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Abstract

This paper explores the question to what extent non-domestic factors provide an explanation of US inflation over the last three decades. Are lagged dependent variables – traditionally interpreted as proxies for inflation expectations – just proxies for oil and commodity prices? To answer this question a simple Phillips curve, which includes energy prices, is estimated for the USA. The results show that crude oil prices, which basically are world market prices, have exerted a strong influence on inflation, while the effects of domestic factors, such as the unemployment rate, have become weaker. These findings help to resolve a puzzle of recent years: given the sharp rise in unemployment, why has inflation not slowed down as much as predicted by the traditional Phillips curve analysis? Furthermore, the empirical results assign a much feebler role to expectations in the inflation process; if indeed inflation is a global phenomenon, the task of controlling inflation expectations by monetary policy may not be as crucial as implied by central banks statements pointing to the importance of anchoring inflation expectations. Are the actions of central banks nothing more than a sideshow?

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U.S. Inflation and Crude Oil Prices: An International Perspective

By Wolfgang Pollan

Abstract

This paper explores the question to what extent non-domestic factors provide an explanation of U.S. inflation over the last three decades. Are lagged dependent variables – traditionally interpreted as proxies for inflation expectations – simply proxies for oil/commodity prices? The results of a Phillips curve covering the years from the first oil price shock to the year 2014 show that crude oil prices, which basically are world market prices, have exerted a strong influence on inflation, while inflation expectations have played a much feebler role in the inflation process since the "Volcker" disinflation. Over the years the effects of domestic factors, such as the unemployment rate, have weakened.

Keywords: Commodity prices, expectations, inflation, monetary policy, Phillips Curve

JEL codes: D840, E120, E130, E310, E320, F410

Geographic Descriptors: U.S.

U.S. Inflation and Crude Oil Prices: An International Perspective

By Wolfgang Pollan

One of the few good ways we have to test analytical ideas is to see whether they can make sense of international differences in outcomes by appealing to international differences in institutional structure and historical environment. The right place to start is within each country separately, studied by someone who knows the peculiarities of its history and its data.

You might think that this (...) ought to be obvious. But in fact the usual approach is just the opposite. More often than not we fail to take institutional differences seriously. One model is supposed to apply everywhere and always.

Robert M. Solow (1986, S23)

I. Introduction

Akerlof – Shiller (2009) have recently lamented the easy acceptance by economists of the lack of money illusion as incorporated in the natural unemployment rate hypothesis, and have challenged the economic profession to seriously test the natural rate theory (2009, pp. 46-47). Though there is ample evidence supporting the existence of money illusion in the behaviour of economic agents, much of the literature on the Phillips curve (PC) seems to uncritically accept that there is no trade-off between inflation and unemployment. This paper takes up the challenge formulated by Akerlof and Shiller and re-examines the PC literature, with a focus on the role of energy prices as a driver of inflation since the early seventies.

The rapid rise in the price of oil and other raw material prices in 2008 and the steep decline at the beginning of 2009, as well as the corresponding rise and drop in the inflation rate in the OECD countries, have made it obvious to most financial analysts that movements in the prices of raw materials exert a strong influence on inflation.

International organisations, such as the OECD, the IMF, the EU, as well as national research institutes in Europe[1], have repeatedly pointed to the strong impact of the surge in commodity prices on economic activity and inflation. The title of an analysis by the IMF: "Is inflation back? Commodity prices and inflation" (*IMF,* 2008, pp. 83-128) well illustrates the concern about (continuing) inflation risks arising from large increases in commodity prices in international organizations[2]. The tendency to incorporate world-wide developments such as the development of crude oil prices into economic forecasts has a long tradition in Europe, where even the larger economies are seen as only a small part of the world economy; in the United States, however, the idea seems to linger that U.S. economic events tend to influence economic developments in other economies but not vice versa.

Instead of focusing on external factors such as raw material prices and exchange rates, some U.S. studies of inflationary phenomena persist in relying on domestic cyclical factors such as unemployment, the gap between potential and actual output, and labour costs. These studies are unable to explain why the sharp rise in unemployment in recent years has not pushed the rate of inflation towards zero or even into negative territory. This is the puzzle of the "missed deflation". *Gordon* (2013, p. 9) has called the lack of attention to external factors a case of collective amnesia. *Rusnak et al.* (2013) show that this puzzle is created by model misspecifications, foremost by the omission of commodity prices. Some years earlier *Kohn* (2007, p. 182) characterized inflation models that exclude energy prices as of little use for the FOMC, and *Bernanke* (2008) acknowledged the limitations of national monetary policy: "Rapidly rising prices for globally traded commodities have been the major source of the relatively high rates of inflation we have experienced in recent years, . . ."[3].

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[1] *Barrel – Pomeranz* (2008), *Pain et al.* (2008), *Cecchetti et al.* (2008), *Vogel et al.* (2009), *European Central Bank* (2010A, 2010B, 2011), *Moccero et al.* (2011), *IMF* (2008, 2013).

[2] See the *OECD*, Economic Outlook (2008, 2009, 2011, 2012,).

[3] The increasing scepticism of members of the Federal Open Market Committee with regard to the PC and the frustration over the lack of an alternative model is documented by *Meade – Thornton* (2012). See also *Ajmera et al.* (2012).

The standard model of the "nonaccelerating inflation" rate of unemployment (NAIRU)[4] can be written as

(1) $\Pi_\tau = \alpha + \beta(L)\Pi_{\tau-1} + \gamma(L)(u - u*) + \delta(L)z + \varepsilon$

where Π_τ is the rate of inflation and z are supply terms and L is a polynomial in the lag operator.

The first term in equation *(1)* may be called the inertia term. In a Phillips curve with backward looking expectations the inertia term not only represents inflation expectations but also, as forcefully pointed out by *R. Gordon* (see, e.g., 2011, p. 23), structural characteristic of the economy, staggered wage and price setting rules, and, as will be argued in this paper, the protracted effects of changes in the price of raw materials. In the triangle model of the Phillips curve developed by *Gordon* (1997, 2011), which is followed closely in this paper, the demand side is represented by the unemployment gap, u-u*; the supply side is represented by shock variables to be discussed later.

A key restriction used in many papers on the expectations augmented Phillips curve is that the β coefficients sum to 1. There is a value of the unemployment rate, u* (the natural unemployment rate or the NAIRU), below which the price level forever accelerates and above which the price level forever decelerates.

