Oil and the Macroeconomy:

Lessons for Monetary Policy

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by Ethan S. Harris, Bruce C. Kasman, Matthew D. Shapiro, and Kenneth D. West

EXECUTIVE SUMMARY

Much ink has been spilled on the big oil shocks of the past. This paper analyzes the latest run-up in oil prices and the monetary policy response to that rise. Our focus is on US policy. But to properly frame the discussion, we also describe global developments in oil markets and the economy.

In the 1970s, oil price movements occurred in the context of increasing inflation punctuated by supply shocks: sudden drops in actual or expected supply due to a geopolitical event. The oil price increases of the 2000s were driven, at least initially, by persistently high demand—particularly from emerging market economies—and a stubbornly weak supply response. The final doubling of oil prices in the first half of 2008 was more like past supply shocks—it clearly was not due to strong demand because the global economy was weakening and oil consumption growth was slowing.

The impact of rising oil prices on the global economy has been uneven, suggesting different challenges for different central banks. Some nations have benefited strongly from the recycling of petro-dollars (most notably Asian emerging markets) while others have benefited very little (e.g. the United States and Japan). Inflation pressures have also varied, with the strongest pressure in the United States and many emerging market economies.

How should central banks respond to oil price movements? A standard new Keynesian framework suggests central banks should target "sticky prices" (like the core CPI) and ignore flexible prices (like oil). Stepping outside this simple framework, however, there are good reasons for policymakers to pay attention to oil. In particular, they should worry about oil if high headline inflation—the overall rate of inflation as reported in official statistics and highlighted in press reports—can change inflation expectations (that is, if inflation expectations are not perfectly anchored). Indeed, based on an econometric study of measures of inflation expectations and a simulation of new Keynesian model, we find that oil prices can be important for inflation expectations.

Policy makers faced some very tough choice in the last decade and it is important to evaluate those choices with the minimum possible 20-20 hindsight. Nonetheless we have some mild criticisms of the Fed responses to oil prices. We believe the Fed was a bit too eager to dismiss the trend-like rise in oil prices as it continued into 2005 and 2006. It is understandable that even after a long price run-up the Fed was reluctant to extrapolate ever rising prices ahead. However, by that point the Fed had already "forgiven" a substantial amount of "one-time" inflation and since they were relying on oil price futures to predict future inflation they had no expectation that the extra inflation would be reversed. Moreover, the boom in oil prices coincided with booms in two other asset markets—credit and housing—and the combination of strength in all of these markets

should have been a warning sign. The Fed found comfort in the continued moderate readings from their preferred measures of inflation expectations, but waiting for measures of inflation expectations to pick up was a risky tactic, given that once these expectations rise, the problem is likely to be very hard to reverse. Perhaps the Fed should have recognized that slow, perfectly predictable rate hikes were not imposing adequate restraint.

We are more sympathetic to Fed actions in the fall of 2007 and into 2008. Clearly the Fed was gambling a bit with its anti-inflation credibility as it hesitated to tighten even as inflation expectations inched higher. However, the Fed decisions need to be considered in the context of the considerable downside risks to growth. The capital markets crisis had eased back only slightly by summer 2008 and while consensus forecasts called for only a mild "growth recession," most forecasters saw major downside tail risks. Anti-inflation credibility is a form of "capital" and it has no value if it is never used. It made sense for the Fed to use some of its hard won anti-inflation credibility when there was a high risk of a major recession in 2008; it made much less sense to risk it when the going was good in 2005 and 2006.

While oil prices have been pushed to the background by the capital markets crisis, when that crisis ends the challenges of the last decade will return.

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1. Introduction

This paper examines the role of oil in the macroeconomy with the aim of evaluating and guiding central bank responses to oil price movements. Oil prices increased steadily and substantially this decade. They rose from a low of about \$20 per barrel at the end of the 2001 recession to highs of \$140 in mid-2008. The seven-fold increase of oil prices rivals the oil shocks of the 1970s in the size of the price increase. The experience this decade, however, is strikingly different from the 1970s. First, the oil price increase this decade was gradual—unfolding over the six years from the recovery from the 2001 recession to the middle of 2008. Second, macroeconomic performance was very different than in the 1970s. Though inflation was creeping up this decade, it did not spike as it did in the 1970s. Correspondingly, this decade has not seen the sharp episodes of tight money that were forced by the inflation of the 1970s.

Of course, much has changed since oil prices peaked in July of 2008. Output has collapsed world-wide and with that collapse, oil prices have dropped sharply, to under \$40 per barrel. In the summer of 2008, prior to the financial market meltdown and the sharp onset the world-wide recession, there was substantial uncertainty about the course of oil prices. The forward price of oil was flat for many years ahead at the peak levels. There were forecasts of declining prices, but there were also forecasts of oil prices going about \$200 per barrel. Firms such as airlines were locking in forward delivery of prices at peak prices. Hence, though oil prices have now collapsed, it is important to bear in mind the situation looked very different before the financial crisis.

This paper analyzes the latest run-up in oil prices and the monetary policy response to that rise. Our focus on monetary policy distinguishes our paper from recent studies such as Kilian (2008) and Hamilton (2009a, 2009b).

Sections 2 and 3 in the paper cover various analytical and empirical aspects of oil prices and the macroeconomy. Section 2 reviews some standard approaches for studying oil prices and embedding them in a macroeconomic model. Section 3 discusses a number of microeconomic and macroeconomic aspects of the behavior of oil prices. Not all of the detail in sections 2 and 3 is used in our monetary policy discussion; one of the purposes of sections 2 and 3 is to summarize important developments in oil and the economy even if some aspects of those developments are not central to our monetary policy discussion.

Sections 4 through 6 and the Appendix present analytical and empirical analysis of the relationship between oil prices and monetary policy. U.S. policy in recent years is the center of the analysis. In section 4, we focus on core versus headline, or overall, inflation. In the section 5 of the paper, we take a close look at inflation expectations. In section 6, we discuss recent monetary policy in response to oil price movements in the context of the core/headline distinction. An Appendix analyzes a benchmark new Keynesian model modified to include an external oil sector.

In section 7, our final section, we summarize our findings and offer conclusions.

Before moving forward, we should present a series of disclaimers. We are not experts in the oil market, neither in the microeconomics of oil supply and demand nor the macroeconomics of the effects of oil on economic aggregates. The aim of this paper is to analyze the monetary policy response to oil shocks, especially during the 2000s. To do so, we need to take stands on the sources of the movements in oil and their likely macroeconomic consequences. Though we hope we bring some fresh insights, we have not attempted a definite or exhaustive survey of the causes and effects. Instead, we aim to elaborate the macroeconomic and oil market context that frame recent monetary policy actions.

2. ANALYTIC FRAMEWORK

The analytic framework we use in this paper draws on two strands of literature. First, we need a framework for discussing the determinants of oil prices. By way of background, we present the standard Hotelling (1931) model as a baseline where price net of costs grows at the rate of interest. This model, however, as we will discuss, makes it hard to rationalize short-run movements in prices in response to temporary shocks.¹ Accordingly, we augment the model (informally) to consider factors that create temporary wedges between the long-run Hotelling path for energy and the short-run flow supply and demand equilibrium price. This approach underlies the microeconomic analysis in the paper.

Second, we need to embed the oil market into a macroeconomic model in order to address the central question of the paper—how should monetary policy respond to oil prices? For our baseline model, we use the new Keynesian model that is now the workhorse for analyzing monetary policy—modified in a simple way to account for oil prices shocks. Like the Hotelling model, the baseline new Keynesian model omits important features that appear to be pivotal in understanding the policy response to oil. Again informally, we will discuss extensions to the baseline model that appear to be central for understanding policy responses to oil. This approach underlies the monetary policy analysis in the paper.

2.1 Equilibrium in the oil market: Long-run and short-run arbitrage conditions

The starting point for understanding oil prices is Hotelling's idea that in equilibrium oil owners must get a price that makes them indifferent between selling today or holding back and selling tomorrow. Specifically, the scarcity rent—the difference between price of oil and its cost of production—should rise with the rate of interest, that is,

(2.1) $P_{t+1} - MC_{t+1} = (1+r_t) (P_t - MC_t),$

¹ Many others have made arguments similar to the ones that we are about to make on the adequacy of the Hotelling model. See, for example, Hamilton (2009a), which also contains some references to additional literature on this model.

where P is real price of oil, MC is marginal cost of extraction, and r is the real required rate of return.

If the expected future scarcity rent is too high today, producers will have an incentive to hold back production to take advantage of the high return, causing current prices to rise enough to restore balance. Of course in a multi-period world, this arbitrage condition must hold into the indefinite future. Integrating the expression forward, would give an expression for the level of the real price of oil.

There are broad lessons to learn from this stylized model. Expression (2.1) says that oil prices (net of extraction costs) will have the random walk behavior of asset prices. That means that price changes should be largely unpredictable. Moreover, they should not move much in response to current conditions unless changes in current conditions imply permanent changes about market conditions.

The asset price character of oil prices also means that one should expect them to be quite volatile and to move for reasons that are hard to explain. Such volatility can arise either from rational revaluation of the prospects for the market, or be noise or bubbles that can characterize asset markets.

While the Hotelling model is the natural benchmark for the price, especially for the longrun (i.e., the forecast of the price into the future), it does not capture all the features of the market for oil. In particular, there are features of the market where current flow demand and supply have effects on the price that could lead to important divergence of the spot price from the Hotelling path. It is critical to take these features into account, for example, in understanding the collapse of prices in late 2008.

What breaks the link between the pricing condition for oil in the ground and the value of oil available for immediate delivery for industrial use? A similar arbitrage condition holds once the oil is above the ground,

(2.2)
$$P_{t+1} = (1+r_t) (P_t + S_t - CY_t),$$

where S_t is the storage cost per period and CY_t is the convenience yield from holding oil above ground (refiners, distributors and end users find it useful to have some readily available inventory).

These arbitrage conditions have some important implications. Normally the futures curve should slope upwards gradually (in industry jargon: *in contango*). In practice the futures curve can slope upwards steeply or slope downward (in industry jargon: *backwardation*) with futures prices below current prices.

A steeply upward sloping curve occurs during periods of unusually low spot prices. For example consider a sharp temporary drop in demand during a recession. The arbitrage conditions imply that sellers should hoard inventory rather than sell today, restoring the normal gradual upward slope of the futures curve. However, two things seem to limit this

arbitrage behavior. First, there is a limit on the size and flexibility of storage capacity. Second, many producers may be reluctant to withhold supply due to ongoing income needs. In fact, at the extreme the supply curve could bend backward for national oil companies. If oil funds much of the national budget, then there is a strong incentive to increase production to make up for lower prices.

Backwardation (a downward sloping futures curve) occurs when there is a sudden shortage of oil and it is difficult to boost production immediately. When supply drops abruptly (or less likely, demand surges abruptly) price jump to clear the market and given the extreme inelasticity of supply and demand the jump can be dramatic. Futures prices jump much less on the assumption that long-run supply and demand responses will end the shortage. During these periods we would expect inventories to get very lean, but not go to zero due to the rising marginal "convenience yield."

Now, there is an apparent problem in this line of analysis. The same P_t appears in equations (2.1) and (2.2)! Hence, they both cannot independently describe the equilibrium for oil prices. In the next section, we address this point by distinguishing between the value of oil in the ground and oil above the ground immediately available for use.

2.2. *q* for oil

There is potentially a significant difference between the value of oil in the ground versus the value of oil available for immediate delivery.² While the following dichotomy is a simplification, it is a useful point of departure.

- Oil in the ground is an asset. It is priced according to the Hotelling exhaustible resource arbitrage condition where price net of extraction costs rises at the rate of interest. Consequently, oil in the ground has an asset value that is related to the present discounted value of current and future spot prices. As with other asset prices, movements in the asset value of oil should be largely permanent—arising from revisions in expectations about the present value of future demand, supply, and cost.
- Oil ready for delivery is an industrial commodity used for current energy supply and for production of processed industry materials. The price of delivered oil is determined by *flow* supply and demand conditions that are only loosely connected to the long-run asset value of oil in the ground.

The ratio of the current spot price of oil to its asset value in the ground is *Tobin's q for oil*. Why is this ratio not always equal to one? In the *q* theory of investment (e.g., Hayashi (1982)), the answer is that adjustment costs keep the desired capital stock from equaling its actual value period-by-period. The technology for converting oil in the

 $^{^{2}}$ Barsky and Kilian (2001) make this point by stressing that marginal cost in expression (2.1) may be upward sloping and therefore subject oil prices to changes in flow demand.

ground to oil delivered introduces a number of factors that can create a wedge between the Hotelling intertemporal arbitrage condition and the spot price of oil.

Extraction costs, short run. The technology for extracting oil from the ground is subject to increasing marginal cost, in some instances very steeply so. There are a fixed number of wells sunk at a point in time. There is limited scope for increasing the flow from them, and increases in flow can come at the cost of future recovery. There are also marginal sources of supply (e.g., stripper wells) that are increasingly costly on the margin.

Extraction costs, new capacity. Drilling new wells are subject to increasing marginal cost, gestation lags, etc., just like conventional investment projects. If new capacity means exploiting new fields, the gestation lags could run in the decades.

Transportation bottlenecks. Pipelines have limited capacities. Supertanker transportation rates are subject to wide fluctuations depending on demand (Kilian 2009).

Storage. Storage above the ground can serve to affect the gap between the asset value of oil in the ground and the spot value of delivered oil. Storage costs will vary depending on supply and demand conditions.

Official intervention. Historically, oil prices have been the subject to substantial official intervention. In the 1960s, the price of oil was set by the Texas Railroad Commission. In the 1970s, there were controls on the price of domestic oil in the United States. In the recent episode, government purchases of strategic reserves may have affected spot prices.

While this list is surely incomplete, it makes clear that there may be large and prolonged deviations of spot from asset value of oil in the ground.

In Section 3 of this paper, we will present evidence on the value of delivered oil versus oil in the ground. It is a critical ingredient in distinguishing hypothesis about the short-run determinants of movements in the price of oil.

2.3. Embedding oil in a macroeconomic model

This simple framework does not have a mechanism for exploring the policy response to oil prices. We need an expanded model to assess how central banks should adjust policy in general, and how policy should have responded to oil prices this decade in particular. Robert Solow (1980) called his article on this question, "What to do (Macroeconomically) When OPEC Comes." While OPEC is not at the centerpiece of our discussion, it is worth noting how closely the model and the implied policy prescription remains. Absent sticky prices and wages, there is no clear course for monetary policy to act in response to a price shock. Relative prices will change. Real wages will fall. And output will remain at its possibly lower full-employment equilibrium level.

Sticky prices, of course, change this picture substantially. Shocks to relative prices have real effects. In the Appendix, we present a benchmark new Keynesian macroeconomic model modified to include an external oil sector. While the apparatus of this model is different, the lessons are quite similar to the ones that Solow drew in 1980. Recall first some terminology conventionally used in the literature on inflation.

Headline inflation is overall inflation, typically measured by the overall CPI or PCE deflator.

Core inflation is a measure that strips movements in headline inflation that comes from movements in volatile relative prices food and energy prices before computing inflation.

The distinction between the two measures of inflation is vital for policy. In Section 4, we discuss how the benchmark model supports a policy that targets core rather than headline inflation. That inference is closely related to Solow's prescription to "accommodate" supply shocks, though most new Keynesian models expresses this policy in terms of the response to inflation rates rather than price level shocks.

In an important sense, we use the model as foil. A central question—one to which we devote substantial attention in the paper—is whether oil shocks feed into inflation expectations. If so, inflation expectations can become unanchored, potentially leading to a drift in the target for policy or a costly disinflation. In the context of the model, it makes a substantial difference whether persistently high inflation is just a series of positive residuals or a shift in the constant.

Another feature of the story that is brought into resolve by its omission from the model is the role of other external factors—notably world demand and inflation and the prices of other assets and commodities. In Section 3, we discuss the importance of these features. Clearly, a complete model would take them into account, and perhaps endogenize oil prices. Instead, we take the shortcut of modeling oil as exogenous to the United States, and then discuss informally world factors that both affect the price of oil and would also enter as shocks in the new Keynesian model.

3. OIL AND THE ECONOMY: THE 2000s

In this section, we explore macroeconomic and microeconomic aspects of oil and the economy. Our focus is on the recent episode: the steady increase in oil prices beginning with the recovery from the 2001 recession, the rapid increases in 2007 and 2008, and the even more rapid decline in 2008.

