

Oil and food prices

SUMMARY

US retail food price increases in recent years may seem large in nominal terms, but after adjusting for inflation have been quite modest even after the change in US biofuel policies in 2006. In contrast, increases in the real prices of corn, soybeans, wheat and rice received by US farmers have been more substantial and can be linked in part to increases in the real price of oil. That link, however, appears largely driven by common macroeconomic determinants of the prices of oil and of agricultural commodities rather than the pass-through from higher oil prices. We show that there is no evidence that corn ethanol mandates have created a tight link between oil and agricultural markets. Moreover, increases in agricultural commodity prices have contributed little to US retail food price increases, because of the small cost share of agricultural products in food prices. In short, there is no evidence that oil price shocks have been associated with more than a negligible increase in US retail food prices in recent years. Nor is there evidence for the prevailing wisdom that oil-price driven increases in the cost of food processing, packaging, transportation and distribution have been responsible for higher retail food prices. Similar results hold for other industrialized countries. There is reason, however, to expect food commodity prices to be more tightly linked to retail food prices in developing countries.

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Do oil price increases cause higher food prices?

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1. INTRODUCTION

The persistent increase in agricultural commodity prices since 2006 has raised concerns among policymakers about a global food shortage and about inflationary pressures. For example, the *Financial Times* on 23 May 2007, reported that ‘retail food prices are heading for their biggest annual increase in as much as 30 years, raising fears that the world faces an unprecedented period of food price inflation’ (see Wiggins, 2007). The director of the International Food Policy Research Institute in 2008 testified before the US Congress that rising prices for agricultural crops were causing food riots in many developing countries, and that, according to the Food and Agriculture Organization of the United Nations, 37 countries were facing food crises (see Rosegrant, 2008). In 2011, the World Bank predicted that millions more people would be driven into poverty by higher food prices in the absence of policy changes (see Inman, 2011). In response to these concerns, the US National Bureau of Economic Research convened a panel of academic experts in 2012 to study the recent

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increase in food price volatility (see Chavas *et al.*, 2013). Moreover, numerous government agencies pondered the causes and policy implications of price volatility in food and agricultural markets (see, e.g., Interagency Report to the G20, 2011).

There is widespread concern that this global food crisis also has an impact on food prices in industrialized economies. For example, the *Chicago Tribune* on 21 February 2008, reported that ‘increases in the price of basic commodities such as grain and milk have resulted in a tighter squeeze on American families as they face the fastest rise in food prices in nearly 20 years’. Many news outlets highlighted extraordinary increases in individual food prices such as a 26% increase in the price of a gallon of whole milk from January 2007 to January 2008 or a 15% increase in the retail price of bread from mid-2007 to mid-2008, and local newspapers such as the Sacramento Bee in California warned that ‘things like hamburger that used to be everyday food are becoming luxuries’. While these food price increases pale in comparison to those reported in some developing countries, as documented in Ivanic *et al.* (2012), this evidence spurred new research on the pass-through from agricultural commodity prices to the retail price of food in the US (see, e.g., Leibtag, 2009; Berck *et al.*, 2009; Roeger and Leibtag, 2011).

The worldwide surge in food crop prices in recent years followed a surge in the price of crude oil, raising the suspicion that oil and food crop prices have become more closely linked in recent years (see, e.g., Tyner, 2010). Mallory *et al.* (2012) provide evidence that this link was strengthened by the increased reliance on biofuels in industrialized economies, notably in the United States. The United States had pursued policies favouring the production of ethanol from corn for a long time, but a further shift in US policy occurred in 2005 when policymakers refrained from providing liability waivers for the use of the environmentally harmful gasoline additives traditionally used in producing high octane fuels.¹ This decision effectively made ethanol produced from corn the only gasoline additive available to US gasoline producers after May 2006. This shift in US policy was followed by the introduction of renewable fuel standards mandating the use of ethanol in the production of gasoline.² It was also followed by a surge in the price of corn and other crops, often collectively referred to as food commodities.

Similar policy changes also took place in many other industrialized countries, but typically at a later stage. For example, the European Union introduced in 2003 a biofuel target of 5.75% for renewable fuels to be used for transport fuels. This target initially was voluntary, however. It was replaced by a mandatory 10% renewable transport fuels target only in 2009. Another difference is that in Europe biodiesel is the main biofuel for transport. Ethanol accounts for only 28% of the biofuel market.

¹ Corn in American English is maize in British English. We follow the American usage, given that our data are obtained from the US Department of Agriculture.

² For a detailed review of the legislative process culminating in US biofuel mandates see Anderson and Elzinga (2014), Carter *et al.* (2013), and Abbott (2013).

European biofuels are produced mainly from rapeseed, sugar beets and cereals. Domestic production is supplemented by imports of ethanol and biodiesel initially mainly from the United States and increasingly from Latin America.

Many observers agree that oil prices affect food prices in a variety of ways (see, e.g., Westhoff, 2012). Some have gone as far as claiming that ‘food prices mirror oil prices’ (see Dancy, 2012). While the latter position does not seem tenable, there are good reasons to suspect a causal link. For example, corn is used both as food and as a raw material in producing ethanol. To the extent that the latter competes with crude oil in producing refined products such as gasoline and diesel, all else equal, one would expect higher oil prices to be reflected in higher corn prices. In addition, corn is also used to feed farm animals. The resulting increases in the cost of producing meat and dairy products puts upward pressure on meat and dairy prices. Moreover, corn competes with other agricultural commodities for fertilizer and for scarce water and land resources, adding to the pressure on food prices. Finally, the prices of all agricultural products will be affected to the extent that diesel is used to power mechanized farm equipment.

In fact, corn is but one example of a food commodity, the price of which is directly linked to the price of crude oil. Additional examples include sugar cane, which may be used to produce ethanol or food, soybeans which may be used to produce biodiesel or food, other oil seeds which may be used to produce vegetable oil or biodiesel, and grains which may be used to produce cereals or for heating buildings.

The potential price pressures from rising oil prices are not limited to the production stage of food commodities. Higher energy costs may also raise the cost of food processing, food packaging and distribution. In particular, the cost of transportation is a potentially important component of the price of food, as is the cost of producing plastic and foam packaging.

The objective of this paper is to examine what the evidence is for a link from oil prices to food prices. We are not the first to raise this question. There is a rapidly growing literature using time series data to study the link between oil prices, agricultural commodity prices and food prices. The modelling techniques used and the main conclusions reached in this literature have been reviewed by Serra and Zilberman (2013). Much of this literature is based on atheoretical time series models that are inherently incapable of establishing or quantifying causal links in the data.³ Hence, claims in this literature about how oil prices ‘impact’, ‘influence’, ‘feed back to’ or ‘drive’ food prices must be discounted. What these studies document at best is that oil prices increased prior to food prices in recent years, but that observation is uncontroversial.

What is needed to quantify causal relationships between the price of oil and crop and food prices is a structural econometric framework that acknowledges the underlying identification problem. One concern is that there is not only causality

³ Examples are the use of so-called Granger non-causality tests as a means of establishing causality and the use of reduced-form VAR impulse responses or the interpretation of the coefficients of reduced-form vector error correction models or vector autoregressive models as measures of *causal* impact.

running from oil prices to food prices, but also causality running in the other direction. A case in point is the dramatic shift toward more mechanized agricultural production in China in recent years. For example, the use of tractors (excluding small tractors) in China increased by 20% in 2006, by 23% in 2007 and by 46% in 2008. The reasons include a shortage of unskilled labour, as workers migrate to cities; higher farm incomes which facilitate the purchase of machinery; and government subsidies for agricultural equipment. Such an expansion of agricultural activity involves a shift in the global demand for crude oil, invalidating the premise of one-way causality from the price of crude oil to agricultural commodity prices.

A second concern is that, even abstracting from reverse causality in agricultural commodity markets, the oil price increases after 2003 did not occur in isolation, but were the result of changes in the global economy. Thus we cannot treat these oil price increases as though they occurred all else equal, as many existing studies explicitly or implicitly do. An example illustrates this point. It has been shown that much of the surge in oil prices between 2003 and mid-2008 was associated with an unexpectedly booming world economy, notably in emerging Asia (see, e.g., Kilian and Hicks, 2013; Kilian and Murphy, 2014). This economic expansion was also associated with higher incomes in countries such as China, which caused higher demand for food in general and higher global demand for high-quality foods in particular including wine, meat and dairy products, for example. This shift in demand for food products in turn has affected the demand for agricultural commodities such as corn. For example, the US Grains Council reported in 2013 that for the first time in history China is set to produce more corn than rice, reflecting a new pattern of demand. Thus, observed increases in food commodity prices are by no means attributable to the increase in the price of oil alone. Put differently, if the same increase in the real price of oil had been caused by oil supply disruptions in the Middle East, the response of food crop prices would have been quite different. Moreover, the precise causes of the observed surge in the real price of oil matter for the persistence of the response of oil and food prices.

A third concern is that the pass-through from oil prices to food prices depends on the reaction of the domestic central bank, as stressed by Hamilton (2012), making it more difficult to isolate empirically what is unique about the response of food prices.

The econometric analysis in this paper is designed to help us quantify many of the relevant channels of transmission in question, keeping in mind the complications discussed above. Our approach complements recent work in the resource economics literature that uses structural dynamic econometric models to quantify the effects of biofuel policies on agricultural commodity prices with notable contributions by Hausman *et al.* (2012) and Carter *et al.* (2013). Their estimates of the effects of biofuel policies on crop prices range from less than 10% to 34%.⁴ In contrast, our work is not

⁴ Closely related work includes the comparative statics analysis of the effects of the 2009 Renewable Fuels Standard in Roberts and Schlenker (2013) by means of a structural model of major agricultural commodity markets.

concerned with the effects of these policies as such, but with understanding the dynamic relationship between oil prices, agricultural prices, and ultimately food prices, especially after the change in US biofuel policies in 2006.

