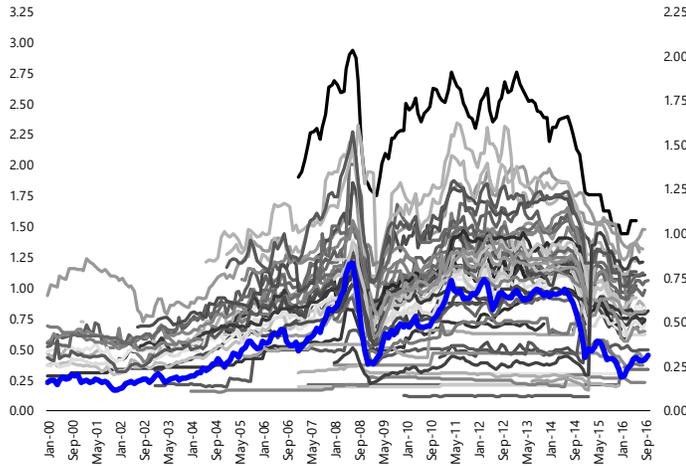
¹⁰ The Kpodar and Abdallah (2017) study covers 162 countries. However, our sample is limited to 110 countries owing to the availability of corresponding monthly data on the remaining macroeconomic aggregates for the purpose of the analysis in this paper.

Figure 1. Monthly Retail Fuel Prices
(\$U.S. per liter)

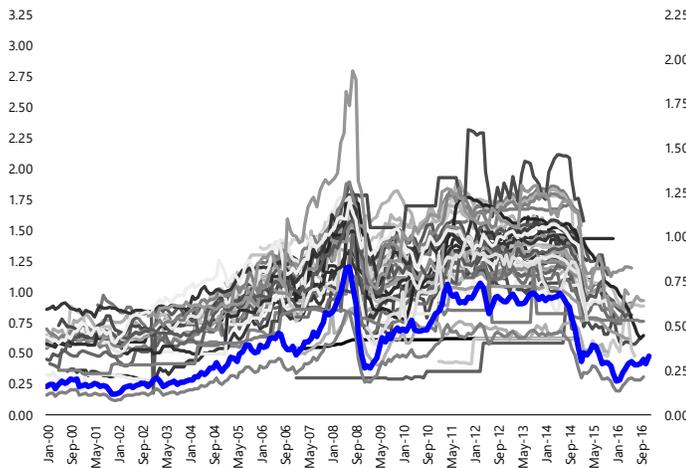
A. High-income countries



B. Emerging countries



C. Low-income countries

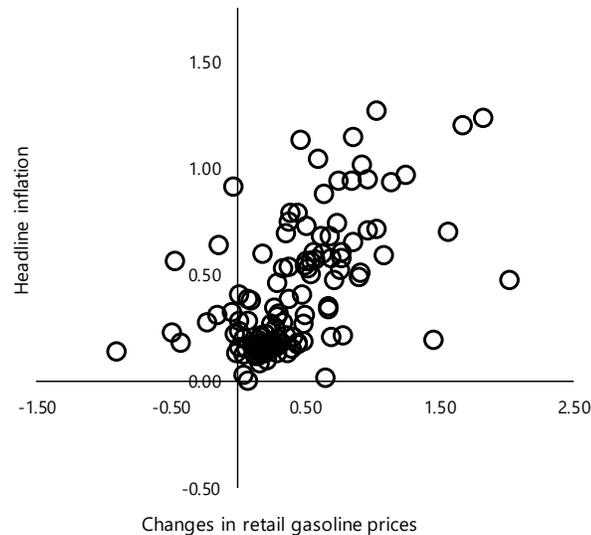


Source: Kpodar and Abdallah (2017).

Note: Retail fuel prices (USD per liter, left axis). The solid blue line corresponds to the international crude oil price (USD per liter, right axis).

Figure 1 displays the evolution of monthly domestic retail fuel prices for three groups of countries since 2000. It shows the monthly U.S. dollar price of a liter of fuel. As the figure suggests, levels and changes can be very heterogeneous across countries. Moreover, not only the distribution of these changes has not been uniform, but also their incidence has not always been common to all countries. For instance, retail fuel prices appear to display somewhat less variability in some emerging and low-income countries mainly reflecting a prevalence of regulated fuel prices.

Figure 2. Changes in Retail Fuel Prices and CPI Inflation
(Average over 2000–16)



Source: IMF staff calculations.

Note: The scatter plot contains data for 110 countries, for which data on both headline CPI inflation and fuel prices were available.

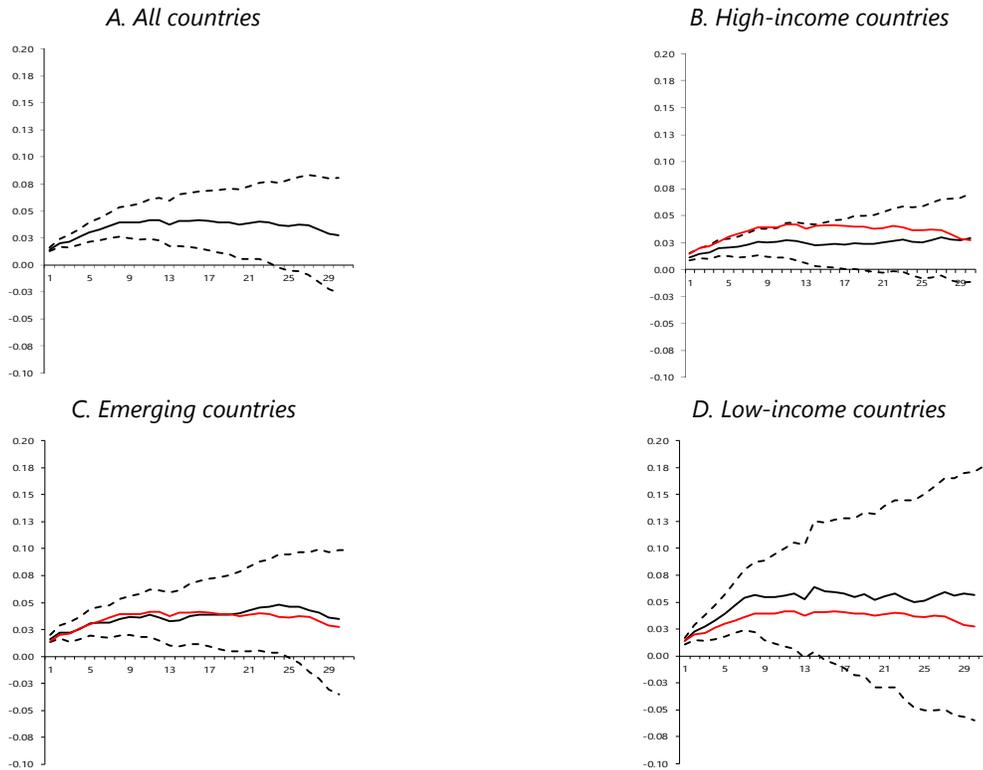
V. EMPIRICAL FINDINGS

A. By Income Level

As discussed earlier, our impulse response functions to fuel price shocks are estimated using local linear projections. The responses are accumulated and shown in levels up to a 30-month horizon. The 16th and 84th percentiles (dashed lines), obtained from the bootstrap procedure, are shown on both sides of the point estimate. The size of the shock is normalized so that it raises the price of fuel by 1 percent on impact in all country groups, for comparability. Figure 3 displays the (accumulated) estimated impulse response functions of domestic inflation, for different country income groups. For the full sample of countries (Panel A), inflation responds positively to retail domestic fuel price shocks. The response is around 0.014 percent, one month after the shock, increasing to a peak of around 0.04 percent, eight months after the shock. The effect is only transitory, essentially decaying to around 0.025 percent, and is statistically insignificant two years after the shock.