A complete account of the determinants of oil price is beyond the scope—both of this paper and the authors' expertise. Indeed, the very substantial variance across expert

opinions on the determinants of the price of oil is an important fact of this market. Oil, like many goods determined in asset markets, is subject to price movements that are nearly impossible to predict and often difficult to rationalize fully *ex post*.

That said, the following summarizes salient features of the behavior of oil prices recently.

From the early 1970s through the start of this decade oil price increases have tended to come in sharp and short bursts. These bursts have generally not lasted longer than eighteen months and have been associated with geopolitical events—the Yom Kippur war (1973), the Iranian revolution (1979) and the first Gulf War (1990). These price spikes also followed an extended period of strong global growth and building inflation pressures. Thus, a healthy debate continues to rage about the relative role of demand and supply in determining oil price movements. See Barsky and Kilian (2001) for the revisionist view that inflationary pressure and aggregate demand were important causal features of the 1970s oil price shocks; see Blinder and Rudd (2008) for a defense of the view that they were exogenous geopolitical events superimposed on a period of worldwide inflation.

We are not, in this paper, revisiting the debate over the 1970s. The picture we will paint for the 2000s, however, has more resonance with the Barsky-Kilian perspective on oil markets than the supply shock one. That is, oil prices in the 2000s were driven by high world aggregate demand operating against tightening supply, but not supply shocks.

It is also important to be clear what the sources of the change of oil prices matter for. In the new Keynesian model that we analyze below and that is the basis for much of central bank policy, it does not matter for policy whether the change in prices is from supply or demand. On the other hand, it is important to understand the role of these factors because it provides the context for the change in oil prices. In particular, if oil prices are high because of good economic times, one will not see a negative correlation of oil prices and economic activity that arises if oil prices increase because of supply disturbances.

Regardless of the explanation favored for past episodes, this decade's run up in oil prices is different in its dynamics. For more than four full years—from early 2002 through mid-2006—the dollar price of oil (adjusted for inflation) moved steadily higher. Prices never rose more than 30% over a two quarter period, but cumulatively increased more than three-fold (Figure 3.1). Alongside this increase, global GDP accelerated into mid-decade and unemployment rates moved steadily lower across the globe. Global consumer price inflation excluding food and energy remained broadly stable over this period (Table 3.1, Figure 4.2).³

³ Global GDP and CPI are GDP-weighted averages of national data, where GDP weights are determined via relative sizes of economies in US dollars. National GDP is converted to USD using annual averages of market exchange rates (not PPP-adjusted). Countries in global variables are United States, Japan, Canada, Australia, Euro area, Norway, New Zealand, Sweden, Switzerland, United Kingdom, Argentina, Brazil, Chile, Colombia, Ecuador, Mexico, Peru, Venezuela, China, Hong Kong, Indonesia, India, Korea, Malaysia, Philippines, Singapore, Taiwan, Thailand, Czech Republic, Hungary, Poland, Romania, Russia, South Africa, and Turkey.

Following a modest retreat in oil prices during the second half of 2006, oil ascended much more rapidly. In the year ending in July 2008, oil prices had more than doubled reaching a record high above \$140 per barrel. During this period, global growth remained solid, but global CPI inflation took off, rising above 5% on a year ago basis, its highest level since 1991. Soon after oil prices peaked the global economy fell into a deep and synchronized economic downturn. And oil prices have collapsed, reversing more than half their earlier rise. Our analysis of events during this period suggests the following. Sections 3.1 through 3.4 make the following points.

1) The rise in oil prices this decade seems to be a consequence of rising global aggregate demand and sluggish supply. Oil has become closely aligned with movements in global growth and other cyclical indicators. As a result, oil prices are behaving much more like other commodities whose relative price moves up and down with global growth.

2) Although energy price increases lifted US headline CPI inflation, global headline and core inflation remained stable from 2002 through 2006. Globally, both headline and core inflation rose sharply over 2007-8. This rise appears to be linked in part to cyclically high levels of resource utilization.

3) Oil has had an important impact on relative growth performance. A large income transfer to oil producing nations appears to have reinforced a rotation in growth from developing market (DM) to emerging market (EM) countries this decade.⁴ Non-oil producing EM countries appear to have been large beneficiaries of trade recycling from oil producing countries.

4) In the US, rising energy prices has weighed on real consumption by depressing real purchasing power and through other channels. The impact on consumption was partially offset by a combination of a weaker dollar and strong demand from emerging markets (from oil and non-oil exporters), which significantly spurred US export performance.

Sections 3.5 through 3.9 focus on microeconomic and market determinants of oil prices. These sections make the following points.

5) Supply and demand elasticities are low, meaning small shocks can lead to big changes in prices.

6) Various approaches to computing the long run value of oil have been proposed. None have been particularly successful.

7) A novel application of q theory that we propose here suggests that oil prices were overshooting by 2008.

⁴ Throughout the paper, data from EM countries refers to data from JP Morgan's list of over 20 emerging markets. This list excludes OPEC countries. See previous footnote for a list of the countries.

8) Futures prices tell a somewhat different story, since they typically forecast "no change."

9) We have no direct evidence on the role of speculation in the oil market. But we do note that conditions were ripe for a bubble in 2008.

3.1. Oil in the global business cycle

The close alignment of oil prices with key cyclical variables this decade argues strongly for viewing oil price movements as an endogenous element of this decade's global business cycle. In particular,

- Oil has moved closely with other commodities. For example, industrial metals prices have risen almost as much as oil over this period (Figure 3.2). They also seemed to "lead" oil in the final rise. This underscores the point that the rise in oil prices was not unique to supply and demand conditions in the oil market, but reflected factors common to all commodities: strong demand from commodity-intensive users combined with limits on new supply.
- Oil is positively correlated with GDP growth. As Figure 3.3 shows, West Texas Intermediate (WTI) oil⁵ prices have generally traced the ups and downs of global GDP growth over the last decade or so. This positive correlation has strengthened in the last decade. It contrasts starkly with the negative correlation of GDP growth and oil prices during the stagflationary period of the 1970s to early 1980s.

There has been a litany of regional disruptions to oil supply in recent years—including the start of the Iraq war and Hurricane Katrina—but there has been no global supply-side disturbances that can explain this decade's oil price run-up. A restrained trend growth in supply (discussed below) may be a factor. The absence of a significant geo-political trigger helps explain why the rise in prices up to 2007 contrasted with previous price spikes.

While there is considerable circumstantial evidence suggesting that oil price movements have aligned with global demand, outsized cumulative increases in oil prices were not matched by unusually strong global oil consumption. Indeed Hamilton (2009a, 2009b) describes the final years of this period as one of rising demand meeting stagnating global production. Figure 3.12 below documents such stagnation for non-OPEC production. From 2002-2007 global oil consumption grew at a 1.6% pace, roughly similar to the 1.5% growth recorded during the 1990s expansion (Figure 3.4). Beneath this aggregate, the composition of global demand has changed dramatically. In 1999, emerging market economies accounted for less than 45% of global crude oil consumption, but the share had risen to 51% in 2007. Over this period emerging market oil consumption accelerated, while consumption for developed nations ground to a halt (Figure 3.5). This rotation was likely caused by three factors:

⁵ We follow the standard practice of using West Texas Intermediate (WTI) as the benchmark for oil prices. WTI is also the underlying commodity of futures contracts discussed below.

- (1) a shift towards more energy intensive production and consumption in emerging market economies,
- (2) more rapid growth in these countries (Figure 3.6), and
- (3) government programs that tended to subsidize energy consumption in EM economies.
- 3.2. Oil and global inflation

Global core and headline inflation remained broadly stable through 2006, though both rose substantially in 2007-08 (Figure 3.7). To an important degree the rise in core inflation aligned with the rise in global resource utilization rates above the 1990s cyclical peak during 2007, highlighting the role of the business cycle in global price setting this decade (Figure 3.8). As well, the pattern may reflect a delayed reaction; Kilian (2008) argues that shocks to oil demand have a slow cumulative effect on headline CPI in the US. Whether or not core inflation in the US and elsewhere is contained in the face of rising energy prices depends jointly on how the economy responds to inflation and how policy responds to it.⁶ The modest increases in core inflation in the face of energy shocks may indicate the credible and appropriateness monetary policy (e.g., Blinder (2006)). But it is important to consider inflation expectations along with actual inflation, and in any event initial stability may presage a delayed response. Global inflation did rise significantly as the expansion matured and as oil prices continued to rise. Headline inflation spiked above 5% in 2008, its highest level in nearly two decades. Core inflation also rose by more than a full percentage point over 2007-8.

3.3. Recycling of oil revenues: Emerging market countries are the winners

The sustained rise in oil prices since 2002 provides a useful laboratory for examining how a major income transfer is transmitted in an increasingly connected global economy. In short, this decade's rise in oil prices proceeded in tandem with a significant shift in spending towards emerging market economies—both those that are oil consumers and oil producers. To provide context and background, we document this shift in detail. The essential point is that because of the recycling, different countries face a different "net shock" from oil prices. Readers not interested in the details of the shift can skip to section 3.4 without loss of continuity.

The sustained rise in the price of oil this decade has generated a massive transfer of wealth from the oil producing countries to oil consuming countries. In 2007, world spending on oil was roughly \$5.9 trillion, an amount that was roughly three times as large as in 2002 (Table 3.2). Comparing actual spending on oil to what would have been spent if consumption had been flat at 2001 levels, there was a cumulative \$8 trillion in extra

⁶ Research using backwards looking Phillips curves has also found that energy prices seem not to feed into core inflation in the US (Hooker (2002), Cavallo (2008)), though they appear to in Europe (Cavallo (2008)). The US pattern could be because there is a low structural response of inflation to energy prices, or because expectations of inflation were very well anchored because of the Fed was expected to offset inflationary shocks.

global spending on oil over this five year period. OPEC countries received almost half of the revenues from this consumption (\$2.9 trillion). The big losers were developed economies (\$2.7 trillion) and emerging Asia (\$1.0 trillion). In terms of exposure to oil, by 2007 the net cost of oil as a share of GDP had risen to the 2 to 3 percent range in each of the major developed economies, but the exposure in some countries in emerging Asia was twice as high.

While the oil exporters' gain is a net loss to oil importers, the wealth transfer gets recycled through international transactions. With their wealth gains oil exporters purchase goods and services from oil importing nations, helping to offset some of the drag of higher oil prices on importers GDP. In addition, the portion of oil revenues that is saved tends to be recycled to the oil importing economies through financial markets. This, in turn, stimulates growth by lowering borrowing costs and raising other asset prices.

The lack of quality national product account data from OPEC nations makes it difficult to do a full accounting of the recycling of oil revenues. Looking at national account data through a somewhat different lens—the net commodity exporters (NCE) that do provide GDP account —does provide some indication of how this process has worked. Real net exports subtracted about 2% points annually from growth in the major net commodity exporting (NCE) countries from 2003 to 2007. Domestic demand growth in the NCE countries soared to nearly 8% annualized over this period, or nearly three times the average during the previous decade. As the group makes up about 10% of global GDP, this suggests real net trade with the NCE group alone added almost 0.5%-point per year to the remainder of global real GDP growth.

A closer examination of the oil producing countries is possible, through nominal trade data. On this score, our analysis of OPEC's trade flows reveals three keys points. Table 3.3 shows the marginal propensity to import out of export revenue (MPI). Table 3.4 shows the raw data on merchandise trade with OPEC over the recent period of rapid increase in oil prices.

Low short-term spending elasticities. The short-run MPI is estimated as the annual change in imports divided by the annual change in exports (both in US dollars). Over the past two and a half decades, OPEC's MPI within one year has been roughly \$0.34 to the dollar. As shown in Table 3.3, this estimate varies across countries, with Kuwait spending the smallest share and Bahrain and the UAE spending the most.

Rising long-run elasticities. The long-run MPI is estimated as the ratio of the 5-year change in imports to the 5-year change in exports. OPEC spent on imports roughly one-half of every dollar in export revenue. Again, the results vary by country with the UAE spending dollar-for-dollar. Over the most recent 5-year period (2002-07), the long-run MPI has moved up considerably to \$0.71. The rise has been fairly broad-based.

Emerging markets take the lion share of recycling. In the 2002-07 period, exports from OPEC jumped \$446 billion and roughly \$325 billion was recycled back to the rest of the world in the form of imported goods. These petrodollars were not returned in proportion to each country's share in oil expenditures. Rather, much of the windfall reflects a transfer of income from developed to emerging markets. Emerging market exports to OPEC rose \$186 billion from 2002 through 2007 compared to a \$181 billion increase in import, a ratio of imports to exports of 103%. For developed markets, this ratio was just 52%.

Within the EM, the offset was almost two for one in Latin America, versus a near one for one offset in CEEMEA (Central Eastern Europe, Middle East and Africa) and EM Asia. To be sure, the value of trade between OPEC and Latin America and CEEMEA is relatively low partly because Latin America and CEEMEA each contain major oil exporters. As a result, most of OPEC's trade with the EMs occurs with EM Asia. Within EM Asia, China, India, and Singapore all ran a trade surplus with OPEC in 2007. They also experienced a greater rise in the value of exports to OPEC than in the value of imports from OPEC over the 2002-07 period. No doubt, these countries also import oil from non-OPEC sources and so their net gain in the oil for goods trade is unclear. However, China also ran a trade surplus with Russia and Canada in 2007, suggesting that trade with oil exporters more broadly has also resulted in a net export gain.

Among the G-3, the variation in the degree of OPEC oil-revenue recycling is striking. For the 2002-07 period, the rise in US exports to OPEC offset only 34% of the rise in imports. Japan's offset was fairly similar, with export growth equal to 30% of import growth. By comparison, the Euro area fared much better. The level of Euro area exports rose \$58 billion from 2002 to 2007, versus a \$66 billion increase in imports: a ratio of 88%. The Euro area's advantage may owe to its specialization in the production of capital goods, especially Germany's. However, a portion of the gain also reflects the collapse in Euro-US dollar exchange rate over this period.

Clearly many emerging economies felt a different kind of oil shock than many developed countries. Not only did these countries drive a relatively price inelastic surge in demand for oil, but they benefited disproportionately from the recycling of petro-dollars. Revenue recycling means each country faces a different overall shock from the rise in oil prices. For countries with high levels of recycling—such as EM Asia—the rise in oil prices is probably best viewed as an indicator of strong aggregate demand, with relatively little supply shock in terms of income transfer. By contrast, countries which did not benefit significantly from recycling—such as the US and Japan—the energy shock felt like an exogenous supply shock, even if those countries contributed to the general surge in oil demand and the rise in oil prices.

As this discussion makes clear, oil revenues do not recycle necessarily to the countries with large oil import bills. Indeed, since the aggregate balance of payments for a nation is determined jointly with the difference between its domestic saving and domestic investment, the amount of recycling back to the US will be limited by its aggregate trade deficit. Likewise, it is not surprising that the EM countries are the net exporters to the oil exporting countries. These countries, led by China, have had substantial external surpluses over the period.

The impact of rising energy prices on the US economy needs thus to be viewed against the backdrop of broader global macroeconomic developments. Rising oil prices was a negative income shock which reduced both household purchasing power and corporate earnings for the non-energy producing sector. As noted in both Kilian (2008) and Hamilton (2009a), the key mechanism whereby energy price shocks affect the economy are through a drag on consumer and business spending on goods and services other than energy. But there may have been significant positive effects on US growth from the strength in global demand that has contributed to rising oil prices as well as from the direct effects of recycling surpluses from oil producing nations. Kilian (2008) also finds offsetting effects when oil prices rise because of a shock to demand, though he concludes that in the long run the effect on the US economy is negative.

The impact of these developments is clear in relative performance. Across countries, this decade has seen an enormous shift in relative growth performance between the US and EM countries. In the next subsection, we further elaborate on the US performance.