This paper explores the question to what extent external factors can provide an explanation of the U.S. inflation rate over the last three decades. In particular, to what extent are lagged dependent variables – traditionally interpreted as proxies for inflation expectations – simply proxies for oil/commodity prices. For this purpose a parsimonious Phillips curve, which includes energy prices as supply shocks, is estimated for the United States.

The results show that energy/commodity prices have exerted a strong influence on inflation, while the effects of domestic factors such as the unemployment rate have weakened: given the hike of energy/commodity prices in the years since 2005, there

[4] *Fair* (2008), *Gordon* (2013).

is no contradiction between a persistently positive rate of inflation and the high unemployment rate; this constellation is rather a mild manifestation of stagflation as experienced in the seventies.

The empirical results also suggest that during the years of the oil price shocks from the early seventies to the early or mid-eighties a price-wage spiral developed, along the lines of the proponents of the accelerationist view of inflation. But, as a result of various structural changes in the economy and of a tight monetary policy ("Volcker disinflation"), inflationary expectations ceased to play an important role in subsequent years: the persistence of inflation found in several studies is largely due to the delayed effects of energy prices and not to the fact that inflation expectations are guided by past inflation. This result runs counter to the hypothesis that the Phillips curve is vertical, thus undermining the basis of the NAIRU analysis.

This paper is organised as follows. The second section reviews the literature of the impact of oil price shocks on inflation and economic activity: the effects of changes in oil prices on consumer price inflation are drawn out over time. A review of the development of crude oil prices in section 3 draws attention to the difference in the time path during the first and the second oil price shock on the one hand, and the subsequent years on the other, differences which can be expected to have repercussions on the impact of oil/commodity prices on inflation and on how inflation expectations were formed. A brief discussion of slowly evolving structural factors, drawn from the PC literature, complements this section. The variables used in the empirical part are specified in section 4. The dependent variable is the headline inflation according to the Consumer Price Index. Commodity and oil prices are represented by crude oil prices as well as an index of commodity prices.

Section 5 contains the regression results of Phillips curves for headline and core inflation. These regressions, which explore various specifications involving prices of crude oil, are run for the period from 1973 to 2014; the whole period is broken up into two sub-periods: a period (1973-1981) covering both oil shocks and a period (1982-2014) covering more recent years. Conclusions are contained in the final section.

II. The impact of oil price shocks on inflation and economic activity

Interest in this topic has been revived in recent years in academia as well as in international economic organisations (*Alquist et al.,* 2013, *Blanchard – Gali,* 2007, *Cecchetti – Moessner,* 2008, *Hamilton,* 2009, 2012, *Kilian,* 2008, 2009, *Lizardo – Mollick,* 2010, *Blinder – Rudd,* 2013, and the literature cited in note 1), and has produced a number of studies dealing with the impact of commodity price surges on economic activity and inflation. Economic historians will also remember the first and second oil price shocks (e.g., *Blinder – Rudd,* 2013, and the literature cited there).

The effects of commodity price changes on consumer prices can conveniently be characterised as direct and indirect (*ECB,* 2010A). The pass-through of changes in commodity prices to retail prices takes time. While the direct effects of oil price increases show up rather quickly in higher energy prices charged to consumers, indirect effects that occur as a result of the impact of oil prices on productions costs (such as in the production of chemical and pharmaceutical goods, food stuff and transport services) are transmitted with a longer delay. According to *IMF* (2008) estimates, oil price changes are transmitted with an average lag of 9 to 12 months. *Nordhaus* (2007) puts the indirect effects at 80 percent of direct effects[5]. Clearly, fossil fuel/commodity intensity as well as policy feedback rules matter a great deal in the transmission of commodity price changes to the consumer over time (*Barrel – Pomerantz,* 2008, *IMF,* 2008, *Vogel et al.,* 2009).

In sum, the direct and indirect effects of oil price shocks are drawn out over time; that is, a change in commodity prices at time t will not only affect consumer prices at time t, but also at time $t + 1$, $t + 2$, etc. As a result, if the basis of analysis is quarterly data, the change in retail prices in one quarter will be strongly correlated with the change in retail prices in subsequent quarters.

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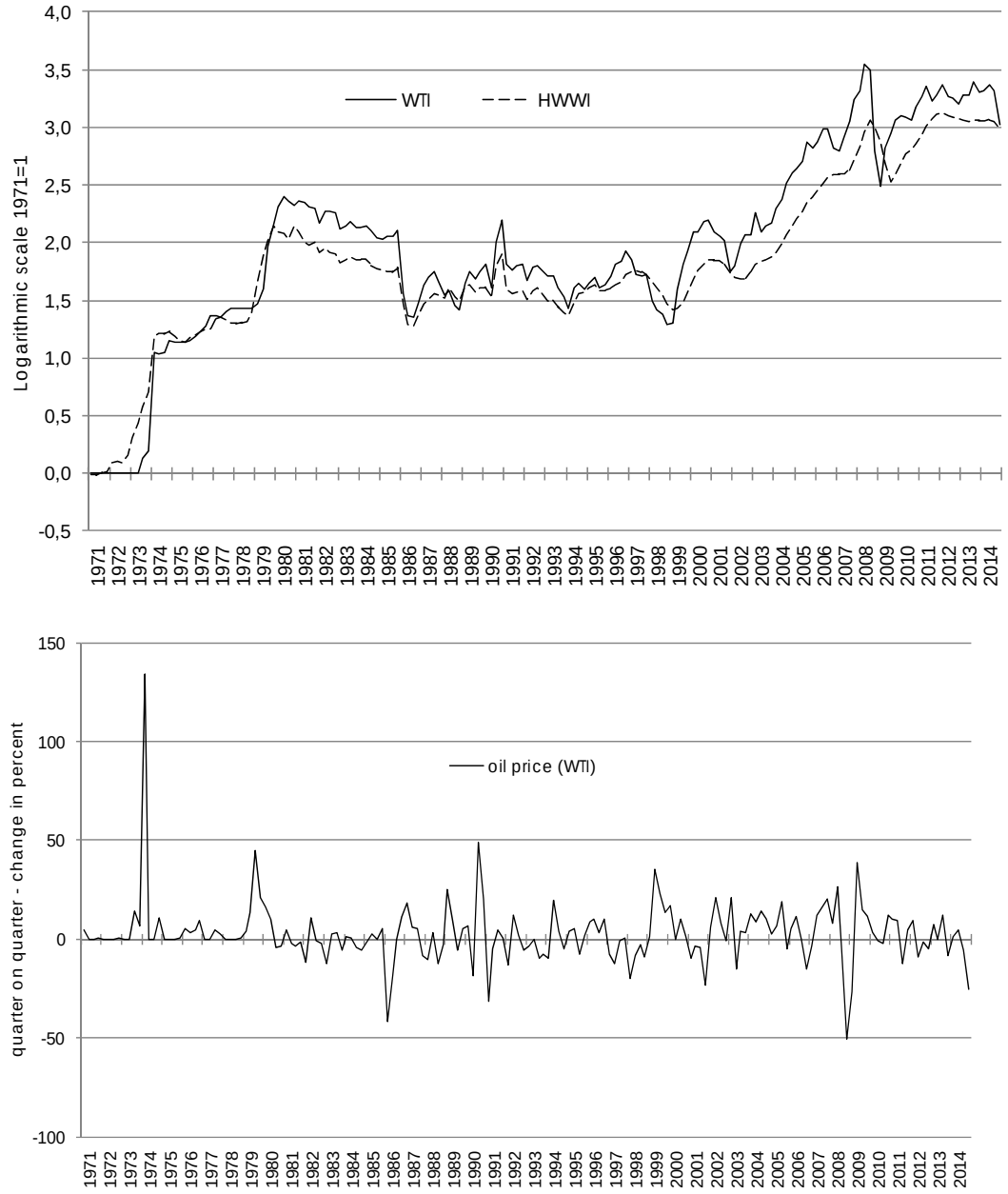
[5] And then there may be second-round effects as – in the model of competing income claims (*Layard et al.*, 1991) – economic agents attempt to compensate for the loss of real income caused by past inflation, or, in more general terms, as economic agents adapt to inflation expectations and act accordingly.

