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Another Pass-Through Bites the Dust? Oil Prices and Inflation

A salient feature of recent oil price hikes has been the reduced impact that they seem to have had on general price levels worldwide when compared with previous oil shocks. This paper gathers stylized facts on the evolution of the pass-through of changes in oil prices to general inflation for a broad number of countries so that this decline in the impact of oil price hikes can be quantified and various hypotheses that might explain it can be evaluated.

The current surge in oil prices has also been associated with small effects on output. We find suggestive evidence that can explain both this association with output and the reduced impact on inflation. We show that a decline in the exchange rate pass-through, a reduction in the use of oil per unit of GDP, and a macroeconomic environment characterized by low inflation (which, among other things, has limited the need for reactive monetary policy) help to explain the relatively mild effects of the current oil shock on the global economy. Although we focus on the inflationary consequences of oil shocks, the factors we highlight are also consistent with the limited effects of the current oil shock on global economic activity.

The casual observation that inflation is lower now in many countries compared with what it was in the 1970s and 1980s, despite increased oil prices, is not a definitive demonstration of a lower pass-through. In the first place, although nominal oil prices have recently set new records, real oil prices are not as high as they were in those earlier decades. The effects of recent oil shocks are being dampened because they have been accompanied in most countries by appreciations of the currency. Also, the high inflation of the 1970s and 1980s was not due to the oil shocks alone; macroeconomic policies then were very accommodative of inflationary shocks. The improved macroeconomic policies in many countries today may also have contributed to a smaller pass-through. Finally, oil prices are not entirely exogenous to the general equilibrium of the world economy, and the effects of an oil price increase on world inflation and output will depend on the nature of the increase, namely, whether it results from a decrease in supply or from strong demand.

The main contribution of this paper is the extension of the calculation of the pass-through of oil price increases to inflation to a larger set of countries and the verification of whether the recent decrease of the pass-through is limited to the United States or whether it can be generalized to the world economy. We find that the pass-through has decreased worldwide during the last thirty years. The cross-country nature of our investigation allows us to study in greater detail the factors underlying the decline in the pass-through and mitigates the problem of endogeneity of the oil price that United States–centered studies might face.

In the next section we review current theoretical arguments about the effects and intensities of the oil pass-through. We also relate this literature to the literature on exchange rate pass-through. In the third section we report the main stylized facts on which we base the econometric investigation. In the fourth section, we estimate the pass-through by augmenting a Phillips curve model with oil parameters.[1] We then proceed to estimate multiple breakpoints for the model for each country. In the section after that, we adjust the estimations to control for the exchange rate pass-through and the decline in oil intensity, both of which help to explain the decline in the inflationary impact of changes in the price of oil. In the section that follows these reestimations, we estimate rolling vector autoregressive models and calculate the impulse responses of oil shocks on the economy for a smaller (because of data limitations) sample of countries. In the conclusion, we review the available hypotheses on the decline of the oil pass-through as well as the main stylized facts that support each of them.

A Primer on the Oil Pass-Through

An oil shock is the classic supply shock in traditional macroeconomic models. Labor becomes more expensive in all sectors of the economy as workers adjust their inflation expectations in the wake of the shock. Margins fall throughout the economy, and aggregate supply contracts, pushing prices upward. Agents calculate through the equilibrium of the economy and end

1. This methodology follows Hooker (2002).

up compounding these price hikes into a larger pass-through. However, if nominal wages are inflexible (perhaps because firms are locked into long-term collective labor contracts), most of the macroeconomic adjustment to an oil shock should take the form of higher unemployment rather than higher inflation, with stagflation as the macroeconomic result. Since the 1980s, labor markets worldwide have, if anything, become more flexible; hence, within this framework, one should expect larger pass-throughs and shallower recessions from oil shocks. However, the impact of the recent oil price increase on both inflation and economic activity has been small. An alternative view of labor markets is to focus on the impact of real wage rigidities. Blanchard and Galí show that in a new Keynesian model a reduction in real rigidities reduces the trade-off between output and inflation stabilization, and hence, the increased flexibility of the labor market could explain both the decline in the impact of oil prices on prices and economic activity.[2]

A somewhat more modern view would include the reaction function of the economic authorities. In this scenario the critical choices are exchange rate regime, monetary targeting, and cyclicality of fiscal policy. Strict countercyclical fiscal policies would increase the pass-through and reduce output costs by boosting aggregate demand when production is more expensive. Strict inflation targeting would, on the other hand, reduce the oil pass-through, either through the direct compensatory effects of interest rates or through increased credibility of monetary policies. In the first case, the output costs of the shock are increased, whereas in the second they are not. Increased exchange rate flexibility among oil importers should increase the volatility of oil price inflation in terms of domestic currency. Thus increased countercyclicality of fiscal policies combined with the worldwide trend toward inflation targeting and greater exchange rate flexibility leads to an ambiguous effect on the pass-through and the output costs of oil shocks. However, stable fiscal policy together with credible inflation targets could help to explain the recent evidence. In addition, flexible exchange rates, in the context of inflation stability, may help to absorb external shocks without a large domestic impact.

Current macroeconomic models stress how inflation shocks are related to the complete structure of costs in an economy. The effects of oil shocks on inflation should differ by the expected persistence of the shock. Hence one could argue that the pass-through for recent oil shocks has been lower because

2. Blanchard and Galí (2007).

these shocks were expected to be only temporary spikes (like those of 1990 and 1999) rather than the long-lasting hikes that they have turned out to be. However, as we show in the section on oil shocks and vector autoregressions (VARs), recent futures contracts reflect the growing belief of market participants that current high oil prices will persist; yet inflation has not increased substantially.

It can also be argued that globalization and increased competition worldwide have limited the ability of producers to pass their higher costs on to consumers. In such a scenario, producers engaged in stiff competition might prefer to take a transitory cut in their profit margins than to give their competitors an opportunity to increase their market share. However, it is unclear why persistently higher costs for all producers worldwide would not be passed on eventually. This argument would predict a fall in corporate profits in industrial countries as a result of the oil shock, leading eventually to faltering investment and growth. Instead, and adding to the paradox, the current oil shock is correlated with higher corporate profits and healthy global growth.

Obviously, the theoretical case for reduced pass-through is not clear cut. There are valid arguments that would lead one to expect increases in the pass-through but also valid arguments for reductions; in the end, which set of effects predominates is an empirical question. We will use alternative econometric methods to identify the pass-through and to observe its evolution over time in a variety of countries. We will show that one important factor that substantially helps to explain the observed facts is the average reduction in the oil intensity of economic activity in countries around the world.

This paper is related to the literature on the decrease of the exchange rate pass-through, not only in a methodological sense but also because it is possible that the explanations for both phenomena are related. Evidence for reduced exchange rate pass-through for industrial economies can be found in Campa and Goldberg and for a broad sample of countries in Borensztein and De Gregorio and Goldfajn and Werlang, among others.[3] Most of this work measures the decrease in the exchange rate pass-through but does not identify its causes. Taylor, Choudhri and Hakura, and Gagnon and Ihrig, however, find that a low-inflation environment was an important cause of the reduced exchange rate pass-through in the 1990s.[4] In analyzing the inflation-

3. Campa and Goldberg (2002); Borensztein and De Gregorio (1999); Goldfajn and Werlang (2000).

4. Taylor (2000); Choudhri and Hakura (2006); Gagnon and Ihrig (2001).

ary effects of currency depreciations, it is possible to argue that purchasing power parity (PPP) does not hold at the microlevel, but recently Burstein, Eichenbaum, and Rebelo have argued that the explanation for a small exchange rate pass-through is the low response of nontradable goods.[5] Therefore, in the context of oil, we can interpret a lower pass-through as limited "second round" effects of oil on inflation, which certainly depend on the degree to which inflationary expectations are anchored. Recent work on exchange rate pass-through by Frankel, Parsley, and Wei, using narrowly defined commodities, confirms, among other things, that the inflation environment is important in explaining pass-through.[6] Thus the literature on the exchange rate pass-through reveals that microeconomic as well as macroeconomic factors affect the way changes in exchange rates are transmitted to the general price level.

The effect of oil shocks on inflation has received less attention, although several authors have studied the impact on U.S. inflation and output. Mork, and more recently Hamilton and Herrera and Davis and Hamilton, argued that nonlinearities and asymmetries are the main features behind the observed relationship between oil and prices.[7] Hooker, on the other hand, estimated Phillips curves and tested for breakpoints to study changes in the oil price pass-through for the United States.[8] He found that the pass-through decreases after the 1980s and that neither nonlinearities nor the reduced dependency of the economy on oil and on energy in general can explain the bulk of this decrease. Hooker's evidence also supports the idea that a low-inflation environment is important in keeping the pass-through at low levels. Barsky and Kilian emphasized that oil shocks are endogenous to the U.S. economy and argued that such shocks were not as important as was generally thought in explaining the stagflation of the 1970s in the United States.[9] Finally, in a recent paper, Blanchard and Galí examine the effects on output and inflation of the recent oil shock and attempt to answer why the current shock has had smaller effects on output and inflation, finding similar results to ours. We put emphasis on reduction in the use of oil, the improvement of monetary policy, and the presence of offsetting shocks.[10]

5. Burstein, Eichenbaum, and Rebelo (2005).
6. Frankel, Parsley, and Wei (2005).
7. Mork (1989); Hamilton and Herrera (2001); Davis and Hamilton (2003).
8. Hooker (2002).
9. Barsky and Kilian (2004).
10. Blanchard and Galí (2007). They also give importance to a decline in real rigidities, an issue that we do not explore here.

We interpret the offsetting shocks in the sense that an increase in the price of oil, in contrast to previous ones, is largely caused by an increase in world demand rather than by a shortage of supply. Their study is more limited, examining six industrialized economies, with a particular emphasis on the United States. We show that the reduction in the oil price pass-though to inflation is a much more widespread phenomenon, applying not only to developed countries, but also to developing ones.