3.4. US consumers feel the pain

Within the US there has been a significant change in the composition of US growth (Figure 3.9). Since the end of the 2001 recession exports have trended sharply upward as a share of GDP. Yet during this period, the external balance remained substantially negative. This figure shows that Americans were not as spendthrift as the large external balances or the very low personal saving rate might suggest. We note in the next section that energy demand is highly inelastic. Rising energy prices thus are associated with rising expenditures on energy. In the US in recent years, such rising energy expenditures were accomplished at least in part by squeezing non-energy consumption, which declined from 67 to 66 percent since the start of the decade—a sharp reversal of the upward trend. Similarly, an increasing share of the external imbalance is attributable to paying the energy bill. We focus on the consumer rather than firms because energy makes up a relatively large share of spending—about 7% at its peak—than it does for cost share in private industries which generally average less than 2%.⁷

Table 3.5 shows an estimated response of aggregate US consumption growth to changes in oil prices. The estimates are based on a non-structural regression, so the correlations it uncovers need to be interpreted with caution. The regression includes, among other controls, current and lagged real disposable personal income (DPI) growth. Since the direct income effect of oil prices is reflected in the deflator for personal income, the

⁷ Moreover, oil is unique among commodity prices in how it passes through to finished consumer goods prices. Note that consumption of fresh food makes up a larger share of US consumption than gasoline. However, commodities make up far less of the value added in retail food than crude oil does for retail motor fuel. To wit, whereas crude oil accounts for roughly 70% of the value added in a gallon of gasoline, milled field corn makes up less than 2% of the cost of a box of corn flakes cereal (despite being roughly 70% of the volume). The remainder reflects packaging, processing, advertising, transportation, and other costs. Thus, changes in the input cost of food tend to be absorbed by a multitude of other margins.

regression is meant to capture the incremental price effect. Broadly, these results support the view in the literature that there are multiple channels through which energy price changes affect consumption (Kilian (2008)). In addition to reducing discretionary income, higher energy prices may create uncertainty about the future and prompt a rise in precautionary saving. In addition, consumption of durables that are complementary in use with energy (notably autos) will tend to decline more than spending on other goods. Using our estimated consumption relationship that allows energy prices to influence consumption in two ways—directly and indirectly through depressing real disposable income—we can estimate the size of the drag on consumption from rising energy prices this decade.

Figures 3.10 and 3.11 show the estimated effects of oil prices on consumption growth based on the estimates in Table 3.5. In Figure 3.10, the solid line measures the effect of oil price movements on consumption through changes in real DPI, i.e., by isolating the contribution of gasoline prices to overall PCE deflator movements. The dashed line is the incremental effect of oil prices based on the estimated coefficient. Figure 3.11 sums these effects. The results suggest that the oil price drag on consumption has been substantial this decade. It is also interesting to note that the boost to consumption lift from the collapse in oil prices in 2009:1 is estimated to be the largest on record. Of course, these results (both the drag 2002-08 and the rebound in 2009) may overstate the effects of oil price movements; as noted above, there are offsetting effects when oil price movements are driven by demand.

3.5. Supply and demand equilibrium

The previous subsections have focused on the demand side. To summarize, the period since the 2000s was one of strong world aggregate demand, especially in emerging markets. Despite brief disruptions such as the war in Iraq, supply shocks do not appear to be a precipitating factor in the run-up in prices in this period. Strong world demand alone cannot explain movements in price. There needs to be consideration of the supply-demand balance both in the period in question and over time.

Demand is highly inelastic, especially in the short run; supply has also been constrained as well (Hamilton (2009a, 2009b)). On the demand side, the surge in oil prices in the 1970s caused a shift in consumption towards less energy intensive activities, leaving the remaining consumption more price inelastic. And in many emerging market economies such as China energy price subsidies insulated local demand from global price increases.

While our narrative has focused on the role of strong demand in driving up prices, supply also played a role. On the supply-side, capacity constraints have developed at each stage of production until the economic collapse in the second part of 2008: OPEC had been running at close to its productive capacity since 2004, refinery capacity was tight, storage facilities were and are limited, and tanker capacity was tight. As Figure 3.12 shows, despite the surge in oil prices in the past decade, the annual growth in oil supply has been steadily falling outside of OPEC. In the early part of the decade the Former Soviet Union (FSU) was increasing its average daily supply by about 1 million barrels per day (roughly 10% growth)) and while choppy, supply from other non-OPEC producers was rising. By

contrast, in the last several years, the annual change in non-OPEC oil output has turned negative. Some of this can be traced to supply disruptions, but the more fundamental story seems to be that oil is getting harder and harder to extract.

The upshot is that a relatively small shock can cause a major change in prices.

3.6. What is the long-run equilibrium price of oil?

There is remarkably little agreement in the industry about how to calculate the long-run equilibrium price of oil, or fair value. Industry experts generally adopt five approaches (Ahn and Morse (2008)). We describe these, and then in the next subsection, propose another approach.

Accounting. One approach is an elaborate adding up of current and expected supply and demand. On the supply side, this includes detailed analysis of the speed of depletion of key fields, analysis of geopolitical events affecting the market, estimates of the cost of bringing new fields on line, etc. On the demand side, it generally involves estimating growth and price elasticities for a wide range of consumers.

Marginal cost. Another approach is to calculate the marginal cost of production. This requires identifying the most expensive current supply source and assuring that the source has enough spare capacity to remain the marginal source in the face of rising demand. The favorite example of this seems to be the Canadian tar sands. "Industry experts generally believe these tar sands are economical at \$85-\$95/bbl [barrel] and the barrier should trend lower as technology improves and economics of scale are exploited" (Ahn and Morse (2008)).

Rule of thumb. A popular industry rule of thumb is that the retail price should be 3 to 4 times finding and development costs. A survey of 50 top oil companies found these costs averaged \$17.46/bbl (Ahn and Morse (2008)). That implies a fair value of \$52 to \$70 per barrel.

Peak oil. Sitting the background is the idea that as a finite resource, oil will run out some day (Ahn (2008)). This may or may not coincide with technological breakthroughs that sharply reduce the demand for oil. Thus if there is some terminal price beyond which zero oil is consumed, current prices should be determined by working back to the present a price path that satisfies the Hotelling conditions. The problem with this is that small wags of the future "tail" can cause today's equilibrium oil price to move dramatically. Peak oil seems to come back every 20 years or so.

Cost regression. A more elaborate approach is to regress oil prices on a variety of cost variables. For example, Ahn and Morse (2008) use data from December 2003 to October 2007 and regress the five-year forward price on a variety of measures of the cost of oil production. The results suggest the equilibrium price in August 2008 was \$80/bbl in the equation without the exchange rate and \$88/bbl using the equation with the exchange

rate.⁸ Presumably there is some reverse causation going on here with the hot oil market bidding up the price of oil production.

3.7 Measuring q for oil

Here we describe an application of the familiar q approach to measuring asset values. Our novelty is use of data in which there is unusually little ambiguity about whether value is determined by oil or other asset—namely, mergers and acquisitions of firms whose principal asset is oil reserves.

3.7.1. Stock market value

The value of the numerator of q for oil, the spot price, is straightforward to measure. The value of the denominator, the value of oil in the ground, is more complicated to measure. One approach we considered would be to use the stock market value of oil companies. But large oil companies, in addition to owning oil reserves, have interests in distribution, refining, and sales of petroleum products, as well as lines of business not closely related to oil. While it might be possible to separately value these lines of business, errors in doing so might well be of the same order of magnitude, so we have not pursued that exercise in detail. Nonetheless, a quick look at the stock of two large, integrated oil companies is revealing. Figure 3.13 shows how little the stock price of Exxon and BP responded to the dramatic run-up in oil prices from the beginning of 2008 to their peak in mid-year. The prices were down for much the first half of 2008. They started down before the peak in oil prices in mid-year and were down substantially by the time the stock market meltdown related to the financial crisis hit in late September. Hence, despite the record profits of the oil companies during the run-up in oil prices, their asset values had a very damped response to oil prices—precisely what a q theory of the spot market price of oil would predict.

3.7.2. Using mergers to estimate the value of oil in the ground

An alternative methodology for valuing oil in the ground is to use the market price of reserves.⁹ Occasionally, individual oil wells are sold, but this market is likely to be far from representative (e.g., stripper wells). Mergers and acquisitions of firms whose principal asset is oil reserves, however, provide a financial market assessment of the value of oil in the ground. Daniel Ahn has done such a calculation based on data for mergers and acquisitions of oil companies provided by John S. Herold, Inc. The financial market value of a barrel of proven reserves is calculated by taking the market value of a merger or acquisition of a firm whose principal asset is proven reserves. An obvious complication is the valuation of assets other than oil in the ground. These assets get valued as part of the M&A process. While there are clear difficulties in doing so, these

⁸ The exchange rate was Bloomberg's DXY dollar index, with is based on six major world currencies: the euro, the Japanese yen, the British pound, the Canadian dollar, the Swiss franc, and the Swedish krona. ⁹ The authors would like to thank Daniel Ahn of Barclays Capital for supplying data and advice on this section.

values are presumably more reliable than done in conventional q calculations, which reflate book value of historical investments, because they are part of a financial transaction. Moreover, the calculations are based on mergers and acquisitions where the value of the proven reverses account for at least half of the value of the transaction.

Figure 3.14 shows the financial market value of proven reserves in the ground (black line). The above-ground price of oil-measured as the average of oil and gas forward prices—is shown for comparison (grey line). The ratio of the above ground price to the value of oil in the ground (ratio of gray line to black line) is a measure of q. For the period from 2002 to the beginning of 2006, except for some temporary fluctuations in the value of oil in the ground, the market value of oil in the ground and oil for above-ground delivery trend together closely. Beginning in 2007, they diverge persistently, with the value of oil in the ground being relatively flat and the value of delivered oil persistently higher. There is some volatility in the M&A data but two points are fairly clear. First, there was a persistent negative valuation gap from the middle of 2006 until the end of 2008. Second, the value of proven reserves was not following the pattern of aboveground prices. Like the stock price of the oil companies shown in Figure 3.13, the price of oil in the ground did not move at all in response to the sharp escalation in oil prices in early 2008. These results are quantitatively very significant. By the middle of 2008, q for oil, measured as the ratio of the two series in Figure 3.14, was 1-3/4. By the end of 2008, it was back to one.

The evidence from the stock market value of large oil companies and from the M&A value of smaller ones suggests that the price of oil was (a) warranted from 2002 to the beginning of 2006 (because prices and asset values moved commensurately), but (b) temporarily high from mid 2006 through early 2008 (because the increases in prices were not reflected in the asset value of oil). This evidence points to flow supply and demand factors as the explanation of the high and spiking oil prices. For reasons discussed above, flow supply and demand equilibrium price is not necessarily tightly linked to asset values because of a wide range of adjustment costs.

3.8. Future prices

Futures prices provide another window into long run versus short run equilibrium in the oil market. Surprisingly, in 2008 they tell a different story than do our q calculations. Figure 3.15 shows that, for most of 2008, the forward price of oil was essentially equal to the current spot price. For example, in January 2008, the spot price was \$93 dollars per barrel and the 10-year ahead forward price was \$87 per barrel. As spot prices spiked in the first half of 2008, the forward prices moved up essentially one-for-one. In June the spot price was \$134 per barrel, and the forward price at all horizons was essential equal to the spot price. Thus the forward oil market was consistent with the hypothesis that the changes in the spot price of oil were essentially permanent. Hence, the futures market does not tell the same story as the stock market valuation of the large oil companies or the M&A-based estimates of the q for oil. These markets did not appear to perceive the increase in oil prices during 2008 as permanent.

The decline in oil prices in 2008 also shows an interesting story. As oil prices started to decline from their peak in mid-year, the entire forward curve shifted down with the spot price. By September, the price for immediately delivery had fallen over 30% to levels just about \$100 per barrel. The forward curves for August and September, like the ones during the run up in prices in the first half of the year, are essentially flat. Alquist and Kilian (2008) document that this flat pattern has been pervasive over the last 20 or so years.

The situation changed dramatically in the final quarter of 2008, when the financial crisis was in full swing and there was a clear understanding that there would be a sharp and perhaps protracted world-wide recession. Spot prices fell by almost \$20 per month through the remainder of the year—reaching \$40 per barrel at the end of the year. Instead of moving one-for-one as it had for the first 8 months of 2008, the forward curve remained somewhat anchored at the long end with future valuation in the \$80s. By the end of the year, the long-futures price had fallen to \$72 per barrel, but this value was almost twice the spot price.

Indeed, the premium of the futures price over the spot price at the end of 2008 was as large as it has ever been in the available data. Figure 3.16 shows the spot price and its difference with the 1- and 2-year ahead futures prices for data since 1987.¹⁰ The positive slope of the yield curve—\$21 dollars over the 2-year horizon in December 2008—is the largest positive forward premium (*contango* in the language of futures markets) exhibited in the sample. This outcome is completely consistent with the view that the world was temporarily awash in flow supply of oil relative to demand that had collapsed owing to the financial crisis. It points toward a current (January 2009) market assessment of the long-run price of oil somewhat above \$70, and that the very recent declines in spot price reflect the world-wide slump.

What is striking is the complete absence of negative forward premium (*backwardation*) in the earlier part of 2008.

To summarize, consider how the q for oil results of Section 3.7 and the evidence from the forward price of oil in this section relate to each other and shed light on equilibrium in the oil market in 2008. As discussed in Section 2, changes in the flow demand for oil can have sharp effects on the price of delivered oil even if they are temporary. Costs of extraction, delivery, and storage can detach the spot price of oil from its long-term asset value. The high worldwide demand for oil in the first half of 2008 and the collapse in demand in the second half of 2008 accordingly could account for sharp increase and decrease of oil prices in 2008. The evidence from the q for oil calculations and the stock price discussed in Section 3.7 support this view. Likewise, the sharp upward slope in the forward curve for oil prices in late 2008 suggest strongly that the market perceived demand to be temporarily low. It remains a puzzle, however, that the forward curve for oil was quite flat when oil peaked in mid-2008. The results on q for oil and the stock

¹⁰ Futures prices at greater that 2-year horizons have been available only recently. The long futures prices are thinly traded (see Alquist and Kilian 2008).

prices suggest that such expectations of continued high oil prices had not been capitalized in the market value of petroleum companies or the value of oil in the ground.

3.9. Speculation

Proving whether there was a bubble or not is beyond the scope of this paper, but it is worth noting that the market was ripe for a bubble in 2008. Data on oil market fundamentals are very poor: for example, there is no publicly available data for judging the amount of inventories held in the ground or in many of the rapidly growing EM economies. It is our impression that oil was increasingly viewed as a "hot"new asset class. Indeed, with the collapse in housing, credit, stocks, etc., it could be argued that commodities were the only hot asset. Many investors were new to the market and may have seen the surge in buying as a signal of fundamental value. Experts were widely divided over what fair value was, so there was not an obvious counterparty to a bullish trade.

While it appears that oil prices were overshooting in 2008, the markets were not convinced and the futures curve remained relatively flat as oil prices surged. As we will see, most central bankers chose to accept the prices in forward markets.

4. INFLATION METRICS AND MONETARY POLICY: FACTS AND THEORY

In this section we explore the distinction between headline and core inflation. Headline inflation is overall inflation; core inflation excludes inflation in energy and food (though the fact that it excludes food is not important for our analysis). Section 4.1 summarizes recent inflation developments. Through much of the 2000s, rising oil prices lead to headline inflation rates distinctly higher than core inflation rates. Section 4.2 then reviews some theoretical literature on which measures of inflation are appropriate targets for a central bank. In particular, it considers the question: in the presence of shocks to oil prices that cause headline and core inflation to deviate, what inflation metric should the central bank target?

4.1 Headline and Core Inflation from 2002 to 2007

We begin with a word on patterns of oil price movements. Hamilton (2009a) and Alquist and Kilian (2008) conclude that a good model for real oil prices is a random walk, though in statistical terms the random walk cannot be distinguished from a stationary but very persistent process. This persistence manifests itself in a spiky pattern (Figure 3.1). Oil prices either jumped to a new level and stayed there for a long time as in 1974-75, 1979-80 and 1986 (to the downside) or they spiked up and came down quickly as in 1990-91. The last decade witnessed a new kind pattern: a sustained upward trend. As Blinder and Rudd (2008) point out, "an *ever-increasing* relative price of energy is fundamentally illogical; but recent events have shown the world that such a path can persist for a long time" (p. 12). Headline inflation ran ahead of core inflation for much of the period of persistent oil price increases. See Figure 4.1 for the United States. In the United States, from December 2001 to December 2007 the cumulative gap between US headline and core PCE inflation was 3.9 percentage points (almost 0.7% per year). Suppose that the Fed wants to on average keep core inflation at 1.75%.¹¹ Relative to that rate of inflation, the cumulative "overshoot" of core prices was 1.5 percentage points and of headline inflation was 5.4 percentage points. These are relatively big numbers: the average 0.9 percentage point overshoot of headline inflation was 50% above the "target."

Table 4.1 shows similar calculations for the UK and Japan, as well as the United States and Euro area. For the period as a whole, headline inflation has overshot the ECB target by about twice as much as the Fed, but the core has actually been below target. On average headline inflation has been right in the middle of the Bank of England's 1 to 3% range. Headline inflation in Japan has been below the midpoint of the 0 to 2% target range (which only was officially announced in March 2006).