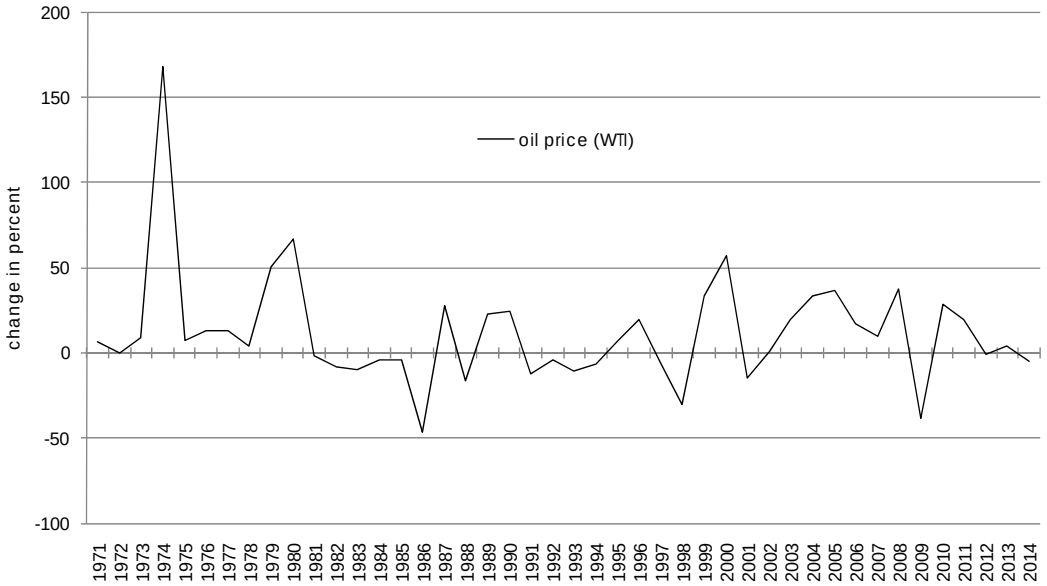
Figure 1: 1. panel: WTI and HWWI-(total) in levels, quarterly data
2. panel: quarter-on-quarter-relative change



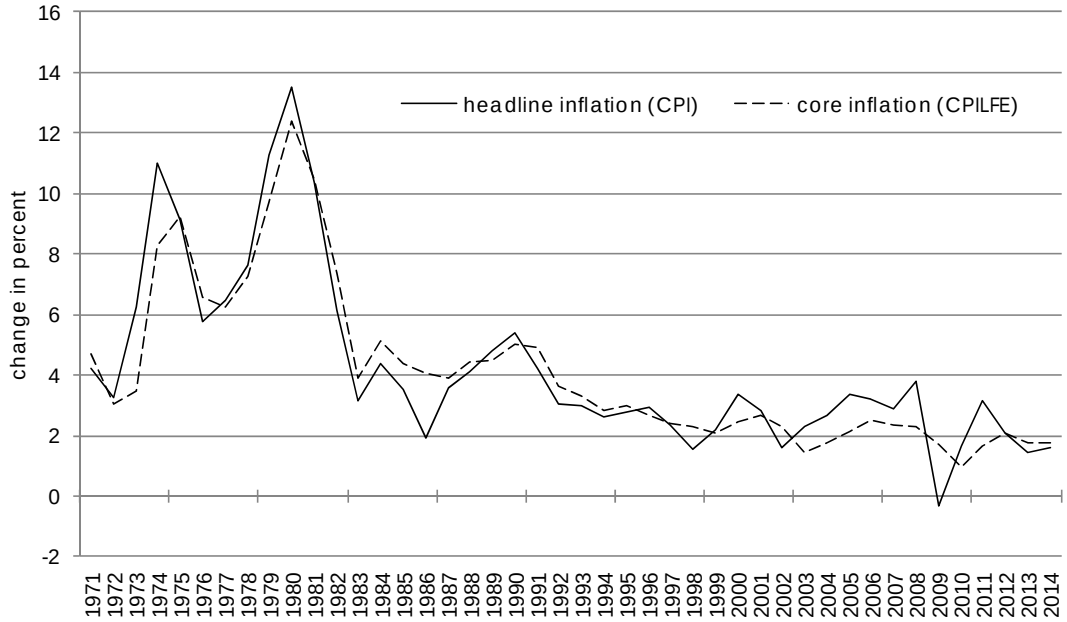
Source: Federal Reserve Bank of St. Louis and U.S. Department of Energy: Energy Information Administration; HWWI.