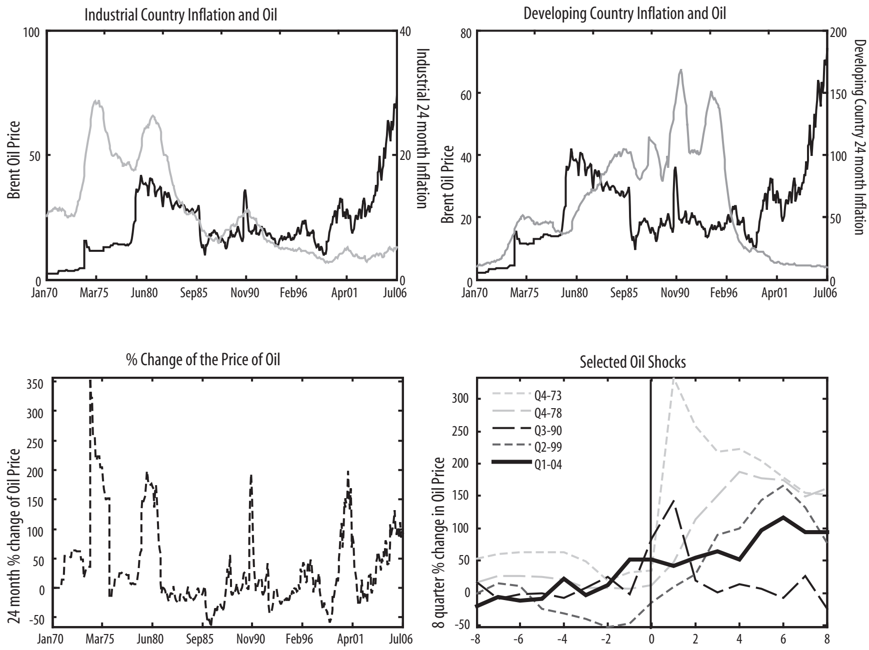
Stylized Facts

The conventional wisdom is that large oil shocks have historically been followed by high inflation in many countries and even by hyperinflation in some. The top two panels of figure 1 plot the nominal price of oil in U.S. dollars and the average inflation rate for industrial (left panel) and emerging economies (right panel; note the different scales in the two panels) since 1970.[11] The bottom-left panel tracks the twenty-four-month nominal percentage change in the price of oil since 1970; the five oil shocks typically identified in this literature (1973, 1979, 1991, 1999, and 2004) are clearly evident. The bottom-right panel compares these oil shocks in more detail, showing that the four most recent shocks were similar in intensity when measured this way, whereas the first shock seems to have been much stronger. The 1991 shock seems quite transitory compared with the others, and the current shock seems to be one of the longest lasting.

The trajectories of average inflation rates seem quite different in the two sets of economies. In the industrial economies, a secular reduction in inflation rates starting in the mid-1970s was followed by an interruption in the early 1980s, after which inflation continued to fall, finally stabilizing at about 2 percent a year. Emerging economies had inflation rates comparable with those in the industrial countries in the early and mid-1970s. Inflation then steadily increased through the 1980s, peaking in the late 1980s and early 1990s. Around the mid-1990s average inflation rates for the emerging economies began to fall and by now seem to have converged, hovering around 5 percent since the turn of the century.

11. All three series are from the International Financial Statistics (IFS) database of August 2006 (Washington: International Monetary Fund, Statistics Department) (http://ifs.apdi.net/imf/logon.aspx). The quarterly inflation series is the year-on-year percentage change in the consumer price index.

FIGURE 1. Nominal Price of Oil and Average Inflation Rate over Forty Years[a]



Source: International Financial Statistics, September 2006.
Q4-73 = fourth quarter of 1973, and so on (for all figures).
a. The x-axis of the bottom right panel shows time in quarters before and after the oil shock, which is fixed at zero.

Despite these differences, both series share a strong positive reaction to the oil shocks of the 1970s (the 1973 shock caused by the Yom Kippur War and the 1979 shock sparked by the Iranian Revolution). There is also a common positive reaction to the 1991 oil shock (the First Gulf War), although the effect seems to have been longer lasting among emerging economies; inflation in the industrial countries suffered only a temporary deviation from its downward trajectory. Also note that in some periods oil prices and inflation in industrial countries move very closely in tandem. These episodes might be thought of as high pass-through periods, although there was no exceptional situation in the oil markets during these periods (for example, the second half of the 1980s and the years immediately following the Asian crisis). Obviously, looking at simple correlations is not enough.

A simple way of describing the relationship between oil shocks and inflation is to calculate the simple pass-through coefficient of oil price inflation to general inflation. This coefficient is usually defined as the ratio between

TABLE 1. Pass-Through Coefficients, Inflation, and Oil Shocks[a]

	Start of shock period			
Indicator	*Q4-1973*	*Q1-1979*	*Q2-1999*	*Q1-2004*
Pass-through coefficient[b]				
Industrial economies	0.20	0.25	0.11	0.06
Emerging economies	0.23	0.33	0.14	0.12
Inflation (percent per year)[c]				
Industrial economies	31	28	8	6
Emerging economies	35	37	11	10
Change in inflation (percentage points)				
Industrial economies	11	8	2	–1
Emerging economies	10	14	–6	–6
Change in oil price (percent)				
Nominal	154	148	132	116
Real	99	92	107	88

Source: Authors' calculations.
Q = quarter.
a. All percent changes are over eight quarters.
b. Coefficients represent the ratio between accumulated inflation and oil price change for a twenty-four-month horizon.
c. Change in inflation represents the level change from the twenty-four-month period after the oil shock versus the previous twenty-four-month period. Individual episodes of high inflation ($\pi > \mu + 3\sigma \approx 100$ percent) were eliminated to avoid distortions.

general price level inflation and oil price inflation for a given horizon. It is typically presented in the exchange rate pass-through literature as a measure of how much of a given devaluation has been passed on to the domestic inflation rate. Table 1 shows pass-through coefficients for four oil shocks. We define an oil shock as an event when oil prices rise more than 50 percent in a year and the price rise persists for at least six consecutive months.[12]

The first two rows of table 1 show average oil pass-through coefficients in industrial and developing economies for a twenty-four-month window following each oil shock. These coefficients were very similar in the mid-1970s but then diverged as both increased in the late 1970s. By the late 1990s, both pass-through coefficients had fallen, and by the time of the Second Gulf War in 2003 they had fallen further, especially among the industrial economies. To avoid outliers we have excluded all individual episodes of inflation over 100 percent, most of which occurred in the 1970s, so that

12. The pass-through coefficient makes sense only when the change in price persists until at least the end of the horizon for which it is being calculated. Otherwise, the variation that has been undone is not taken into account. This is why the 1990–91 Persian Gulf War shock is not included in our definition in table 1.

we do not overweight hyperinflationary episodes in our sample of emerging economies.

This exclusion criterion captures, as expected, the oil shocks of 1973–74 and 1978–79, as well as those of 1999–2000 and 2004–05. It is interesting that the 1999 and 2004 oil shocks were precipitated, like the others, by events in the Middle East, but other developments, mainly strong demand, helped keep oil prices high. The 1999 shock was caused by a political regrouping of the OPEC countries, which had lost cartel discipline over the years as non-Arab members entered. Although this event triggered the price hike, it is generally accepted that prices were sustained by strong demand due to rapid economic growth in the United States and in China. In 2003 several supply-side factors, such as the Iraq War and later the escalation of the Nigerian civil unrest and the hurricane disasters in the Gulf of Mexico, caused oil prices to rise sharply again. However, one of the main causes behind the current oil shock is unrelenting world economic growth, particularly in China. Some have pointed to an additional possible source of demand driving prices upward, namely, the speculative positions taken in the oil market by agents seeking higher yields. In all, it does seem that the most recent oil shock has many more sources than did previous ones.

Table 1 also shows, in the second panel, average inflation levels during each episode in the two groups of economies. High inflation seems to be correlated with higher pass-through coefficients, just as it is in the exchange rate pass-through literature. The third panel shows the change in average inflation in the two years before and after the oil price rise. It seems that a central difference among the four oil shocks is that the first two shocks correlate with significant increases in inflation, whereas the two most recent shocks are correlated either with stationary (in the case of industrial economies) or falling (in the case of emerging economies) inflation. Finally, the last panel in table 1 shows the relative size of the increase in the oil price during the twenty-four-month horizon. The last two oil shocks are comparable in magnitude to previous ones, both in real and nominal terms, although they occurred in an environment of lower inflation.

Obviously, the data in table 1 face all the problems and limitations to which unidentified correlations are subject. In particular, when oil prices and inflation move together, it may be that we are not properly identifying the effect of one on the other, but rather we are observing the consequences of shocks on other markets or parameters. In the next two sections we use econometric methods to identify more precisely the impact of oil shocks on inflation by controlling for other relevant variables in the economy.

The Oil Pass-Through and Structural Breaks in the Traditional Phillips Curve

Almost all studies that attempt an estimation of a pass-through (for the exchange rate or for oil), in the end, boil down to an estimation of a Phillips curve. In this section we follow Hooker in estimating the effect of oil prices on reduced-form Phillips curves.[13] We estimate a traditional Phillips curve equation with several lags of inflation, the output gap, and the percentage change in oil prices. We extend this estimation to the broadest set of countries possible, estimating oil-adjusted Phillips curves for thirty-three economies, of which twenty-one are industrial and twelve are emerging.

Preferred Phillips curves for different countries vary substantially in specification. For example, they frequently include dummy variables that reflect common knowledge among economists of structural breaks or other anomalies in the economy in question. For example, for the United States, dummies for the Nixon price controls usually improve these estimations substantially; in emerging economies, dummies for particularly violent social and economic events usually prove useful. These dummies are usually quite noncontroversial but are also very necessary, especially in emerging markets (and more so in those markets with periods of hyperinflation).

Although the structure of the Phillips curve thus varies from country to country, we choose to sacrifice the fitness of our estimations on the altar of comparability and do not include dummies for any country. In addition, to expand the sample of countries as far as possible, we use either industrial production or real GDP indexes as proxies for economic activity, depending on their availability.[14]

The evidence presented in the previous section suggests that the correlation between oil price shocks and inflation has decreased. We therefore test the

13. Hooker (2002). See Rudd and Whelan (2005) and Galí, Gertler, and Lopez-Salido (2005) for a review and discussion of alternative forward-looking Phillips curves and their empirical relevance.

14. We are aware that this choice of variables could lead to substantial defects in the quality of our measure of output gaps. For example, some emerging economies in the last few decades have to some extent deindustrialized as a result of trade liberalization and instead have specialized in other activities in which they have a comparative advantage (for example, India's specializing in services). Although these processes usually happen over a longer horizon than economic fluctuations, it is nevertheless also true that they could make industrial production indexes quite nonrepresentative of the economy as a whole. In any case, and considering the scarcity of quarterly aggregate production data, we still view industrial production data as a reasonable proxy for economic activity. All series are from the IFS dataset.

regressions for multiple structural breaks on all parameters following Bai and Perron.[15]

Estimating the Pass-Through

We estimate a generalized Phillips curve of the following form:

$$\pi_t = \alpha + \sum_{i=1}^{4} \beta_i \pi_{t-i} + \sum_{i=0}^{4} \gamma_i \left(y_{t-i} - \bar{y}_{t-i} \right) + \sum_{i=0}^{4} \theta_i \text{oil}_{t-i}^{us\$}, \tag{1}$$

where π is the quarterly percentage variation of the general consumer price index (CPI), y is the quarterly percentage variation of the industrial production index, $\bar{y}$ is the Hodrick-Prescott filtered trend of y, and $oil^{us\$}$ is the quarterly percentage change in the price of a barrel of Brent crude oil in U.S. dollars.