Inflation developments outside the major economies were also instructive.¹² Here we focus only on regional aggregates. As in a number of developed economies, both core and headline inflation were well behaved in emerging markets through the end of 2006. As Figures 4.2 and 4.3 show, both unit labor costs and core inflation fell over this period and headline inflation was subdued

Unfortunately, other things were not so calm. The long boom in emerging market growth, was putting increasing pressure on capacity in emerging market economies—for example, a simple gauge of resource utilization rose above its 1993-2000 average in 2004, peaking at 2 standard deviations above trend in 2008 (see below, Figure 6.4). Policy makers adopted a number of measures to dampen inflation expectations—rising policy rates, reserve requirements and exchange rates, imposing capital controls and price controls—without curbing the pressure. Throughout 2007 and 2008, emerging market inflation accelerated significantly. By the end of the period, core inflation had surged in emerging markets and picked up slightly in developed economies as a group.

4.2 Theory: Oil Prices and Monetary Policy in New Keynesian Models

In this section we review a literature that uses a certain class of formal models to consider how monetary policy should respond to inflation when there are alternative measures of inflation. These models take as given that inflation expectations are anchored; that is, the public correctly perceives the inflation target of the central bank. The basic conclusion of these models is that variability of core inflation is a better measure of economic welfare than is variability of headline inflation. Hence core inflation is a more appropriate target than headline inflation. After outlining the logic of these models, we

¹¹ The assumption here is that this is the midpoint of the comfort zone of the committee. This seems to be the case both from public comments and from the initial 3-year ahead forecast of FOMC members in October 2007. A few FOMC members may favor a lower band.

¹² This discussion draws heavily on Hensley et al. (2008).

return to note the dependence of the models on the assumption that inflation expectations are anchored.

The theoretical approach that we review has come to dominate both academic and central bank analyses of monetary policy. This is the so-called new Keynesian approach, exposited quite thoroughly in Woodford (2003). Our appendix develops a new Keynesian model that incorporates oil prices. We use it below to illustrate some of our arguments and conclusions about recent US monetary history.

In the new Keynesian model, optimal government policy includes a role for monetary policy because of price and wage stickiness. This stickiness is feasible because of imperfect competition in product and labor markets. Staggered setting of prices and wages leads to relative price distortions that can be ameliorated by monetary policy.

We begin first by reviewing results on the form of the loss function for optimal policy, and then turn briefly to the form of policy rules. Consider a baseline version of this type of model—closed economy, all prices and wages set according to scheme originated by Calvo (1983), labor the only factor of production—that appears in textbooks such as Woodford (2003) and Galí (2008). In such a model, to maximize the expected utility of the representative household, the central bank should target a weighted sum of variation in (sticky) wage inflation, (sticky) price inflation and the output gap. The weights depend on the parameters of tastes and technology. That is, optimal monetary policy trades off variability in inflation and real activity, with the terms of the tradeoff determined by parameters of tastes and technology. See, for example Woodford (2003, ch.6) or Erceg et al. (2000).

The parenthetical "sticky" was inserted in the previous paragraph to emphasize that the goal is to ameliorate effects of sticky wages and prices. Aoki (2001) shows that if there is a competitively produced consumption good, optimal monetary policy ignores fluctuations in the price of this good. This result holds regardless of the volatility of the price of such a good. The intuition is that fluctuations in the price of a competitively produced good are market signals that serve to appropriately direct resources. In other words, Aoki's result, and the related results in Mankiw and Reis (2003), suggest that variability of core rather than headline inflation is a better target for monetary policy, if the difference between the two is due to inflation in competitively produced consumption goods.

Of course, Aoki's (2001) result further implies that core inflation itself might not be a good target, if some products that are included in the core inflation index are sold in competitive markets. (This point has been made, for example, by Wynne (2008).) It would take us too far from our topic to pursue this point. So we take as given that with respect to choice of price index, the question is whether to target core or headline inflation. For the purpose of our present discussion of new Keynesian models, we assume that the sole difference between the two inflation measures is inflation in the price of oil.

To consider the possible role of oil requires extensions of the model described above. The first two extensions follow from the fact that oil is not only consumed but is a factor of production. This has two implications. A direct implication is that exogenous increases in oil prices have effects similar to an exogenous fall in productivity: we require more resources to produce a given amount of output. In the jargon of new Keynesian models, the efficient level of output changes when oil prices move exogenously (Bodenstein et al. (2008), Nakovy and Pescatori (2009)). Policy should therefore recognize that many of the real effects of oil prices are ones that reflect desirable reallocation of resources, just as policy should recognize that technology shocks lead to desirable reallocations.

A second implication is more subtle. Bodenstein et al. (2008) extend the baseline model described above to allow for oil that is consumed and used in production. They conclude that insofar as oil feeds into decisions made by producers with market power, optimal monetary policy will depend in part on variation in oil use. But they also conclude that as a practical matter, energy shares are sufficiently small in the US that the resulting policy will be very similar to one that ignores oil use variation. Hence they conclude that the measure of consumer price inflation variability that is appropriate for monetary policy is variability of core rather than headline inflation.

Third, oil prices are determined in a global economy, with the US market arguably taking oil prices as given. This raises the question of how monetary policy should operate in open economies. To our knowledge, and even limiting ourselves to literature that builds closely on the framework described above, there is not a consensus how open economy considerations affect policy. One vein of research (Clarida et al. (2002)) argues that optimal monetary policy is essentially the same in open and closed economies. More recent research (Engel (2009)) finds that optimal policy in an open economy may be quite different than that in a closed economy if sticky prices lead to divergences in prices of a given good across countries. In open economies, then, this class of models does not deliver a clear guideline as to appropriate measure of inflation.

But even Engel's (2009) results imply quantitatively large effects only if the import and export sectors are large. It is our sense that the US remains sufficiently insensitive to world factors that the closed economy advice is probably a good starting point. For example, we noted in section 3 that although growing global demand boosted U.S. exports, the most visible effect of rising energy prices was an increase in energy expenditure and a squeezing of non-energy expenditures. We thus summarize our review of results on the form of the loss function for optimal monetary policy as: in closed or nearly closed economies, and in the class of models that have come to dominate academic and central bank thinking on monetary policy, the measure of consumer price inflation variability that is relevant is core rather than headline inflation.

What form of policy rule will allow the central bank to achieve its goals of appropriately trading off variability in core inflation against variability in real activity (and variability in wage inflation, when wages are sticky)? Under some simplifying assumptions about dynamics and commitment, an interest rate rule that sets the interest rate in response to real activity and to actual or expected inflation can achieve the optimal tradeoff. Under

dynamics rich enough to well-mimic actual behavior, the optimal interest rate rule might implicitly or explicitly respond to various signals about the state of inflation and real activity, and not take a simple textbook form. Hence one might want to look to headline inflation, or to inflation in oil prices, as a signal, even if the goal is to achieve a desired level of variability of core inflation. We acknowledge this possible role for oil prices, but use our limited time and space to focus on other issues.

Let us now step outside this class of models to note the possible crucial dependence of the model's results on the assumption that inflation expectations are model consistent and therefore by assumption anchored as long as the central bank follows a stabilizing policy. Bean (2006) agrees that logic such as that spelled out above calls for targeting core inflation. But he also notes that if we accommodate oil price increases, there is substantial risk:

Can we be sure that households and firms will behave appropriately and that medium-term inflation expectations will remain anchored? At present, that is not something the literature helps us answer. But given the potential costs of restoring credibility once it is lost, it may be better to err on the side of caution.

Hence a key question in our analysis of US monetary policy is whether a focus on core inflation might have let inflation expectations drift upwards. We focus on this question—both in the data and with simulations of the new Keynesian model—in the next section. The workhorse new Keynesian model presumes that inflation expectations stay anchored. In Section 5 we explore the validity of this presumption. In Section 6 we evaluate monetary policy in the 2000s—policy that was implemented under the presumption of anchored inflation expectations.

5. INFLATION EXPECTATIONS: ARE THEY ANCHORED?

In Section 5.1 we examine various measures of inflation expectations. In Section 5.2 we study whether they remain anchored following oil price shocks. In Section 5.3 we use a version of the new Keynesian model to see how stable inflation will be in response to a five year, persistent escalation of oil prices such as we saw in the 2000s.

5.1. Inflation expectations in the 2000s

In recent years central bankers can with considerable justification point to changing inflation dynamics as evidence of improved anchoring of inflation expectations. For example, in a speech in March 2007, Fed Governor Mishkin argued that central bank credibility had helped alter inflation dynamics. He noted that inflation had become less persistent, with a sharp decline in the sum of coefficients on lagged inflation in a simple autoregression. More sophisticated tests of persistence from Stock and Watson (2007) and Cecchetti et al. (2007) confirm an anchoring of trend inflation not just in the United States, but in a number of developed economies. Moreover a number of studies have

shown that inflation had become less sensitive to the unemployment gap and to energy price shocks (e.g., Hooker (2002), Carlstrom and Fuerst (2008)).

Mishkin (2007) argues that given the importance of expectations in the standard new Keynesian Phillips curve model, "a natural first place to look for explanations of changing inflation dynamics is a possible change in the expectations-formation process." He argues that the anchoring in the inflation trend is due to anchoring of inflation expectations. He points to low and stable measures of inflation expectations. "With expectations of inflation anchored, any given shock to inflation—whether it is from aggregate demand, energy prices or the foreign exchange rate—will have a smaller effect on expected inflation and hence on trend inflation."

The Federal Reserve monitors three measures of inflation expectations: surveys of consumers, surveys of economists, and market-based measures (there is no survey of firms' inflation expectations in the United States).¹³ Each measure is only a noisy proxy for the underlying economic concept that ultimately matters: businesses' price-setting behavior.

Both the University of Michigan and the Conference Board compile consumer surveys, but judging from Fed speeches and meeting minutes, the Fed puts much more weight on the former. The Michigan one-year expectation spiked to 5.2% in May 2008, up almost two percentage points from the same month a year earlier. More importantly, consumers' long-run expectations—the amount they expect prices to rise over the next five to ten years—rose to 3.4%, from an average of about 3% over the prior five years (Figure 5.1). Given the stability of this series in prior years, this seemed like a plausible sign of deteriorating inflation expectations.

The Fed monitors two main surveys of economists: the Philadelphia Fed's Survey of Professional Forecasters (SPF) and confidential surveys of primary dealers. We discuss the SPF. The 10-year CPI forecast from the SPF, after dipping slightly in 2007, in the first half of 2008 rose to the same level it held at for most of the past decade (again see Figure 5.1). While the Fed put significant weight on this measure—it appears in its large-scale forecasting model FRB/US, for example—this survey too has disadvantages. It appears perhaps too stable, indicating forecast inertia rather than a super-credible central bank.

Finally, the Fed tracks measures of inflation expectations derived from the bond market by comparing nominal interest rates with rates on securities that are inflation protected. The 5-year, 5-years forward "breakeven rate" is its preferred benchmark (Figure 5.2). Breakeven rates carry two key advantages over surveys: they are timely, and they are based on market-transaction where substantial sums are resting on the implied forecasts. Deriving true inflation expectations from breakevens requires adjusting for premiums for liquidity, convexity and inflation risk.¹⁴ The 5-year breakeven estimate increased

¹³ This section draws heavily on Harris and Pandl (2008a, 2008b).

¹⁴ In October 31, 2008, the Cleveland Fed suspended posting its liquidity-adjusted inflation forecasts based on TIPS. According to announcement on its WWW page, "We have discontinued the liquidity-adjusted

relatively sharply during the first quarter of 2008. Yet, as of mid-June, 5-year breakeven estimate of expected inflation was about 2.5%, only slightly above their average since 2004. A big problem for the Fed was that it could not be sure how much of this move to the middle is due to expectations of rate hikes.

Outside the United States, what data is available suggests a pattern similar to the United States: expectations were well contained for most of the oil price run-up, but inched up in the summer of 2008. The UK breakeven estimate (Figure 5.2) had a steadier, and in 2008, a more considerable increase. Most countries have surveys of economists, many have surveys of consumers and least common are market-based measures of inflation expectations. For example, in the Euro area, a qualitative measure of consumers' 1-year inflation expectation is compiled monthly by the European Commission, but the answers generally track current headline inflation. The ECB asks economists to provide both inflation forecasts and the probability of inflation exceeding 2% for four or five years ahead. In the summer of 2008 the median long-term inflation forecast was stable at 1.9-2.0%—i.e. exactly matching the ECB's target of "below, but close to, 2%." However, the probability that inflation could be at 2.0% or above was rising: from 46.8% a year earlier, to 50.4% in the Q2 2008 survey to 56.9% in the Q3 2008 survey. Finally, the ECB publishes a seasonally adjusted 5y5y breakeven rate in its Monthly Bulletin. The rate moved above its long-term average (2.25%) at the end of 2007 and to above 2.50% in the summer of 2008.

5.2. Do oil prices move expected inflation: Empirical results

In this section, we present some direct evidence on the inflation expectations-oil price linkage. To do so, we estimate a simple time series model of expected inflation, actual inflation, and oil prices. We consider four different measures of expected inflation. From the University of Michigan Survey of Consumers, we use the median values of the annual percent change of expected price a 1-year and 5- to 10-year horizons. From the US nominal and inflation-protected Treasury yield curves, we use the implied breakeven inflation rates for 5-year ahead, 5-year inflation (horizon 5 to 10 years) and 10-year inflation (horizon 0 to 10 years). We do not perform an econometric analysis of the Survey of Professional Forecasters because it has so little movement.

The statistical model is specified as a recursive vector autoregression with core inflation ordered ahead of the expected inflation measure. The change in log nominal oil prices is treated as exogenous. The VAR is estimated with three lags. It is estimated using monthly data over the sample periods indicated in Table 5.1. The 1-year Michigan inflation expectations go back to the 1978, but we started the estimation in 1983 so that it applies to the post-Volcker deflation regime. The estimation period of the other series begins at different dates according to availability of data.

TIPS expected inflation estimates for the time being. The adjustment was designed for more normal liquidity premiums. We believe that the extreme rush to liquidity is affecting the accuracy of the estimates."

The first column of numbers in Table 5.1 shows the p-value for the test of the hypothesis that the coefficients of oil price change are jointly zero in the regression of expected inflation. The second column of numbers gives the results of the same test for the coefficients of core inflation. Oil prices are strongly significant in explaining the Michigan 1 year inflation expectations and moderately significant in explaining the Michigan 5-10 year inflation expectations and the 10-year TIPS implied inflation. They are not significant for the 5-year ahead, 5-year TIPS implied inflation, for which there is only a short sample. Core inflation also moves the Michigan expectations, though not too much should be made of this result because the estimated effects are quite small.

Figure 5.3 shows the historical contribution of oil price changes to the measures of expected inflation based on the estimated VAR and the historical series for oil prices. There are very significant moves down in the 1-year Michigan expected inflation coming from the collapse in oil prices in 1987 and the spike in oil prices at the time of the first Iraq war. The results thus illustrate that there is non-trivial response of this series to oil prices. In the 1990s, oil was on average a negative factor for inflation expectations. Toward the end of the decade, the drop in oil prices was an important contributor to the falling inflation expectations.

Our focus is the 2000s. Oil price changes significantly raised inflation expectations on average throughout the decade. Their effect on inflation expectations is not that persistent, so the volatility of oil price changes—despite the fairly persistent increases there were some declines—shows up in Figure 5.3. The response to oil price changes of the longer-horizon measures of inflation expectations have a similar pattern as the 1-year expectations, but the response of long-term expectations is much more muted. It is not surprising that the long-run inflation expectation measures move less than short-term ones. Nonetheless, it is important to note that long-term inflation expectations measures are not entirely anchored with respect to movements in oil prices.¹⁵

For the 5-year ahead TIPS expectation, the Fed's confidence that expectations were relatively well anchored has some justification. The 10-year TIPS expectation does suggest some persistent pass through of oil to headline inflation expectations. It is as if the markets are expecting—for the next five years that there would be more of the same experience as recently—that headline inflation would run high, but there was no longer-term shift in the inflation target.

The Fed tends to discount the Michigan inflation expectations result, in part because they are well known to react sharply to oil price changes in the way we document. One interpretation of these reactions is that household respondents put too much weight on prices they see frequently, e.g., gasoline. And that the boost that energy prices give to the survey measures of expectations subside once the price shock passes. We caution, however, against being overly dismissive of the household expectations data. While it is true that the 1-year expectations move up and down with oil, the 5- to 10- year

¹⁵ Using the Michigan survey data, Huang and Trehan (2008) conclude that inflation expectations are well anchored. Their setup and method of calibrating stability of expectations are quite different from ours, with one notable distinction that we include oil prices in our regressions and they do not.

expectations are smoother. The persistent increase in oil prices in the 2000s pushed up this longer-run measure of inflation expectations persistently. Moreover, Figure 5.3 shows that the consumers' survey responses and the 10-year TIPS estimate moved very similarly in response to the accumulation of oil price increases since 2002.