Figure 2: Yearly inflation rates: WTI, CPI, CPILFE

Panel 1



Panel 2



Source: Federal Reserve Bank of St. Louis and U.S. Department of Energy: Energy Information Administration.

III. Structural changes in the U.S. and world economies

A look at the development of oil and raw materials prices

Before entering into a discussion of the results of the regression analysis it is instructive to inspect the graphs of the development of the oil/commodity price as well as of the inflation rates.

Oil exports (crude oil plus refined products) have been a leading commodity in world trade, comprising 13 percent of total commodity trade by value in 2006, with nearly all nations significantly affected by developments in oil markets, either as producers or consumer, or both (*Smith,* 2009, p. 146).

In nominal terms, oil prices (as measured by West Texas Intermediate) increased sharply in the years 1973-74 and from that level continued to increase at a more modest pace. The second oil price shock produced another steep increase in the price of oil during the years 1979-80; this price hike was followed by a slow retrenchment of oil prices. In 1986 oil prices collapsed and reached a level just below that attained before the second oil price hike (see Figure 1, panel 1).

Except for the short-lived spike of 1991 (first Iraq war), oil prices fluctuated around the price established in 1986 into the first years of the new millennium; then prices increased steeply, peaking at the beginning of 2008; a sharp reversal followed at the end of 2008.

Two features distinguish the first and the second oil price shock from later developments: the strength of the price increase, and the persistence of the new price level. During the first shock, the higher price level was maintained for about 6 years; during the second shock for about 5 years. By contrast, the following period, starting in the early eighties, exhibited great fluctuations, and peak or bottom levels were never maintained for long. Even the most recent oil price hike, reaching its peak in 2008:2, was a short-term event, with the price dropping to a level less than half in 2008:4. A similar picture is provided by the development of an aggregate index of prices of raw materials (HWWI, see Figure 1).

During the period covering the first and second oil price shock, the movements of headline and core inflation were almost parallel, with core inflation lagging behind headline inflation. It is remarkable that during the second oil price shock core

inflation was almost as high as headline inflation (and considerably higher than during the first oil price shock), even though, as measured by the yearly inflation rates of the price of crude oil, the second oil price shock was considerably milder than the first oil price shock. This is *prima facie* evidence that a strong price-wage-price spiral got underway in the second half of the seventies and that inflation expectations along the lines suggested by adherents of the NAIRU hypothesis were formed and were a major force in generating inflation[6]. This appears not to be true, however, for later years. Thus, the value of the coefficients of the lagged inflation terms estimated over the period of the oil price shocks should be considerably higher than those estimated over years that were characterised by short-term fluctuations.

The interpretation that there was a substantial shift in the inflation process is supported by a number of studies. *Blanchard – Gali* (2007) find that for several industrialized countries an oil price shock in the 1970's had a stronger effect on inflation (and a stronger negative effect on output) than in later decades and identify 1984 as the breakpoint. Similar results are reported by *Davis* (2012) who credits the break in the response of core inflation to commodity price shocks to a Federal Reserve policy (Volcker disinflation) which succeeded in anchoring inflation expectations: after the mid-eighties inflation expectations were relatively unresponsive to commodity price fluctuations. A break in the response of inflation to commodity prices after the Volcker disinflation was also found by *Gubler – Hertweck* (2013)[7].

If indeed the Volcker disinflation managed to break inflation expectations in the early eighties by engineering a severe recession in 1981-1982, then the period of the two oil price shocks should be regarded as a singular time period[8]. The whole period,

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[6] See *Orphanides* (2005), who documents that inflation expectations (NBER/ASA) exceeded realized inflation rates for several years after 1980.

[7] See also *Blanchard – Riggi* (2011) who divide their sample into pre- and post-1984 periods.

[8] *Taylor* (2000) suggests that one reason for this disparity between the two periods is the extent to which firms respond to increases in costs by raising their own prices depending on how persistent the increase is expected to be, and persistence is higher in high-inflation environments. For support of this claim in an international setting see *Gelos – Ustyogova* (2012).

which covers the years beginning just before the first oil price hike and ending in 2014 is therefore broken up into two sub-periods: the years of the oil price shocks (1973:1-1981:4) and the years 1982:1-2014:4, covering the period of "Great Moderation" (ending around 2005) and the years thereafter. Results for the whole period are presented only to ease comparison with results from other studies which range over long time periods.

Slowly evolving structural factors in the U.S. economy

While the Volcker disinflation (and similar developments in other OECD countries) can be considered a singular event that suggest that the period from the early seventies to the present be broken up into two sub-periods there were several structural factors at work which changed fairly gradually throughout the whole period and which are likely to have dampened inflationary pressures over the last three or four decades.

An abundance of factors has been proposed in the PC literature which can be interpreted as giving rise to a negative trend in the inflation rate. *Gordon* (1997, pp. 29-30) points to the contrast between labour militancy, relatively strong unions, and a relatively high minimum wage in the late 1960s, and labour peace, relatively weak labour unions, and a relatively low minimum wage in the 1990s[9]. Other factors that may have decreased inflationary pressures include the increase in global competition and immigration of unskilled labour (*Gordon,* 1997, p. 39). Increasing intensity of foreign competition is also cited by the OECD (*Pain et al.,* 2008, p. 16) as an important factor in changing the response of inflation to cyclical domestic factors, making the economy more sensitive to measures of foreign economic slack.

Perhaps the most tractable change over the years has been the sharp decline in *energy intensity* in the advanced economies since the 1970s, reducing the indirect first round effects of commodity price shocks (*IMF,* 2008, *Blanchard – Galí,* 2007, *Blinder – Rudd,* 2013, *Katayama,* 2013). Of course, there may be other factors at play

[9] For a wide-ranging discussion of the link between institutional variables and the NAIRU in OECD countries, see *Gianella et al.* (2009).

which *interact* with the pass-through of energy prices into consumer prices. As Barrel *and Pomerantz* (2008), *Blanchard – Galí* (2007), *Hamilton* (2012) and others have noted, *second round effects* of oil price shocks are much smaller than they were thirty years ago. This may be due to a more flexible labour market and a credible monetary policy, which is the focus of the "trend literature" (*Ascari – Sbordone,* 2014, *Cogley – Sbordone,* 2008, *Coibion – Gorodnichenko,* 2011, 2015).