The full pass-through from an oil price shock to inflation, (φ), is obtained by inverting equation 1, which is

$$\phi = \frac{\sum_{i=0}^{4} \theta_i}{1 - \sum_{i=1}^{4} \beta_i}. \tag{2}$$

To study how the pass-through coefficient may have changed, we divide the time series and estimate the parameters for each segment. It is, however, preferable to determine potential breaks in the relationship given in equation 1 endogenously, and we proceed to do this by testing the specification of the Phillips curve for multiple structural breaks as suggested in Bai and Perron.[16] This methodology assumes that the date (T_i) and the amount of structural breaks (m) can be jointly estimated with the parameters using the least squares principle. For example, in the case of one break $\{\beta_i, \gamma_i, \theta_i\} \equiv \delta$ are estimated for each possible break date T. In this way $\{\beta_i, \gamma_i, \theta_i\}$ are a function of the break date, and this break is chosen such that the sum of squares of residuals among all T are minimized.

Having found the structural breaks in the estimation of equation 1, we use these breaks to estimate the pass-throughs for the countries in our sample. Hence, rather than imposing breakpoints, we allow the data to show us when

15. Bai and Perron (1998, 2003).
16. Bai and Perron (1998).

the pass-throughs have fallen, and we allow the breakpoints to differ across countries.[17]

Results with Estimated Breakpoints

Before estimating the oil-adjusted Phillips curves for each of the countries in our sample, we estimate it for all industrial economies in the aggregate and search for structural breaks. The aggregate series for CPI and industrial production are constructed by International Financial Statistics (IFS) as a geometric mean of the individual series in the group.[18] We find an interesting structural break in 1980, just after the oil shock caused by the Iranian Revolution. The estimated pass-through falls from around 0.15 to 0.03. The economic interpretation is as follows: before 1980, a 100 percent increase in the price of Brent crude was passed through as an increase of 15 percentage points in inflation. After 1980, a similar shock would have increased inflation in the industrial economies by only 3 percentage points. In the remainder of this subsection, we extend this estimation to the largest possible sample of countries that the available data allow.

Specific details on the breakpoints and pass-through for each country are presented in the appendix. Of the thirty-three countries subjected to this method, only seven showed no evidence of structural breaks.

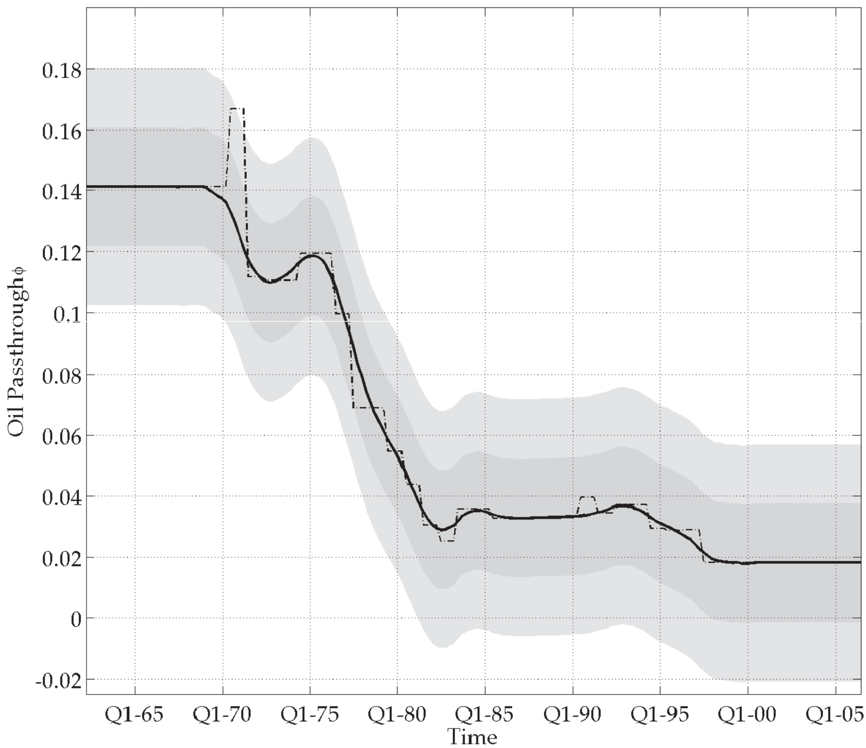
Figure 2 shows the results of the estimation using endogenous windows calculated using the Bai-Perron structural break method. The figure plots average pass-through coefficients for the countries that have data throughout the forty years of our sample; this corresponds to twenty-three of the thirty-three countries.[19] We take the twenty-three pass-throughs for each year (allowing for

17. Hansen (2001) and Perron (2005) provide a review of the literature on structural breaks, and we will only briefly discuss the main intuition that sustains the methodology that we apply. Estimation for multiple breaks was carried out using Matlab code based on the GAUSS code provided by Pierre Perron at his web page (http://people.bu.edu/perron/). Lag lengths for the right-hand variables were selected using the Hannan-Quin information criterion.

18. For consumer prices, weights were calculated using the PPP (purchasing power parity) value of GDP, while the weights for the industrial production index are calculated using value added in industry. Weights are normally updated every five years. This means that, potentially, some of the decrease of the pass-through could be attributed to changes in the relative weight of the countries in the sample. For example, better performing countries tend to gain, in time, more weight. We believe this is probably not an enormously important effect, especially given the results below.

19. We prefer to report the average trend over a consistent set of countries so as to not induce a reader to think that the results are driven by the entrance and exit of countries from the sample. However, we have also done equivalent calculations for the total sample of thirty-three countries and obtained similar results.

FIGURE 2. Average Pass-Through over Time Using Endogenous Windows[a]



Source: Authorscalculations.

a. Window lengths are endogenous since they are determined by the dates when we find evidence of a structural break. Pass-throughs were calculated for each section of the time series, and the average pass-through was calculated after the two highest and two lowest observations were eliminated. The dotted line represents the average pass-through coefficient, and the dark line represents a least squares quadratic polynomial smoothing of the same series. Both series are calculated over the sample of twenty-three countries that have data for the whole period. The darker area represents the confidence interval of ±1 standard deviation (s.d.) around the trend and the lighter band represents an interval of ±2 s.d. around the trend.

structural breaks) and take away the two highest and two lowest outliers. With the remaining nineteen pass-throughs, we take a simple average, represented by the dotted line in figure 2. This series has discrete jumps due to changes in one or more of the coefficients that we are including in the sample. For expositional purposes the pass-through average was smoothed using the least squares quadratic polynomial fitting provided by Matlab, which is resistant to outliers and gives a better indication of the overall direction of the average pass-through. We calculated the standard errors using the delta method.

Figure 2 shows a worldwide trend of declining pass-throughs. Conservatively (on the basis of the results for the fixed number of countries), we can say that the pass-through has decreased by more than six-sevenths, from about 14 percent to less than 2 percent. The confidence intervals (of 1 and 2 standard deviations) also tell us that this decrease is actually statistically significant. At first glance it may seem surprising that the international decline in pass-through coefficients occurs at the same time as the oil shocks of the 1970s and 1980s. Here it is important to interpret correctly the Bai-Perron structural breaks methodology. What the method does is to find whether there is evidence that a break (or more) would help the fitting of the equation we are estimating. If there is a gradual change in regime, the methodology will choose the date that makes the best fit, both before and after the break. As such, a given break date should not be interpreted as evidence of something specific that happened that year, especially since we have forgone modeling details of each specific country for comparability. This methodology is, however, useful in that it lets the data pick the best date to separate the series and thus exonerates the investigator of subjectivity when dividing the data, which in this case is very relevant given the large number of countries under analysis.

A few additional results from the extended appendix tables are worth highlighting. The first is that most industrial countries display significant falls in their pass-through. In the case of the United States, we find, as did Hooker, a break in the early 1980s: the pass-through declines from 0.07 to 0.03 after 1981.[20] We also obtain similar results for Canada as did Khalaf and Kichian.[21] In this case we find that the pass-through decreases from 0.05 to 0.02 (see appendix).

A special case is Israel, which has been at center stage of many past oil shocks. Israel's pass-through has fluctuated dramatically, eventually falling to negative levels. It is very likely that, because Israel's macroeconomics (and politics for that matter) are so volatile, this Phillips curve methodology is not well suited to estimating the pass-through for this economy. The mildly negative pass-throughs of several of the African economies are also puzzling. Again, however, it is probably safe to say that the pass-through has fallen in these countries during the last three decades, but the negative estimated pass-throughs suggest certain weaknesses of this methodology. Our emerging economies sample has several problems: it is small (as a result of data limitations), it includes oil producers (which do not normally encounter economic difficulties with oil price increases), and it includes several countries that have

20. Hooker (2002).
21. Khalaf and Kichian (2003).

experienced severe high inflation and even hyperinflationary episodes, such as Argentina and Chile. In the case of Argentina, the hyperinflation of the early 1990s, coupled with the oil shock, tends to push the pass-through coefficient well above 1, which is difficult to interpret. Similarly, the period of highest inflation in Chile, which was unrelated to oil shocks and instead more related to fiscal imbalances and lax monetary policy, happened to coincide with the first oil shock. It seems clear that the assumptions required for these estimations to be valid are not present for some emerging economies. However, note that the final pass-through estimated for emerging economies reflects the global trend toward falling pass-throughs, as more stable macroeconomic environments (which are more suitable for estimating Phillips curves) have prevailed. It is quite obvious that the estimated pass-through for these countries is reflecting other factors in addition to oil shocks, such as credit crunches, balance of payments crises, and so on. These other factors may have coincided with oil shocks but were only triggered by the ensuing global recessions.

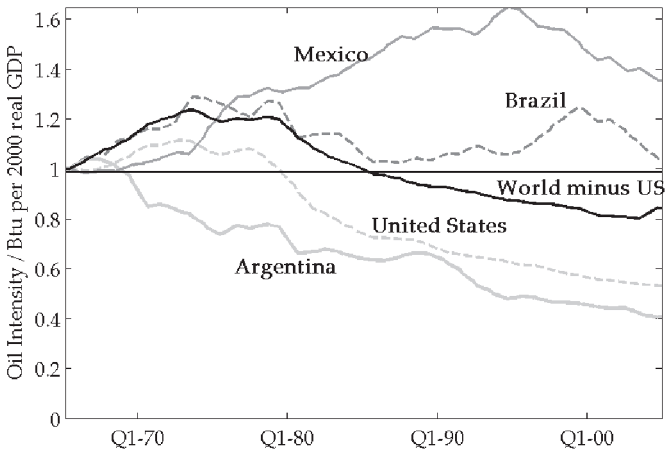
The Effects of Exchange Rates and Oil Usage

One problem with estimating Phillips curves in a large sample of countries is the currency denomination of oil prices. It is quite natural to specify oil prices in U.S. dollars when one estimates the Phillips curve for the United States. However, this might be a problem for the rest of the world, since significant fluctuations in oil prices usually are accompanied by important adjustments of the exchange rate. Nonetheless, U.S. dollar-based estimations provide a good starting point for investigating the global inflationary impact of increases in the oil price. In addition, oil prices enter into the Phillips curve mainly because they affect production costs. However, the world's oil intensity has changed over time, and it is helpful to control for changes in oil intensity across countries.