Thus, in a period such as we saw from 2002 to mid-2008, where oil prices caused headline inflation to run persistently ahead of core, there is a risk of expectations becoming unanchored. In the next section, we simulate a new Keynesian model to evaluate this concern.

5.3. Persistent oil price increases: simulated response

The findings of the previous section suggest that oil prices have a special role in inflation expectations and therefore the Fed, notwithstanding the implications of the benchmark model, might want to take into account oil prices directly, or headline inflation rather than core inflation, when setting interest rates. The results in the previous section are strictly empirical. The new Keynesian model presented in the Appendix also suggests to us that expectations about core inflation might become unhinged if there is a long sequence of positive shocks to energy. To explain this result requires that we briefly describe the model and some results.

Our model takes as its starting point a new Keynesian model found in texts such as Galí (2008, ch. 3) and Walsh (2003, ch. 5.4). In this starting point model, there is a composite consumption good. Labor is the only factor of production. The economy is closed. Our extension adds "energy" as a second consumption good and second factor of production. We assume that all energy is imported. Part of the good that we produce is used to pay for imported energy, with the remainder consumed. Trade is balanced every period. The real price of energy is exogenous. Households consume a Cobb-Douglas aggregate of energy and the good that we produce; firms produce with a Cobb-Douglas production function that requires labor and energy.

Most of the Appendix is devoted to documenting that this model strongly argues for targeting core rather than headline inflation. That is, when we make the domain of our analysis similar to that of earlier studies such as Bodenstein et al. (2008), Dhawan and Jeske (2007) and Duval and Vogel (2008), we find results similar to ones found in those studies. Let us first summarize this traditional domain, and then move to a non-traditional domain that involves a long sequence of positive energy price shocks. To make sense of the discussion requires introduction of a few elements from the model. The Appendix contains a complete discussion.

In our model, core inflation, which we denote π_{qt} , is simply inflation in the price of our produced good. Headline inflation is inflation in the market basket purchased by consumers. This market basket has a weight θ on energy, a weight 1- θ on our good. US data suggests that a plausible value of θ is low, perhaps as low as .02 if one interprets energy narrowly as direct purchases of oil and gas, but in any case not higher than .06 even if one interprets energy more broadly.

In any event, whatever the value of θ , headline and core inflation are related via

(5.1) $\pi_{ht} = (1-\theta) \times \pi_{qt} + \theta \times (\text{inflation in the price of energy}).$

We assume a simple monetary policy rule in which the interest rate responds only to a measure of inflation, with both core inflation π_{qt} and headline inflation π_{ht} considered candidate measures. If i_t is the interest rate, our two monetary policy rules are:

(5.2a) "target core": $i_t = 1.5\pi_{qt}$

or

(5.2b) "target headline": $i_t = 1.5\pi_{ht}$

These rules obviously are quite simple, but are adequate for our purposes. One novelty of our analysis relative to studies cited above is that we allow for a rich set of possible assumptions about stickiness and persistence of prices and wages; we experiment with 10 different sets of parameters in all. These various assumptions lead to similar conclusions. We noted in section 4.2 above that models such as ours suggest that welfare, measured as expected utility of a representative household, is a weighted sum of variances of measures of inflation and real activity. Smaller values imply higher expected utility. Which variances are appropriate depend on assumptions about price and wage stickiness. But in all 10 of our specifications all the relevant variances are smaller under core (equation 5.2a) than headline (5.2b) inflation targeting. Hence expected utility is higher under core than under headline inflation targeting: our model finds results found using similar models in the past. See the Appendix for details.

We bury the (lengthy) development and presentation of these results in the Appendix (sections A.1 through A.4), because the salient point of such results is that we are working with the type of model that has been used in the past to endorse a core rather than a headline inflation target. We now ask a question that, to our knowledge, has not been addressed with this class of models: What happens if there is a long series of generally positive shocks to energy prices?

To answer this question, we assume core inflation targeting (equation (5.2a)), on the presumption that core inflation has been the target for US monetary policy. One of the implicit maintained assumptions of the model is that expectations are model consistent and policy is credible; the public correctly understands the monetary rule and the inflation target (normalized to zero). In our view, that maintained assumption is called into question if core inflation is above target for an extended period of time. So, our question is: can a plausible series of energy price shocks push core above target for an extended period of time?

We constructed our series of energy price shocks as follows. We fit an AR(1) in the real oil price, quarterly (last month of quarter), 1983:2-2008:2. We used the 26 quarterly

residuals, 2002:1-2008:2, as shocks. As one might imagine, the residuals in this deliberately chosen period tend to be positive, with an average value of 7.4% (or about 30%, at an annual rate); 18 of the 26 residuals were positive, while only 8 were negative. We assume that we begin in the steady state of the model. We fed in this series of 26 shocks and ask how core inflation responds, for each of our 10 parameter sets.

The results varied somewhat across parameter sets. But in every parameter the response of core inflation was positive in every quarter. That is, core inflation was above target; the core price level (relative to the trend implied by the target inflation rate) rose monotonically through the 26 quarters. None of the 8 negative shocks to energy prices sufficed to move core inflation back to or below its target (steady state) value of zero for even a single quarter.

The actual numerical value of the rise varied from parameter set to parameter set. But the annual rate of core inflation was typically about 2%-4% above target. This range applies even if we truncate our sample a year or two prior to 2008:2. See Appendix section A.5 for more details.

Of course, the United States did not see core inflation at this level (2% to 4% above a target presumed to be around 1.75%) in the actual data. We noted above that core inflation remained stable (Figure 4.1 and associated discussion). Obvious reasons that our simulations say otherwise include that we start off the exercise with all variables (including core inflation and real activity) at steady state, that we are shutting down other shocks—no collapse in credit markets at the end of the sample in our exercise!—and that the model itself makes simplifying assumptions. But we take as the lesson of this calculation that even when expectations are well anchored, core inflation can and will accelerate if there is a long series of positive energy shocks. And in our view, such an event can plausibly be precisely the trigger for inflation expectations becoming unanchored, as indicated in the results in Section 5.2 and as noted in the quotation from Bean (2006) in Section 4.2.

6. MONETARY POLICY AND OIL PRICES, 2002-2008 AND BEYOND

6.1. Surging oil prices and monetary policy 2002 to 2007

The surge in headline inflation documented in the previous section provided a series of challenges to policy makers. Here we first consider the response to the steady rise through 2007 and turn to the boom into the summer of 2008. As we will see each stage of the oil price rise posed a unique challenge to central banks. Of course, we attempt to look at the episode with the information at hand in real time rather than 20-20 hindsight. Note that while we discuss the actions of other central banks, the Fed is at the center of our narrative and other banks are brought into the picture mainly for comparative purposes.

The chronically high headline created a problem for central banks regardless of whether their official target was core or headline inflation. An effective inflation target should be "transparent"—easily understood by the public—and achievable—so the public has confidence that deviations from plan are corrected in a reasonable period of time. The experience of this period illustrates that there is no "right" policy rule. On the one hand, chronic high headline inflation makes a core targeter look increasingly incredible. Hence as the commodity boom continued, a growing refrain in the press was that inflation was low as long as you didn't drive, heat your house or eat.

The Fed was on the defensive, explaining why the core was the right measure (and not some kind of dodge to avoid responsibility) and explaining why a growing list of inflation indicators—the dollar, oil and gold prices, real interest rates, etc—might not be good indicators of the underlying inflation risk. As we saw in the previous section, measures of inflation expectations suggest the Fed had not completely won the public relations battle. While most FOMC members seem to favor average inflation of less than 2%, economists, markets and the general public all expected, to varying degrees, that the Fed will on average overshoot its "target" in the decade ahead.

It is also worth considering the Fed's focus on the core in the context of the broader policy environment during this period. By the end of this period not only were there concerns about the persistence of headline inflation, but there were growing signs of a potential bubble in the housing and credit markets. None of these booms was unique to the United States—home prices boomed in many countries and the surge in oil prices seemed more correlated with the strength of emerging markets than the United States. Nonetheless, with its high sensitivity to oil and with a weak dollar, a case can be made that the Fed was too sanguine about the ongoing low core inflation. It seemed that the Fed was relying too much on its anti-inflation credibility and not enough on actual policy tightening.

Of course, with the collapse in oil prices and the jump in global spare capacity, we now know that much of the overshooting of headline inflation in the United States and Euro area is being reversed as of this writing (January 2009). The collapse of oil prices and of world-wide aggregate demand, however, was not built into expectation of central bankers even at the end of this period (summer of 2008). In forecasting oil prices, the Fed and many other central banks were assuming futures markets were as good as any forecast model, suggesting the prices of oil and other commodity prices would level off—not fall—in the years ahead. The committee wrote,

Rates of both overall and core inflation were expected to decline over the next two years, reflecting a flattening out of the prices of oil and other commodities consistent with futures market prices, slack in resource utilization, and longer-term inflation expectations that were expected to remain generally well anchored.¹⁶

¹⁶ Monetary Policy Report to Congress, July 15, 2008

www.federalreserve.gov/boarddocs/hh/2008/july/fullreport.htm.

The Fed and other central banks were also predicting only a modest rise in spare capacity, and that headline inflation would converge to a core level still at the upper end of their formal or informal targets (see Table 6.1 for FOMC projections). It remains an open question how the Fed and other central banks would have responded had inflation not collapsed as a result of the financial crisis.

In sum, the Fed may have overplayed its hand in trying to focus public attention on core rather than headline inflation. It ended up forgiving a significant stretch of above "target" inflation. As we will see, this legacy of persistently high headline inflation, added to the policy challenges in 2008.

It is worth asking: if the Fed was too complacent about high headline inflation, what should they have done differently? Some economists argue that the Fed should not have cut rates to 1% in 2003. But given the deflation risks at the time, this seems like an appropriate application of "risk management." A more appropriate criticism is that the Fed stuck to its "measured pace" tightening in the face of persistently high headline inflation, the signs of "froth" across the capital markets and the housing market, and the persistent increase in oil and other commodity prices. The slow and steady rise in rates from emergency low levels did not provide real restraint on the economy or asset markets. So our advice—based, we believe, on information available at the time rather than with hindsight—is that they should have put a bit of "fear of the Fed" into the market. Possibilities include mixing in a few 50 basis points hikes, speeding up the tightening process, and having a somewhat higher target rate at the end of the series of rate increases.^{17,18}

6.2. Oil and monetary policy in 2008

The final blowout boom in oil prices in 2008 provided an even bigger challenge to policy makers. How would the new generation of policy makers, with their commitment to targets and transparency, respond to the worst stagflationary environment since the 1970s? The oil surge not only added to building inflation pressure, but also added downside risks to a global economy already facing extreme economic and capital markets stress. At the time there was a hot debate among energy economists about how much of the increase was "fundamental"—limited supply and concerns about "peak oil"—and how much was "speculative"—driven by either investment flows or simply price-trend extrapolation. (See our discussion of oil valuation in section 3.) Regardless of the exact cause, the fact that the surge in oil prices was accompanied by a sign of weaker energy

¹⁷ See Taylor (2007), who presents a counterfactual simulation that suggests that such policies would have smoothed the up and down of the housing market.

¹⁸ Harris (2008) argues that the Fed's "open mouth operations" during this period also erred on the side of being too easy. Specifically, Chairman Greenspan and other Fed officials may have encouraged asset bubbles by arguing that the rise in prices was justified by economic fundamentals or by denying that a bubble could be identified. Harris concludes, "My advice to the Fed is simple. When asset markets are hot, do not add fuel to the fire by denying that a bubble exists or arguing that economic fundamentals are pushing up prices." Putting a new twist on an old expression, when it comes to a potential asset bubble, "If you don't have anything bad to say, do not say anything at all."

demand in the United States (and stable demand elsewhere) means that the shock clearly was not a signal of strong global demand.

Which risk was greater in the summer of 2008: an "ungluing" inflation expectations or an "ungluing" of the economy? More precisely, was there a greater risk that inflation expectations would rise and "reglue" at a stubbornly high level or that negative feedback loops would build, causing a "low growth equilibrium" or a "nonlinear break" in the economy. Furthermore, how did central banks handle the possibility of a bubble in the oil market?

In light of the collapse in capital markets, the economy and oil prices following the Lehman bankruptcy the correct policy choice in the summer of 2008 is obvious. In real time, however, there was a deep split in the economics profession about whether aggressive policy responses—including both big rate cuts from the Fed and financial sector bailouts in both Europe and the United States—were warranted and about the relative risks to growth and inflation of expansive monetary policy. Thus, oil prices and upward pressure on inflation expectations ended up being a sideshow in 2008 and for policy decisions for the foreseeable future. Nonetheless, it is useful to try to ascertain the lessons for inflation and monetary policy from this episode.

6.3. Pick your poison: oil prices, recession risks and inflation expectations

How serious was the recession risk from the vantage point of the summer? The consensus forecast in the spring and summer of 2008 was for weak, non-recessionary growth in the year ahead. For example, the consensus forecast in the July Wall Street Journal poll was for moderate growth and a gradual tightening of Fed policy. The market was even more confident that the Fed would be hiking rates (again see Figure 6.1). Outside the US forecasters were even more confident. In its July survey Consensus Economics was not expecting negative GDP growth in any of the countries covered. Central bank forecasts, where available, also assumed a relatively benign baseline.

Despite the optimistic baseline forecast, most economists saw major downside risks in the year ahead. The average forecaster saw a 63% chance that the economy would be in recession during the next 12 months (Figure 6.2). Despite a cut in the funds rate to just 2% and extraordinary efforts to open up the capital markets, there seemed to be a negative feedback loop between the economy, asset prices and credit. Credit spreads had stabilized following the resolution of Bear Stearns, but remained at recessionary levels; the Senior Loan Officer survey showed the fastest tightening in lending standards in the history of the survey; home prices were continuing to drop; financial institutions continued to report large loses and aggressive attempts to reduce leverage.

In the summer of 2008 there was a growing split in the central bank community about whether inflation expectations were becoming unglued or not. The audience at the Fed's Jackson Hole Conference in August 2008 seemed evenly split between those who were more worried about the credit crunch—most business economists and US central
bankers—and those worried more about rising inflation risks—most academics and European central bankers.

Within the Fed the easing back of the credit crisis, combined with signs of rising inflation expectations, unleashed a major debate between FOMC "hawks" and "doves." On the one hand, there were one or two hawkish dissents at each FOMC meeting through August 2008 and for the year as a whole there were the most dissents since 1992 (Figure 6.3); in speeches, hawks like Philadelphia President Plosser, argued that the "very accommodative stance" of policy would need to be reversed "sooner rather than later" (Plosser (2008)). Thus at the June FOMC meeting, "A significant majority of participants viewed the risks to their forecasts for output growth as weighted to the downside, and a similar number saw the risks to the inflation outlook as skewed to the upside." (Monetary Policy Report)

Despite the very vocal concerns of the hawks, the majority of the FOMC was not convinced that expectations were unglued (or at least not convinced that they were unglued "enough" to warrant hiking rates). In response to this hawkish rhetoric and growing expectations of rate hikes (Figure 6.1 above) both Vice Chairman Don Kohn and Chairman Bernanke gave speeches confirming that concerns about inflation expectations had risen, but not enough to trigger a rate hike. For example, in a speech on 10 June, Bernanke (2008) warned "The Federal Open Market Committee will strongly resist an erosion of longer-term inflation expectations, as an unanchoring of those expectations *would be* destabilizing for growth as well as for inflation" (emphasis added). Reading the sentence carefully, he was talking about a hypothetical situation when he said that unanchored expectations "would be destabilizing." Testifying to Congress on July 15-16, Bernanke was noncommittal: "balancing the risks to the outlook for growth and inflation is a significant challenge."

Was this just wishful thinking? Should the Fed have moved from "open mouth operations" to actual policy tightening? While inflation expectations were clearly rising in the summer of 2008, this does not necessarily mean that they were becoming "unglued." If inflation expectations were reacting to current inflation in a "linear" fashion and if inflation was likely to fall in the coming year, then the rise in expectations should not have been a concern. This is the case if either there was a bubble in energy prices or if prospective weak economic growth was likely to bring down inflation.

The ECB, viewing the world rather differently from the Fed, did tighten in the summer of 2008. In our view, this was a bit of overkill since growth was already weakening rapidly. On the other hand, the ECB correctly worried about its credibility in 2005 and 2006— after all, it is a relatively new central bank and its official target was headline inflation.