The remainder of the paper is organized as follows. Section 2 reviews the salient data and highlights the facts to be explained. Section 3 shows how case studies may be used to gauge the impact of oil price shocks on food prices, while controlling for changes in global real economic activity. Section 4 examines the evidence for a structural break in the relationship between oil and food prices in May of 2006, when US policy toward ethanol changed with the implementation of the Energy Policy Act of 2005, which established a closer link between oil prices and corn prices. The main results are in Section 5, which attempts to gauge the quantitative importance of each of the main channels of transmission from oil price shocks to food prices. We distinguish in particular between the effect of real oil price shocks on the prices paid and received by US farmers on the one hand and their effect on the cost of marketing food to retail customers in the US on the other. Section 6 distinguishes between common and idiosyncratic determinants of global agricultural commodity prices and discusses implications of our evidence for industrialized and for developing economies. The concluding remarks are in Section 7.

2. FACTS ABOUT FOOD PRICES

Consumers tend to be aware of rising food prices more than rising prices for other goods with the possible exception of gasoline because food items are purchased on a regular basis. Figure 1 plots the cumulative per cent growth in US consumer prices since May 2006 for all food items in the aggregate as well as for the four most import-

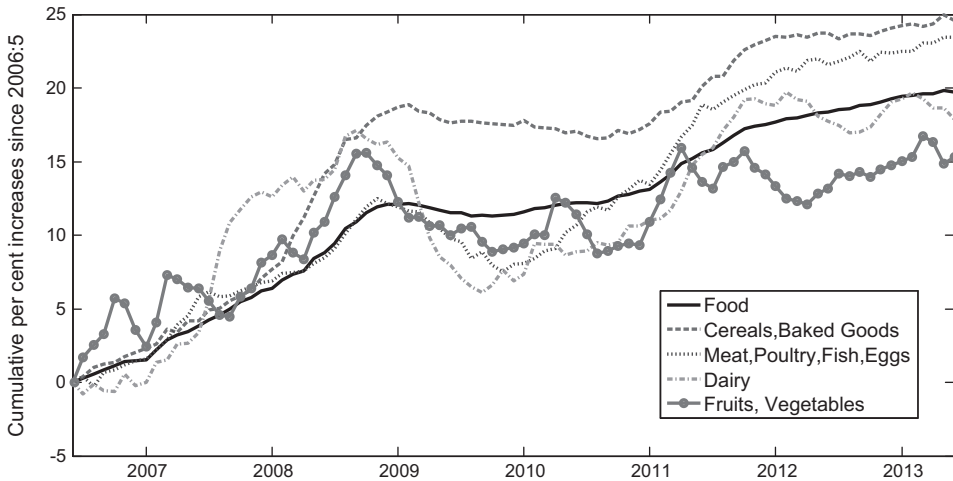


Figure 1. Cumulative percentage growth in US consumer prices for food since May 2006

Notes: Authors' computations based on the data described in the appendix.

ant components of food consumed at home. It shows that overall food prices have increased by 20% in only seven years. The price of cereals and baked goods increased even faster at a rate of almost 25%, with the price of meats, poultry, fish and eggs close behind. The consumer price of the remaining items grew at a slower pace, but even the price of fruits and vegetables rose by 15% in only seven years.

This evidence confirms the impression that indeed food prices have been rising persistently in recent years. Of course, so have all prices. In fact, in a country with a moderate 2% rate of inflation one would expect all prices to increase by about 15% in seven years. Thus, the real question is whether food prices have increased more than other consumer prices. Figure 2 addresses this question by expressing the food prices underlying Figure 1 relative to an index of US consumer prices excluding food. This transformation results in a measure of the real price of food that conveys how much consumers have to give up in terms of other consumer goods to purchase these food items. Figure 2 illustrates that overall the real price of food has increased by only 7% since May 2006. This means that a household spending \$1,000 a month on food would have had to cut back other expenditures by \$70, provided that it cannot economize its expenditures by changing the composition of its food purchases or by reducing its overall food purchases. This aggregate result hides the fact that the price of some food items such as *fruits and vegetables* hardly changed, while others such as *cereals and baked goods* or *meats, poultry, fish, and eggs* experienced double digit per cent price increases in real terms, but it is nevertheless representative for the overall impact of food price inflation on retail consumers.

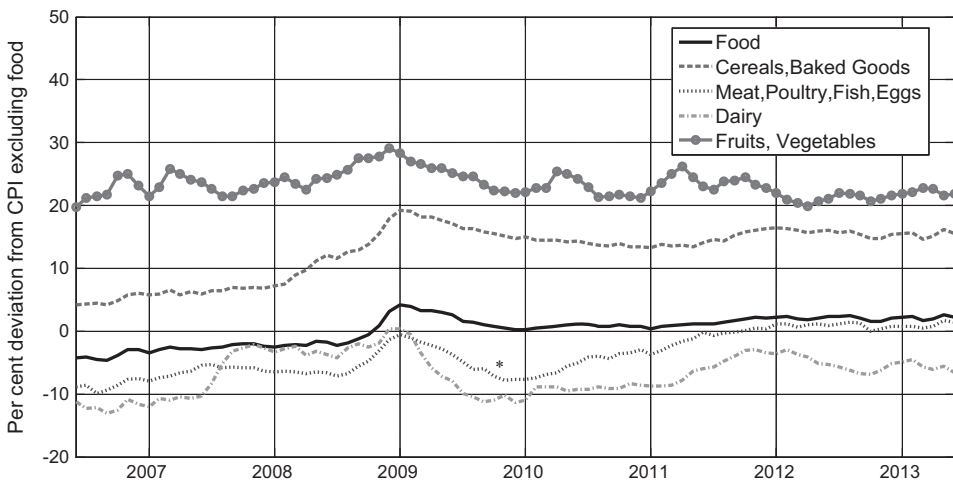


Figure 2. US consumer food prices relative to non-food consumer prices, 2006:5–2013:5

Notes: Authors' computations based on the data described in the appendix.

2.1. Food price increases in historical perspective

The evidence in Figure 2 raises several questions. One question is how these price increases compare with historical experience. Another important question is how the prices faced by consumers compare with the prices paid and received by US farmers and how they compare with the price of crude oil and oil products such as diesel fuel. Table 1 provides a systematic comparison. It focuses on the price of crude oil and diesel fuel, the price paid by US farmers for agricultural inputs such as fuel, fertilizer, and animal feed, the price received by US farmers for key agricultural products such as corn, wheat, soybeans and rice, and for livestock such as cattle, hogs, broilers and turkeys, and finally the price paid by US consumers for food. The prices received by US farmers typically closely mirror the spot prices quoted on commodity exchanges and reported by the International Monetary Fund. The data sources are described in the appendix. All prices in Table 1 have again been expressed in real terms by normalizing them relative to the index of US consumer prices excluding food items. Table 1 contrasts the experience from January 1974 until April 2006 with that since May 2006.

Table 1 reveals some striking contrasts. Whereas prior to May 2006 real retail food prices overall had been declining at the rate of 0.6% per year, they increased on average by 0.9% per year after May 2006. At the same time, the rate of growth in the real price of crude oil accelerated from 1.2% on average prior to May 2006 to 4.2% on average after May 2006. This evidence raises the question of whether there might be a relationship, as conjectured by many observers.

Interestingly, the perhaps more relevant increase in the real price of diesel fuel after May 2006 was only 2.2% per year on average, which is reflected in a 2.5% per year increase in farmer's fuel costs. By comparison, the real price of fertilizer increased much more than the real price of crude oil, as did the real price of animal feed. This pattern appears consistent with a shift in the demand for agricultural products and possibly with a shift in the composition of agricultural products after May 2006 and with an expansion into marginal farm land. Likewise, the real price increases for corn and soybeans and to a lesser extent for wheat and rice far exceed the increases in the real price of crude oil and farm fuel. These increases are all the more striking compared with the systematic declines characteristic of previous decades. The corresponding increases in the real price of livestock tend to be more modest, but again are striking in historical comparison.

The increases in the real price received by farmers for products such as corn, wheat, soybeans and rice can be reconciled with the modest increases in the real price of food after May 2006 by observing that these farm products account for only a small fraction of the retail cost of food products. Overall, agricultural products account for less than 20% of the cost of food to consumers, with the remainder accounted for by the cost of processing, packaging, advertising, transporting and distributing food to retail markets. For example, the share of livestock prices in the cost of meat to consumers may be as high as 50%, while the share of wheat in the cost of

Table 1. Percent Changes in Selected U.S. Prices Relative to Non-Food CPI

	(a) 1974.1–2006.4		(b) 2006.5–2013.5		Correlation With Crude Oil	Average Annual Growth	Percent Change in Volatility: (a) to (b)
	Cumulative Growth	Average Annual Growth	Cumulative Growth	Average Annual Growth			
Energy Prices	46	1.2	35	4.2	1.00	4.2	31.2
	NA	NA	17	2.2	0.85	2.2	NA
Crude Oil							
Diesel Fuel							
Fuel	NA	NA	20	2.5	0.85	2.5	NA
Fertilizer	NA	NA	69	7.5	0.12	7.5	NA
Animal Feed	NA	NA	91	9.2	0.30	9.2	NA
Farmers' Prices Received	-82	-5.2	182	14.7	0.17	14.7	10.5
	-83	-5.6	65	7.1	0.10	7.1	29.4
Wheat	-79	-4.8	130	11.8	0.30	11.8	-5.4
Soybeans	-88	-6.6	67	7.3	-0.11	7.3	-29.7
Rice							
Cattle	-77	-4.5	25	3.1	0.07	3.1	-10.1
Hogs	-57	-2.6	32	4.0	0.26	4.0	-15.1
Broiler	NA	NA	81	8.4	-0.03	8.4	NA
Turkey	-70	-3.7	27	3.4	0.17	3.4	23.2
Food	-17	-0.6	7	0.9	-0.74	0.9	10.3
Cereals/Baked Goods	NA	NA	12	1.6	-0.54	1.6	NA
Meat/Poultry/Fish/Eggs	-36	-1.4	11	1.5	-0.56	1.5	-41.1
Dairy	NA	NA	5	0.7	-0.29	0.7	NA
Fruits/Vegetables	10	0.3	2	0.3	-0.18	0.3	-44.2
Nonalcoholic Beverages	4	0.1	-1	-0.1	-0.51	-0.1	-36.1
Other Food at Home	-5	-0.2	6	0.8	-0.65	0.8	-14.0
Food Away from Home	-6	-0.2	7	1.0	-0.77	1.0	69.8
Alcoholic Beverages	-23	-0.8	2	0.3	-0.75	0.3	15.5

Notes: The data are described in the appendix. NA denotes missing entries resulting from gaps in the available data. The percent change in volatility is based on the ratio of the standard deviations of the percent growth rate in the respective periods. The correlations refer to correlations between the monthly growth rates in the real price of oil and in the series of interest.