Changes in Oil Intensity

The first argument that comes to mind to explain both the low pass-through from increases in oil prices to inflation and the weak recessionary effects of the recent oil price surge is that the world economy has changed structurally since the oil shocks of the 1970s. The economic importance of oil has declined as industrial economies have become more services oriented and as previous oil shocks have driven these economies to adopt more energy-efficient

FIGURE 3. Oil Intensity in Selected Economies[a]



Source: U.S. Energy Information Administration.
a. Oil intensity is measured in BTUs (British thermal units) per unit of real GDP in 2000 and has been normalized by setting oil intensity in 1960 equal to 1.0.

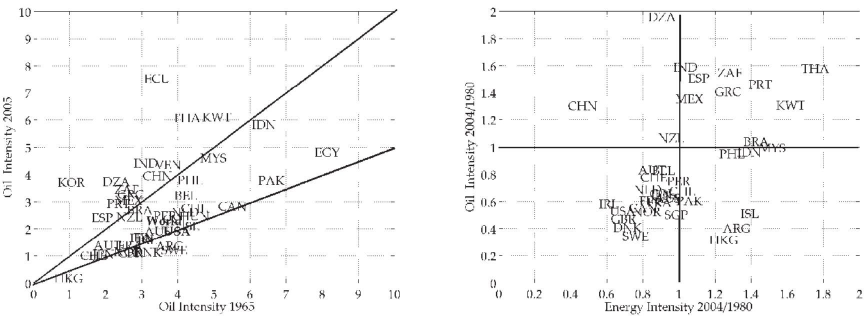
technologies as well as diversify their energy consumption. As economies become less dependent on energy (and as fuels represent a smaller proportion of total costs), the effect of an oil shock of a given size is smaller.

There is plenty of circumstantial evidence to support the energy efficiency thesis for the United States. For example, Peterson and others show that consumption of petroleum and natural gas, measured in BTUs (British thermal units) per unit of real GDP, has fallen by half in the United States.[22] Simple calculations from British Petroleum official datasets on worldwide oil consumption show that in 1965 the average U.S. citizen consumed 20.69 barrels of crude oil and that by 2005 consumption had increased to 25.55 barrels. However, oil consumption per capita has grown by much less than GDP per capita, making U.S. GDP less oil intensive. In 1965 it took 1,338 barrels of crude to produce $1 billion of U.S. GDP (in 2000 dollars), but in 2005 it took only 753 barrels, or 44 percent less.

However, not all countries have achieved an equivalent reduction in oil intensity. Figure 3 compares the evolution of oil intensity in the United States with that of the major Latin American economies and the rest of the world.

22. Peterson and others (2006).

FIGURE 4. Stylized Facts on Oil and Energy Importance in Time



(a) Oil Intensity in the World Economy

(b) Oil Intensity vs. Energy Intensity

Source: U.S. Energy Information Administration.

Argentina has followed a similar process as the United States, sharply reducing its oil intensity. Brazil, on the other hand, has maintained its oil intensity roughly constant, and Mexico has increased its oil intensity. Mexico, of course, is an important oil producer, and hence its rise in oil intensity is easy to rationalize.

To get a broader sense of how differently oil intensity has evolved in different countries of the world, figure 4a plots ratios of oil consumption to real GDP for a set of forty-five countries in 1965 and 2004. The 45-degree line sets off those countries that have increased their oil dependency (those above the line) from those that have reduced it. The line at 22.5 degrees further separates those countries that, like the United States, have reduced oil dependency by half or more (those below the line) from the rest.

Figure 4a confirms that most countries in the sample have reduced their oil intensity and that most of those that have increased their intensity are oil producers. The United States has experienced one of the largest declines. Given that the United States accounts for about 30 percent of world output, its reduction in intensity has driven world oil intensity down. On average, however, world oil intensity has decreased only 27 percent, or somewhat less than the decline in intensity of the industrial countries as a group. In general, we find that oil intensity has decreased in many countries, but not uniformly. The United States is not a representative case, although given its importance in the world economy it helps to explain why there have not been significant global repercussions, in terms of higher inflation and lower output, as a consequence of the sharp and persistent increase in the price of oil.

A decrease in oil intensity can be caused by substitution of other energy sources or by a fall in the total energy needed to produce a unit of GDP. Figure 4b plots, on the *y*-axis, the ratio of oil intensity (barrels of oil per unit of real GDP) in 2004 to that in 1980. Numbers exceeding 1 thus indicate an increase in oil intensity. The *x*-axis similarly plots the ratio of the energy efficiency index (BTUs of energy per unit of real GDP) in 2004 to that in 1980. Once again we find that the United States has reduced its energy use and has not substituted other energy for oil to any substantial degree (it is close to the 45-degree line, and hence consumption of energy and oil has declined somewhat proportionally) but that not every country has done likewise. Most of the countries in the sample (which overrepresents industrial countries) have become both less oil and less energy intensive. Countries below the 45-degree line have substituted other fuel sources for oil. Most of the industrial economies are slightly below the 45-degree line, indicating that some mild substitution has occurred. However, many of the emerging economies in our sample have actually increased their energy intensity, perhaps because they have attracted energy-intensive industries from the industrial world.

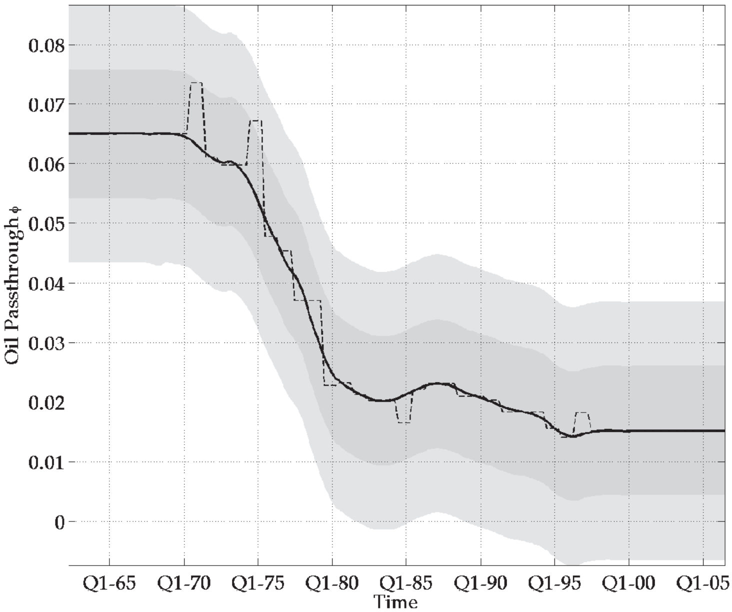
Reestimations of the Phillips Curve

In this subsection we revise Phillips curve estimates in two different ways. We start by measuring world oil prices in domestic currencies, and thus we combine the pass-through of changes in oil prices (in U.S. dollars) with the pass-through of changes in exchange rates to inflation. Figure 5 presents the estimated average pass-through using the following specification of the Phillips curve:

$$\pi_t = \alpha + \sum_{i=1}^{4} \beta_i \pi_{t-i} + \sum_{i=0}^{4} \gamma_i \left(y_{t-i} - \bar{y}_{t-i} \right) + \sum_{i=0}^{4} \theta_i \text{oil}_{t-i}^{lo\$}, \tag{3}$$

in which the only difference with equation 1 is that $\text{oil}^{lo\$}$ is the quarterly percentage change in the price of a barrel of Brent crude in local currency. As the figure shows, the sharp fall in the pass-through in the late 1970s survives this alternative specification, and the estimates of the pass-through in the last couple of decades are similar. What is different is that the pass-through estimates for the 1970s are much smaller, almost half of what they were in the previous analysis. In this case the pass-through falls from just under 0.07 to a little more than 0.01. This evidence suggests that almost half of the inflationary effect of the oil shocks of the 1970s was due to oil-induced devaluations rather than to a direct effect of the increase in world oil prices.

FIGURE 5. Average Pass-Through over Time Using Endogenous Windows, by Oil in National Currency[a]



Source: Authors' calculations.

a. Window lengths are endogenous as in Figure 2. The pass-through has been calculated using the specification in equation 3, where the percentage change in the price of oil has been calculated in terms of local (national) currency. The dotted line represents the average pass-through coefficient, and the dark line represents a quadratic polynomial smoothing of the same series. Both series are calculated over the sample of twenty-three countries that have data for the whole period. The darker band represents the confidence interval of ±1 standard deviation (s.d.) around the trend, and the lighter band represents an interval of ±2 s.d. around the trend.

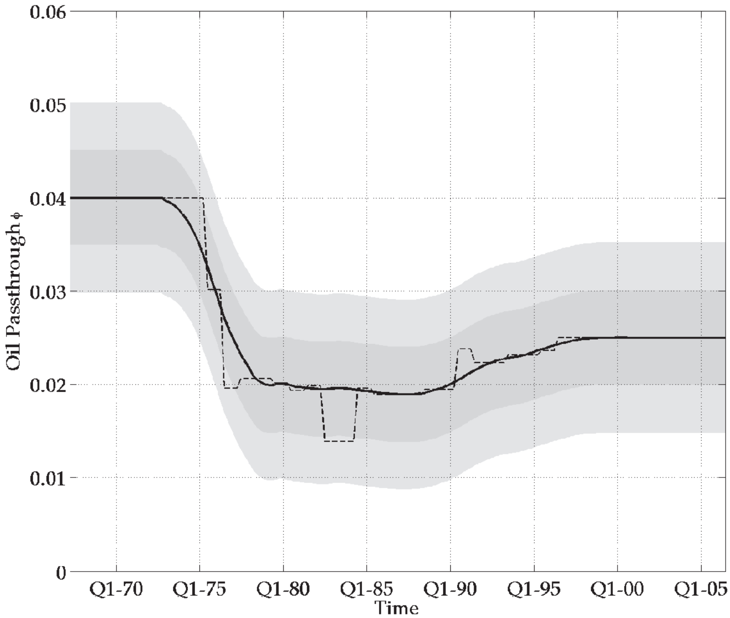
The second correction to our estimations is to control for the changes in the importance of oil in each economy.[23] We reestimate structural breaks and calculate the average pass-through using the following specification for the Phillips curve:

$$\pi_t = \alpha + \sum_{i=1}^{4} \beta_i \pi_{t-i} + \sum_{i=0}^{4} \gamma_i \left(y_{t-i} - \bar{y}_{t-i} \right) + \sum_{i=0}^{4} \theta_i \left(\omega_t \quad \text{oil}_{t-i}^{lo\$} \right), \tag{4}$$

in which ω_t is the oil intensity of the economy, normalized to 1 at the start of the series and defined as the amount of oil (in barrels) consumed per unit of

23. Hooker (2002) also controlled for changes in the level of oil intensity of the U.S. economy. His results remain similar to this new specification.