While it is a tough judgment call, and it is hard to avoid creeping 20-20 hindsight, we think the Fed's decision to remain on hold in the summer of 2008 was correct. The risk of a nonlinear break in the economy diminished in the earlier part of the summer, but remained a major risk. Moreover, if the Fed never draws on its reservoir of anti-inflation

credibility, then it is of no value. A point in time when there was serious risk of a sharp economic downturn is the right time to use that capital.

Before we conclude this discussion of policy, it is worth drawing a few lessons from the emerging market economies' policy response to rising energy and headline inflation, in both the early and late parts of the period of rising oil prices.

In section 3 we argued that emerging market economies accounted for most of the demand surge that drove oil prices higher. We also noted that EM economies—particularly in Asia—benefited the most from the recycling of petro dollars. It is perhaps then not surprising, as we argued above, that there were signs of overheating in the emerging markets as early as 2007 and by 2008 a serious inflation problem was brewing. In a large measure this reflected an unwillingness to take politically tough decisions. A number of economies tried to control inflation with price controls on the offending items. As Figure 6.4 shows, real central bank interest rates remained unusually low as resource utilization surged and inflation rose. It is hard to escape the idea the emerging markets were "saved" from inflation by the capital markets crisis.

This also colors the way we see the developed economies. The surge in oil prices globally was due to a tepid supply response in the face of very strong demand from emerging markets. Thus if easy monetary policy contributed to the oil price boom, most of the excess ease came from emerging markets, not the United States and certainly not Europe, where core inflation was never a real concern. This raises a sticky question for policy makers: what should central bankers do if other central bankers are making a policy mistake? If we put aside possible cooperative or non-cooperative aspects to policy, such as "jawboning" monetary policy makers in other countries, we have given our policy prescription above: central banks should tighten if this is needed to keep inflation expectations under control.

7. CONCLUSION

The seven-fold increase in oil prices from the beginning of 2002 to the peak in July 2008 rivals the increases experienced in the 1970s in magnitude, though not in speed. The increases in oil prices in the 1970s came in two, sharp episodes. The increases this decade were the results of a sustained series of increases over a six and a half year period.

The movements in oil prices are driven by many factors affecting supply and demand. The intertemporal linkages of oil through the exhaustible resource constraint mean that oil behaves like an asset. Perceptions of changes in the supply and demand balance over a long horizon can lead to substantial swings in the current price of oil. Yet, oil is an industrial commodity subject to increasing marginal cost of extraction, delivery, storage, and so on that can place a wedge between the long-run valuation of oil in the ground and the price of delivered oil. These considerations imply that flow supply and demand considerations can move oil prices substantially.

This theoretical point is critical for understanding elements of the run-up in oil prices, but especially for explaining its collapse since the middle of 2008. Absent factors that detach

the spot market from the long run supply/demand equilibrium, even a business cycle event such as currently unfolding should not have much effect on the equilibrium price of a storable asset. That prices moved down so sharply in the second half of 2008 in response to the slowdown in industrial demand for oil implies that the equilibrium had been in the region of very steeply sloped costs of extraction and distribution.

Our analysis supports an emerging consensus among macroeconomists expert in oil— Hamilton (2009a, 2009b), Kilian (2008, 2009)—that a proper accounting for the sources of fluctuations in the oil market is critical for understanding the behavior of prices in the 2000s. In particular, strong world-wide aggregate demand is the main ingredient to understanding the sustained increase in the price of oil from 2002 to mid-2008. Our analysis emphasizes that global supply and demand conditions determine the price of oil, and points to very strong demand from emerging markets as a principal factor in the rise in oil prices. This demand emanated from real factors associated with emergence of China and India as economic powerhouses and with the recovery of emerging economies from the crises of the late 1990s. We also highlight that this emerging market growth was strongly accommodated by expansionary monetary policy. Emerging market policy rates were low throughout this period.

Supply factors did not cause spikes in prices owing to geopolitical shocks (although uncertainty about security in the Middle East certainly contributed to fluctuations in price during the decade). Of course, oil prices are determined in equilibrium. The trend in non-OPEC supply flattened during this period and incremental fields in Saudi Arabia and elsewhere looked like they would be more expensive to exploit in the longer run. So with strong emerging market demand, it was reasonable to be forecasting a higher equilibrium price for the long run.

The increases in oil prices this decade occurred during a period where inflation was low, inflation expectations were relatively well anchored, and where the credibility of the Fed and other developed-economy central banks was high. This macroeconomic environment shaped the Fed's response to the oil price increases during the 2000s. In particular, the Fed was targeting core inflation. Moreover, because core inflation was contained, it maintained low interest rates for a longer period coming out of the 2001 recession than it might otherwise have, and stopped raising interest rates earlier (or stopped at a lower level) than it might have had it put more weight on headline inflation.

To be sure, the policy of targeting core inflation and therefore letting oil price increase pass through to the level of headline prices is the optimal response to an exogenous change in oil prices in the benchmark new Keynesian model. In that model, prices and wages are sticky, so that it is efficient to not force prices down when a flexible price or a price determined in world markets jumps up. This policy recommendation is confirmed by our analysis of a new Keynesian model modified to allow for an external oil sector. It is also essentially the same policy recommendation made by Solow (1980) using an aggregate supply, aggregate demand framework. Notwithstanding the recommendation implied by the benchmark model, we believe that the Fed should have put more weight on the increases in headline inflation this decade when formulating its policy. That is, the Fed should have paid some attention to the signals coming from oil prices and raised interest rates faster and higher than it did in 2004 to 2006. Why do we make this policy recommendation despite the implications of the model? The model assumes that inflation expectations are completely anchored. This paper presents two lines of analysis that suggest that relying too strongly on this feature of the model is risky for policy makers.

First, inflation expectations increase when oil prices increases. One-year ahead price change expectations by consumers respond quite strongly to changes in oil prices. Longer-term consumer expectations and longer-term expectations from inflation-linked also respond somewhat to oil. Perhaps these responses are excessive. Perhaps they are too much conditioned on an historical correlation that is not warranted given the current policy regime. Nonetheless, the Fed should not lightly ignore these findings given that the assumption of anchored expectations is critical for the optimality of allowing oil price increase to pass through to headline prices.

Second, even within the model that presumes anchored inflation expectations, core inflation will increase substantially if there is a sequence of shocks to oil prices such as we saw in 2002 to 2008. Our simulations show that core inflation can rise in response to the sequence of oil price shocks the US economy experienced. Thus, the model lends some credence to the nervousness of the public about how oil feeds inflation. That is, it is very hard for the public to sort out a sustained increase in headline inflation that comes from a sequence of positive oil price shocks from a shift in the target inflation rate.

Oil prices, of course, were only one of the signals in the 2002-2006 period that got discounted with the Fed's focus on core inflation and its containment. The emphasis on core instead of headline inflation pushed policy in the same direction, i.e., a level of comfort with sustained low interest rates, than did the Fed's willingness to discount asset and housing market price boom as long as core inflation was contained.

Finally, notwithstanding our recommendation that the Fed put somewhat more weight on movements in oil prices, especially when they lead to a sustained excess of headline over core inflation, we endorse the Fed's decision to cut the Funds rate once the magnitude of the shock to housing was apparent. Oil prices were still increasing, and headline inflation was not decelerating. We believe, however, that the balance of risks had shifted sharply toward recession by fall 2007, and therefore overrode the concern that inflation pressure was building. Had that shock not occurred, however, we believe that the US was at substantial risk of seeing a sustained increase in inflation going forward.

Appendix A SMALL SCALE NEW KEYNESIAN MODEL

In this section, we develop a small scale model to aid in interpretation of questions related to oil and monetary policy. This model adds imported energy to baseline models such as the ones developed in textbooks such as Woodford (2003) and Galí (2008). Our analysis proceeds in traditional calibrated fashion, and should be considered a complement to the empirical and narrative work presented in other sections of our paper. Section A.1 presents the model, section A.2 the parameter values that we choose in our calibration. Because the basic setup is familiar, we skip over many details.

A key question in our analysis is the contrast between headline and core inflation targeting. Sections A.3 and A.4 focus on this contrast. In section A.3 we present some impulse responses for a relatively simple parameterization of the model, comparing the responses under headline and core inflation targeting rules. In section A.4 we use the model to compute how standard deviations of certain variables vary with the targeting rule. We find that headline inflation targeting leads to an increase in volatility of all the variables that figure into welfare calculations in analyses such as Woodford (2003). Hence we conclude, as did Bodenstein et al. (2008), Dhawan and Jeske (2007) and Duval and Vogel (2008), that core inflation targeting is preferable.

In section A.5 we put aside headline inflation targeting, on the belief that core inflation targeting better characterizes U.S. monetary policy. We feed in a series of energy price shocks matched to ones realized in 2002-2008, and ask how core inflation will respond. We find that core inflation accelerates, and substantially. We interpret this as raising doubts about the reasonableness of the model's assumption that expectations are model consistent.

A.1 Model

We add imported energy to an otherwise familiar model. We assume a representative agent economy in which firms combines labor (N) and energy (E) to produce a single good (Q) that is either consumed or exported to pay for imported energy. All energy is imported. Trade is balanced each period. The real price of energy is exogenous, and is the only shock whose effects will be analyzed.

Notation: In general, upper case values denote levels, lower case values denote logs. Throughout, inessential constants are omitted. Table A.1 lists parameters, along with parameter values whose rationale will be presented in section A.2 below. Define:

(A.1a) N_t : labor supplied by households, used in production;

(A.1b) C_{qt} : household consumption of the produced good Q;

(A.1c) *C_{et}*: household consumption of energy;

(A.1d) E_t : energy used by firms in production;

(A.1e) P_{qt} , P_{et} : nominal price of the produced good and of energy;

(A.1f) $\psi_t = \log \text{ real price of energy} = \ln(P_{et}/P_{qt});$

(A.1g) $\omega_t = \log \text{ real wage} = \ln(W_t/P_{qt})$, where $W_t = \text{nominal wage}$;

(A.1g) $\pi_{qt} = \ln(P_{qt}/P_{qt-1}) = \text{core inflation};$

(A.1h) $\pi_{wt} = \ln(W_t/W_{t-1}) =$ wage inflation;

(A.1i) Q_t = real gross output.

The model is standard, apart from the use of energy as a factor of production. We assume the usual continuum on [0,1] of monopolistically competitive firms that produce differentiated products. Household consumption C_{qt} is the usual Dixit-Stiglitz aggregate of these differentiated products. Prices and wages are sticky, and are reset in Calvo fashion with probabilities $1-\xi_p$ and $1-\xi_w$ respectively. Prices and wages that are not reset may be indexed to the general rate of price or wage inflation. Firms take as given wages and the price of energy. The latter is assumed to evolve exogenously. A complete derivation would begin by indexing firms and households by *i* and *j* ($0 \le i \le 1$, $0 \le j \le 1$), and derive a set of first order conditions. The next step would be to make suitable assumptions about markets in state contingent claims, and then aggregate to obtain variables that are functionally the same as individual firm and household variables, but without the firm and household subscripts. Because this derivation is familiar (see references above), we simply present the aggregate relations that result.

The household's per period utility function is separable in consumption and leisure, with consumption C_t a Cobb-Douglas aggregate of C_{qt} and C_{et} :

(A.2) per period utility = $\ln(C_t) - f_n(1+\gamma)^{-1}N_t^{1+\gamma}$, $C_t = C_{qt}^{1-\theta}C_{et}^{\theta}$.

The parameters satisfy $0 \le \theta < 1$ and $\gamma > 0$, $f_n > 0$. The household's discount factor is β . Households take as given all prices.

The gross output production function is isoelastic in labor and energy:

(A.3) $Q_t = A_t N_t^{\alpha n} E_t^{\alpha e}, 0 < \alpha_n, \alpha_e < 1, 0 < \alpha_n + \alpha_e \le 1.$

In (A.3), A_t is productivity, assumed to evolve exogenously, and held constant in the analyses that we complete.

First order conditions for the firm include ones that state that the real marginal revenue product of each factor equals its real cost. Given the production function (A.3), these conditions may be written:

(A.4)
$$\alpha_e(Q_t/E_t) = M_t(P_{et}/P_{qt}),$$

(A.5) $\alpha_n(Q_t/N_t) = M_t(W_t/P_{qt}),$
 $M_t = \text{markup}.$

We temporarily put aside presenting other first order conditions to log linearize an identity that will be used to solve our log linear model. The identity for nominal gross output is

(A.6)
$$P_{qt}Q_t = P_{qt}C_{qt} + P_{et}C_{et} + P_{et}E_t.$$

In light of the utility function (A.2), the first two terms on the right hand side of (A.6) may be written

(A.7)
$$P_{qt}C_{qt} + P_{et}C_{et} = (P_{qt}^{1-\theta}P_{et}^{\theta})C_t$$
.

Substitute (A.7) into (A.6), use (A.4) to eliminate E_t from (A.6), and divide through by P_{qt} . Take logs, recall that $\psi_t \equiv \ln(P_{et}/P_{qt})$, that lower case values denote logs, and, as always, omit constant terms. The result is

(A.8)
$$q_t = c_t + \theta \psi_t - \ln[(M_t - \alpha_e)/M_t].$$

Let

(A.9) \overline{M} = steady state value of M_t , $\mu_t = \ln(M_t)$, $\zeta = \alpha_e / (\overline{M} - \alpha_e)$.

Then a log linearization of the last term on the right hand side of (A.8) leads to

(A.10) $q_t = c_t + \theta \psi_t - \zeta \mu_t$.

Recall that the log of the markup is the negative of the log of real marginal cost, call it mc_t . Hence (A.10) can be written

(A.11) $q_t = (1-\theta)c_{qt} + \theta c_{et} + \theta \psi_t + \zeta m c_t$,

where (A.2) has been used to write $c_t = (1-\theta)c_{qt} + \theta c_{et}$.

Equation (A.11) is one of 10 equations that determine the 10 endogenous variables q_t , c_{qt} , c_{et} , n_t , ω_t , e_t , mc_t , π_{qt} , π_{wt} and i_t , where i_t is the nominal interest rate. Three first order conditions from the household include

(A.12)
$$c_{et} = c_{qt} - \psi_t$$
,
(A.13) $\pi_{wt} - d_w \pi_{wt-1} = \beta \mathsf{E}_t (\pi_{wt+1} - d_w \pi_{wt}) + \lambda_w (c_{qt} + \gamma n_t - \omega_t), \lambda_w = (1 - \xi_w)(1 - \beta \xi_w) / [\xi_w (1 + \eta_w \gamma)]$,
(A.14) $c_{qt} = \mathsf{E}_t c_{qt+1} - \mathsf{E}_t (i_t - \pi_{qt+1})$.

In (A.13), (A.14) and in the remainder of this section E_t is mathematical expectations, and is not to be confused with the level of energy E_t used in production. For energy used in production, we shall henceforth need to reference only the log e_t but not the level. We trust that using E_t in this way will cause no confusion.

Equation (A.12) states that the marginal rate of substitution between the two consumption goods (Q and energy) equals the relative price ψ_t . Equation (A.13) describes wage setting under the assumption of Calvo pricing and wage indexation. The parameter d_w $(0 \le d_w \le 1)$ is the degree to which wages are indexed to the previous period's rate of wage inflation. The formula for λ_w reflects: the household's rate of time preference β and labor supply elasticity γ (see A.2); the probability that a given wage will not change in a given period (apart from automatic indexing) ξ_w ; the elasticity of substitution across labor varieties η_w . The scale variable $c_{qt} + \gamma n_t - \omega_t$ is the gap between (a)the marginal rate of substitution between consumption of our produced good and leisure, and (b)the real wage. (See Galí (2008, ch. 6) and Woodford (2003, ch. 3) for the derivation of equation (A.13).) Finally, equation (A.14) states that the household does not expect to be better off by consuming one fewer unit of Q today, lending at rate i_t and consuming the proceeds tomorrow. (The intertemporal condition (A.14) of course also holds for c_{et} and c_t ; for the purpose of our solution, it is most convenient to express it in terms of c_{qt} .)

Four conditions from the production side of the model are

(A.15)
$$q_t = a_t + \alpha_n n_t + \alpha_e e_t$$
,
(A.16) $\omega_t + n_t = \psi_t + e_t$,
(A.17) $\pi_{qt} - d_p \pi_{qt-1} = \beta \mathsf{E}_t (\pi_{qt+1} - d_p \pi_{qt}) + \lambda_p m c_t$, $\lambda_p = [(1 - \xi_p)(1 - \beta \xi_p)/\xi_p]$,
(A.18) $mc_t = -q_t + [\alpha_n/(\alpha_n + \alpha_e)](\omega_t + n_t) + [\alpha_e/(\alpha_n + \alpha_e)](\psi_t + e_t)$.