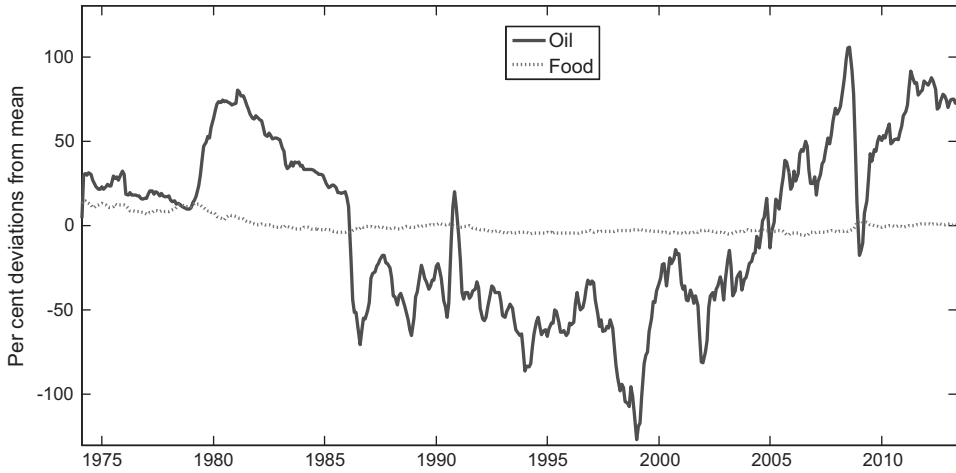


Figure 3. Price of crude oil and US food consumer price index relative to US non-food CPI, 1974:1–2013:5

Notes: Authors' computations based on the data described in the appendix.

bread historically has been only about 5%.⁵ This means that all else equal a doubling of the price of wheat will be associated with only a 5% increase in the price of bread.

To summarize, what Table 1 conveys is that there is no evidence of a tight statistical relationship between oil prices and US retail food prices, contradicting Dancy's (2012) claim that food prices mirror oil prices. Figure 3 illustrates the lack of fit. Whereas the real price of oil fluctuates within +100% and –100% of its long-run mean, the real price of food remains within a few percentage points of its mean. Not only are the magnitudes quite different, but the probability that the price of food increases when the price of oil increases is less than 47%, indicating the absence of a systematic relationship. Moreover, there is no evidence that the fit improves after May 2006.

Table 1 shows a stronger statistical relationship between oil prices and the grain crop prices received by US farmers, in contrast. The reasons will be examined in detail further below. For now, it is useful to examine the degree of comovement of agricultural product and oil prices and the extent to which this comovement has strengthened in recent years. Figure 4a compares the evolution of the real price of corn, wheat and soybeans prior to May 2006 with that of the real price of oil. We exclude the real price of rice because of its lesser importance for US agriculture and because one would not expect it to be linked as tightly to oil as some of the other grain prices. Whereas real agricultural product prices show comparatively small variation

⁵ Detailed information about the farm value shares for selected food products are provided by the Economic Research Service of the US Department of Agriculture (<http://www.ers.usda.gov/data-products/price-spreads-from-farm-to-consumer.aspx>)

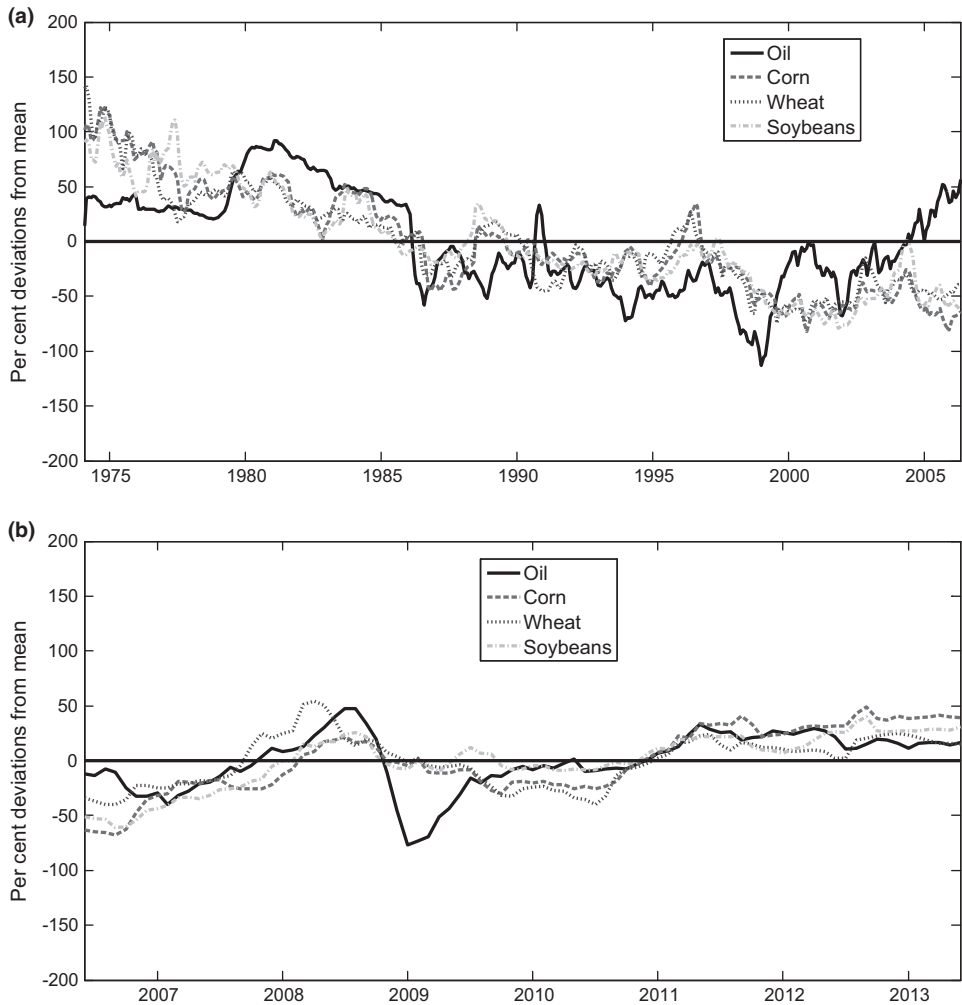


Figure 4. Real prices received by US farmers and real price of crude oil: (a) 1974:1–2006:4; (b) 2006:5–2013:5

Notes: Authors' computations based on the data described in the appendix.

about a declining trend, the real price of oil exhibits much larger variation about its long-run mean with no indication of a long-run trend. Figure 4b shows that the secular decline in the agricultural product prices is reversed after May 2006 and the comovement between the real price of oil and real agricultural product prices becomes more pronounced. This comovement, however, remains far from perfect.

There are several potential explanations of this evidence. One possible explanation is that the increased comovement reflects increased demand for oil associated with an economic boom in emerging economies, followed by rising real incomes in emerging economies and higher demand for agricultural products worldwide. Another potential explanation is that higher oil prices are associated with increased prices for agricultural inputs that drive up crop prices. A third and complementary potential explanation is

that US agricultural policies created a tighter link from oil prices to agricultural product prices. Finally, yet another possible explanation is the financialization of global commodity markets after 2003. Kilian and Murphy (2014), Kilian and Lee (2014), and Fattouh *et al.* (2013) show that this last explanation is not supported by the oil market data, making it implausible that it would apply to other commodity markets and allowing us to focus primarily on the first three explanations. For related evidence on the role of financial speculation in the wheat market we refer to Janzen *et al.* (2014).

2.2. Has the volatility of the real price of food increased?

As discussed in the introduction, the premise of much of the policy debate has been that the volatility of food prices is said to have increased since the shift in US biofuel policies. This fact is usually taken as self-evident. While several studies have reported evidence of rising food price volatility, that evidence in many cases is problematic from a statistical point of view.⁶ Table 1 illustrates that the premise of rising food price volatility is difficult to sustain. The last column of Table 1 presents the per cent change in the volatility of the monthly growth rates in period (a), referring to January 1974 to April 2006, and period (b), referring to May 2006 to May 2013. For example, the volatility of the growth rate of the real price of oil increased by 31%. This increase reflects the sharp drop in oil prices in late 2008, following the financial crisis. There is no indication of increased volatility beyond this one episode.

If there were a close link from oil to food prices, one would expect a similar increase in the volatility of agricultural crop prices. However, only the growth rate of wheat prices shows a similar increase in volatility, whereas that of corn prices increases by only 10%, that of soybeans actually falls by 5% and that of rice falls by 30%. This evidence argues against the view that price volatility in food commodities has risen systematically. Moreover, comparing wheat and corn in particular shows that the smaller volatility increases apply to the growth in the real price of corn which, according to conventional wisdom, should be most exposed to higher oil price volatility.

Likewise, with the exception of live turkeys, there is no evidence of an increase in the volatility of livestock prices. In fact, the price volatility for cattle declined by 10% and that for hogs declined by 15%, again contradicting conventional wisdom. Finally, although the volatility of the growth rate of the real price of consumer food increased, it did so only by 10% compared with the 31% increase for crude oil. Volatility changes for components of the real food price index range from -44% to 16% with the exception of food away from home with a 70% volatility increase. This evidence is not supportive of a general increase in the volatility of retail food prices or of a spillover from oil price volatility to price volatility in agricultural markets.