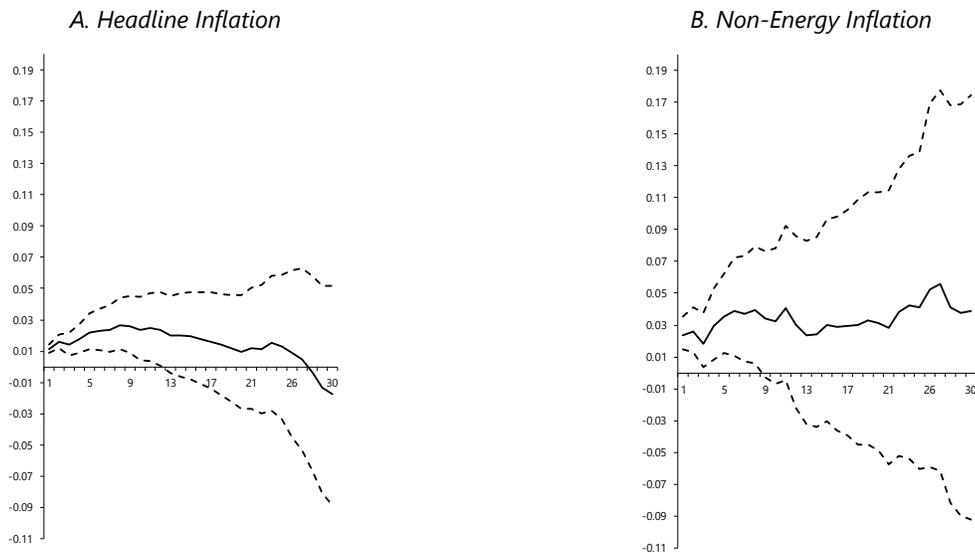
However, the findings for the full sample of countries can potentially mask a significant heterogeneity in the magnitude and the persistence of the effects of such shocks across country

Figure 3. Dynamic Response of Inflation (accumulated) to a 1 Percent Fuel Price Shock



Note: Results from the baseline model. The estimate (solid line) and the 16th and 84th percentiles (dashed lines) from a block bootstrap procedure with 1000 replications are shown. The solid red line is the estimate for the full sample of countries (repeated from Panel A).

Figure 4. Dynamic Response of Inflation (accumulated) to a 1 Percent Fuel Price Shock
(Restricted Sample, in Percent)



Note: Results from the baseline model, estimated using a restricted sample of 77 countries, for which both, CPI excluding energy and headline CPI, are available over the same period; dashed lines are the 16th and 84th percentiles from the bootstrap distribution.

groups. For instance, as shown in Figure 3, low income countries exhibit the largest response of around 0.06 percent, followed by emerging countries (around 0.036 percent), and advanced countries (around 0.025 percent) over the same horizon. At the same time, emerging countries display the most persistent and long-lasting response to the shocks among all income groups. The relatively large and persistent response for the emerging economies group—which is predominated by fast growing emerging economies in Developing Asia—is consistent with the evidence in Cunado and Perez de Garcia (2005) who also finds a sizeable inflationary impact of oil price shocks in this sample of countries. Overall, the above results suggest that the spillover from fuel price shocks to domestic inflation is somewhat modest and does not generally lead to sustained effects. This is consistent with empirical evidence suggesting that unpredictable changes in fuel prices historically have been followed by a one-time adjustment in the price level, resulting in a blip in the inflation rate rather than sustained increase in inflation (Kilian and Lewis 2011).

We compile data on non-energy inflation for 77 countries (out of the original sample of 110 countries in this study). We restrict our sample to those 77 countries for which data on both, non-energy inflation and headline inflation, are available over the same period.¹¹ We then estimate, separately, the impulse responses of both non-energy inflation and headline inflation to the same fuel price shocks. The results shown in Figure 4 suggest that the effects of fuel price shocks on non-energy inflation are positive and significant and are somewhat slightly larger than their effects on headline inflation. Hence, fuel price shocks lead to indirect and second round effects on domestic inflation. The shortcoming of not using this measure of non-energy inflation in our analysis must be traded-off with the possibility of estimating our dynamic responses of interest using much longer time periods and 33 more countries. Hence, headline inflation will be used for the remainder of our analysis.

B. By Economic Fundamental

There are several potential explanations behind the pattern of differentiated responses of inflation to fuel price shocks across country groups. On the one hand, economies that have a relatively high energy intensity—compared to other country groups—are expected to experience larger movements in domestic inflation due to fuel price shocks. This is the case of emerging and low-income countries, for which the responses of domestic inflation were estimated to be, on average, higher than that of the low energy intensive high-income economies.

On the other hand, the persistence in the inflationary effects of retail fuel price shocks in emerging economies is suggestive of possible second-round effects. Such effects may come largely because of rising inflation expectations following the incidence of shocks in this group of countries (Cunado and Perez de Garcia, 2005). This is because, for example, forward-looking workers and employers may build higher inflation into future wages and prices. In this sense, labor market rigidities, such as the rigidity of wages, can play an important role here through the wage spiral channel. Finally, the importance of the role of monetary policy for containing

¹¹ Data on CPI excluding energy was compiled for 77 countries using various sources, including the IFS, IMF STA, Haver, and CEIC databases. For a number of countries, this variable was not readily available, and was imputed using information on the weights of energy in the CPI basket.

inflationary pressures associated with energy price shocks has been well highlighted in the literature (Bernanke, Gertler, and Watson, 1997; Barsky and Kilian, 2002 and 2004; and Blanchard and Galí, 2007). For instance, to the extent that the public views the central bank's policy response as sufficiently credible, fuel price changes should not be associated with sustained effects in inflation. Hence, the response of inflation expectations to energy prices can be very important for monetary policy. The consensus is that a central bank with perfect credibility should target core inflation (excluding volatile commodity prices such as the price of fuel). Nevertheless, if energy prices have excessive impact on inflationary expectations, larger monetary policy responses to energy price changes may be warranted (Cavallo, 2008; Harris et al., 2009). But assuming that there is a generally high degree of central bank credibility, there is no reason for such expectations to develop.

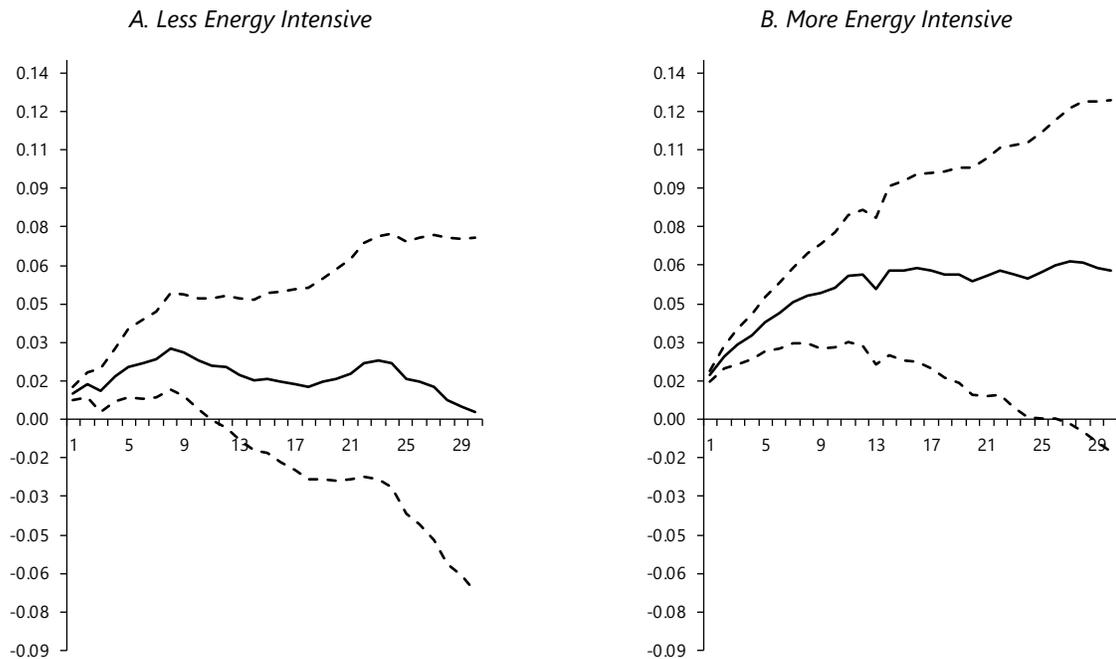
We carefully explore the role of these three fundamentals—energy intensity, flexibility of wages, and monetary policy credibility—to better explain the observed differences in the size and the persistence of the estimated effects of fuel price shocks on domestic inflation across country groups.¹² To do so, we divide our sample of 110 countries into groups, as follows:

- a. *Energy intensity.* We use data on the share of energy in the economy from the OECD library, over 2000–14. We then classify a country as relatively *more energy intensive* if its net inland quantity of energy consumed relative to total real output produced fall *above* the medians of their respective cross-country distribution. Otherwise, a country is classified as relatively *less energy intensive*.
- b. *Wage flexibility.* We use data on the extent to which centralized collective bargaining is used in the wage setting process. Data are from the 2014 *Global Competitiveness Report* published by the World Economic Forum (WEF). This indicator, ranging from 1 (centralized) to 7 (decentralized) provides a score reflecting the flexibility of wage determination. We classify a country as having relatively *more flexible wages* if the score on this indicator falls *above* the median of the cross-country distribution. Otherwise, a country is classified as having relatively *less flexible wages*.
- c. *Monetary policy credibility.* We use the Central Bank Autonomy index developed in Arnone et. al (2009). The index measures the ability of the central bank to select the objectives of monetary policy and its policy instruments. It also takes into account provisions in central bank legislations with regard to policy formulation and its objectives as well as the limitations on central bank lending to the government. These dimensions are important for establishing and strengthening monetary policy credibility. We classify a country as having a relatively *more credible monetary policy* if the score on this indicator falls *above* the median of the cross-country distribution. Otherwise, a country is classified as having a relatively *less credible monetary policy*.

¹² These factors have been found to be important in the literature in explaining the extent to which fuel price shocks affect inflation (Blanchard and Galí, 2007; Gelos and Ustyugova, 2017).

Figures 5a–5c present the effects of a 1 percent fuel price shock on domestic inflation for the different country groups. The results suggest that the above fundamentals matter a great deal in explaining the differential in the response of inflation to retail fuel price shocks across country groups. First, as expected, we find that the inflation response is significantly larger in the group that is classified as *more energy intensive*. The peak (accumulated) response of inflation (0.061 percent) for this group is around 120 percent higher than that of the group of *less energy intensive* countries (0.027 percent). De Gregorio et al. (2007) also find that, in a group of advanced countries, the spillover from fuel price shocks on domestic inflation depends on the level of energy intensity (Figure 5a).

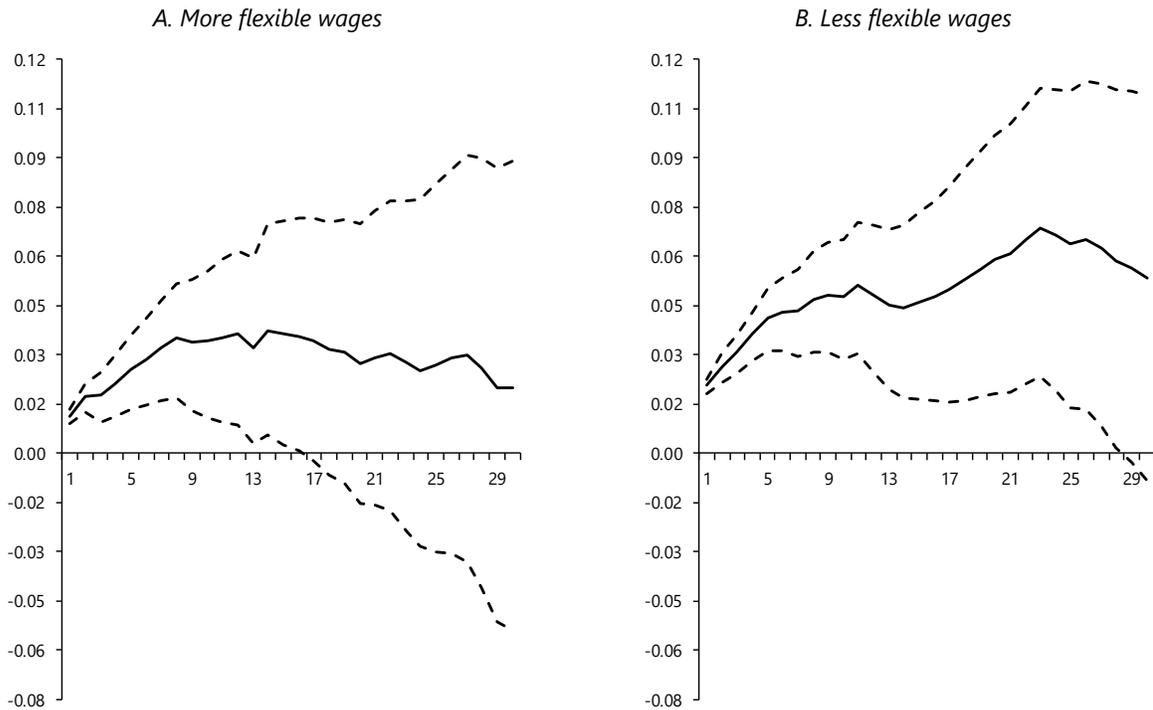
Figure 5a. Dynamic Responses of Inflation (accumulated) to a 1 Percent Fuel Price Shock
(By Energy Intensity, in Percent)



Note: Each panel includes, for the baseline model, the estimate (solid line) and the 16th and 84th percentiles (dashed lines) from a block bootstrap procedure with 1000 replications.

Second, Blanchard and Galí (2007) show that the presence of some rigidity in the adjustment of wages to shocks is a necessary ingredient to generate significant fluctuations in measures of inflation and output. Figure 5b illustrates this point by showing our estimated inflation response is significantly larger in the group classified as having *less flexible wages*. The peak response of inflation (0.069 percent) for this group is around 85 percent higher than that of the group characterized by *more flexible wages* (0.037 percent). The effects are also notably more persistent for the former group, with the effects lasting more than two years after the shock, compared to around only one year for the group of countries with more flexible wages (Figure 5b). This could potentially imply the prevalence of sizeable wage spiral effects in this group of countries. This result is in contrast with the results in Gelos and Ustyugova (2017) who found that, in a group of 31 advanced and 61 emerging and developing countries over 2001–10, the inflationary impact of global fuel price increases does not appear to be significantly affected by labor market factors.