Equation (A.15) is the logarithmic version of the production function (A.3), while (A.16) follows from (A.4) and (A.5). Equation (A.17) results from the assumption of Calvo pricing. In this equation, d_p , $0 \le d_p \le 1$, is the degree to which prices are indexed to the previous period's aggregate inflation rate and ξ_p the probability that a firm will not be able to change its price (apart from automatic indexing).¹⁹ Finally, (A.18) is one way of writing the standard expression of marginal cost for our production function.

An identity ties price and wage inflation to the increase in the real wage

(A.19)
$$\omega_t = \omega_{t-1} + \pi_{wt} - \pi_{qt}.$$

In addition to (A.11)-(A.19), our tenth and final equation is a monetary policy rule. We assume a very simple rule in which the monetary authority responds to core or headline inflation:

- (A.20a) $i_t = f_{iq}\pi_{qt}$, or
- (A.20b) $i_t = f_{ih}\pi_{ht}$.

In (A.20b), π_{ht} is headline inflation. Because the share of energy in consumption is θ , headline and core inflation are related via

(A.21) $\pi_{ht} \equiv \pi_{qt} + \theta \Delta \psi_t \equiv (1 - \theta) \pi_{qt} + \theta \Delta p_{et}$.

¹⁹ Our formula for λ_p omits Galí's (2008) and Blanchard and Galí's (2007) adjustment term that accounts for decreasing returns to scale. One can think of a fixed capital stock with share $1-\alpha_n-\alpha_e$ operating in the background, as in Erceg et. al (2000) or Bodenstein et al. (2008), in which case the dynamics of the model are unchanged. Alternatively, were we to insert the adjustment, numerical results would be unchanged were we to simultaneously decrease the calibrated value of ξ_p modestly.

We consider policies in which f_{ih} (when core inflation is the target) or f_{iq} (when headline inflation is the target) is sufficiently large to deliver a stationary solution. The monetary policy rules (A.20a,b) omit the output gap, interest rate smoothing and a shock for simplicity. Because, as well, we focus on the effects of energy price shocks, we hold constant the productivity shock a_t in (A.15).

We assume that the real energy price ψ_t follows a stationary AR(1) processes,

(A.22) $\psi_t = \rho_{\psi} \psi_{t-1} + \varepsilon_{\psi t}$, $\varepsilon_{\psi t} \sim \text{i.i.d.}$ with finite variance, $|\rho_{\psi}| < 1$.

A.2 Parameter Values

We experiment with 10 sets of parameters, constructed as: 5 sets of non-energy parameters, with each set paired with two sets of energy parameters. In these 10 sets, we experiment with both headline and core inflation targeting. We assume that the period in the model corresponds to a quarter.

Table A.1 lists parameter values. We divide them into three categories. The first category, listed in panel A in the table, are parameters that are held constant across all parameter sets. With one exception, these are parameters that relate neither to wage or price stickiness nor to energy. The quarterly discount factor β is set to 0.99, the Frisch labor elasticity γ to 1.0, labor's share in the production function α_n to 0.7, the elasticity of substitution across labor and across varieties to 6.0, and the steady state markup \overline{M} to 1.2. The only wage or price parameter held fixed across parameter sets is the probability of not being allowed to reoptimize one's price ξ_p , which is set to 0.67. This implies a mean price duration of 3 quarters.

The monetary policy parameter is set to 1.5 on the measure of inflation being targeted. That is, the core and headline targeting rules are

(A.23a) $i_t = 1.5\pi_{qt}$,

(A.23b) $i_t = 1.5\pi_{ht}$.

Our second category of parameters relates to wage and price stickiness. We experiment with five different assumptions about such stickiness, because related research using similar models has found that the model's behavior is sensitive to such assumptions (Blanchard and Galí (2007), Duval and Vogel (2008)), though in the end we found little such sensitivity to the answers to the questions that we consider. The five assumptions are associated with five parameter sets labeled A through E, and described in panels B and C of Table A.1. Parameter set A assumes flexible wages and no indexation of wages

and prices, and hence matches the model exposited in textbooks. Parameter set B introduces sticky wages. The assumed degree of stickiness matches that of prices, with the probability of not being able to reoptimize ξ_w set to 0.67. Parameter sets C through E maintain the same assumptions about ability to reoptimize prices or wages, i.e., $\xi_p = \xi_w = 0.67$. Parameter set C assumes full price indexation but no wage indexation, D assumes full wage indexation but no price indexation, E assumes full price and wage indexation. Recent empirical work has found that similar models fit U.S. data best if they have full wage and price indexation (Giannoni and Woodford (2004), Christiano et al. (2005)). Hence parameter set E is perhaps the one that generates the most realistic results.

The third and final category of parameters relates to energy. We experiment with two different assumptions about energy. The two assumptions are associated with parameter sets labeled 1 and 2, and are described in panel D of Table A.1. Parameter set 1 makes low end assumptions about the importance of energy, while parameter set 2 makes high end assumptions. The share of energy in consumption θ is set to match approximately one of the following averages: the share of gas and oil consumption in total consumption in 1990s (parameter set 1, θ =0.02); the share of total energy in consumption, in the 1980s and mid 2000s (parameter set 2, θ =0.06). Energy's share in the production function α_e is similarly set to either the low ($\alpha_e=0.01$, parameter set 1) or high ($\alpha_e=0.02$, parameter set 2) of observed shares of energy in gross output in the 1997-2007 period. The values in parameter set 1 are similar to those chosen in Blanchard and Galí (2007, p48), those in parameter set 2 (column (5)) similar to ones Bodenstein et al. (2008, p17) (with some slippage in both cases because our model is not identical to either of these). The AR coefficient for the evolution of the real oil price ρ_{ψ} is set to 0.97, which is the estimated AR(1) coefficient using quarterly (last month of quarter) of the log real oil price (West Texas intermediate relative to CPI ex food and energy), 1983:O2-2008O2.

We reference a complete parameter set by combining an assumption about wage and price stickiness with an assumption about the importance of energy. For example, parameter set A1, whose impulse responses are shown in the next section, assumes price stickiness but no wage stickiness and no price or wage indexation, along with the low end assumptions about the importance of energy.

A.3 Impulse Response to an Energy Price Shock, Parameter Set A1

We use the model to examine the impact of a 10% increase in the real oil price ψ_t , in parameter set A1. The pictures of responses for parameter set A2 (not displayed) have the same shape, but, unsurprisingly, are larger in magnitude. We comment briefly below on impulse responses when parameter sets B through E are used.

The path of the energy price shock is presented in Figure A.1F. By assumption, this exogenous shock declines monotonically at a rate of .97 per quarter. This is the *only* one of the impulse responses that is not annualized.

In terms of endogenous variables, we present responses of the headline inflation (Figure A.1A), core inflation (Figure A.1B), the interest rate (Figure A.1C), consumption relative to flexible price consumption c_t^* (Figure A.1D) and consumption c_t (Figure A.1E). We multiply the model's responses by 4 to present results at annual rates. We use consumption as our measure of real activity (recall that nominal final sales equals nominal consumption), c_t relative to c_t^* as an indicator of both the welfare effects of policy and the state of excess demand. Each figure has the response under core and under headline inflation targeting. We first work through the response under a headline inflation target.

By assumption, the share of energy in consumption is 2% (θ =0.02). Thus, absent any response from the economy, the presumed 10% increase in energy price would result in a 0.2% increase in headline inflation, or a 0.8% at an annual rate. We see in Figure A.1A that when headline inflation is targeted, the actual increase is about 0.55%. Why is the increase less than 0.8%? In short, this is because an induced rise in the interest rate puts the economy into recession, thus dampening the incipient increase in inflation. Specifically: in accordance with equation (A.23b), we see in figure A.1C that the interest rate that corresponds to a .55% rise in headline inflation is one of about $1.5 \times 0.55 \approx 0.85\%$. We see in figure A.1D that .85% interest rate hike caused $c_r - c_t^*$ to fall by .7%. The Phillips curve (A.17) incorporated in the model yielded slackening of inflation. As we have seen, the incipient rise in headline inflation of .8% instead turned into an actual increase of .55%; we see in Figure A.1B that core inflation actually fell by about .25%.

In subsequent periods, the energy price slowly reverts to its original level. There was slight continued inflation as measured by either core or headline, again via the Phillips curve. Clearly the dynamic response in periods 1, 2, ... is, well, not very dynamic: simply adding energy to the baseline New Keynesian model does not change the fact that this baseline does not have interesting dynamics in response to AR(1) shocks. But this does not mean that there are no lingering effects from the oil price shock. Note in particular (Figure A.1E) that consumption is still about 1.2% (annualized) below steady state in period 1. Consumption returns only slowly to its pre-shock value.²⁰ Note as well that although a fall in consumption is desirable following a positive energy price shock, headline targeting causes consumption to fall well below c_t^* (Figure A.1D).

Turn now to core inflation targeting. The enormous 10% jump in energy prices causes little direct movement in core inflation, since energy prices are such a small part of core (Figure A.1B). Hence when core is targeted, interest rates move hardly at all (Figure A.1C). The slight movement in core inflation does, via the Phillips curve, cause a slight uptick in consumption relative to c_t^* , though the magnitude is so small that in Figure A.1D it looks as if c_t - c_t^* stays at zero. Nevertheless, c_t - c_t^* is positive, and slowly decays back to zero. As well, core and headline inflation and interest rates stay above steady state, and slowly decay back to zero (Figures A.1A, A.1B, A.1C).

²⁰ Apart from the effects of price stickiness (which are small, from period 1 forward), the model implies that consumption will fall by $[\alpha_e/(1-\alpha_e)]+\theta$ times the shock in oil prices. Since $[\alpha_e/(1-\alpha_e)]+\theta \approx .03$, consumption falls by about .3% on a quarterly basis, or 1.2% when annualized.

The story is similar in other parameter sets, though indexing of prices or wages leads to smaller initial responses and distinctly more persistence. For example, when prices and wages are both indexed (parameter set E), there is a hump shaped response of core inflation π_{qt} under both targeting rules. But all the pictures suggest, as do Figures A.1B, A.1C, A.1D and A.1E, that headline inflation targeting increases volatility, with the possible exception of volatility in headline inflation itself.

We acknowledge that had we included interest rate smoothing in the monetary policy rule, the responses we saw in the Figures for parameter set A1 would likely be muted, making the core and headline targeting rules behave more similarly on impact. But of course the differences between the two rules would also be more persistent.

A.4 Relative Volatility of Headline and Core Inflation Targeting

For each of our 10 parameter sets (A1, A2, B1, ..., E1, E2) we computed the relative standard deviation of each variable, under the assumption that the only source of volatility is energy price shocks. Since this is a relative calculation, we do not have to take a stand on the size of the standard deviation of $\varepsilon_{\psi t}$ (the shock to the energy price, see equation A.22): the ratio is the same regardless of this value.

Of course, other exogenous shocks—to technology or monetary policy, in our model cause volatility as well. But absent shocks to energy prices, headline and core inflation targeting rules are identical. This means that impulse responses to other shocks, and hence volatility due to other shocks, will be the same under the two targeting rules (under the assumption that energy shocks are independent of other shocks.) Hence if energy price shocks cause the standard deviation of a variable, say core inflation π_{qt} , to be higher under headline than under core inflation targeting, then the standard deviation would also be larger if we were recognize that other shocks also affect volatility.

Table A.2 present some results on volatility. In the Table, *y* means that the volatility of the indicated variable was higher under headline inflation targeting, *n* when it was lower. As can be seen, with occasional exceptions for headline inflation π_{ht} itself, core inflation targeting resulted in lower volatility. This is of course clear in the impulse responses presented above.

The variables listed in the Table were chosen largely in light of the welfare analyses in Erceg et al. (2000), Woodford (2003) and Giannoni and Woodford (2004). If we were to remove energy from the model, these authors suggest that welfare measures would be weighted sums of the variances of the following variables: parameter set A: price inflation and $c_t - c_t^*$; B: price inflation, $c_t - c_t^*$ and wage inflation; C: the change in price inflation, $c_t - c_t^*$ and the change in wage inflation; E: the change in price inflation, $c_t - c_t^*$ and the change in wage inflation. (In equilibrium, in the model without energy, $c_t - c_t^*$ is equal to the output gap.) The

preponderance of y's in Table A.2 suggests that targeting core inflation is preferable from a welfare standpoint.

Whether the welfare gain is large or not of course depends on how important energy shocks are for overall volatility.

A.5. Response to a Long Series of Positive Energy Price Shocks

We close by using the model to consider what happens to core inflation if there is a long series of positive energy price shocks. We assume core but not headline inflation targeting, on the presumption that core inflation has been the target for U.S. monetary policy. One of the implicit maintained assumptions of the model is that expectations are model consistent and policy is credible; the public correctly understands the monetary rule and the inflation target (implicitly subtracted from the inflation rate, since all variables, including inflation, are expressed as deviations from mean). In our view, that maintained assumption is called into question if inflation is above target for an extended period of time.

We constructed such a series of energy price shocks as follows. We used the sample also used to calibrate the AR(1) parameter for the energy shock in the model, i.e., an AR(1) in the real oil price, quarterly (last month of quarter), 1983:2-2008:2. We used the 26 quarterly residuals, 2002:1-2008:2, as shocks. As one might imagine, the residuals in this deliberately chosen period tend to be positive, with an average value of 7.4% (or about 30%, at an annual rate); 18 of the 26 residuals were positive, while only 8 were negative. We assume that we begin in the steady state of the model. We fed in this series of 26 shocks and ask how core inflation responds, for each of our parameter sets.

For a given set of assumptions about wage and price stickiness (i.e., choice of parameter set A, B, C, D or E), the response was of course smaller for parameter set 1 than parameter set 2. For a given choice of parameter set 1 or 2, responses in parameter set A (no wage stickiness) were distinctly smaller than in other four parameter sets, which were broadly similar. But in every parameter set (including parameter set A), the response of core inflation was positive in every quarter. That is, the core price level rose monotonically through the 26 quarters, relative to the trend implied by the target inflation rate. (Recall that all variables, including inflation, are measured relative to their mean; the mean value of inflation is the target value of the monetary authority.) Thus this implies inflation in excess of target in a string of 26 consecutive quarters. None of the 8 negative shocks to energy prices sufficed to move core inflation back to or below its target (steady state) value for even a single quarter.

End of period values for cumulative inflation (relative to the trend implied by target inflation) and average annual inflation (again relative to target) are given in Table A.3 Parameter sets B through E implied end of period cumulative increase in core prices of about 15-20% when parameter set 1 was used, 30%-40% when parameter set 2 was used. For example, in parameter set E2, core prices rose (cumulatively) by 21.1% by 2006:4,

26.1% by 2007:4 and 32.2% by 2008:2. If we divide by the number of years corresponding to the length of the sample (e.g., by 6, if the ending point is 2007:4), we find that core inflation averaged 4.3% per year. The figure for parameter set E1 is 2.2% per year.

Of course, the U.S. did not see core inflation at this level in the actual data. Obvious reasons include that that we are starting off the exercise with all variables (including core inflation) at steady state, that we are shutting down other shocks—no collapse in credit markets at the end of the sample in our exercise!—and that the model itself makes simplifying assumptions. But we take as the lesson of this calculation that even when expectations are well anchored, core inflation can and will accelerate if there is a long series of positive energy shocks. And such an event can plausibly be precisely the trigger for inflation expectations becoming unanchored.