⁶ For example, it is common to focus on nominal rather than real prices, to compute variances of non-stationary time series, and to report correlations of trending data.

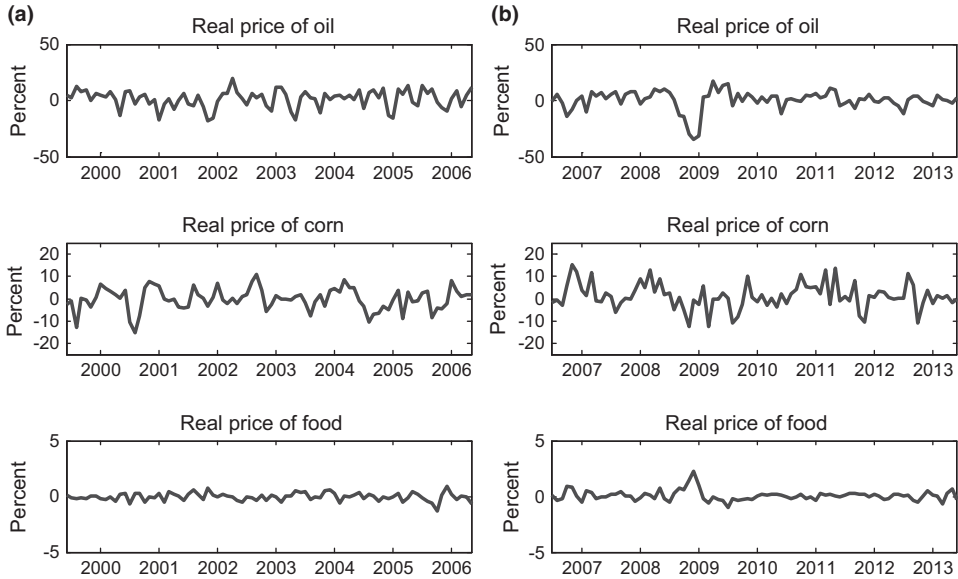


Figure 5. Percentage growth rates of selected prices before and after May 2006: (a) 1999:5–2006:4; (b) 2006:6–2013:5

Notes: Authors' computations based on the data described in the appendix.

Rather than relying on summary statistics, Figure 5 plots the per cent growth rates of the real price of oil, the real price of corn, and the real consumer price index (CPI) for food. To facilitate visual comparison we show the data for exactly seven years before and after May 2006. One would be hard pressed to detect visually a substantial shift in volatility in May 2006 for any of these time series. Although there is an unusually large positive spike in consumer food prices in late 2008, this spike is offset by lower volatility in subsequent years. This plot should put to rest the popular view that there has been a substantial increase in food price volatility in recent years. It is also noteworthy that the positive spike in the growth rate of real retail food prices coincides with a negative spike in the growth rate of real price of oil, but no large spike in either direction in the growth rate of the real price of corn.

2.3. Has the correlation in the growth rates of the real prices of food and oil increased?

A closely related position in the literature is that the positive correlation between per cent changes in oil prices on the one hand and in agricultural commodity prices and retail food prices on the other has increased in recent years (see, e.g., Interagency Report to the G20, 2011, p. 10). Table 1 shows that prior to May 2006 the contemporaneous correlation between the growth rate in the real price of crude oil and the growth rate in real agricultural crop prices ranged from -0.03 to -0.09 . After May 2006, we find correlations ranging from -0.1 to 0.3 between the real price of oil and

the real price of crops. To put these results in perspective, it is useful to compare these correlations with those between the growth rate in the real price of oil and the growth rate in the real prices farmers pay for fuel, fertilizer and animal feed. While the correlation of 0.85 for fuel matches that of diesel fuel, as expected, the correlations of 0.3 for animal feed and 0.12 for fertilizer are much more modest, arguing against a tight statistical link. Similar results apply to the growth rate in the real price of livestock whose various correlations with the growth rate in the real price of oil range from -0.02 to 0.06 before May 2006 and between -0.03 and 0.26 after May 2006. Neither set of results provides strong evidence for a tight statistical link between changes in the real price of oil and in real agricultural prices.

Turning to the real retail price of food in Table 1, the results are even weaker. Prior to May 2006, the contemporaneous correlation between the growth rate in the real price of food and that in the real price of oil was -0.13 , meaning that there was essentially no linear relation. After May 2006 this correlation falls to -0.74 . In short, there is no support for the popular notion of a tight statistical link between increases in the real price of oil and increases in the real price of food. Of course, the absence of a positive contemporaneous correlation does not rule out the existence of a conditional correlation between these real prices such that an unexpected increase in the real price of oil is followed by a delayed positive response of the real price of food. This separate question will be examined in detail in section 5.

3. A CASE STUDY APPROACH

Given that both the real price of oil and the real price of agricultural products are endogenous with respect to the global economy, one cannot interpret the comovement of food and oil prices as evidence of a causal relationship. One potential solution to this problem would be to instrument for oil prices using oil supply shocks associated with unrelated political events in the Middle East. The objective of the use of these instruments is to isolate the component of the real price of oil that is not associated with unanticipated fluctuations in the global business cycle. The problem is that existing oil supply shock instruments are weak in the statistical sense. Their lack of predictive power for the real price of oil invalidates the use of conventional instrumental variable estimators (see Kilian, 2008a, b).

An alternative approach is to rely on case studies. Of particular interest is the sharp spike in oil prices that occurred after July 1990, when Saddam Hussein invaded Kuwait. It is well established that this major oil price spike was driven by oil supply disruptions and by concerns among oil market participants about pending additional oil supply shortfalls in case the war were to engulf Saudi Arabia. Put differently, this oil price spike was clearly not related to the strength of the global business cycle (see, e.g., Kilian and Murphy, 2014). This means that we can think of this variation in the real price of oil as exogenous with respect to US agricultural product markets.

If there is a relationship between oil prices and agricultural prices because higher prices for oil-intensive agricultural inputs push up the price of agricultural product prices, then this is the historical episode where we would expect to see a reaction in the cost of farm inputs such as fuel and animal feed as well as in agricultural product prices. Figure 6a clearly shows a spike in the real price of oil in 1990, but no apparent response of real corn, wheat or soybean prices, demonstrating that there is no tight causal link between oil prices and agricultural commodity prices at least prior to May 2006. This finding is reinforced in Figure 6b which shows that only fuel prices, but not fertilizer or animal feed prices responded to this exogenous oil price shock. This evidence means that proponents of such a causal link have to make the case that this

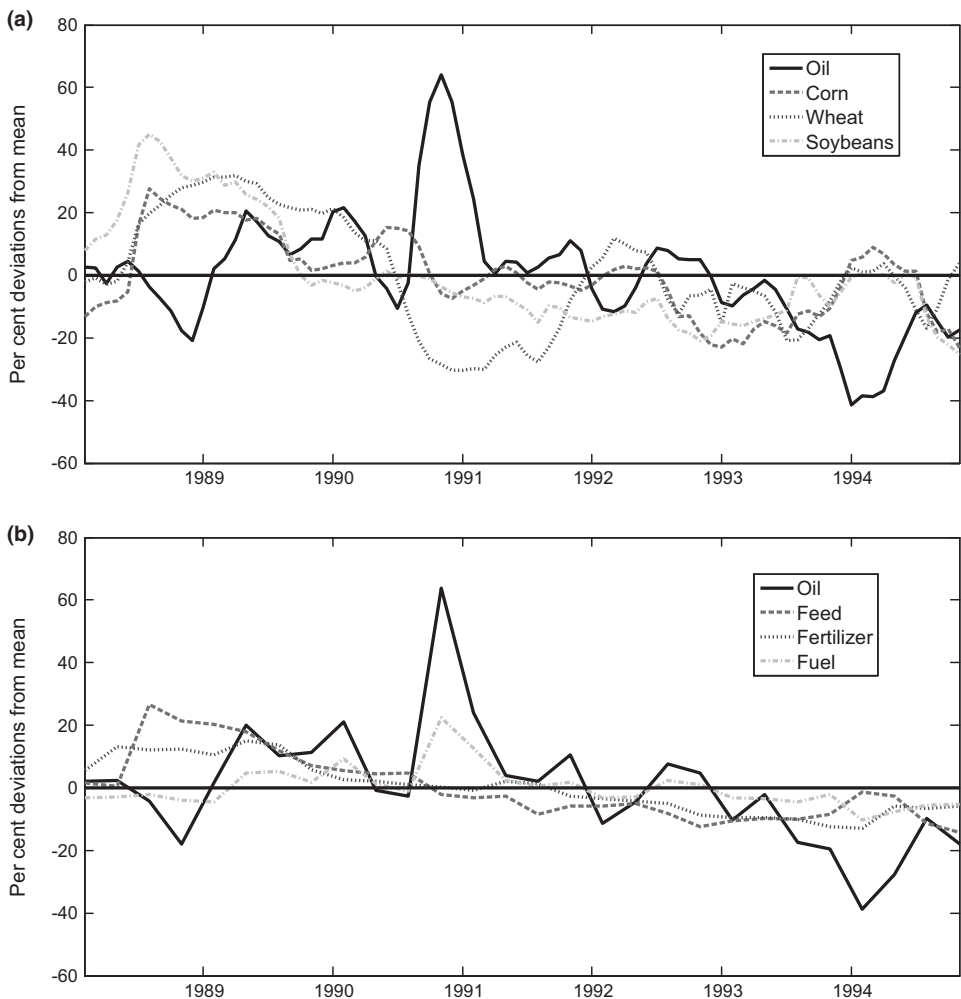


Figure 6. Case study of (a) farm crop prices and (b) farm input prices during 1990

Notes: Authors' computations based on the data described in the appendix.

link emerged only in recent years. A natural candidate for such a structural shift is changes in US biofuel policies.