FIGURE 6. Average Pass-Through over Time Using Endogenous Windows, by Oil in National Currency and by Oil Intensity[a]



Source: Authors' calculations.

a. Window lengths are endogenous as in Figure 2. The pass-through has been calculated using the specification in equation 4, where the percentage change in the price of oil has been multiplied by oil instensity. The dotted line represents the average pass-through coefficient, and the dark line represents a quadratic polynomial smoothing of the same series. Both series are calculated over the sample of eighteen countries that have data for the whole period. The darker band represents the confidence interval of ±1 standard deviation (s.d.) around the trend, and the lighter band represents an interval of ±2 s.d. around the trend.

real GDP. Thus this case combines both the decline in the effective pass-through from the oil price in domestic currency and the decline in oil intensity. The average pass-throughs are presented in figure 6. The pass-through falls from 0.04 to 0.025, and there is a small overlap of confidence intervals at ±2 standard deviations (s.d.). It should be noted that since data on oil intensity are not available for all countries our sample is reduced to twenty-four countries, eighteen of which have data for the entire study period, and it over-represents industrial countries.

From figures 5 and 6 we can conclude that two very important factors in the decline of the effect of oil prices on inflation have been a decline in the use of oil per unit of GDP and a decline in the impact of exchange rate changes on inflation. Even after we adjust for these two factors, there is, however, still some, albeit weak, evidence of a decline in the impact that oil has on inflation. In what follows we check these results using an alternative empirical approach, and we examine other factors that may have contributed to the decline in the oil pass-through.

Oil Shocks and VARs

The estimation of Phillips curves provides persuasive evidence for the decline of the oil price pass-through, but we want to check the robustness of the results using a more theory-free empirical analysis, while taking into account the interactions of the different variables. Indeed, digging into the details on a country-by-country basis, we find some results that are difficult to explain, which are to a large extent the result of difficulties in estimating Phillips curves across countries. Therefore, to strengthen the evidence on the decline in the pass-through, in this section we use a different methodology to address the same issue. We attempt, using vector autoregressions (VARs), an estimation that involves a clearer identification of the interaction of different economic variables. Unfortunately, this methodology requires higher-frequency data and more variables, forcing a dramatic sacrifice in sample size.

The VARs are estimated for rolling windows of data starting between 1960 and 1974, depending on data availability. For our methodology we follow Wong, who used rolling VARs to argue that the effectiveness of monetary policy has fallen in the United States.[24] However, our interest is in the orthogonalized impulse response of the CPI to an oil price shock. Our hypothesis will be that the impact of oil shocks has decreased as the rolling windows move closer to the present. In this case the measure of the pass-through will be the integral of the impulse response function for the VARs in each window. We will analyze whether these integrals have decreased over time. The main advantage of the rolling VAR methodology is that it is an unstructured way of analyzing parameter changes and instability over time.

The main handicap, as already noted, is that it requires more data: higher frequency for lags and more variables for the structure of the model. Given these data limitations, we try to approximate the best benchmark model, bearing in mind that our aim is not to investigate VAR modeling or inflation modeling as such but rather to observe the changing effects of oil shocks given the model. Again, for the purpose of comparability across countries,

24. Wong (2000).

we will sacrifice optimization of the fit of the model by not including dummies or controlling for country-specific factors.

Methodology

Since the nature of oil shocks has changed over time, using the triangular decomposition in the VARs is particularly critical. For example, pass-throughs may be constant over time, but the intensity of oil shocks may change. A Cholesky decomposition mixes these two elements of the effect of an orthogonal shock, since it consists of calculating the relative response of endogenous variables to orthogonalized shocks. This is why Cholesky impulse response functions are reported in terms of standard deviations of the shock. As a consequence, although we can determine whether the shock has statistically significant dynamic effects, we do not know whether those effects are of economic importance. Moreover, we cannot properly compare impulse responses across different windows in time, since it is perfectly plausible that the intensity of orthogonalized shocks has varied over time. In the primer section on the oil pass-through, we reported some differences in the intensity and length of the fluctuations of oil prices during the five potential shocks in the post–World War II period that we have analyzed. The 1973 Yom Kippur shock seems to have been the most intense, but the shocks since then have varied in length. When we estimate pass-throughs using the triangular decomposition, we can observe and compare the economic importance of these shocks.

Data limitations substantially limit our sample to only nine industrial economies (Canada, Denmark, France, Germany, Italy, Korea, Japan, the United Kingdom, and the United States) and three emerging economies (Colombia and Chile, which are the countries with the longest comparable series in Latin America, and Israel, which is always difficult to interpret).

IMPULSE RESPONSE FUNCTIONS AND ROLLING WINDOWS. We estimate a VAR model by ordinary least squares (OLS). Because we use rolling windows of data, a slightly different approach must be taken in calculating the impulse response functions if we want to compare them through time.[25] All estimations are in levels and include a time trend. The general system is the following:

$$y_t = c + \beta_i t + \sum_{i=1}^{p} \Phi_i y_{t-i} + \varepsilon_t, \tag{5}$$

where $\boldsymbol{y}$ is the vector of variables of the VAR, with $\varepsilon \sim N(0,\Omega)$. Estimating $\hat{\Phi}$, $\hat{\Omega}$ by OLS, we can write the moving average representation as

25. See Hamilton (1994) for details.

(6) $$y_t = \hat{\mu} + \varepsilon_t + \hat{\psi}_{t-1}\varepsilon_{t-1} + \cdots.$$

The object of interest is the amount by which we must revise our forecast of CPI (y_{CPI}) given new information for the price of oil (y_{oil}):

(7) $$\frac{\partial E\left(y_{CPI,t+s} \middle| y_t\right)}{\partial y_{oil,t}} \quad \forall\ s = 1, 2, \ldots \text{ horizon.}$$

Given an oil shock, $\varepsilon_{oil,t} > 0$, we can revise our estimate for the other shocks by using the information contained in $\hat{\Omega} = T^{-1} \sum_{i}^{T}=1\ \hat{\varepsilon}_t\hat{\varepsilon}_t'$. Concretely we want to find how a unit change in $y_{oil,t} = \varepsilon_{oil,t}$ leads to changes in the vector of innovations ε, and then we use this information together with the $\psi_t + s$ for each s for the relevant horizon to find by how much we should revise our forecast for CPI given y_t, ε_t.

We use the triangular decomposition $\Omega = ADA'$ where A is the lower triangle and D is a diagonal matrix giving the variance of $u_t = A^{-1}\ \varepsilon_t$, where u_{jt} (j identifies a variable in the VAR and $-j$ the other variables different from the j one) is the residual projection of $\varepsilon_{j,t}$ on $u_{-j,t}$ and so has the interpretation of new information of $y_{j,t}$ beyond that contained in $y_{-j,t}$. The effect of $\varepsilon_{j,t}$ on ε_t is given by the column j of matrix A denoted by a_j and in our specific case corresponds to the column A_{oil}. In this way the orthogonalized impulse response function is given by the following expression:

(8) $$\frac{\partial E\left(y_{CPI,t+s} \middle| y_t\right)}{\partial y_{oil,t}} = \psi_s A_{oil} \quad \forall\ s = 1 \ldots \text{ horizon.}$$

We use the triangular decomposition instead of the more popular Choleski decomposition so as to isolate the estimated variance of the variable being shocked.

The Choleski decomposition is the following:

(9) $$\Omega = ADA = AD^{1/2}D^{1/2}A' = PP'.$$

In this case the impulse response function is given by

(10) $$\frac{\partial E\left(y_{CPI,t+s} \middle| y_t\right)}{\partial y_{oil,t}} = \psi_s A_{oil} \sqrt{d_{oil}} \quad \forall\ s = 1 \ldots \text{ horizon,}$$

where d_{oil} is the element along the diagonal of D corresponding to the orthogonalized variance of the price of oil.

Under the Choleski decomposition, both $\hat{\Phi}$ and $\hat{\Omega}$ are functions of the data of each particular window so that the simulated $\hat{\psi}$ and $\hat{A}$, $\hat{D}$ will change when the estimated window changes. The impulse response functions will also change due to changes in $\hat{\Phi}$, $\hat{A}$, and $\hat{D}$. Hence, comparing them could be misleading since a decrease in the level of the response could be due to a decrease in the size of the shock $\sqrt{d_{oil}}$. Instead, by using the triangular decomposition, we can interpret equation 8 as the consequence on log CPI of a one unit rise in the log of the price of oil.

THE MODEL AND VARIABLES. In the general case for countries other than the United States, the variables used are those suggested by Kim and Roubini, that is, the log of the price of Brent crude in U.S. dollars, the U.S. federal funds rate, the log of the industrial production index, the log of the CPI, the log of M1, short-term interest rates, and the log of the exchange rate to the U.S. dollar.[26] A time trend is also added. The model for the U.S. economy follows the work of Wong and Bernanke and Mihov and includes the log of the price of Brent crude, the log of the industrial production index, the log of the CPI, the federal funds rate, the log of total reserves, and the log of nonborrowed reserves.[27]

We deliberately do not impose any structure on the VARs, and we use a set of variables and an ordering that are as conventional as possible. We do this to focus on the evolution of the estimates over time and to permit international comparability rather than focus on the specifics of VAR estimation for each country. One should be cautious in interpreting the regressions and impulse response functions for France, Germany, and Italy, since those countries converted to a monetary union during the sample period.

Results

The results of the VAR estimations are summarized in figure 7, which shows the integrals of the twenty-four-month impulse response functions for all the VARs estimated for each country on rolling windows of 200 months.[28]

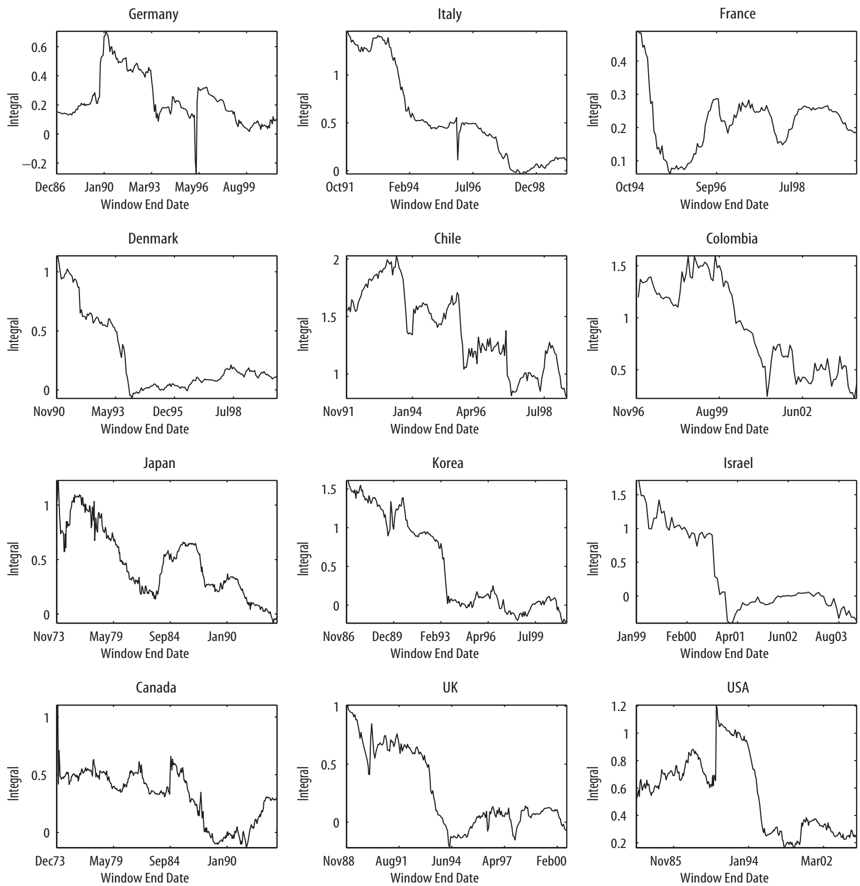
Figure 7 seems to provide additional evidence of a decrease in the pass-through. All of the countries in the sample show reductions in the pass-through up to the turn of the century. It is interesting to note that the United

26. Kim and Roubini (2000).

27. Wong (2000); Bernanke and Mihov (1995). Three lags were chosen by Hannan-Quin information criteria for the United States and were used in all specifications for comparability.