(1)	(2)	(3)	(4)
Parameter	Description	Eq'n No.	Value
β	subjective discount factor	n.a.	0.99
γ	Labor supply elasticity	A.2	1.0
α_n	labor share in production function	A.3	0.7
η_w	elasticity of substitution across varieties of labor	A.13	6.0
\overline{M}	steady state markup	A.9	1.2
ξp	prob. of not changing price	A.17	0.67
f _{ia}	weight on core inflation, when that is the target	A.20a	1.5
fih	weight on headline inflation, when that is the target	A.20b	1.5

A. Parameters Held Fixed in All Specifications

B. Description of Parameter Sets

А	sticky prices, flexible wages, no indexation of wages or prices
В	sticky prices and wages, no indexation of wages or prices
С	sticky prices and wages, indexation of prices but not wages
D	sticky prices and wages, indexation of wages but not prices
E	sticky prices and wages, indexation of both wages and prices

C. Other Non-Energy Parameters

(1)	(2)	(3)			(4)		
Parameter	Description	Eq'n No.		Value	in Para	imeter S	Set
	-	-	<u>A</u>	<u>B</u>	<u>C</u>	<u>D</u>	E
ξw	prob. of not changing wage	A.13	10^{-8}	0.67	0.67	0.67	0.67
d_p	degree of indexation of prices	A.17	0	0	1.0	0	1.0
$\hat{d_w}$	degree of indexation of wages	A.13	0	0	0	1.0	1.0

D. Energy Parameters

(1)	(2)	(3)	(4)	(5)
Parameter	Description	Eq'n No.	Set 1	Set 2
θ	energy share in consumption	A.2	0.02	0.06
α_e	energy share in production	A.3	0.01	0.02
$ ho_{arphi}$	AR coefficient for oil price shock	A.22	0.97	0.97

Notes:

1. Parameter sets are defined by combining the parameters listed in panel A (which are common to all parameter sets) with one of the sets in panel C and one of the sets in panel D. For example, parameter set A1 fixes parameters as indicated in panel A, column 4A in panel C, and column (4) in panel D.

2. Each parameter set is then combined with each of two monetary policy parameters, one corresponding to core inflation targeting, one to headline inflation targeting. See equations (A.20a) and (A.20b)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
Parameter Set			Var	iable		
	π_{qt}	$C_t - C_t^*$	$\Delta \pi_{qt}$	π_{wt}	$\Delta \pi_{wt}$	π_{ht}
Al	y	У	У	у	У	n
A2	У	У	У	у	У	n
B1	у	у	у	у	у	n
B2	У	у	у	у	у	n
C1	У	у	у	у	у	у
C2	у	у	у	у	у	у
D1	У	у	у	у	у	у
D2	У	У	у	у	у	у
E1	у	У	у	y	y	у
E2	y	У	y	y	У	y

 Table A.2.
 Is the Standard Deviation Higher under Headline Inflation Targeting?

Notes:

1. See Table A.1 for definitions of parameter sets and variable definitions.

2. A y indicates higher and an n indicates lower volatility under headline than core inflation targeting. See section A.4 for further discussion

End Date					Parame	eter Set				
	A1	A2	B1	B2	C1	C2	D1	D2	E1	E2
2006:4	6.2/1.2	12.4/2.5	12.7/2.5	25.7/5.1	13.8/2.8	28.1/5.6	9.8/2.0	19.7/3.9	10.5/2.1	21.1/4.2
2007:4	8.2/1.4	16.5/2.8	16.1/2.7	32.6/5.4	16.7/2.8	34.0/5.7	12.7/2.1	25.7/4.3	13.0/2.2	26.1/4.3
2008:2	9.7/1.5	19.6/3.0	19.5/3.0	39.5/6.1	20.0/3.1	40.7/6.3	15.7/2.4	31.7/4.9	16.0/2.5	32.2/5.0

Table A.3.Cumulative / Mean Core Inflation Rates Resulting from A Series of Energy Price
Shocks

Notes:

1. See note 1 to Table A.1 for definitions of parameter sets.

2. A series of energy price shocks was computed for the 2002:1-2008:2 period. These were fed into the model, assuming all variables were initially in steady state. For each parameter set, the figure to the left of the slash is the resulting cumulative rise in core prices; the figure to the right of the slash is the mean annual inflation rate. The cumulative rise is relative to the trend associated with target inflation, and mean annual inflation rate is relative to target inflation. For example, the figure "6.2/1.2" in A1, 2006:4 indicates that by 2006:4, the sequence of energy price shocks fed in from 2002:1 to 2006:4 led to core prices rising 6.2 percent relative to trend, implying an annual rise in inflation 2002:1-2006:4 of 1.2 percent above target. The "9.7/1.5" figures in 2008:2 for parameter set A1 are the corresponding values if we continue the experiment through 2008:2.

Figure A.1A. Response of Headline Inflation



Notes to Figures A.1A through A.1F:

1. Figures A.1A through A.1F plot responses to a 10 percent positive shock to the energy price. The energy price response (Figure A.1F) is not annualized. All other responses are annualized.

2. The horizontal axis is quarters. The vertical axis is percentage change. The "target core" and "target headline" lines depict the responses when the monetary policy rule targets core inflation (equation A.23a) versus headline inflation (equation A.23b).

3. The figures are based on parameter set A1. See section A.3 of the Appendix for further discussion.

Figure A.1B. Response of Core Inflation



Figure A.1C. Response of Interest Rate



Figure A.1D. Response of c-c*



Figure A.1E. Response of Consumption



Figure A.1F. Response of Energy Price Shock



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Table 3.1.Oil and the Macroeconomy: 2002 - 2008

	Cumulative real	Global real	Global	Change in global
	oil price increase	GDP growth	CPI inflation	unemployment rate
1Q2002 - 3Q2006	231.5	16.1	13.5	-0.6
4Q2006 - 2Q2008	71.7	5.3	7.0	-0.3

Note: See footnote 3 for source of global data.

	Cost (\$	ibn)	Cost (%G	DP)	Net marg. co	ost (\$10)	Net cost since 2001eop (\$bn)	
	Gross	Net	Gross	Net	\$bn	%GDP	Gross	Net
Global	5,878	93	11.6	0.2	13	0.0	8,145	265
Developed	2,956	692	8.0	1.9	100	0.3	4,231	2,659
US	1,428	348	10.3	2.5	50	0.4	2,020	1,328
Euro area	773	271	6.3	2.2	39	0.3	1,123	1,077
Japan	348	127	8.0	2.9	18	0.4	515	516
Emerging	2,921	-599	21.4	-4.4	-87	-0.6	3,913	-2,395
EM Asia	1,332	301	18.6	4.2	44	0.6	1,769	1,054
China	542	103	16.7	3.2	15	0.5	690	336
India	190	49	16.1	4.2	7	0.6	254	176
Korea	164	60	16.9	6.2	9	0.9	228	228
Taiwan	77	28	20.1	7.4	4	1.1	107	107
ASEAN	817	40	63.8	3.2	6	0.5	418	801
Latin America	518	-65	15.8	-2.0	-9	-0.3	701	-318
Brazil	151	9	11.3	0.7	1	0.1	204	36
Chile	24	9	14.4	5.2	1	0.8	27	27
Colombia	16	-8	7.6	-4.1	-1	-0.6	22	-33
Mexico	140	-37	13.6	-3.6	-5	-0.5	192	-168
CEEMEA	1,071	-835	33.4	-26.0	-121	-3.8	1,443	-3,130
OPEC	389	-744	22.3	-42.7	-108	-6.2	512	-2,859
Poland	37	13	8.6	3.2	2	0.5	48	48
Russia	186	-183	14.4	-14.2	-27	-2.1	261	-663
Turkey	46	17	7.0	2.6	2	0.4	65	65

Table 3.2. Crude Oil Consumption, 2007

Note: Net values are net of domestic production. Consumption and production data are from 2008 BP Statistical Review. All dollar costs are based on the annual average OPEC crude basket. Net cost since 2001 is the cumulative net cost using net consumption and OPEC crude price from 2002 through 2007. All figures are based on annual averages. Global consumption does not net to zero in 2007 owing to a net fall in global inventories as well as a few minor technical details that drive a wedge between consumption and production. CEEMEA includes all countries of Central and Eastern Europe, Middle East, and Africa.

Crude oil consumption, 2007

	Memo: 2007	1985-200	2007	
	exports (US\$	Short-run	Long-run	Long-run
OPEC	897	0.34	0.51	0.71
GCC	447	0.36	0.50	0.72
Saudi Arabia	194	0.37	0.31	0.45
UAE	120	0.43	0.98	1.37
Kuwait	46	0.09	0.38	0.40
Qatar	38	0.22	0.29	0.64
Oman	26	0.11	0.72	0.62
Bahrain	23	0.58	0.32	0.41
Iran	79	0.21	1.14	0.59
Other OPEC	371	0.38	0.46	0.72

Table 3.3.OPEC's Marginal Propensity to Import out of Export Revenue (MPI)

Source: IMF Direction of Trade. GCC (Cooperative Council for the Arab States of the Gulf) includes UAE, Bahrain, Saudi Arabia, Oman, Qatar, and Kuwait.

	OPEC	exports	OPEC	mports	Trade offset ratio
·	ch 02-07	07 level	ch 02-07	07 level	ch 02-07
Global	446	675	325	465	0.73
Developed	265	411	139	232	0.52
United States	106	153	36	54	0.34
Canada	8	11	3	5	0.45
Euro area	93	144	81	127	0.87
United Kingdom	7	11	9	17	1.27
Japan	71	121	21	37	0.30
Australia	4	7	5	10	1.33
EM	181	264	186	233	1.03
Latin America	11	18	21	28	1.97
Argentina	0	0	3	4	18.50
Brazil	7	12	11	14	1.55
Chile	0	1	1	2	3.99
Colombia	1	2	3	4	3.33
Mexico	2	3	2	3	1.25
Peru	0	1	1	1	1.57
CEEMEA	22	29	22	28	1.03
Czech Republic	0	0	1	1	4.23
Hungary	0	0	1	2	11.07
Poland	0	0	1	1	4.68
Romania	1	1	1	1	1.09
Russia	1	1	4	6	4.64
Slovak Republic	0	0	0	0	3.10
South Africa	9	12	2	3	0.24
Turkey	10	13	12	13	1.16
EM Asia	149	218	143	178	0.96
China	45	56	53	64	1.19
India	9	15	20	26	2.20
Indonesia	3	6	2	3	0.51
Korea	44	66	15	22	0.34
Malaysia	7	10	9	11	1.36
Philippines	4	6	1	1	0.21
Singapore	22	36	33	39	1.51
Thailand	13	19	9	12	0.70

Table 3.4.Merchandise Trade with OPEC (billions of US dollars)

Source: IMF Direction of Trade.

Estimated Response of US Consumption Growth to Oil Price Sample period: 1961Q1 to 2008Q3 Table 3.5.

	Coefficient	t-Statistic
Constant	4.07	11.56 *
Error correction term	-82.42	-6.23 *
Lagged real PCE growth, ar	-0.17	-3.00 *
Real DPI growth, ar	0.23	4.81 *
Lagged real DPI growth, ar	0.07	1.38
Real fed funds rate	-0.39	-6.82 *
Price of WTI	-0.02	-1.38
Lagged price of WTI	-0.02	-2.22 *
Change in unemployment rate	-3.62	-6.01 *
Percent change in wealth	0.03	2.31 *
Adjusted R-squared	0.52	
Standard error	1.95	
* significant at the 95% confidence level.		

Dependent variable is real PCE growth, %q/q, annualized

Variables expressed at annual rate (ar).

Country	Headline vs. Core	Headline vs. Target	Core vs. Target
US	3.9	5.4	1.5
Euro Area	3.8	2.6	-1.2
UK	3.4	-0.5	-3.8
Japan	2.6	-6.3	-9.0

Table 4.1.Cumulative Inflation in Excess of Targets, 2001-2007

*Assume the following targets: US (1.75), Euro (1.9), UK (2.0), Japan (1.0)

Source: Authors' estimates and Haver Analytics.

	P-value f	for current		
	and lagg	ed values		
Dependent variable:	Oil price	Core	_	
Measure of Expected inflation	growth	inflation	Sample period	
Michigan Survey, 12 months ahead	0.00	0.00	1983:01 2008:12	
Michigan Survey, 5 to 10 years ahead	0.08	0.00	1990:08 2008:12	
TIPS, 5 year, 5 years ahead	0.42	0.92	2001:12 2008:12	
TIPS, 10 year	0.04	0.91	1998:05 2008:12	

Table 5.1.Do Oil Prices and Core Inflation Move Expected Inflation?

Note: Table reports p-value for test that current and lagged value of the log change in oil prices and the level of core inflation (CPI excluding food and energy) are significant in a regression of measures of expected inflation. The regression equation includes three lags of the expected inflation measure and current and three lags of the oil price and core inflation variables. The TIPS expected inflation are measured as of the end of the month.

	June 2008			October 2007			
Indicator	2008	2009	2010	2008	2009	2010	
GDP (Q4/Q4)	1.0 - 1.6	2.0 -2.8	2.5 - 3.0	1.8 - 2.5	2.3 - 2.7	2.5 - 2.6	
Unemployment (Q4)	5.5 -5.7	5.3 - 5.8	5.0 - 5.6	4.8 - 4.9	4.8 - 4.9	4.7 - 4.9	
PCE (Q4/Q4)	3.8 - 4.2	2.0 - 2.3	1.8 - 2.0	1.8 -2.1	1.7 - 2.0	1.6 - 1.9	
Core PCE (Q4/Q4)	2.2 - 2.4	2.0 - 2.2	1.8 - 2.0	1.7 - 1.9	1.7 - 1.9	1.6 - 1.9	

Table 6.1.FOMC central tendency forecasts

Source: Federal Reserve Board

Note: Forecasts assume "appropriate monetary policy" and exclude highest and lowest three forecasts. GDP refers to the growth rate in real GDP. PCE refers to personal consumption expenditure inflation.
Figure 3.1. Real Oil Price



West Texas intermediate crude, deflated by US chain GDP prices

Note: Shaded areas denote U.S. recessions.





Source: JPMorgan.

Figure 3.3. Global GDP and Oil Prices: 1993-2008



percent change over 8 quarters, seasonally adjusted annual rate both scales

Note: Shaded area denotes a U.S. recession. See footnote 3 for source of global data.

Figure 3.4. Real Global GDP and Oil Consumption



Note: See footnote 3 for source of global data.





Figure 3.6. Global GDP



Note: See footnote 3 for source of global data.

Figure 3.7. Global CPI



Note: See footnote 3 for source of global data.





Note: Resource utilization rates are a GDP weighted average across countries. The individual country utilization rates are a weighted sum of the deviation in the unemployment rate and capacity utilization rate from its mean, measured in standard deviation units. Source: JPMorgan



Figure 3.9. US Consumption Excluding Energy and Exports, Share of GDP

Note: Shaded areas denote U.S. recessions.

Figure 3.10. Estimated Effects of Energy Prices on US Consumption Growth: Income and Price Effects



Note: Shaded areas denote U.S. recessions. Based on estimates reported in Table 3.5.

Figure 3.11. Estimated Effects of Energy Prices on US Consumption Growth: Sum of Income and Price Effects



Note: Shaded areas denote U.S. recessions. Based on estimates reported in Table 3.5.

Figure 3.12. Change in non-OPEC Oil Supply



Change from year ago, Millions of barrels per day

Note: "FSU" is "Former Soviet Union."



Figure 3.13. Stock Price of Exxon and BP, 2008



Figure 3.14. Implied Value of Proven Reserves versus Forward Delivery Price

Source: See discussion in Section 3.7.2 of the text.





Figure 3.16. WTI: Spot versus Forward Premium





Figure 4.1. U.S. CPI inflation: Headline versus Core

Figure 4.2. Consumer Prices Excluding Food and Energy



Source. Data are either directly from or derived from national statistics agencies. Developed: United States, Japan, Canada, Euro area, Norway, Sweden, Switzerland, United Kingdom. Emerging: Brazil, Chile, Colombia, Mexico, Peru, China, Hong Kong, Indonesia, Korea, Malaysia, Philippines, Singapore, Taiwan, Thailand, Czech Republic, Hungary, Poland, Russia, Slovak Republic, South Africa.



Figure 4.3. Emerging Markets Wages and Unit Labor Costs



percent change from year ago, both scales

Source. Mostly derived from national statistics offices supplemented with private trade groups. EM sample: Argentina, Brazil, Chile, Colombia, Mexico, Venezuela, China, Korea, Malaysia, Singapore, Taiwan, Thailand, Czech Republic, Hungary, Poland, Russia, Slovak Republic, South Africa, and Turkey.

Figure 5.1. U.S. Inflation Expectations Surveys



Figure 5.2. Five year, Five Year Ahead Break Even Inflation (BEI)





Figure 5.3. Contribution of Oil Price Changes to Expected Inflation: Historical decomposition

Note: Author's calculations based on estimates described in the text and summarized in Table 5.1.



Figure 6.1. Federal Funds Rate, Actual and Expected, June 30, 2008



Figure 6.2. Baseline Forecasts and Recession Probabilities

Source: July 2008 survey, Wall Street Journal





Note: Dissents are from the FOMC meeting. Dissents are coded as "Dovish" for those favoring easing and "Hawkish" for those favoring tightening. "Other" dissents in 1995 related to the use of the Exchange Stabilization Fund to aid Mexico.



Figure 6.4. Emerging Markets Resource Utilization and Average Real Policy Rate