4. WHAT IS THE EVIDENCE FOR A STRUCTURAL BREAK RELATED TO INCREASED ETHANOL PRODUCTION?

Even though the evidence in Figure 4a shows that there has been no obvious link between oil and food prices historically, we have to allow for the possibility that the expansion of biofuel production after May 2006 has changed the link between oil and food prices in recent years. US ethanol policies go back more than 30 years, but an important change in US policy took place with the passing of the Energy Policy Act 2005. At the time, it was standard for gasoline producers to add organic compounds such as methyl tertiary butyl ether (MTBE) or ethanol to the gasoline produced by refineries to raise its octane rating to levels suitable for car engines. As discussed in Anderson and Elzinga (2014), these compounds also served as oxygenates that reduce the emissions of carbon monoxide, as required by the US Environmental Protection Agency (EPA). Finally, in cities with particularly poor air quality, the EPA mandated that only reformulated gasoline be sold which involves blending gasoline with either MTBE or ethanol.

In the late 1990s, MTBE was linked to the pollution of drinking water, prompting a number of US states to ban its use after 2000. These bans effectively served as ethanol mandates at the state level, as shown in Anderson and Elzinga (2014), given that ethanol was the only available alternative means of satisfying the oxygenation requirement and of raising octane levels. Meanwhile oil companies sought legal protection from MTBE-related lawsuits. When the Energy Policy Act 2005 failed to grant a liability waiver for the use of MTBE in states not already subject to MTBE bans, gasoline producers chose to phase out MTBE completely. This decision had far-reaching implications for the price of corn, from which ethanol is primarily produced in the US. For example, Carter *et al.* (2013) report that, by 2012, 40% of US corn production was used to produce gasoline additives, up from only 14% in 2005.

In addition, Congress passed the Renewable Fuels Standard in 2005, which ensured a minimum demand for ethanol and contained additional provisions aimed at subsidizing ethanol production by offering tax credits and imposing import tariffs on ethanol. The latter provisions were dismantled only in 2011 and 2012. The required minimum levels of ethanol production were doubled by the Energy Independence and Security Act 2007. Legislation regarding the use of ethanol continues to evolve. In 2015, the minimum on annual corn ethanol production is set to rise further to 15 billion gallons compared with 4 billion gallons in 2006 (see Carter *et al.*, 2013). Whereas initially environmental concerns were driving biofuels legislation, policymakers' motives have evolved over time to include concerns about energy security and pressures from the agricultural lobby.

We treat May 2006 as the date of a tentative structural break in the relationship between oil, agricultural, and food prices. There is no universal agreement on this date in the literature, but most observers agree that between late 2005 and late 2006 the link between crop prices and oil prices changed. For example, Carter *et al.* (2013) note that informed market participants would have been well aware by late 2006 of the impending boom in ethanol production, and Mallory *et al.* (2012) document a change in the statistical relationship between corn and ethanol futures prices beginning in mid-2006.

Figure 7a shows the per cent deviation of the real price of oil from the real price of corn. There is little evidence of a mean-reverting statistical relationship, as one would expect, given the secular decline in corn prices. This concern may be addressed by

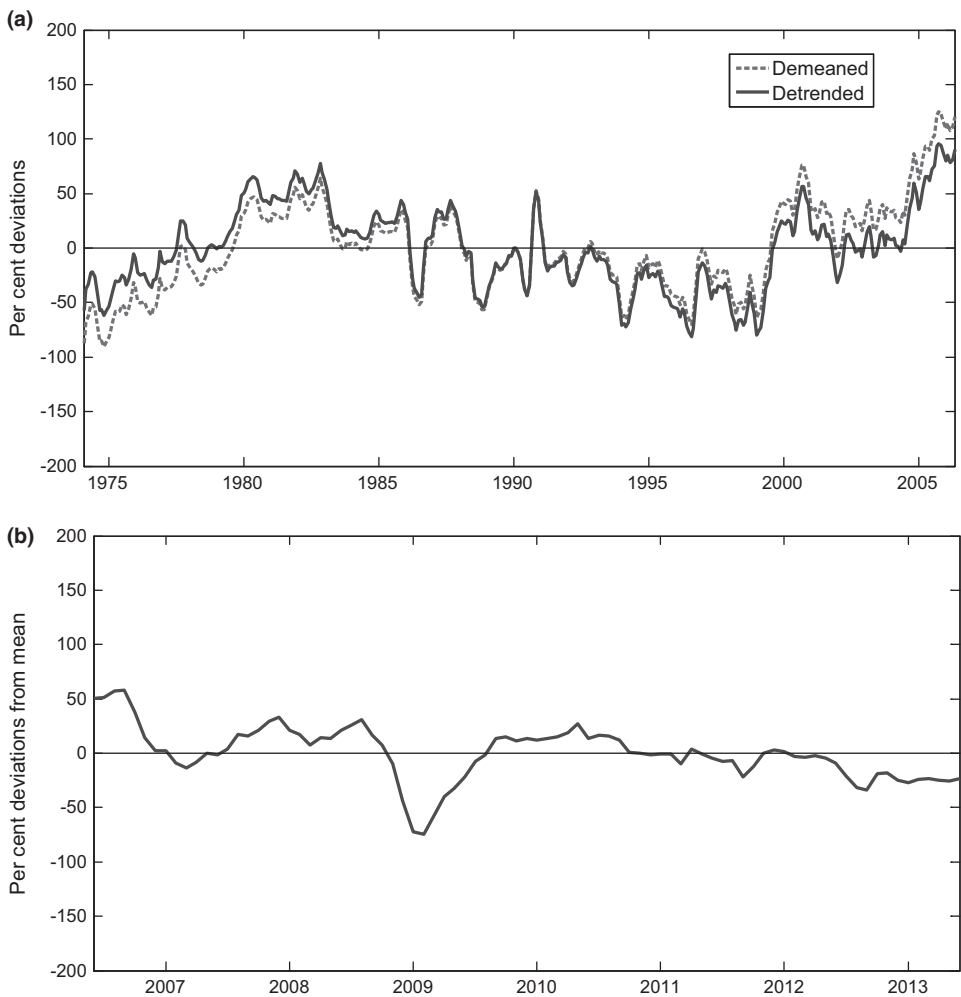


Figure 7. Spread of price of oil to price of corn received by US farmers: (a) 1974:1–2006:4; (b) 2006:5–2013:5

Notes: Authors' computations based on the data described in the appendix.

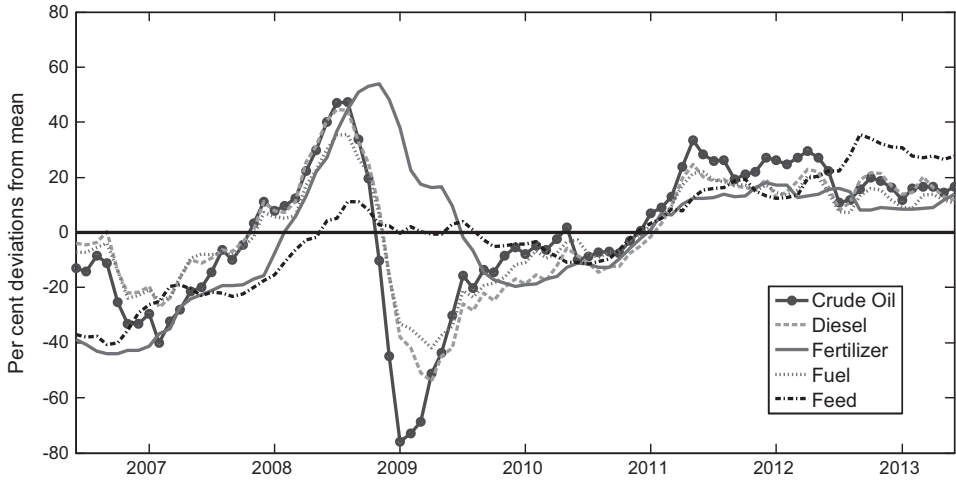


Figure 8. Real price of energy and real price of US farm inputs, 2006:5–2013:5

Notes: Authors' computations based on the data described in the appendix.

removing a deterministic time trend from the spread between January 1974 and April 2006, as shown in Figure 7a, but visual inspection suggests that even in the latter case a common trend, if indeed such a trend exists, must be very weak given repeated substantial and persistent deviations from trend. When fitting a common trend to oil and corn prices since May 2006, as shown in Figure 7b, in contrast, the deviations from the long-run mean appear somewhat smaller and less noisy. One way of making these impressions more formal is to compute measures of the directional accuracy of changes in the real price of oil for changes in the real price of corn. It can be shown that prior to May 2006 the probability that the price of oil and the price of corn move in the same direction is only 51%, where 50% is the benchmark value of this probability in the absence of a systematic relationship. After May 2006, in contrast, this probability rises to 60% and becomes statistically distinguishable at the 10% level from the hypothesis of purely random comovement.⁷

One possible source of this comovement after 2006 is a link between the real price of oil and that of agricultural inputs. Figure 8 suggests a tight link between the real price of diesel fuel and the real price of fuel paid by US farmers. There is also a somewhat less tight statistical link between the real price of oil and the real price of fertilizer. Finally, there is an even weaker link between the real price of oil and the real price of animal feed. This evidence of a statistical relationship after May 2006 is consistent with the hypothesis of higher demand for agricultural products from emerging economies as well as explanations based on a shift in US agricultural policy.

⁷ This assessment is based on the statistical test for directional accuracy proposed in Pesaran and Timmermann (2009).

To conclude, there is at least some evidence of nonrandom comovement after May 2006 between the real price of crude oil and the real price of corn on the one hand, and between the real price of oil and the real price of agricultural inputs such as fuel, fertilizer and to a lesser extent animal feed on the other. The next section attempts to disentangle the channels of transmission from the real price of oil to raw agricultural product prices and ultimately retail food prices in more detail, taking account of the three potential explanations of such a link outlined earlier. Our focus is on responses to real oil price shocks obtained from semi-structural vector autoregressive (VAR) models rather than the unconditional comovement in the data. These models differ from atheoretical time series models in that they impose additional identifying restrictions motivated by economic reasoning and extraneous empirical evidence. Within this VAR framework, the response of food prices to real oil price shocks may be interpreted as the revision in the expected price of food triggered by an oil price shock. This revision reflects the average relationship between food prices and oil prices in the data. As discussed in Section 6, these responses do not necessarily represent causal effects, because oil price shocks do not occur in isolation and are driven by deeper structural demand and supply shocks. Nevertheless, semi-structural VAR models help us characterize and understand the dynamic relationship between oil and food prices.