To capture all of these slowly changing factors a (linear) time trend is introduced into the analysis, a variable that turns out to be very important.

IV. Specification of variables

Price variables

This paper uses the regular series of consumer price indices in two variations: the headline index (Consumer Price Index, CPI) and the index excluding food and energy, the so-called core index (CPILFE). Other studies employ the PCE or adjusted consumer price indices. But the use of price indices that are only available with a great delay seems to be misguided: given the great importance that inflation expectations play in the extended Phillips curve, it would seem reasonable to use those price indices that are available to the public at the time that expectations are formed, i.e., statistics that consumers, employers and employers' associations, wage earners and trade unions consider in their decisions, and not some constructs put together by statisticians and economists *ex post*, such as the GDP deflator or the PCE[10].

The lagged dependent variable

In the Phillips curve literature, it is standard practice to proxy inflation expectations with lagged values of inflation; Rather than estimating many unconstrained coefficients, this paper follows Gordon's lead (*Gordon,* 1997, p. 20) and enters the lagged dependent variable as a series of four-quarter moving averages of rates of

[10] Even farther removed from headline or core inflation is a statistic used by *Ball – Mazumder* (2011, 2014) to measure core inflation: a weighted median of consumer price inflation across industries.

change[11]. This procedure will also be used in the construction of the lagged values of the oil price variable.

Commodity and oil prices

The basic time series used in this paper to represent world-wide phenomena are the prices of oil as measured by the spot oil price (West Texas Intermediate), as well as of raw materials according to the widely used HWWI index.

Other studies have used import prices for this purpose. There are strong reasons for preferring raw material prices over import prices. Consider a country that is autarchic in certain energy products, i.e., does not import crude oil or oil products at all; movements in crude oil prices will not enter the import price index (save in an indirect way through imported energy-intensive products). Thus, wide swings in oil prices will only be marginally reflected in this explanatory variable. Nonetheless, in an economy which is open to international trade (and does not regulate prices of energy products in the fashion of, say, China or Egypt), domestic oil prices will rise and fall *pari passu* with prices in international markets (and will also likely affect the prices of other – domestically – produced energy products)[12]. The 'law of one price' applies: except for transportations costs, traded commodities must sell for the same price within the United States as outside[13].

In a country that is not wholly autarchic in crude oil and oil products, import prices will partially reflect the fluctuations in crude oil prices, but, as the composition of

[11] A similar procedure is employed by *Akerlof et al.* (2000).

[12] There is also a demand effect that, in addition to the cost effect of rising oil prices, will tend to raise domestic prices. Domestic producers of energy will reap windfall gains from the price hike and will be inclined to expand investment in energy production, adding to aggregate demand. This effect is likely to be more pronounced in energy-autarkic economies than in those relying strongly on energy imports. The reverse effects will hold when energy prices decline.

[13] The law of one price may not fully apply to other items that are traded internationally, such as food stuff.

imports change, import prices may indicate a rising or falling impact of world market prices on domestic inflation[14].

Unemployment

See the appendix for the construction of the cyclical unemployment variable.

V. Empirical results

The period 1973:1 to 2014:4: preliminary results

The results for the whole period are only presented to ease comparison with PC studies that cover long time periods; they do, however, indicate some of the changes in the results that can be expected when commodity prices and other variables are introduced into the PC analysis. First note that the sums of the coefficients of the lagged dependent variable are reasonably close to unity in equation 1 and 2, but fall below 0.8 when the variable 'change in commodity prices' is added (equation 3). A further drop is exhibited by equations 4 and 5 when a time trend (more on this later) is added to the explanatory variables. Many of the PC studies constrain the sum of the coefficients of the dependent variable to be unity: this specification (equation 6) depresses the value of the coefficients of the commodity variable to less than one half of the values in the unconstrained specification. The best fit is obtained when the change in foreign exchange rates and the change in the productivity trend are added[15].

[14] At the other extreme of the spectrum is a country that only imports crude oil. In this case, fluctuations in crude oil prices will be adequately represented by fluctuations in import prices.

[15] When a variable representing the Nixon wage controls (*Gordon,* 1982) is added, the estimated coefficient is zero (equation not reported in Table 1).

Table 1: Headline inflation, quarterly data, 1973:1 to 2014:4

Variable	Lags	1	2	3	4	5	6	7*	8*
Lagged dependent variable	1-4	0,820	0,727	0,406	0,194	0,048	1	0,111	
		14,0	*7,4*	*3,9*	*1,9*	*0,4*		*1,0*	
	5-8		1,118	0,361	0,259	0,246		0,248	0,190
			1,2	*3,6*	*2,8*	*2,7*		*2,8*	*2,4*
Cyclical unemployment	0	– 0,190	– 0,223	– 0,215	– 0,205	– 0,207	– 0,123	– 0,208	– 0,198
		– 3,8	*– 3,9*	*– 4,1*	*– 4,3*	*– 4,4*	*– 2,4*	*– 4,5*	*– 4,6*
Change in commodity prices	0-3			0,036	0,039	0,046	0,018	0,044	0,048
				6,2	*7,4*	*8,1*	*3,5*	*7,8*	*11,1*
	4-7					0,016		0,015	0,020
						2,9		*2,8*	*4,3*
Timetrend	0				– 0,572	– 0,707		– 0,645	– 0,731
					– 5,4	*– 6,2*		*– 5,5*	*– 7,6*
Change in foreign exchange rate	0							– 0,031	– 0,029
								– 2,8	*– 2,7*
Productivity trend change	0								– 0,908
									– 3,5
Σ		0,820	0,845	0,787	0,453	0,294	1	0,359	0,190
$\bar{R}^2$		0,577	0,578	0,657	0,707	0,720	0,581	0,731	0,749
D-W		1,5	1,4	1,4	1,5	1,4	1,5	1,5	1,6

Source: Values of constants not listed. Numbers in italics below coefficients are *t*-statistics. The coefficients of the time trend are given as the coefficients multiplied by 10,000. The coefficients of cyclical unemployment are given as the coefficients multiplied by 100. Σ is the sum of the coefficients of the lagged dependent variables. – *) 1973:2 to 2014:4.