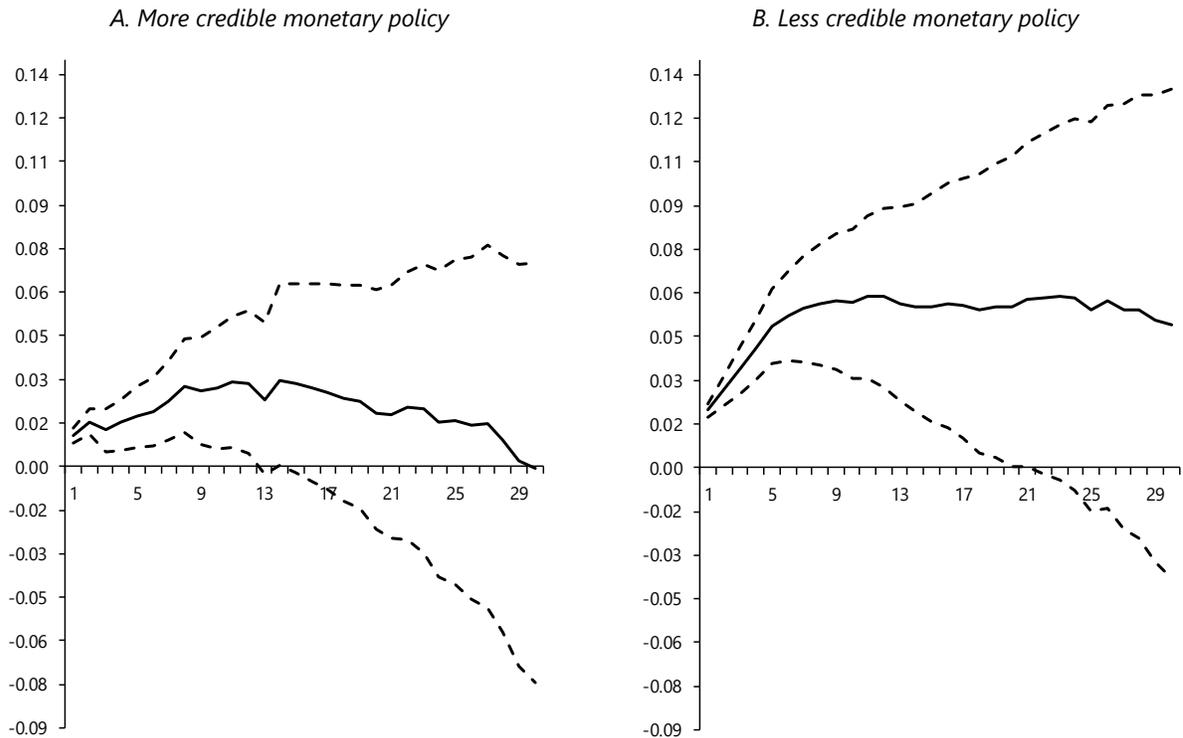
Figure 5b. Dynamic Responses of Inflation (accumulated) to a 1 Percent Fuel Price Shock
(By Wage Flexibility, in Percent)



Note: Each panel includes, for the baseline model, the estimate (solid line) and the 16th and 84th percentiles (dashed lines) from a block bootstrap procedure with 1000 replications.

Finally, we find that the inflation response is significantly larger in the group characterized by less credible monetary policies. The peak response of domestic inflation to fuel price shocks (0.059 percent) for this group is double that of the group characterized by more credible monetary policies. Furthermore, the group of countries characterized by less credible monetary policy regimes experience more lasting and more persistent effects on domestic inflation from fuel price shocks. In fact, the effects last for about two years after the shock, compared to only one year for the group of countries characterized by more credible monetary policy regimes. This result highlights the important role of monetary policy in the transmission of fuel price shocks to domestic inflation. In particular, more credible monetary policies, with a commitment to maintaining a low and stable rate of inflation—including through the widespread adoption of inflation targets—appear successful in anchoring long-run inflation expectations and securing a low-inflation environment in the face of fuel price shocks.

Figure 5c. Dynamic Responses of Inflation (accumulated) to a 1 Percent Fuel Price Shock
(By Monetary Policy Credibility, in Percent)



Note: Each panel includes, for the baseline model, the estimate (solid line) and the 16th and 84th percentiles (dashed lines) from a block bootstrap procedure with 1000 replications.

C. By Size and Sign of the Shock

The results from the linear baseline model presented so far, focus on the dynamic responses of inflation and fuel prices near their unconditional mean, where the magnitude and sign of the shock has no impact on the shape of such responses, merely affecting their scale. However, as discussed earlier, our interest lies not only in small shocks, but also in averaged-sized to large shocks. Hence, in this section, we focus on the response of inflation to the retail fuel price shocks of various sizes and signs.

We estimate those responses using local polynomial projections (Jordà, 2005) as described in section II. In this section, the shock size is now measured in terms of the standard deviation of the fuel price shock, such that a shock size δ equal to one, corresponds to a one standard deviation fuel price shock. We vary the size of δ according to:

$$\delta \in \pm \{0.25, 1, 3\}$$

where δ is the shock size and σ_{gas} is the standard deviation of the retail fuel price shocks.¹³ Small (large) fuel price shocks are defined as shocks for which $\delta=0.25$ ($\delta=3$). The impulse responses are

¹³ The standard deviation of retail fuel price shocks is equal to around 4, 5, and 4.5 percent, for high-income, emerging, and low-income countries in the sample.

all normalized by δ , the shock size (in standard deviation terms), for comparability. In addition, responses to negative shocks are multiplied by minus one, for comparability. The impulse responses are illustrated in figures 6, 7, and 8, for high-income, emerging, and low-income countries, respectively. A summary of the impulse responses is also provided in figures 9, 10, and 11. Two main results are evident. First, positive and negative fuel price shocks have differential impacts on inflation, in terms of both, magnitude and persistence. Furthermore, this asymmetry differs across income groups. Second, such asymmetry is, at least partly, related to the size of the fuel price shocks.

High-Income Countries

In high-income countries, positive fuel price shocks lead to inflationary effects that are *larger* and more persistent than those generated by negative fuel price shocks. For instance, for a typical one standard deviation shock, the response of domestic inflation to positive shocks is higher by about 25 percent after one year—and about 140 percent after two years—relative to its response to negative shocks (Figure 6, Panel A). Furthermore, the effects of positive fuel price shocks are more persistent, lasting for about two years after the shocks, compared to only one year in the case of negative fuel price shocks. Evidence for such asymmetry disappears following the incidence of small shocks (Figure 6, Panel B), but becomes even more pronounced under sufficiently large shocks. The results presented in Figure 6c suggest that the effects of large negative fuel price shocks are humped-shaped and very transitory, lasting for about 8 months, after which domestic inflation reverts quickly to its pre-shock steady-state value. Meanwhile, the effects of large positive shocks are sizeable, leading to a gradual and persistent increase in inflation for up to 27 months after the shock. Furthermore, the normalized (in standard deviation terms) inflationary impact of a large positive fuel price shock is around 0.36 percent, 24 months after the shock (Figure 6, Panel C). This is around 52 percent higher than the impact of a typical one standard deviation positive shock over the same horizon (Figure 6, Panel C).

Emerging Countries

In emerging countries, positive fuel price shocks lead to inflationary effects that are initially *smaller*—in the short run—than those generated by negative fuel price shocks. However, in the longer run, positive and negative fuel price shocks have similar impacts on domestic inflation. For instance, for a typical one standard deviation shock, the response of domestic inflation to positive shocks is lower by about 15 percent after one year relative to its response to negative shocks (Figure 7, Panel A). However, two years after the shock, the effects of positive and negative fuel price shocks on domestic inflation are similar. As in the case of high-income countries, evidence for the asymmetry disappears following the incidence of small shocks (Figure 7, Panel B), but becomes more pronounced under sufficiently large shocks. The results also suggest that the effects of large negative fuel price shocks are humped-shaped, with inflation peaking at around 0.4 percent, 10 months after the shock (Figure 7c, Panel C). Meanwhile, the effects of large positive fuel price shocks are more gradual, with inflation also reaching around 0.4 percent, but around 24 months after the shock.