28. These models were also estimated with different window sizes (190 and 210 months), with similar results.

FIGURE 7. Accumulated Effect of a Unit of Oil Shock on Inflation[a]



Source: Authors' calculations.

a. The shock is measured as 1 U.S. dollar. The accumulated effect is calculated as the integral of the impulse response function for a twenty-four-month horizon. The window width is 200 months.

States displays the same increase in the pass-through up to the 1980s that it showed with the Phillips curve methodology. Chile and Colombia now show very clear reductions in the pass-through, and Korea and Japan show small but positive effects of oil shocks on inflation in the most recent VARs.

Nonetheless, there seems to have been a recent recovery in the pass-through in some countries, in particular Canada and the United States. In comparison, Chile, Denmark, Israel, Japan, and Korea seem to have stabilized the pass-through at low levels. As we argued in the introduction, if the recent oil shocks were expected to be transitory, the pass-through should be low. If this rationalization of pass-through fluctuations has any merit, we should expect the pass-through to increase as the oil shock persists and more data are included. However, we do not see any systematic increase in the pass-through, an issue to which we will return in the next section.

Another interesting feature of these estimations is that they seem to indicate larger decreases in the pass-through from what we found in the previous section. Unfortunately, because of data constraints, both procedures cannot be applied to all countries, nor are the time frames necessarily the same. In addition, the estimations in this section include all of the possible feedback effects that could help dampen the impact of the hike in oil prices on inflation. In any case there are interesting contrasts with the estimations of the previous section. For example, Denmark was included from the database used in the first section of econometric analysis (oil pass-through and structural breaks in the traditional Phillips curve), but we could not find a significant breakpoint. In contrast, in this section we find clear evidence of a decrease in the Danish pass-through, when the data from the early 1970s are excluded from the estimation window.

It is important to note that the VAR estimations of the decline in the pass-through found in this section combine all the indirect effects that stem from movements in other variables. In particular, both the decline in the exchange rate pass-through and the response of monetary policy should be included in the final effect, although oil prices are measured in U.S. dollars. Finally, and to highlight the differences between the two econometric approaches, we are able to find a reasonable estimate for the decline in the Chilean pass-through, whereas in the previous section we could not.

Explanations for the Decline in the Oil Pass-Through

So far we have documented a generalized decline in the oil pass-through for a large number of economies. To do this we have used two alternative statistical methodologies, which seem to consistently show a significant reduction in the effect of oil price changes on inflation in industrial as well as in emerging economies. We have also found that part of the decline in the pass-through is due to a decline in the effect of exchange rate changes on inflation and part is due to a reduction in oil intensity. But even after we take both these factors into consideration, there is still a part of the decline in the impact of oil prices on inflation that we have not been able to explain.

In this section we discuss some additional factors that might explain this residual decline and how these factors can also help explain the reduced impact of the recent oil price increase on world economic activity. This section complements the results of Blanchard and Galí, who argue that the reduction in the oil pass-through to inflation is the result of a combination of factors: a reduction in oil intensity (see the previous section on the effects of exchange rates and oil usage); the presence of an offsetting shock, which in our case is increased world demand that has led, contrary to previous experiences, to the appreciation of the currency in many countries; and improved monetary policy that has reduced inflation and its variability.[29] In this section we analyze all of the potential explanations by looking at the data and correlations. Blanchard and Galí show their conclusions by calibrating a dynamic new Keynesian general equilibrium model and examining the consistency of the time series evidence with their model. In their model, they also include the decrease in real wage rigidity as another factor that explains the reduced impact of oil prices on the economy.

We have already argued that a big part of the decline in pass-throughs can be assigned to a decrease in exchange rate pass-throughs. In the following sections we will look at the change in the nature of commodity shocks, the changes in the persistence of commodity shocks, changes in the regulation of oil markets, changes in the inflation environment, and changes in the responses of monetary policy.

The Nature of Oil Shocks (Supply versus Demand) and the Role of Exchange Rate Movements

In recent discussions of the modest impact of oil prices on world activity, an important explanation has been the nature of the shock. Whereas in previous shocks the driving force was supply shortages, today, it is argued, the rise in the price of oil has to a large extent been driven by demand (mainly U.S. and Chinese demand, coupled with speculation by hedge funds).

This explanation is relevant not only for oil-importing countries but for commodity-exporting countries as well. The global increase in demand for commodities means that the output effects of recent oil shocks should be less pronounced for commodity exporters. In contrast, if the rise in the price of oil

29. Blanchard and Galí (2007).

is caused by supply constraints, the effect on all oil-importing countries will be the same no matter their export structure. Therefore the fact that the recent oil shock has been a demand shock rather than a supply one has important macroeconomic implications. However, to explain the limited inflationary effects, we need to identify additional mechanisms associated with the demand shock, especially given that greater economic activity should induce inflationary pressures. Here is where the effects of the evolution of the exchange rate become relevant. Note that this is a different issue from the decline in the pass-through. The point we make here is that there has been much less currency depreciation during recent oil shocks than during previous ones.

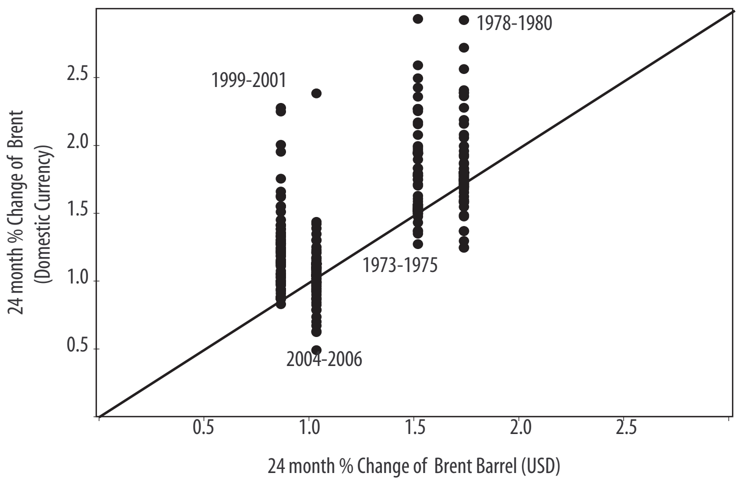
An expansion of demand for all commodities, rather than just oil, generates an appreciation in the currencies of commodity-exporting countries, which offsets the impact of world oil prices in these countries and makes the shock milder in terms of domestic currency. Supply-driven oil shocks, however, are not accompanied by the same offsetting effect on the exchange rate.[30]

Figure 8 plots the change in oil prices in U.S. dollars against the change in oil prices in domestic currencies for 163 countries during each of the four shocks we have identified. The figure shows that there can be some significant differences in the intensity of oil price shocks depending on the currency denomination. If these differences were not very important, one would expect most of the observations in the chart to lie on or near the 45-degree line. However, there are important deviations. It is quite interesting that the three earlier oil shocks were accompanied, in general, by depreciations, which made them more inflationary in terms of domestic currency: in figure 8, most of the points are above the 45-degree line, indicating that the domestic currency shock has been larger than the U.S. dollar shock. In contrast, during the most recent oil shock, a substantial number of countries have experienced an appreciation, which has softened the shock. This shows that the nature of the shock matters, and it allows one to explain the compensatory movements of the exchange rate as well as the reduced impact of the oil price hike on economic activity.

Finally, we can also look at the combination of oil shock pass-throughs and exchange rate fluctuations. If, as a consequence of a supply-driven oil shock, a country also suffers a depreciation, the prices of goods other than oil could rise as a consequence, increasing the inflationary consequences of the oil shock. This could be aggravated by the fact that exchange rate pass-

30. Kilian (2006) explores the distinction further by distinguishing between increases in the demand for oil stemming from strong global demand, which should affect all commodities, and increases in demand for oil that are due to fears of future shortages. In our discussion the latter should be similar to a supply shock in terms of its inflationary consequences.

FIGURE 8. Oil Price Changes in Domestic and Foreign Currency



Source: International Financial Statistics and U.S. Energy Information Administration.

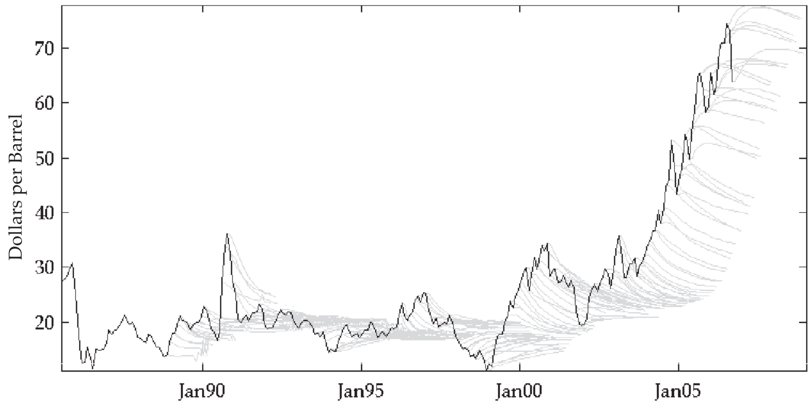
throughs were larger in the past. In the oil shock of 1999 to 2001, however, most currencies depreciated against the U.S. dollar, but the exchange rate pass-through had already declined.

The Persistence of Oil Shocks

The literature on exchange rate pass-through has attributed much of the recent decline of the pass-through to the presence of flexible exchange rates. More generally, Taylor has argued that the low persistence of changes in costs reduces the pass-through from cost to prices, as price setters will be more reluctant to change their prices if there is an increased probability that a given cost increase will be reversed.[31] This argument also applies to flexible exchange rates and the exchange rate pass-through. In contrast, under more rigid exchange rate systems, discrete changes in the exchange rate are unlikely to be reversed, and hence firms will be more prone to change their prices. In particular, when a depreciation occurs, there will be a greater incentive to change prices. Hence the increased popularity of flexible exchange rate regimes could explain the decrease in the pass-through from exchange rate fluctuations to inflation.