5. QUANTIFYING THE CHANNELS OF TRANSMISSION

One way of trying to make sense of the many different potential channels of transmission is to break the analysis into many smaller questions. This section examines and quantifies various links in the chain from oil to food prices. Our baseline results are based on bivariate autoregressions.⁸ Throughout the paper, the VAR models are specified in log-levels. We use six lags to avoid well-known problems of post-model selection inference. Our empirical results tend to be qualitatively robust to using 12 lags and to the treatment of seasonality.⁹ All models include an intercept and are estimated by the method of unrestricted least squares.

⁸ A potential concern in studying the pass-through of oil prices to diesel fuel prices and ultimately to food prices is a possible asymmetry in the relationship between oil and fuel prices. There is a long-standing perception that oil price increases are followed by immediate increases in fuel prices, while oil price declines are transmitted to fuel prices only with a delay. Whether this perception is supported by the data continues to be debated. The evidence appears to be stronger in data at daily or weekly frequency than at monthly frequency. Building on methodological advances on Kilian and Vigfusson (2011), Venditti (2013) recently has shown that in monthly data there is no statistically significant evidence that fuel prices respond asymmetrically to positive and negative oil price shocks. We therefore ignore possible asymmetries in our analysis.

⁹ This level specification is chosen to ensure consistency of the estimates regardless of the possible cointegration of the model variables (see Sims *et al.*, 1990; Inoue and Kilian, 2002). Our approach also avoids the well-known problems associated with pre-tests for unit roots and cointegration in VAR models (see Elliott, 1998). The superior accuracy of the log-levels approach in small samples has recently been demonstrated in Gospodinov *et al.* (2013).

We postulate that the monthly real price of crude oil is predetermined with respect to US agricultural and food prices, which allows us to study the response of the latter prices to oil price shocks using semi-structural vector autoregressions.¹⁰ The assumption of predetermined oil prices means that unpredictable changes in the real price of oil affect agricultural and food prices within the current month, but are not themselves subject to instantaneous feedback from agricultural and food prices. Given the low volatility of consumer prices relative to the nominal price of oil, the feedback from consumer prices to the real price of oil may be safely ignored in the identification of oil price shocks.¹¹

It is important to note that our sample sizes are too short for any model larger than a bivariate model to be employed. For example, the fully structural VAR approach of McPhail (2011), which in turn builds on Kilian (2010), would be infeasible on data since May 2006. Our approach is also designed to avoid the difficulty of credibly identifying additional shocks in structural VAR models including more than one food or crop price.

5.1. Quantifying the pass-through from oil prices to food prices

In discussing the relationship of oil and food prices, a natural starting point is the question of what the pass-through is of unanticipated changes in the real price of oil to the real price of food paid by US consumers. We address this question by fitting the VAR model

$$\begin{pmatrix} p_t^{crude/CPI} \\ p_t^{food/CPI/ex\ food} \end{pmatrix} \sim VAR(6)$$

where p_t denotes any real price expressed in logs and 6 refers to the number of autoregressive lags. The real price of oil is measured in terms of the overall US consumer price index, given that crude oil is not part of the consumption basket. The real price of food is measured relative to the CPI excluding food. This fact allows us to abstract from any general inflationary effects associated with oil price shocks and to focus on the perception that the response of food prices is unusual. One of the concerns in measuring the pass-through from oil prices to consumer prices, recently reiterated by Hamilton (2012), is that the extent of the pass-through depends on the response of the central bank to the inflationary pressures often associated with an oil price shock. By expressing the consumer price of food relative to other consumer prices, we effectively control for this monetary policy response which affects all consumer prices across the board.

¹⁰ To conserve space, in the analysis below, we do not display the own-responses of the real price of oil. It can be shown that these responses are very similar across alternative model specifications for any given sample period.

¹¹ Our approach is consistent with evidence in Kilian and Vega (2011) on the lack of instantaneous feedback from news about US macroeconomic aggregates to the price of oil and to the price of gasoline and has been widely used in the literature in related contexts (see, e.g., Edelstein and Kilian, 2009).

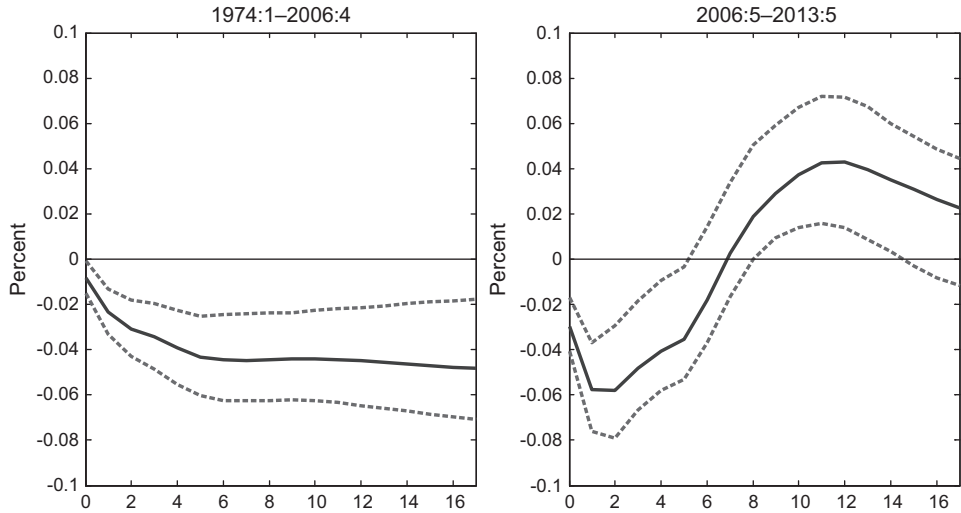


Figure 9. Response to a 1% real oil price shock – consumer food prices relative to consumer prices excluding food

Notes: Estimates from monthly bivariate vector autoregressions under the identifying assumption that the real price of oil is predetermined with 90% bootstrap confidence bands.

When plotting the results, we scale the responses, so that oil price shocks are associated with an unanticipated 1% increase in the real price of oil on impact. To allow for the structural change discussed in Section 4 we present separate estimates for the period from January 1974 to April 2006 and from May 2006 to May 2013. Figure 9 plots the estimated impulse response functions for a horizon from 0 to 17 months. It also plots 90% confidence intervals for each horizon that convey the precision of the estimates.¹² The left panel shows that between January 1974 and April 2006, an unanticipated 1% increase in the real price of oil on average has been associated with a statistically significant decline in the real price of food. In contrast, after 2006, the response of the real price of food changes. The real price of food initially drops sharply and significantly. In months 1 and 2 following the oil price shock, the real price of food drops to -0.06% . This decline is followed by a recovery that culminates in a statistically significant peak of the real price of food of 0.04% after 12 months.

At first sight, the initial drop in the real price of food may seem unexpected. The reason is that in these initial months the real price of gasoline in the consumer basket increases faster than the real price of food, so food becomes relatively less expensive, if only because gasoline is even more expensive. We can control for this effect by fitting the same VAR model with the price of food measured relative to the CPI excluding food and energy. This alternative definition measures how expensive food is compared to other consumer prices excluding gasoline in particular. Figure 10 shows

¹² The confidence intervals for the impulse responses are constructed using a recursive-design wild bootstrap method as proposed in Gonçalves and Kilian (2004). This bootstrap method allows for conditional heteroscedasticity of unknown form in the data.

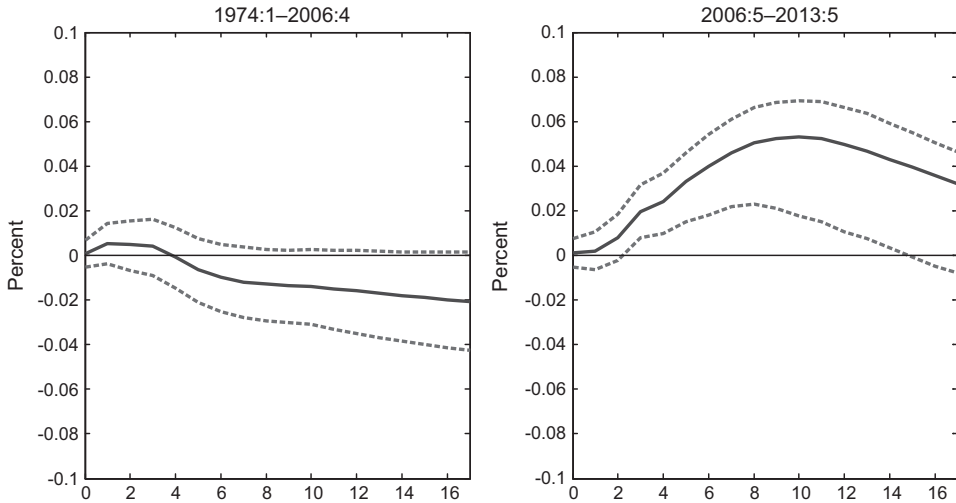


Figure 10. Response to a 1% real oil price shock – consumer food prices relative to consumer prices excluding food and energy

Notes: Estimates from monthly bivariate vector autoregressions under the identifying assumption that the real price of oil is predetermined with 90% bootstrap confidence bands.

that the decline in the real price of food in response to a 1% unanticipated increase in the real price of oil prior to May 2006 is statistically insignificant, while the response after May 2006 now is hump-shaped with a statistically significant peak of 0.05% after 10 months. This evidence supports the notion of a statistically significant relationship between oil price shocks and food prices after May 2006 and the absence of such a relationship prior to May 2006. It is useful, however, to keep in mind that the increases in question are small in magnitude. For example, a household spending \$1,000 on food per month after an unexpected 100% increase in the real price of oil, all else equal, would have to cut back its expenditures by \$50 ten months later. The small magnitude of these responses is consistent with the evidence in Figure 3 that food prices have remained rather stable throughout our sample, even as the real price of oil has fluctuated substantially.