Low-Income Countries

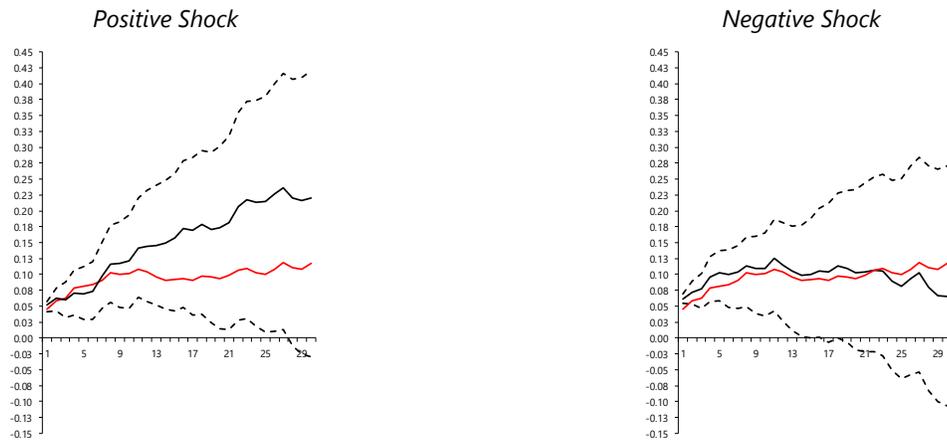
In low-income countries, positive fuel price shocks lead to inflationary effects that are *bigger* and more persistent than those generated by negative fuel price shocks. For instance, for a typical one standard deviation shock, the response of inflation to positive shocks is higher by about 30 percent after 10 months relative to its response to negative shocks (Figure 8, Panel A). As in the case of high-income and emerging countries, the asymmetric effect disappears following the incidence of small shocks (Figure 8, Panel B), but becomes more pronounced under sufficiently large shock, with the inflationary impact of large positive fuel price shocks being more than 400 percent higher than that of negative fuel price shocks of the same magnitude, 18 months after the shock (Figure 8, Panel C). Furthermore, the normalized (in standard deviation terms) inflationary impact of a large positive fuel price shock is around 0.44 percent, 18 months after the shock (Figure 8, Panel C). This is around 30 percent higher than the impact of a typical one standard deviation positive fuel price shock over the same time horizon. Overall, our results suggest that positive fuel price shocks have larger effects on domestic inflation than negative fuel price shocks in the case of high-income and low-income countries.

This asymmetry appears to be reversed in the case of emerging countries, albeit only in the short-run—with asymmetric effects disappearing in the longer run. One hypothesis that could provide an explanation for the larger impact of positive fuel price shocks is that workers respond differently to fuel price increases and fuel price declines. For instance, workers are potentially more sensitive to inflationary news than disinflationary news, and this can manifest itself as a downward rigidity of nominal wages. This is because workers, to the extent possible, will refuse wage cuts in the presence of deflationary pressures but demand wage increases when faced with inflationary pressures that can erode their purchasing power. This is equivalent to the widespread notion that nominal wages are flexible upward but sticky downward. On the other hand, downward rigidity in output prices makes it easier for firms to increase their markup than to decrease it. In other words, higher energy prices would increase the aggregate price level since wages and other prices are downward sticky. However, the reverse does not happen when energy prices fall since wages and prices are not restricted from rising to offset the effects of lower energy prices.¹⁴

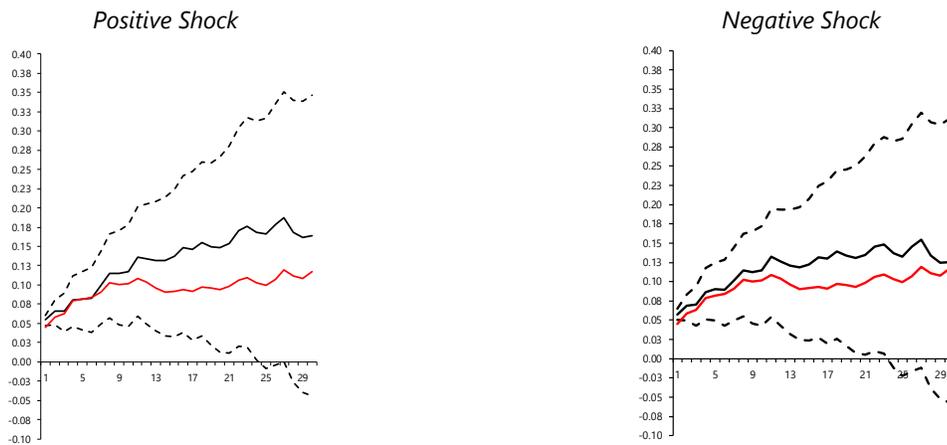
¹⁴ These hypotheses would also provide a rationale for monetary policy reacting asymmetrically to these shocks. For instance, negative fuel price shocks can create downward pressure on (non-energy) inflation through the expectations channel, thereby allowing monetary policy to ease and stimulate the economy. This can in principle lead to an increase in inflation, partially offsetting the disinflationary impact of the negative fuel price shocks, which ultimately explains their relative smaller estimated impact on domestic inflation compared to the impact of positive shocks.

Figure 6. Dynamic (non-linear) Responses of Inflation to Fuel Price Shocks
(High-income Countries)

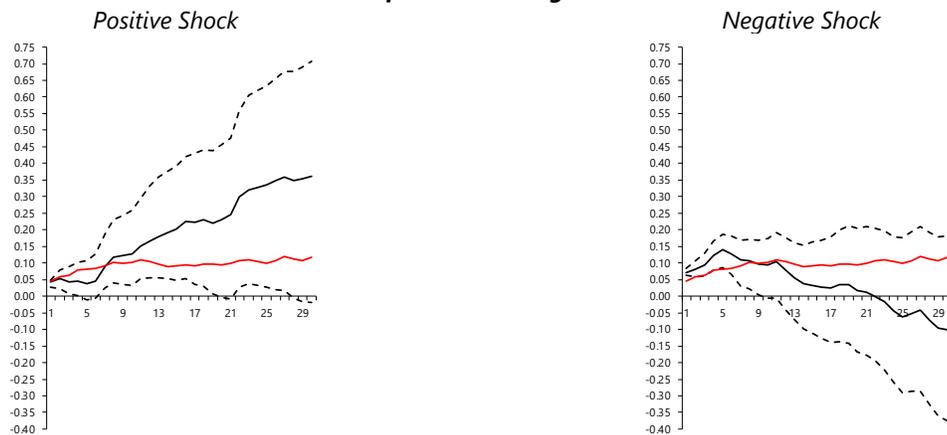
A. Responses to a typical (one standard deviation) shock