31. Taylor (2000).

FIGURE 9. Oil Brent Price and Oil Futures



Source: Bloomberg.

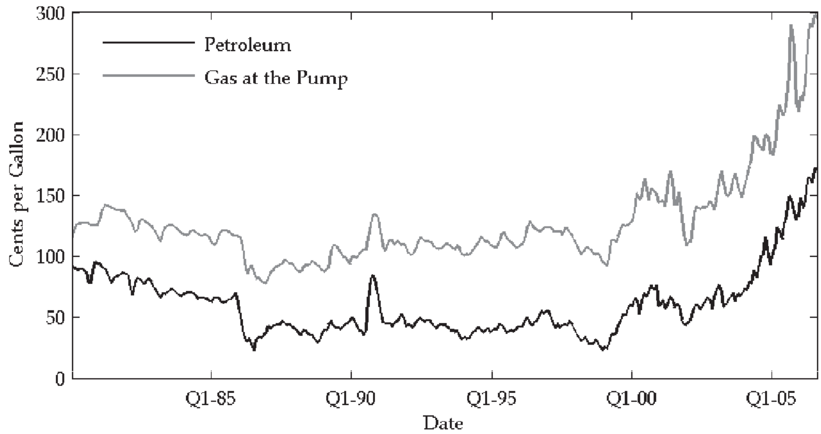
The same argument can also be applied to an oil shock: a smaller pass-through should be expected for a transitory oil shock than for a more persistent shock. This may be what happened with the 1991 and 1999 oil shocks. However, the current oil shock has lasted much longer than the previous ones (see figure 1), and thus the explanation based on transitory versus permanent shocks is not sufficient, since pass-throughs remain low.

The issue is in fact somewhat more subtle: the question is how persistent is a given oil shock expected to be, rather than how long it ends up being. One could argue that the most recent shock has been surprisingly persistent, whereas the previous ones, for which the pass-throughs were higher, were unexpectedly short lived. Of course, it is necessary to explain these wrong perceptions, but we can still go to the data to look at the perceived persistence.

A simple way to address this issue is to look at the prices of oil futures. Figure 9 shows the evolution of the spot price of Brent crude since 1985; the expected evolution of the Brent price as indicated by futures contracts is also shown at various points in the series by the secondary lines emanating from the actual price (which is the dark line). It is quite clear that, up to the later months of 2004, the market still acted as if the shock were partly transitory, as previous shocks had been.

More recently, however, futures contracts are increasingly reflecting the high persistence of the shock, as indicated by the lines representing the most recent futures contracts, which are substantially flatter than the previous

FIGURE 10. U.S. City Average Retail Price of Regular Gasoline, Including Taxes



Source: Bloomberg.

ones. Therefore not only has the current oil shock been more persistent, but it is also increasingly perceived to be so; yet the pass-through has declined instead of increasing as the Taylor hypothesis would suggest. Although the exchange rate pass-through is not determined by the same fundamentals that affect the oil pass-through, the persistence hypothesis should hold for both. Looking at the impact of the oil shock on inflation thus calls the persistence argument into question.

Domestic Regulation of Oil Markets

We have not yet explored the possibility that, as a result of previous oil shocks, domestic oil markets have become more regulated and thus better able to buffer oil shocks. According to this hypothesis, countries may have implemented institutional or de facto price stabilization mechanisms such as countercyclical oil taxes, stabilization funds, or countercyclical administration of strategic oil reserves. In that case oil prices at the pump would not reflect the volatility of international oil prices. Verification of this hypothesis requires datasets of pump prices of oil that are consistent for an important group of countries and for a long period of time, which are very difficult to come by. Figure 10 shows the evolution of the retail price of regular gasoline in the United States and of the wholesale Brent crude price on international markets. Both series move very much in tandem. At least in the United States, there seems to be little evidence that the domestic pump price is being substantially smoothed with respect to the wholesale price.

It is reasonable to expect that domestic oil pump prices will be, in general, more stable than are wholesale prices. But anecdotal evidence does not seem to indicate that domestic stabilization mechanisms have led to any consistent deviation of oil pump prices from wholesale international prices in the countries we are analyzing. This is particularly important for the current shock, which, as we have seen, has been significantly more persistent than have past shocks. Moreover, it seems that it is the oil-exporting countries that tend to strongly subsidize their domestic oil prices, driving a wedge between wholesale and retail prices. It does not seem plausible, therefore, that domestic stabilization mechanisms—at least in these countries—have prevented domestic pump prices from following wholesale prices. In addition, serious attempts have been made in previous oil shocks to stabilize domestic gasoline prices—the Nixon price and wage controls being an important example.

Therefore the issue is not the direct pass-through from oil prices to domestic gasoline prices, but rather it is the second-round effects, that is, the transmission from oil and gasoline prices to other prices in the economy. The low observed pass-throughs are the result of a decrease in the transmission from higher domestic oil prices to prices in the rest of the economy.

The Response of Monetary Policy to Oil Shocks

Another possible explanation of the decline in the oil pass-through is that central banks have become more willing to fight inflation through monetary policy. Central banks around the world have become increasingly independent, with a clear mandate for price stability and, in several countries, the adoption of inflation-targeting regimes. If a central bank is strongly committed to keeping inflation low and fights all supply shocks aggressively to achieve that objective, no change in inflation in response to large swings in oil prices will be observed in that country. As a corollary, the output effects of oil shocks should be larger, although this has not been the case in the current oil shock. One could argue, however, that aggressive central banks accrue a credibility bonus that allows them to anchor inflation at a lower output cost. We find merit in this argument, but we postpone discussion of it to focus first on interest rate fluctuations as a way of measuring the actual responsiveness of monetary policy to oil shocks.

This greater commitment to keeping inflation under control could have increased the response of interest rates to inflation. Indeed, Clarida, Galí, and

Gertler estimated Taylor rules and found that interest rate policies were much more sensitive to inflation during the Volcker-Greenspan eras than during preceding ones.[32] Taylor estimated that the coefficient of inflation in a Taylor rule estimation for the late 1980s was double what it was in the 1960s.[33] Moreover, Bernanke, Gertler, and Watson estimated a structural VAR specifically to identify the response of monetary policy to oil shocks.[34] They found that the endogenous monetary response to oil shocks accounts for most of its effects on the economy.

However, Hooker argued that a reestimation of the VAR of Bernanke, Gertler, and Watson for the post-1979 period shows a significant reduction in the response of monetary policy to oil shocks compared with that of the pre-1979 period.[35] Leduc and Sill also split their sample in 1979 and found that in the more recent sample 40 percent of the decline in output in the United States due to oil shocks was caused by the reaction of the Federal Reserve, whereas in the older sample the Federal Reserve caused as much as 75 percent of the decline in output.[36] These results do not contradict previous estimations of Taylor rules that show an increased reaction to inflation, since the VAR evidence to which we refer here consists of estimations of the reaction to a particular inflationary shock, namely, a rise in oil prices.

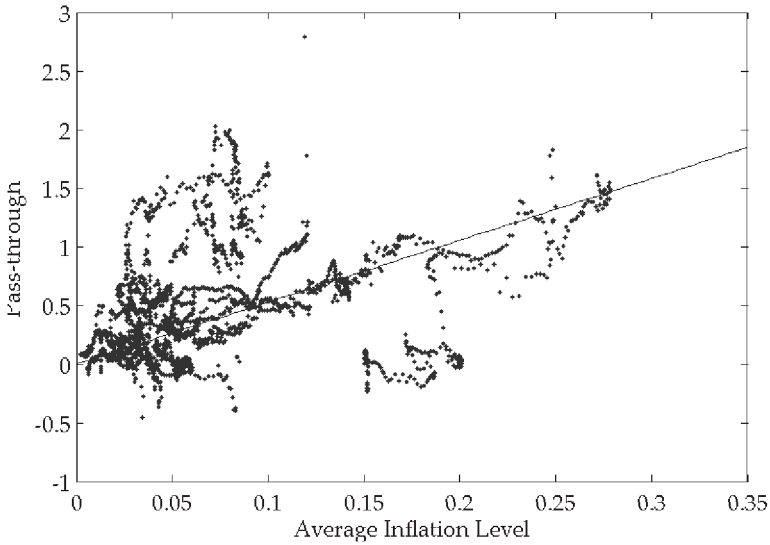
Summing up, there is no broad evidence that the reaction of monetary policy to oil shocks has increased. Such a reaction has occurred in only a few countries. However, in other countries the gain in credibility and the commitment to low inflation may have contributed to the reduction in the oil pass-through, as well as in the exchange rate pass-through, without the need for an increased reaction to oil price hikes. In addition, the fact that interest rates are more responsive to inflation today than they were before may better anchor the second-round effects from oil shocks, thereby reducing their inflationary impact and consequently reducing the reaction from monetary policy.

The Current Low-Inflation Environment

A related possible reason for the reduced impact of the oil shock on inflation is that the global decline of inflation has brought, via a number of mechanisms, a substantial reduction in the second-round effects of oil shocks.

32. Clarida, Galí, and Gertler (2000).
33. Taylor (2000).
34. Bernanke, Gertler, and Watson (1997).
35. Hooker (2002); Bernanke, Gertler, and Watson (1997).
36. Leduc and Sill (2004).

FIGURE 11. Inflation Levels and Pass-Through



Source: Authors' calculations.

A first and traditional explanation in the context of rigid prices, when these are caused for example by menu costs, is that when inflation is low, price changes are less frequent. When deciding prices, firms may postpone their reaction to oil shocks if inflation is low, since they adjust prices infrequently. When inflation is higher, firms are already regularly incurring the costs of changing prices, and so they can more rapidly build the oil shock into their prices. As a result, the oil pass-through should be larger in economies with higher inflation. Something similar has been found in the case of the exchange rate pass-through.[37]

As an exploratory way of investigating the relationship between the level of inflation and pass-through, we use the results from the section on oil shocks and VARs and run a fixed-effects panel regression between the average level of inflation during the window and the integrals of the impulse response functions of the oil price from a shock to inflation as shown by figure 11. The upward-sloping line represents the result of a fixed-effects linear regression between the two series, which delivered a positive and

37. Borensztein and De Gregorio (1999).

significant slope. When we ran this regression for each country, all but one of the coefficients turned out to be positive, and more than half were significantly different from zero. These results support the idea that in countries where inflation has declined the impact of oil shocks on inflation has also declined.

This evidence may also be consistent with the existence of a credibility bonus as mentioned before. As inflation expectations draw closer to the inflation objective, the incentives for price changes in response to supply shocks should be smaller.