It is useful to decompose these results further. Figure 11 provides analogous results for the eight major components of US food expenditures. All food prices are measured relative to the CPI excluding food and energy. There is evidence of statistically significant increases in the real price of *cereals and baked goods*, *meats/poultry/fish/eggs*, *dairy*, *other food at home*, and *food away from home*. The response of expenditures on *fruits and vegetables* is positive, but not statistically significant. There are no large or statistically significant responses in *non-alcoholic beverages* and *alcoholic beverages*.

5.2. Understanding the pass-through from oil to food prices

It is instructive to examine in more detail how oil price shocks are transmitted to food prices at different stages of the production of food. One obvious source of higher food

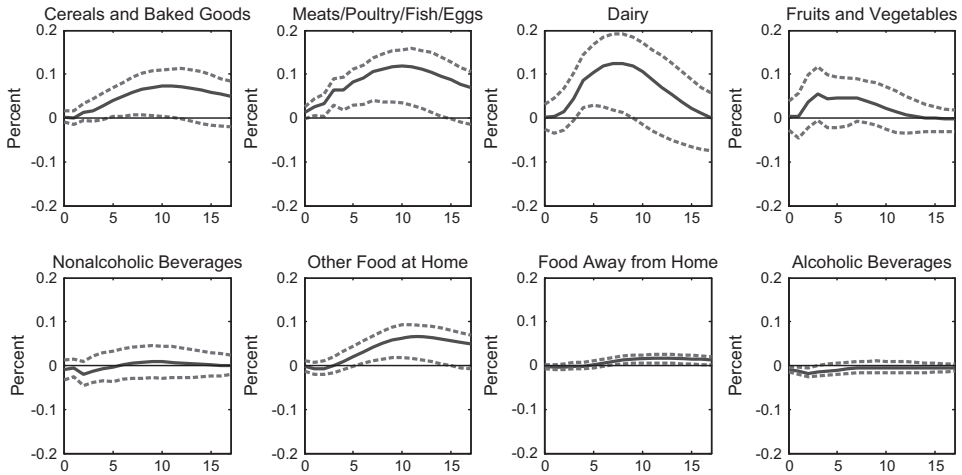


Figure 11. Response of real food prices to a 1% real oil price shock, 2006:5–2013:5

Notes: Estimates from monthly bivariate vector autoregressions under the identifying assumption that the real price of oil is predetermined with 90% bootstrap confidence bands.

prices are increases in the prices of raw agricultural products driven by higher oil prices.

There are several channels by which higher oil prices may be transmitted to the prices of raw agricultural products. For example, it is common to assert that the price of corn in particular is sensitive to the price of oil because of the use of corn in producing ethanol. Upon reflection this link is far from obvious. Much depends on why the real price of oil increases. Gasoline producers blend low-octane gasoline with high-octane ethanol in approximately fixed proportions.¹³ If the real price of oil increases unexpectedly because of a supply disruption in the Middle East, for example, this will not increase the demand for corn. If anything, it will lower the demand for gasoline and hence for corn over time, as economic growth slows down and therefore gasoline demand diminishes.

In contrast, in response to an unexpectedly booming world economy, one would expect gasoline demand to expand, shifting the derived demand for corn as well as crude oil. In the latter case, one would expect positive shocks to the real price of oil to be followed by increases in the real price of corn. This response occurs not because higher oil prices cause higher corn prices, but because both share a common macroeconomic determinant. This is the central message of studies that have shown that recent oil price fluctuations in large part are explained by shifts in demand from

¹³ These proportions have evolved somewhat over time in response to changes in fuel standards. Abstracting from the smaller market segment for reformulated gasoline, gasoline producers currently have converged on a profit maximizing strategy of blending 84 octane gasoline produced by refineries with 115 octane ethanol to produce 87 octane regular gasoline at the pump (see Babcock, 2013, p. 3).

emerging economies (see, e.g., Kilian and Murphy, 2014; Kilian and Hicks, 2013). To the extent that the global economic expansion underlying the 2003–2008 oil price increase is associated with a reduction in gasoline consumption in the US, however, even this link is severed (except to the extent that the US exports ethanol and/or ethanol-gasoline blends). More generally the macroeconomic determinants of the real price of oil would also be expected to raise the real price of wheat and soybeans, although not to the same extent, as higher real incomes in emerging economies alter food consumption patterns. A related indirect channel by which higher oil prices may be associated with higher agricultural prices involves competition for scarce resources such as water and agricultural land in response to a shift in the demand for corn. Of course, this effect arises only if the underlying oil price shock is associated with higher demand for corn.

So far we have considered the case in which high-octane ethanol and low-octane gasoline are used in approximately fixed proportions. To the extent to which it is possible to substitute ethanol for low-octane gasoline, as the real price of oil increases, one would expect higher crude oil prices all else equal to increase the demand for corn and hence the real price of corn. Such flexibility existed only intermittently after May 2006, however, limiting the scope for large responses in the demand for corn.

A potentially more important direct channel of transmission, which applies even in the case of oil-supply-shock driven oil price increases, involves increases in the cost of producing agricultural products. Of particular importance are increases in the cost of farm fuel associated with higher oil prices. Although the notion that higher oil prices are passed through to agricultural crop prices is intuitive, there are some important caveats. For example, this argument does not apply to the cost of fertilizer. Whereas the cost of farm fuel closely mimics the price of diesel fuel and hence depends directly on the price of crude oil, nitrogen fertilizer is produced from natural gas rather than crude oil.¹⁴ Even before 2008, the price of natural gas did not always follow the price of crude oil. After 2008, even the long-run statistical relationship between these prices collapsed with the development of shale gas in the US. While the real price of crude oil recovered, the real price of natural gas plummeted, and the cost of fertilizer decoupled from the price of crude oil.

This means that the direct effect of higher oil prices on the cost of agricultural production is effectively bounded by the cost share of fuels in agriculture. Even granting that this cost share has increased with the surge in fuel prices after 2003, this limits the potential effects of real oil price shocks. Sands and Westcott (2011) report that direct energy use (including not only fuels, but also electricity and natural gas) accounts for

¹⁴ US agriculture depends on nitrogen-based fertilizers, the production of which requires natural gas as the primary source of hydrogen for reaction with nitrogen to yield ammonia. The cost of natural gas accounts for 70–80% of the cost of nitrogen-based fertilizer.

6.7% of total production expenses in the US farm sector in 2005–2008. A doubling of diesel fuel prices, on the basis of these estimates, would be associated with perhaps a 5% increase in farm production costs.

These considerations suggest that the scope for the transmission of real oil price shocks to the real price of agricultural commodities is limited. While there has been a shift in the real price of corn in recent years associated with a one-time persistent shift in the demand for corn, how much of that shift was associated with biofuel subsidies, the prohibition of MTBE, and renewable fuel mandates, and how much of that shift occurred because ethanol production became viable as a cost-effective alternative to crude oil as the real price of oil surged, continues to be debated (see Babcock, 2013). This analysis is further complicated by the fact that, once the initial investment in expanding ethanol capacity has taken place, continued ethanol production only requires the price of ethanol to exceed its marginal cost.

Our analysis focuses on the narrower question of how much of the increase in the real price of corn after May 2006 was systematically related to real oil price shocks. In the interest of parsimony, our econometric analysis below ignores non-linearities in the corn and ethanol market that may arise from shifts in capacity constraints (see, e.g., Abbott, 2013). Our linear regression models provide a first-order approximation to the average response during this period of real agricultural prices to unexpected changes in the real price of oil.

5.2.1. How different is corn? A common conjecture is that after May 2006 oil price shocks raised the price of corn relative to other agricultural commodities that cannot be used to produce gasoline additives. The reason is that presumably higher demand for oil during this period was associated with higher demand for corn used in producing ethanol only after May 2006. This concern may be examined using the model

$$\begin{pmatrix} \dot{p}_t^{crude/CPI} \\ \dot{p}_t^{corn/wheat} \end{pmatrix} \sim \text{VAR}(6)$$

which relates the price of corn to that of wheat. The left panel of Figure 12, which focuses on the period of January 1974 through April 2006 shows a statistically insignificant decline in the price for corn relative to the price of wheat following a 1% unexpected increase in the real price of oil. After May 2006, as shown in the right panel, the response to a 1% unexpected increase in the real price of oil is positive, as conjectured, with a peak response near 0.4%, but the responses are all statistically insignificant.