B. Responses to a small shock



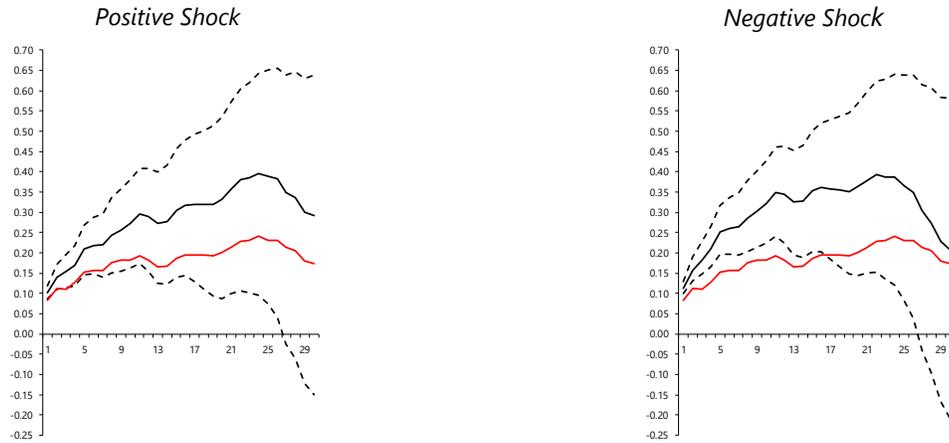
C. Responses to a large shock



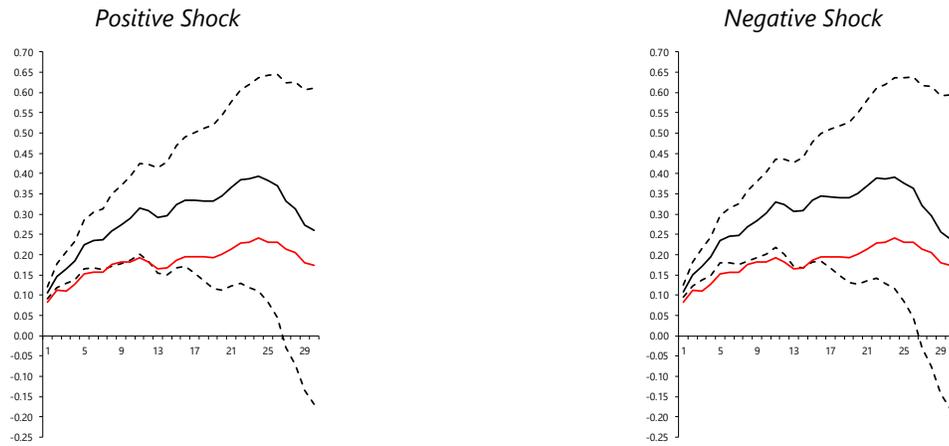
Note: The solid black line is the non-linear response; dashed lines are the 16th and 84th percentiles error bands; Responses are normalized by the shock size (in SD terms); the solid red line is the response from the linear model. Responses to negative shocks are multiplied by *minus* one, for comparability. Small shocks are equal to one-fourth ($\delta=0.25$) of a SD shock. Large shocks are equal to three times ($\delta=3$) that of a SD shock.

Figure 7. Dynamic (non-linear) Responses of Inflation to Fuel Price Shocks
(Emerging Countries)

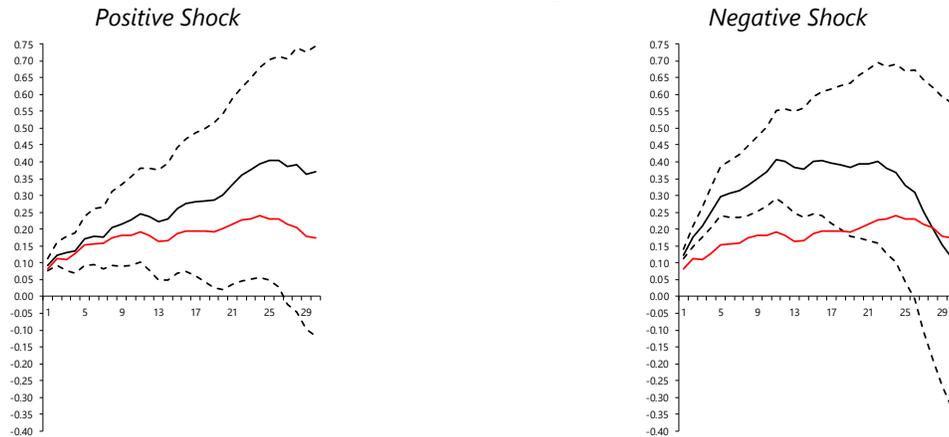
A. Responses to a typical (one standard deviation) shock



B. Responses to a small shock



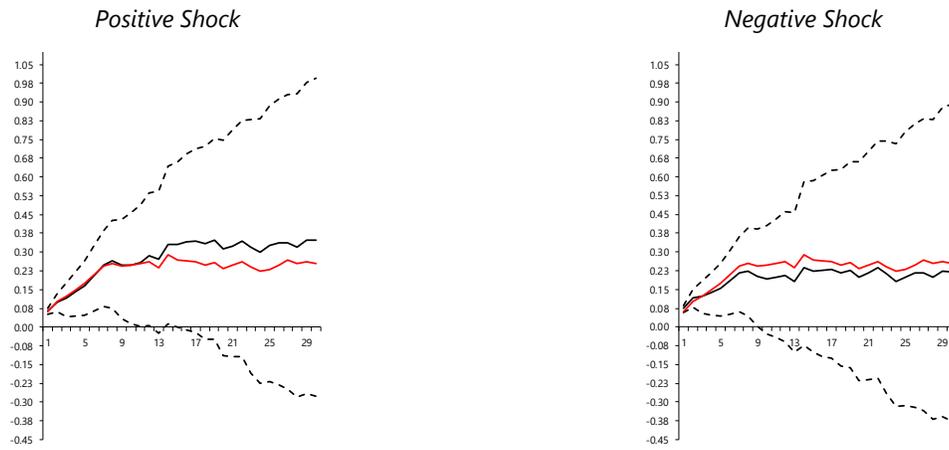
C. Responses to a large shock



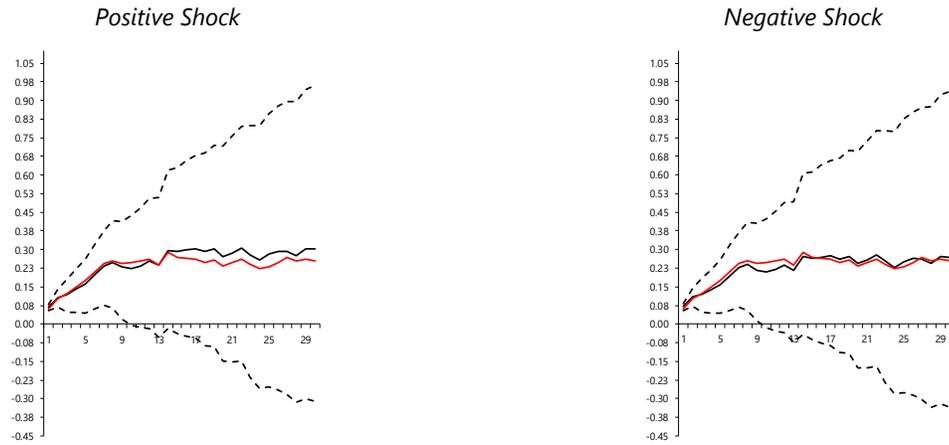
Note: The solid black line is the non-linear response; dashed lines are the 16th and 84th percentiles error bands; Responses are normalized by the shock size (in SD terms); the solid red line is the response from the linear model. Responses to negative shocks are multiplied by *minus* one, for comparability. Small shocks are equal to one-fourth ($\delta=0.25$) of a SD shock. Large shocks are equal to three times ($\delta=3$) that of a SD shock.