Table 2: Headline inflation, quarterly data, 1973:1 to 1981:4

Variable	Lags	1	2	3	5	6*	7*
Lagged dependent variable	1-4	0,745	0,643	0,513	1	0,368	0,247
		6,2	*6,8*	*4,8*		*2,2*	*1,1*
	5-8	– 0,189					
		– 1,5					
Cyclical unemployment	0	– 0,375	– 0,443	– 0,382	– 0,452	– 0,440	– 0,440
		– 4,6	*– 6,3*	*– 5,6*	*– 5,4*	*– 4,7*	*– 4,7*
Change in commodity prices	0-3			0,023	0,005	0,028	0,036
				2,7	*0,5*	*2,7*	*2,5*
	4-7					0,012	0,019
						0,8	*1,1*
Change in foreign exchange rate	0					0,029	0,028
						1,2	*1,1*
Productivity trend change	0						– 0,950
							– 0,8
Σ		0,556	0,643	0,513	1	0,368	0,247
$\bar{R}^2$		0,685	0,672	0,723	0,555	0,723	0,719
D-W		2,0	1,8	2,1	1,4	2,0	2,0

Source: Values of constants not listed. Numbers in italics below coefficients are *t*-statistics. The coefficients of the time trend are given as the coefficients multiplied by 10,000. The coefficients of cyclical unemployment are given as the coefficients multiplied by 100. Σ is the sum of the coefficients of the lagged dependent variables. – *) 1973:2 to 1981:4.

Table 3: Headline inflation, quarterly data, 1982:1 to 2014:4

Variable	Lags	1	2	3	4	5	6	7	8
Lagged dependent variable	1-4	0,287	0,076	– 0,134	– 0,395	– 0,548	1	– 0,277	
		2,4	*0,5*	*– 1,0*	*– 2,9*	*– 4,1*		*– 2,1*	
	5-8		0,268	0,478	0,336	0,288			0,089
			2,3	*4,4*	*3,3*	*2,9*			*0,9*
Cyclical unemployment	0	– 0,084	– 0,153	– 0,138	– 0,147	– 0,110	0,012	– 0,049	– 0,056
		– 1,5	*– 2,5*	*– 2,5*	*– 2,9*	*– 2,3*	*0,2*	*– 1,1*	*– 1,2*
Change in commodity prices	0-3			0,034	0,039	0,049	0,023	0,044	0,042
				6,1	*7,5*	*8,9*	*3,6*	*7,9*	*8,1*
	4-7					0,022		0,023	0,019
						4,1		*4,2*	*3,6*
Timetrend	0				– 0,587	– 0,831		– 0,865	– 0,625
					– 5,0	*– 6,6*		*– 6,8*	*– 5,4*
Change in foreign exchange rate	0							– 0,024	– 0,035
								– 2,3	*– 3,5*
Productivity trend change	0								– 0,564
									– 2,3
Σ		0,287	0,344	0,344	– 0,059	– 0,260	1	– 0,277	0,089
$\bar{R}^2$		0,053	0,084	0,284	0,398	0,465	– 0,099	0,451	0,463
D-W		1,6	1,5	1,6	1,8	1,7	1,6	1,8	2,0

Source: Values of constants not listed. Numbers in italics below coefficients are *t*-statistics. The coefficients of the time trend are given as the coefficients multiplied by 10,000. The coefficients of cyclical unemployment are given as the coefficients multiplied by 100. Σ is the sum of the coefficients of the lagged dependent variables.

Results for the two sub-periods

The high rates of change in the price indices during the first and second oil price shock seem to dominate the results for the whole period; if the whole period is broken up into two sub-periods to take account of the institutional changes that characterized the U.S. economy, the results are very different from those obtained for the whole period.

The period 1973:1-1981:4

The sum of the coefficients of the lagged dependent variables for the period 1973-1981 is lower than for the whole period but remains above 0.5.

This seemingly curious result, namely that the sum of the coefficients of the lagged dependent variable is lower for the period 1973-1981 than for the period 1973-2014, may be *MAINLY* due to two factors: first, as the regression equations are run over longer and longer time periods inclusion, of the variable 'change in commodity prices' without taking account of the decline in energy intensity (and the change in other variables) introduces an ever more serious misspecification into the analysis; second, as in other developed countries (*Pain et al.,* 2008, *Milani,* 2009), the PC in the U.S. has become flatter (compare equation 3 in Table 2 with equation 5 in Table 3), and the imposition of an unchanging unemployment coefficient introduces another misspecification into the analysis. Given these misspecifications, the lagged dependent variables capture the delayed effects of changes in oil prices and of the waning influence of the unemployment rate (as well as the effect of other factors mentioned above, captured by the time trend); as a result, more of the relatively smooth development of the determinants of inflation after the two oil price shocks is reflected in past inflation, raising the sum of the coefficients of past inflation.

Changes in foreign exchange rates and the change in the productivity trend are added in equations 6 and 7[16].

[16] The coefficients of these two variables are only imprecisely estimated, but are close to the corresponding values for the period 1982 to 2014. Adding the Nixon wage control variable ("off" variable) yields a zero coefficient in equations 6 and 7.

All in all, even though the sum of the coefficients of the lagged dependent variable is not equal to one, the evidence provided earlier (the parallel movement of headline and core inflation in the aftermath of the two oil price shocks) and that provided in the studies cited above (suggesting a break in the PC in the early to mid-eighties) lend some support to the presumption of a vertical PC in the first sub-period.

The period 1982:1-2012:4

The explanatory power of the traditional PC (lagged dependent variables, cyclical unemployment) for the sub-period 1982-2014 is considerably below that for the period 1973-2014, close to zero. Adding the commodity price variables to the regression leaves the sum of the coefficients of the lagged dependent variables unchanged but improves the fit of the equations considerably. An even stronger improvement is achieved when a time trend is added to account for slowly evolving factors.

Note the important role played by the time trend. To a great extent, the time trend variable seems to capture the decline in energy intensity: omitting the trend variable (table 1982-2014, compare equation 3 with equation 5) reduces the coefficients of the energy variable and increases the value of the coefficients of the lagged dependent variable[17].

The best fit is obtained when in addition to the commodity price variable another non-domestic variable, namely, the trade weighted foreign exchange rate of the U.S. Dollar, is entered into the regression (equations 7 and 8).