More generally, it could be argued (although we present only circumstantial evidence) that the global decline in inflation has reduced the pass-through from oil prices to inflation. This could be due to a greater commitment to price stability, a credibility bonus, a reduced response of prices to supply shocks due to price rigidities, or even the increase in globalization as recently emphasized by Rogoff.[38] Whatever the reason, we cannot rule out that the impressive decline in the effect of the rise of oil prices on inflation is a result of the lower-inflation environment. The low inflation environment has also helped reduce the exchange rate pass-through, a factor that has contributed in a relevant way to the reduction of the oil price impact, as we showed in the section on the oil pass-through and structural breaks in Phillips curves.

Conclusions

This paper has presented evidence of a significant decrease in the pass-through of oil price changes to general inflation in recent decades. We find that this is a generalized fact for a large set of countries. The paper began by documenting correlations between the CPI and oil prices and then used two estimation strategies to try to properly identify the effect of oil shocks on inflation. First, the traditional Phillips curve was augmented to include oil, and structural breaks were estimated for thirty-three countries. This methodology showed a clear decrease in the average estimated pass-through for industrial economies and to a lesser degree for emerging economies. Even so, the pass-through estimates for the most recent periods in emerging markets seem much more reasonable and consistent with the results from indus-

38. Rogoff (2003). For a discussion on second-round effects of the recent oil shock in the U.K. economy, see Bean (2007).

trial economies. The results hold when oil is valued in local currency, but the pass-through drops less when oil intensity is controlled for. In addition, when we controlled for oil intensity, we found that the decline in the economic intensity of oil use over the years helps to explain the limited impact of more recent oil shocks on inflation. Therefore we conclude that a significant part of the decline in the oil pass-through around the world is explained by the reduction in the effects of exchange rate changes on inflation and by declining oil intensity. However, our estimates show that, even after controlling for these factors, part of the decline in the oil pass-through remains unexplained.

Second, we estimated rolling VARs for a subsample of countries for which we have sufficient data. We derived impulse response functions of inflation to oil shocks and interpreted the integrals of these impulse responses as estimates of the pass-through. We found that the effect of oil shocks on inflation for a twenty-four-month window has decreased for most of the twelve countries in this subsample.

Next, we looked for additional potential explanations for the widely observed decrease in the pass-through from oil prices to inflation. We examined a number of factors that could explain this decline but did not find strong evidence pointing to any single specific explanation. One promising avenue is the current lower-inflation environment, working perhaps through the manner in which monetary policy reacts to oil prices, or through some credibility bonus. A second is the demand-based nature of the current oil shock: because today's high oil prices are to a large extent due to strong world demand rather than to supply shortfalls, movements in exchange rates have not reinforced the consequences of high world oil prices, as has happened in previous episodes. In contrast to the literature on exchange rate pass-through, which predicts that persistent changes in costs should increase the pass-through, the current oil shock has been quite persistent, and perceived as highly persistent by the market, but the inflationary consequences have been moderate. Finally, we found no evidence that regulation of domestic gasoline markets, at least in the United States, has helped ameliorate the inflationary impact of high oil prices.

The reaction of the global economy to the recent oil shock has been very different from that in previous oil shocks. The world economy appears to be much more resilient than it was in previous episodes. Economic activity has suffered little in the current juncture, and inflation has remained under control. Indeed, most traditional estimates of the impact of oil on the economy have been scaled down to fit current developments. We believe our findings help explain this greater resilience. The decline in the oil intensity of economies reduces the impact of oil price hikes on inflation and output. In addition, the movements in exchange rates that accompany the oil shock have less inflationary consequences and hence require a milder reaction from monetary policy—a factor that has been highly relevant in explaining previous slowdowns stemming from oil shocks. Finally, the high oil price in recent years has been the result of high demand rather than of supply shortages as was the case in the past.

TABLE A-1. Breakpoints and Pass-Through Coefficients: Endogenous Windows[a]

	Start year	*B 1*	*B 2*	*B 3*	*Total breakpoints*	*m0*	*m1*	*m2*	*m3*	*m4*
Argentina	1972	82	89	96	3	0	–0.3	4.83	0.02	–0.02
Australia	1962				0	0.04				
Austria	1962	71			1	0.03	–0.03	0.12		–
Barbados	1975				0	0.04				
Belgium	1962	71	85	94	3	0.05	0.77	0.05	0.02	0.02
Canada	1962	91			1	0.04	0.05	0.02		
Chile	1962	74	83	92	3	30.47	–0.04	–0.16	0.08	0.13
Côte d'Ivoire	1970				0	0.03				
Denmark	1962	71			1	0.04	3.11	0.06		
Finland	1962	72	81	90	3	0.1	–0.04	–0.01	–0.11	0.06
France	1962	76	85	96	3	0.25	0.08	0.07	0.01	0.02
Germany	1972				0	0				
Greece	1962	74			1	0.01	0.11	0.27		
India	1962				0	0.05				
Ireland	1962	81			1	0.20	0.58	0.03		
Israel	1962	76	85	94	3	1.16	0.36	0	0.04	–0.08
Italy	1962	74	83	94	3	0.42	0.02	0.03	0.07	0.02

Japan	1962	70	80		2	0.09	−11.13	0.25	0.04	
Jordan	1978	90			1	0	0.11	0		
Korea	1972	80			1	0.20	0.07	0.03		
Malaysia	1972	84			1	−0.02	−0.02	−0.01		
Mexico	1962	79	88	97	3	0.25	0.04	0.11	0.13	−0.18
Netherlands	1962	70	82		2	0.05	−2.76	0.17	0.01	
Nigeria	1972				0	−0.07				
Norway	1962	91			1	0.04	0.03	0.01		
Portugal	1962	77			1	0.12	0.67	−0.08		
Senegal	1973	81			1	0.14	0.31	−0.05		
South Africa	1962	72	95		2	0	0.01	−0.01	−0.03	
Spain	1963				0	0.09				
Sweden	1962	91			1	0.05	0.04	0		
Switzerland	1962	95			1	0	0	0.02		
United Kingdom	1962	79			1	0.28	0.63	−0.07		
United States	1962	81			1	0.08	0.07	0.03		

Source: Authors' calculations.

B = breakpoint.

a. m0 refers to the long-run pass-through coefficient from equation 2 in the absence of breaks; m1 through m4 represent the pass-through coefficients calculated for each part of the series using the estimated breaks if any.

TABLE A-2. Breakpoints and Pass-Through Coefficients: Endogenous Windows Using National Currency[a]

	Start year	*B 1*	*B 2*	*B 3*	*Total breakpoints*	*m0*	*m1*	*m2*	*m3*	*m4*
Argentina	1972	83	90		2	–1.30	–0.41	–0.37	0	
Australia	1962				0	0.03				
Austria	1962	71	84	96	3	0.02	1.19	0.01	0	0.02
Barbados	1975				0	0.04				
Belgium	1962	71	85	94	3	0.03	–1.05	0.04	0.01	0.02
Canada	1962	91			1	0.04	0.04	0.02		
Chile	1962	73	85		2	–0.7	–0.07	–0.5	0.58	
Côte d'Ivoire	1970				0	0				
Denmark	1962				0	0.03				
Finland	1962	70	80		2	0.05	–0.17	–0.01	0.05	
France	1962	76	85	96	3	0.28	0.09	0.05	0.01	0.07
Germany	1972				0	0				
Greece	1962	74			1	–0.01	0.11	0.25		
India	1962	75			1	0.02	0.03	–0.03		
Ireland	1962	77	86		2	0.21	0.16	0	0.02	
Israel	1962	75	85	94	3	0.55	0.39	–0.88	0.03	-0.08

Italy	1962	80			1	0.45	0.25	0.06		
Japan	1962	75			1	0.12	0.07	0.03		
Jordan	1978	88			1	0	0.1	0		
Korea	1972	79	86	98	3	0.32	0.03	0.11	0.04	0.02
Malaysia	1972	84			1	−0.02	0	−0.01		
Mexico	1962	79	88	97	3	−0.25	0.01	0.04	0	−0.13
Netherlands	1962	82			1	0.01	0.03	0.01		
Nigeria	1972				0	−0.05				
Norway	1962	90			1	0.04	0.04	0.03		
Portugal	1962	84			1	0.01	0.11	0		
Senegal	1973				0	0				
South Africa	1962	72	95		2	0	0.02	−0.01	−0.04	
Spain	1965				0	0.2				
Sweden	1962	71	91		2	0.05	−0.64	0.01	−0.01	
Switzerland	1962	95			1	0	0.01	0.02		
United Kingdom	1962	79			1	0.26	0.74	0.06		
United States	1962	81			1	0.08	0.07	0.03		

Source: Authors' calculations.

B = breakpoint.

a. m0 refers to the long-run pass-through coefficient from equation 2 in the absence of breaks; m1 through m4 represent the pass-through coefficients calculated for each part of the series using the estimated breaks if any.

TABLE A-3. Breakpoints and Pass-Through Coefficients: Endogenous Windows Using Oil Intensity and Prices in National Currency[a]

	Start year	*B 1*	*B 2*	*B 3*	*Total breakpoints*	*m0*	*m1*	*m2*	*m3*	*m4*
Argentina	1972	83	90		2	−1.32	−0.43	−0.36	−0.11	
Australia	1967				0	0.03				
Austria	1967	76	84	96	3	0.11	0.02	−0.04	0	0.05
Belgium	1967	74	85		2	0.02	0.13	−0.01	0.01	
Canada	1967	91			1	0.01	0.03	0.02		
Chile	1967	74	82	90	3	−0.71	−1.68	0.89	−0.05	0.21
Denmark	1967	76			1	0.06	−0.01	0.06		
Finland	1967	80			1	0.16	0.01	0.04		
France	1967	76	85	93	3	0.35	0.12	0.06	0	0.02
Greece	1967				0	0.11				
India	1967	76			1	0.05	0.07	−0.02		
Ireland	1967	76	84		2	0.26	0.03	−0.41	0.02	
Italy	1967	80			1	0.56	0.24	0.06		
Japan	1967	75			1	0.11	0.08	0.03		
Korea	1972	80			1	0.16	0.08	0.03		
Malaysia	1972	84	90	98	3	−0.02	−0.01	0.01	−0.01	0
Mexico	1967	79	88	96	3	−0.27	0	-0.01	0	−0.12
Netherlands	1967				0	0.02				
Norway	1967				0	0.03				
Portugal	1967	75	85		2	0.01	0.12	−0.06	0	
South Africa	1967	95			1	0	−0.02	−0.05		
Spain	1969	77			1	0.28	0	0		
Sweden	1967	91			1	0.03	0.02	0		
Switzerland	1967	95			1	0.01	0.01	0.01		
United Kingdom	1967	77			1	0.12	0.01	0.03		
United States	1967	81			1	0.08	0.03	0.03		

Source: Authors' calculations.

B = breakpoint.

a. m0 refers to the long-run pass-through coefficient from equation 2 in the absence of breaks; m1 through m4 represent the pass-through coefficients calculated for each part of the series using the estimated breaks if any.