Figure 8. Dynamic (non-linear) Responses of Inflation to Fuel Price Shocks
(Low-Income Countries)

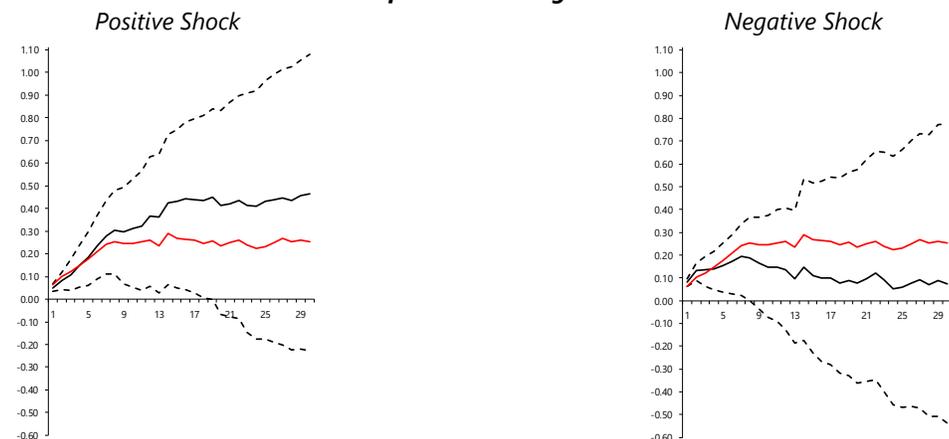
A. Responses to a typical (one standard deviation) shock



B. Responses to a small shock

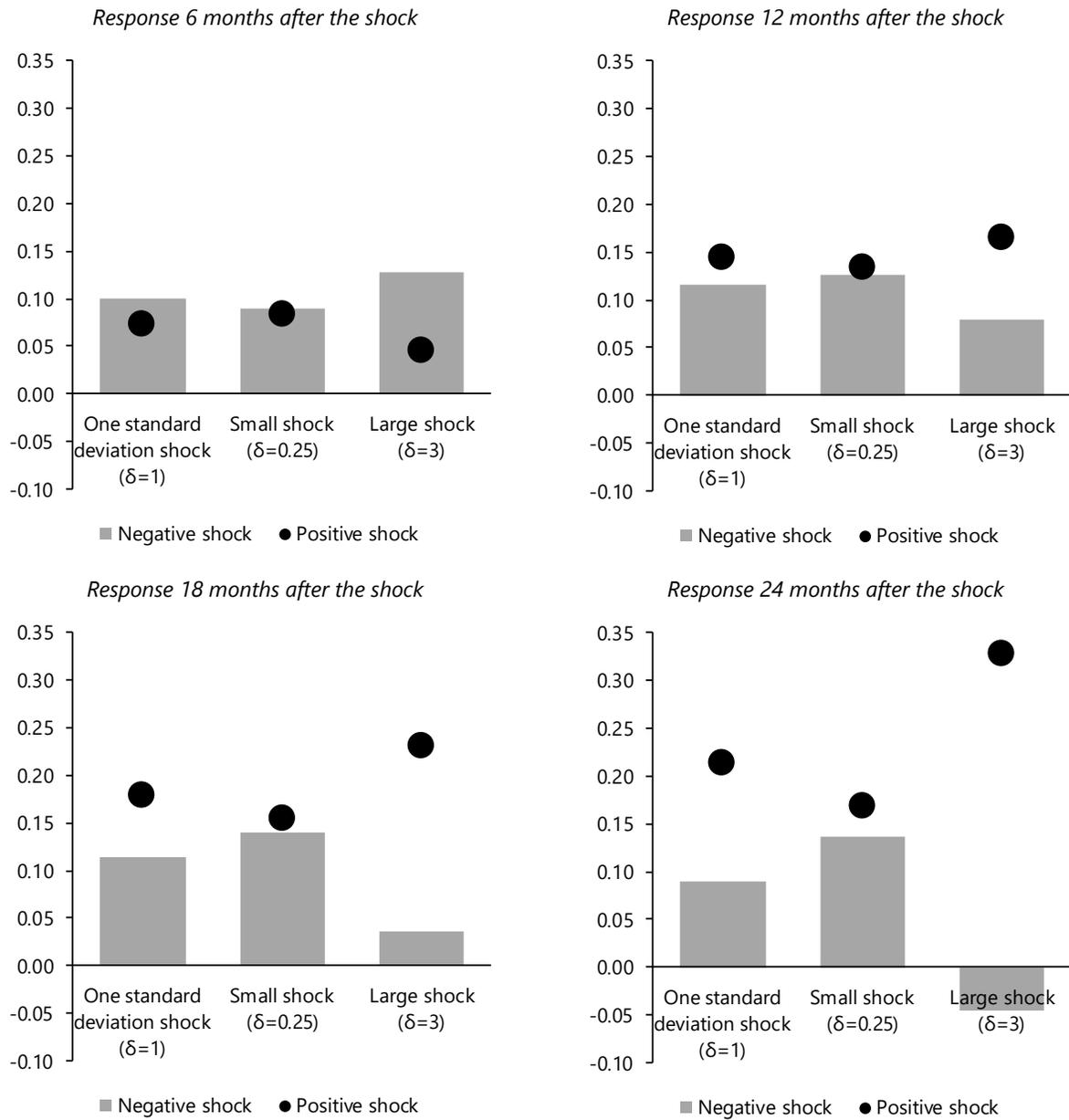


C. Responses to a large shock



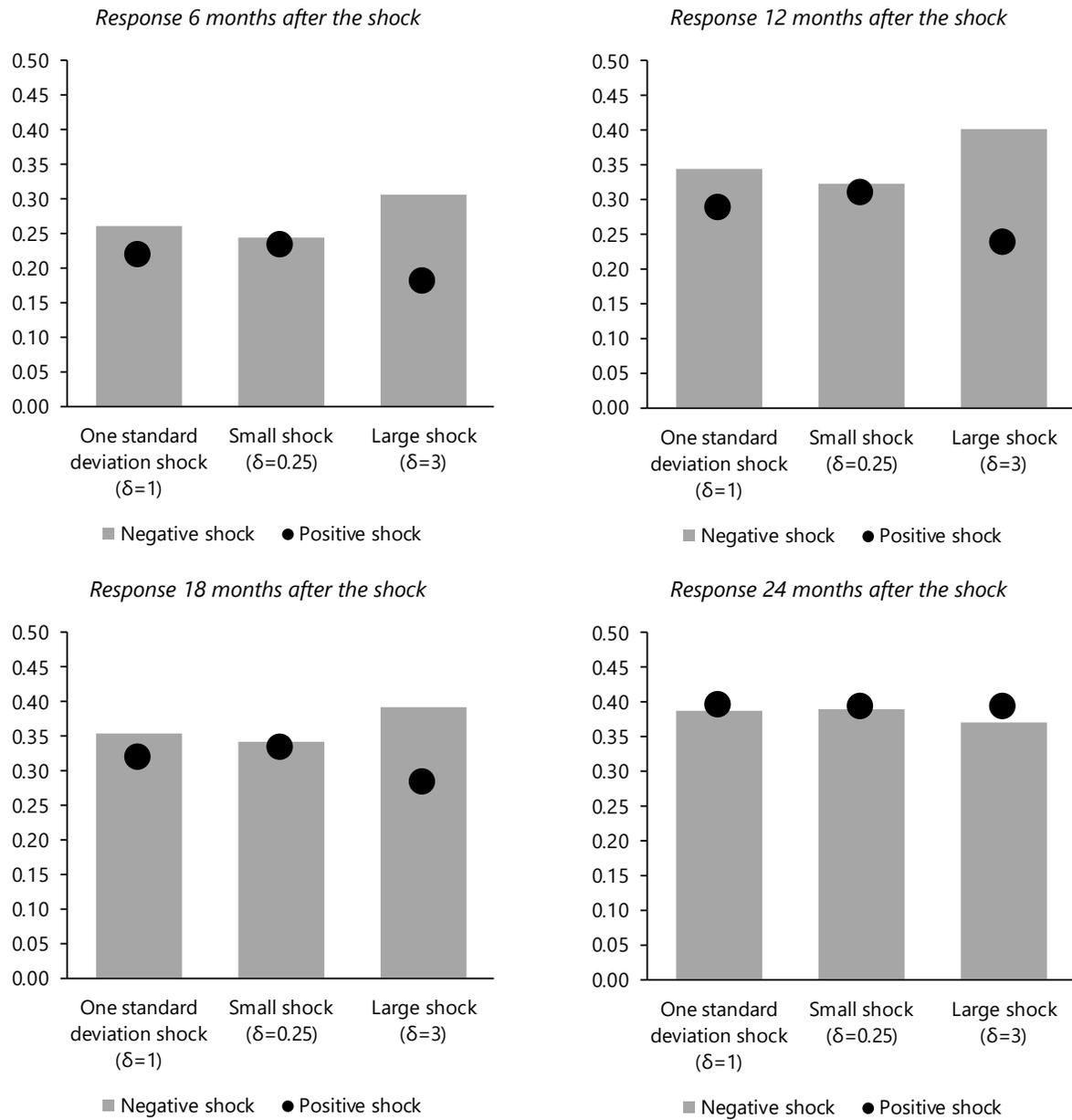
Note: The solid black line is the non-linear response; dashed lines are the 16th and 84th percentiles error bands; Responses are normalized by the shock size (in SD terms); the solid red line is the response from the linear model. Responses to negative shocks are multiplied by *minus* one, for comparability. Small shocks are equal to one-fourth ($\delta=0.25$) of a SD shock. Large shocks are equal to three times ($\delta=3$) that of a SD shock.