[17] *Gordon* (2013) uses a dummy variable to allow the food-energy effect on inflation to be lower in the period 1987:1 to 2013:1 than in the period 1962:1 to 1986:4. While this approach allows some differentiation between two sub-periods, it is important to keep in mind that energy intensity is not a discrete but a continuous variable; moreover, changes in the labour market and the gradual increase in global competition also cannot be represented by a dummy variable and are better represented by a time trend, crude as it is. The same objections can be raised against the procedure used by *Tootell* (2011) who breaks up the period 1970-2010 into two sub-periods, 1970-1985 and 1986-2010, and concludes that in the latter period oil prices are not economically significant for core inflation (CPI).

These results (as well as the results for the whole period) indicate a trade-off between the value of the *coefficients* of the oil price variable and the *coefficients* of lagged dependent variable, suggesting, along the lines of the Koyck transformation (*Theil,* 1971, pp. 259-263), that the lagged dependent variable captures to a great extent the delayed effects of changes in the oil price.

Whether the inertia term is interpreted as backward looking expectations or as structural characteristics of the economy, the PC for the period 1982-2014 makes it clear that the coefficient of this term is far below unity. Thus, taken at face value, in the traditional interpretation of this term there exists a trade-off between inflation and output[18].

Many PC studies (including *Batini – Greenslade,* 2006, *Fuhrer – Olivei,* 2010, *Fuhrer et al.,* 2012, *Ball – Mazumder,* 2011, *Kamenik et al.,* 2013, *Gordon,* 2011, 2013, *Tootell,* 2011) impose the unity constraint on the coefficient of the lagged dependent variable. In view of the results for the period 1982-2012 presented in this paper, this is a serious specification error. It has the effect of substantially biasing the coefficient of the commodity price variables towards zero (see Table 3, equation 6, as well as Table 1, equation 6)[19]. As noted, this practice may be appropriate for the period covering the two energy shocks when there are indications that inflation expectations played a powerful role in driving inflation; it can be justified as an estimation device to capture the role of expectations. But imposing the unity requirement is clearly not warranted on empirical grounds for the years after the second oil shock. It is also not warranted on theoretical grounds: As *Gordon* (2011, p. 10) has emphasized the inflation rate is dominated by persistence and inertia in the form of long lags on past inflation. ". . . the role of past inflation is not limited to

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[18] A similar result is obtained by *Fitzenberger et al.* (2009, p. 494) for Germany: regardless of the measure of expected inflation employed, the sum of coefficients for expected inflation is far below unity. See also *Karanassou et al.* (2003, p. 118) who conclude that the NAIRU should be removed from the tool kit of monetary policy makers: "Our results suggest that the trade-off is far from vertical." A less drastic conclusion was reached by *Fuhrer – Olivei* (2010, p. 27) who find that the effect of lagged inflation has been large at times, but seems to have declined in recent years.

[19] This procedure also reduces the coefficient of the unemployment rate to close to zero for the period 1982-2014. In this specification the trend variable is not significant (equation not reported).

the formation of expectations, but also includes a pure persistence effect due to fixed-duration wage and price contracts, and lags between changes in crude materials and final product prices." Therefore, in view of the many structural *changes* undergone by the U.S. economy over the past forty or fifty years (discussed in section 3) the imposition of the unity requirement introduces a serious misspecification error into the PC analysis[20].

The effect of the cyclical unemployment variable on inflation is much weaker for the years 1982-2012 than for the earlier period, a finding that is in line with results reported by several studies (*OECD,* 2008, *IMF,* 2008), according to which the short- to medium-term response of inflation to domestic cyclical output variations declined over the past decades[21].

VI. Conclusions

The popular as well as the financial press has linked movements in the inflation rate (as measured by the Consumer Price Index) in recent years to movements in crude oil prices. This interpretation is supported by a large body of economic literature which has studied the impact of oil price shocks on inflation and economic activity. Nonetheless, a number of U.S. studies of inflation have persisted in focusing on domestic cyclical factors to the neglect of world-wide developments and, within this framework, have found evidence of strong inflation persistence. These findings assign an important role to monetary policy in anchoring inflation expectations. If, however, the PC framework is extended to include external factors, oil prices in particular, the hypothesis of a high degree of inflation persistence can no longer be maintained: in the accelerationist version of the Phillips curve, the lagged dependent variables

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[20] As *George Perry* (2011, p. 402) put it in a comment on *Ball – Mazumder* (2011): ". . . the model's unitary elasticity between past and present inflation is not supported by the data except in the high-inflation period around the 1970s. At that time wage setting was dominated by union contracts indexed to inflation, the economy was buffeted by large inflationary shocks from several sources and inflationary expectations were measurably rising."

[21] Similar findings are reported by *Stock – Watson* (2009, p. 102) who point out that the performance of PC forecasts is episodic: the link from activity gaps to inflation is not always present.

(proxies for inflation expectations) pick up to a great extent the delayed effects of oil prices.

A look at the course of oil/commodity prices (Figure 1) reveals great diversity over the last four decades: first came sharp rises to higher levels during the first and second oil price shocks, followed by the collapse of the oil price in 1986 and subsequent short-term fluctuations during a period called the Great Moderation. This pattern suggests *prima facie* that oil/commodity prices played an important part, first in boosting inflation to the highest rates in post-war history and setting in motion an accelerationist inflationary process in the first period (1973-1981), then in providing a rather stable environment on the cost side of inflation in the second period (1982-2014), except for the years 2008-2009. Thus, the post-1970 years should be viewed as two periods that have little in common.

During the first period economic actors, labour unions in particular, had the opportunity, the motive and the power to defend themselves against inflation-induced real income losses. During the second period, however, with inflation slowing down to 2 percent in 1986, the labour unions neither had the need, nor, given their weakened position, the power to insist on cost of living increases. Concerns about accelerating inflation, warranted in the aftermath of the two oil price shocks, may no longer be appropriate, given the massive changes in the U.S. and world economies.

If oil prices are introduced into the Phillips-curve (headline inflation) their influence is found to be strong and to extend over several quarters. This influence comes at the expense of lagged dependent variables, which have been interpreted as proxies for inflation expectations. While the sum of the coefficients of the expectations variables is not far from unity for the period 1973-1982, it is close to zero for the period 1982-2014.

Closely related to the effect of oil prices on inflation is the effect of a negative time trend. This trend variable largely embodies the trend towards a less energy efficient economy and thus reflects a structural feature of the economy. Though monetary policy may be one of many factors contributing to a downward trend in inflation, it is not the only factor as claimed by the "trend" literature (*Ascari – Sbordone,* 2014, *Coibion – Gorodnichenko,* 2011, 2015). Other factors cited for reducing inflation

include weaker labour unions, a relatively low minimum wage, the increase in global competition and immigration of unskilled labour.

The results of the empirical analysis assign a great role to factors that are external to the U.S. economy and a small role to domestic factors such as unemployment or other indicators of domestic economic activity. They also assign a much feebler role to expectations in the inflation process during the last few decades. And as a consequence, the task of controlling inflation expectations – or of anchoring inflation expectations in the parlance of central banks – by monetary policy may be not as important as in the wake of the two oil price shocks.

The strong impact of world-economic factors on U.S. inflation and on economic activity raises the question to what extent U.S. monetary policy is still able to control inflation. Are the actions of the central bank nothing more than a sideshow? (pace, *Friedman,* 2009, p. 282)[22].

The institutional framework in the United States (and in other OECD countries as well) governing the creation and propagation of inflation has changed greatly over four or five decades. The economic environment in the United States in the years of the oil price shocks was considerably different from later years. Several slowly changing factors have also profoundly transformed the U.S. economy. Thus, inflation studies covering long time periods, e.g., from the fifties or sixties to the present, may be of little value for policy decisions[23].

This calls to mind an observation made by *Solow* (1986), cited at the beginning of this paper "More often than not we fail to take institutional differences seriously. One model is supposed to apply everywhere and always." For example, an inflation model that applies to, say, Argentina, might not apply to the United States, and vice versa. But as Solow suggests, caution is not only appropriate in the geographical but

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[22] There seems to be consensus that the restrictive monetary policy initiated under Volcker in 1979 engineered a recession and finally brought inflation under control. One might even attribute the collapse of crude oil prices in 1986 to the restrictive stance of U.S. monetary policy. But this was more than 30 years ago, at a time when the U.S. economy played a much larger role in the world economy than now.

[23] Recall *Kohn's* (2007) severe criticism of inflation studies centering only on domestic factors.

also in the time dimension ('everywhere and always'). Arguments based on evidence in an environment with one set of institutions applied to a different environment are subject to the Lucas critique.

Inflation has become a global phenomenon, with commodity prices as one of the main channels. It matters little where demand pressures for raw materials come from, from emerging or developed countries, or where constraints on the supply of these materials are exercised; hence the importance of forecasting the price of oil (*Bernanke,* 2008, *Alquist et al.,* 2013).

The counterpart of the globalisation of inflation is the globalisation of deflation: central banks might find it harder to fight deflation and to directly stimulate the economy than in earlier periods. In globally interconnected financial markets, an increase in liquidity in one market will find its way to other markets where the demand for loans is high (e.g., Brazil, Indonesia and other emerging countries) and, unless sterilised, will stimulate world-wide demand as well as generate a surge in the price level in the receiving countries. Large scale purchases of financial assets by central banks might also reduce international long-term interest rates and lower the value of the foreign exchange rate, and thus, in a round-about way (in addition to raising import prices) stimulate the domestic economy (*Glick – Leduc,* 2011, *Neeley,* 2010, *McCauley et al.,* 2015).

Appendix

Data Sources

FRED, Federal Reserve Economic Data, Federal Reserve Bank of St. Louis, http://research.stlouis.org:

Headline inflation: CPI, Consumer Price Index for All Urban Consumers: All Items, Series ID CPIAUCNS, U.S. Department of Labor: Bureau of Labor Statistics; quarter to quarter log change.

Core inflation: CPILFE, Consumer Price Index for All Urban Consumers: All Items less Food and Energy, Series ID: CPILFENS, U.S. Department of Labor: Bureau of Labor Statistics;

Change in commodity prices: WTI, Crude Oil Prices, West Texas Intermediate, Spot prices,

Series ID: MCOILWTICO, Source: US. Energy Information Administration. 1986:1-2014:4

Series ID: OILPRICE), Source: Dow Jones & Company. 1970:1-1985:4

Spliced through average of 1986:1-1986:4

FRED accessed March 9, 2015.

Productivity Trend Change: Nonfarm Business Sector: Real Output Per Hour of All Persons, Series ID: OPHNFB, HP trend 1970:1-2014:4. with parameter of 6400, quarter to quarter log change.

FRED accessed March 30, 2015.

Change in foreign exchange rates: Trade Weighted U.S. Dollar: Major Currencies, Series ID: TWEXMTH, quarter to quarter log change.

FRED accessed March 17, 2015.

Cyclical unemployment

The procedure of estimating a time-varying natural unemployment rate was pioneered by R. Gordon and applied by many economists estimating a Phillips-curve, with the goal of extracting long-term shifts in the unemployment-inflation

relation from the data. In view of the many discretionary choices to be made in estimating a time-varying unemployment rate (*Gianella,* 2009, *Wolfers,* 2011) a simpler approach has been chosen in this paper to extract the long-term trend from actual unemployment data. As Ball and *Mankiw* (2002, pp. 122-123) suggest the Hodrick-Prescott (H-P) filter (*Hodrick – Prescott,* 1997) trend is close to the path of the time-varying natural unemployment rate. A similar result is reported by *Claar* (2006). *Blinder – Rudd* (2013) used a similar procedure.

The H-P filter was computed over the period 1970-2014, with a smoothing parameter of 1600 for quarterly data. This trend is then used as the NAIRU or u*. Deviations from u* are then entered into the Phillips curve in the form of the variable UNCYC:

UNCYC = UNRATE – u*

HWWI Consult GmbH, 2010:

HWWI: HWWI (total, all commodities). The HWWI (total, all commodities) employs the following weighting of commodity groups: food 5.5 percent, industrial raw materials 15.4 percent, energy raw materials 79.2°percent (of which coal makes up 4.5 percent, and crude oil 74.6 percent).

Nixon controls: the "off" variable is equal to 0.4 in 1974:2 and 1975:1, and 1.6 in 1974:3 and 1974:4. *Gordon* (1982, Table 2, note f). Only "Off" variable applies. ("On" variable applies to five quarters 1971:3-1972:3, not in period covered.)

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