Figure 9. Summary of Dynamic Responses of Inflation to Positive and Negative Fuel Price Shocks (High-income Countries, in Percent)



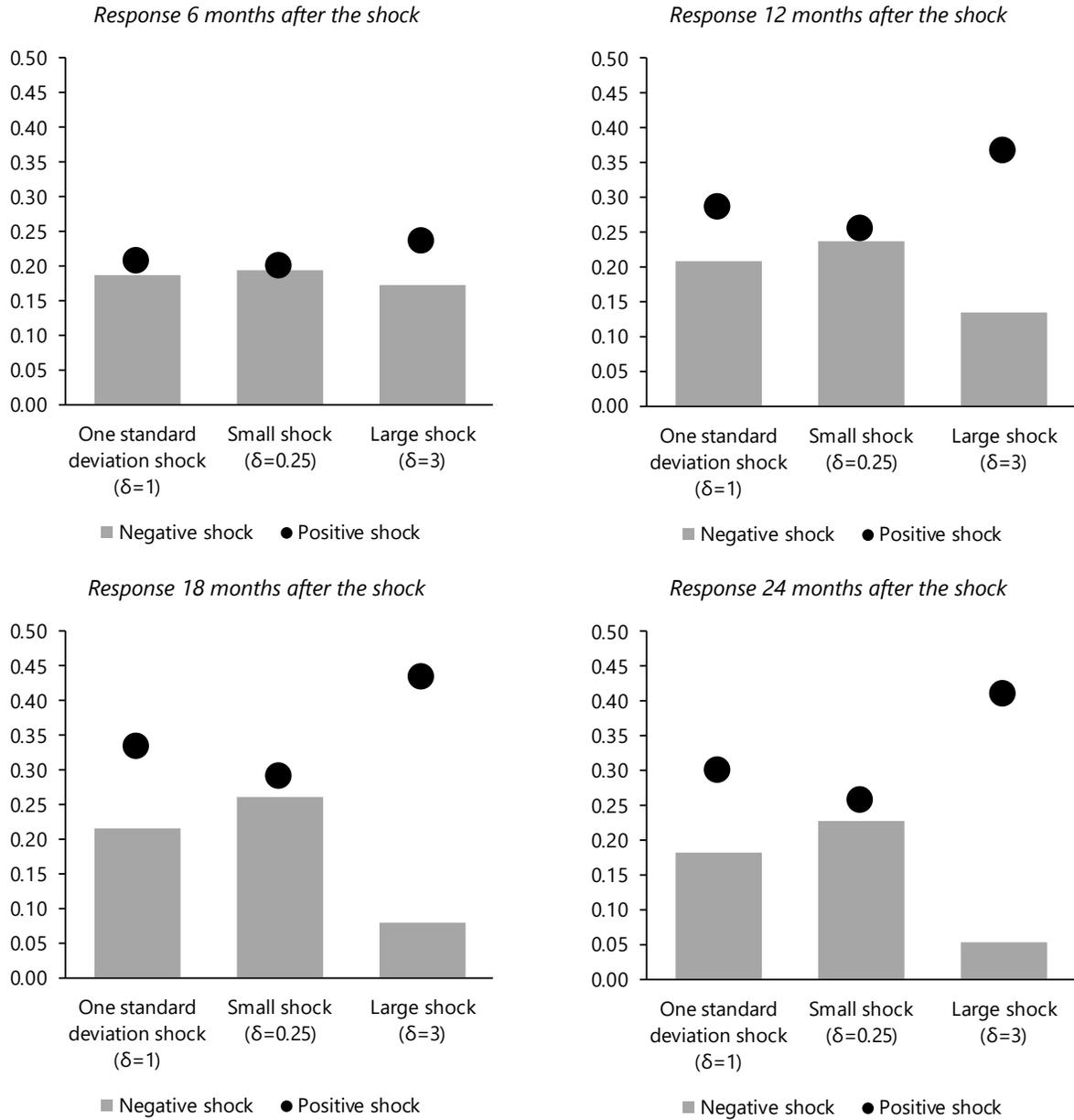
Note: Summary of inflation responses from figures 6a–6c; all responses are normalized by the shock size (in SD terms); the responses to negative shocks are multiplied by *minus one*, for comparability.

Figure 10. Summary of Dynamic Responses of Inflation to Positive and Negative Fuel Price Shocks (Emerging Countries, in Percent)



Note: Summary of inflation responses from figures 7a–7c; all responses are normalized by the shock size (in SD terms); the responses to negative shocks are multiplied by *minus* one, for comparability

Figure 11. Summary of Dynamic Responses of Inflation to Positive and Negative Fuel Price Shocks (Low-Income Countries, in Percent)



Note: Summary of inflation responses from figures 8a–8c; all responses are normalized by the shock size (in SD terms); the responses to negative shocks are multiplied by *minus one*, for comparability.

VI. CONCLUSION

This paper estimates the dynamic responses of domestic inflation to fuel price shocks. Unlike most other studies on the relationship between fuel price changes and inflation, we use a rich novel dataset on monthly retail domestic fuel prices for a large set of high income, emerging and low-income countries over 2000–16. We find that, on average, the effects of fuel price changes are modest and do not contribute to a sustained impact on inflation. However, the short to medium-term effects vary considerably across different income groups. We attempt to explain this heterogeneity in the effects across countries and find that both, the magnitude and the persistence of the impact of changes in fuel prices on domestic inflation depend on key economic fundamentals, including energy intensity, wage flexibility, and central bank credibility, with the latter two factors being potentially crucial in amplifying the effects of fuel price shocks. We also find compelling evidence of asymmetry in the response of domestic inflation to fuel price shocks, with price increases leading to more pronounced and more persistent effects on inflation than price decreases, especially in the case of high-income and low-income countries. Our results also suggest that while such asymmetry holds in the case of typical shocks, it dissipates under small shocks and gets amplified under sufficiently large shocks. This can have direct implications for the formulation of fiscal policy. Policy decisions that pertain to increasing energy prices—including those that aim at counteracting pollution and environmental damages—and the pace at which they are implemented, should potentially consider such non-linearity. From this perspective, coordination with the Central Bank is key to avert potential negative macroeconomic consequences—especially in the context of the “timing” and the “size” of the increase, and considering the cycle of wage negotiations with labor unions, in order to avoid transforming a transitory supply-side shock into a demand-side shock with wage spiral effects and direct implications on monetary policy.

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