Wheat was chosen as the benchmark in Figure 12 because it is relatively less prone to being used as a biofuel than corn. In contrast, soybeans have played an increasingly important role in the production of biodiesel after 2006, so the effect of real oil price shocks on this relative price is ambiguous *ex ante*. A similar exercise involving the model

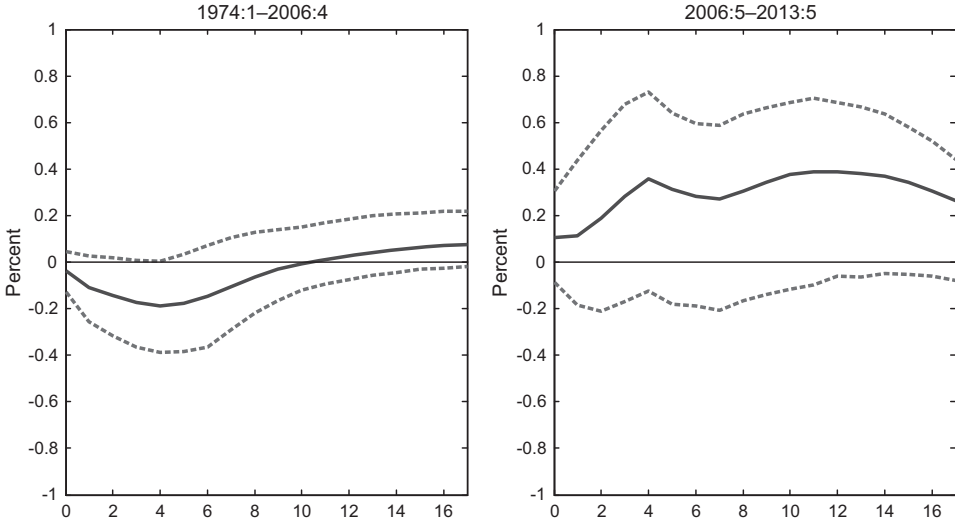


Figure 12. Response to a 1% real oil price shock – corn price received by US farmers relative to wheat price received by US farmers

Notes: Estimates from monthly bivariate vector autoregressions under the identifying assumption that the real price of oil is predetermined with 90% bootstrap confidence bands.

$$\begin{pmatrix} \hat{p}_t^{crude/CPI} \\ \hat{p}_t^{corn/soybeans} \end{pmatrix} \sim \text{VAR}(6)$$

indicates that soybean prices have been less responsive to oil price shocks in recent years than corn prices. Figure 13 shows no statistically significant response of the price of corn relative to soybeans prior to May 2006, as expected, but a statistically significant hump-shaped response with a peak of 0.4% after May 2006.

5.2.2. The response of prices received by US farmers. Figure 14 focuses on the question of how sensitive the real price of corn, wheat, soybeans and rice received by US farmers has been to oil price shocks before and after May 2006. The premise of many policy studies has been that one would expect a larger response after May 2006 for corn and for crops that compete with corn for land and water because of the shift in US biofuel policies. We estimate pairwise VAR(6) models for the real price of oil and the real prices of corn, wheat, soybeans, and rice, respectively, for the time periods before and after May 2006. There is no evidence of a statistically significant response of the real price of any of these crops prior to May 2006. After May 2006, the responses of all four real crop prices to a real oil price shock are larger and consistently positive. The real price of corn exhibits the largest, most persistent and most statistically significant response. The peak response after about one year is 0.7%. The peak response of the real price of soybeans of 0.5% occurs already after four months and is marginally statistically significant. The response of the real price of wheat is

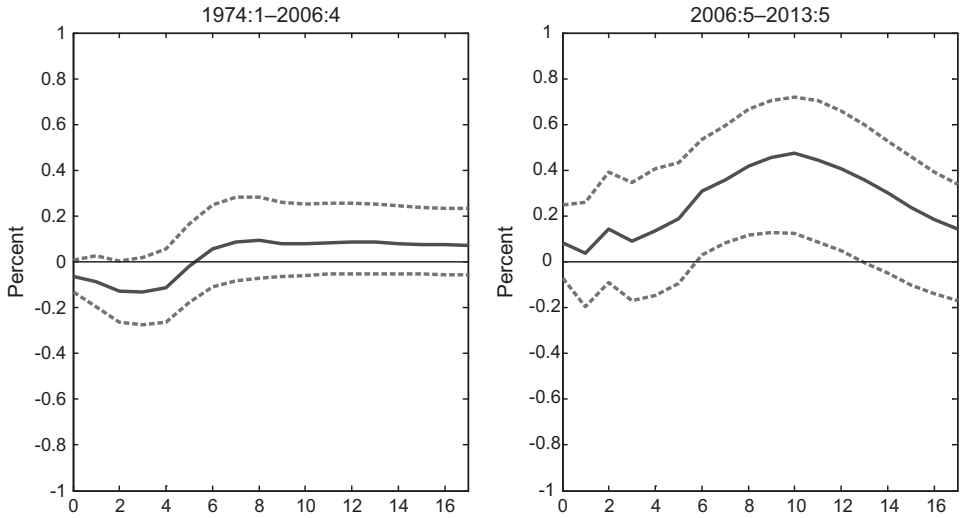


Figure 13. Response to a 1% real oil price shock – corn price received by US farmers relative to soybean price received by US farmers

Notes: Estimates from monthly bivariate vector autoregressions under the identifying assumption that the real price of oil is predetermined with 90% bootstrap confidence bands.

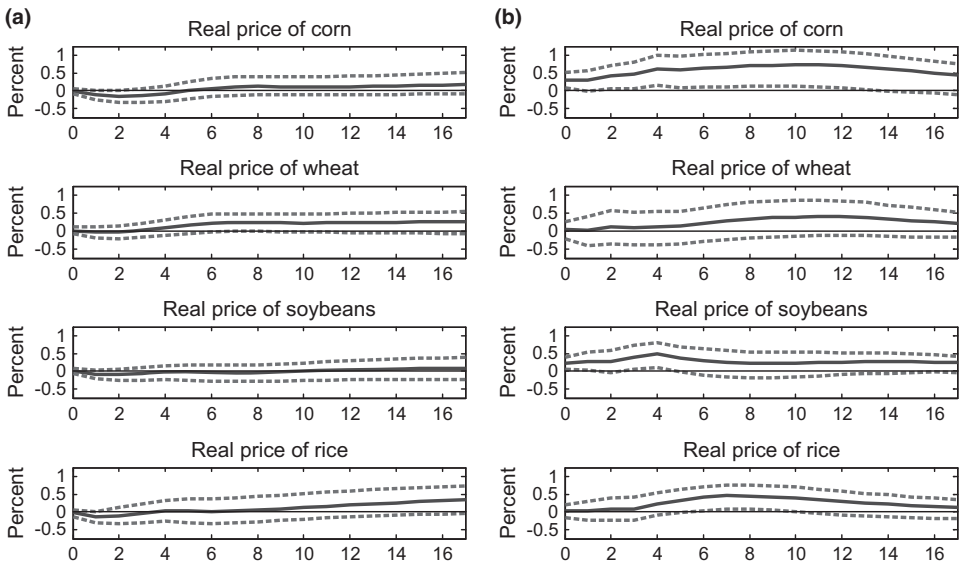


Figure 14. Response of grain prices to a 1% real oil price shock: (a) 1974:2–2006:4; (b) 2006:5–2013:5

Notes: Estimates from monthly bivariate vector autoregressions under the identifying assumption that the real price of oil is predetermined with 90% bootstrap confidence bands.

more delayed, reaches a peak of 0.4% after about one year, and is statistically insignificant. Finally, the real price of rice shows a statistically significant peak response of 0.45% after 8 months. This evidence is consistent with the perception that after May

2006 at least the real prices of corn and rice (and to a lesser extent the real price of soybeans) have been sharing a common determinant with the real price of oil. In Section 6, we investigate this common component in more detail.

Figure 15 focuses on the evolution of the real price of livestock received by US farmers in response to a 1% real oil price shock. Estimates of pairwise VAR(6) models for the real price of oil and the real prices of cattle, hogs, broiler, and turkey, respectively, suggest that prior to May 2006 there is no evidence of a statistically significant response to real oil price shocks. The missing result for the real price of broiler chicken reflects gaps in the data. Fitting the same models on data after May 2006, to the extent that we can compare, all response estimates are larger than before, indicating a strengthening of the relationship between real oil price shocks and real livestock prices. The response of the real price of turkey is large and statistically significant with a peak value of 0.7% after three months. The positive response of the real price of hogs with a peak value of 0.3% is smaller, but statistically significant; that of the real price of cattle is in between with a peak value of 0.5%, but is statistically insignificant.

5.2.3. The response of prices paid by US farmers. The responses in Section 5.2.2 may reflect the use of grain crops in the production of biofuels, they may reflect a shift in the demand for agricultural commodities not related to biofuels, or they may reflect the increases in the cost of agricultural production associated with higher oil prices. The link between the price of crude oil and the cost of fuel is self-evident.

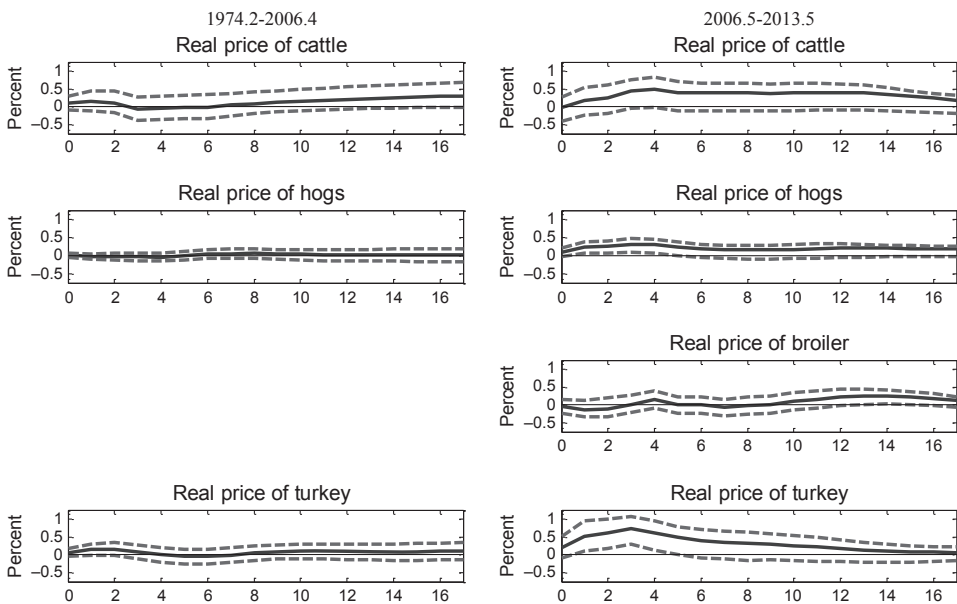


Figure 15. Response of livestock prices to a 1% real oil price shock: (a) 1974:2–2006:4; (b) 2006:5–2013:5

Notes: Estimates from monthly bivariate vector autoregressions under the identifying assumption that the real price of oil is predetermined with 90% bootstrap confidence bands.

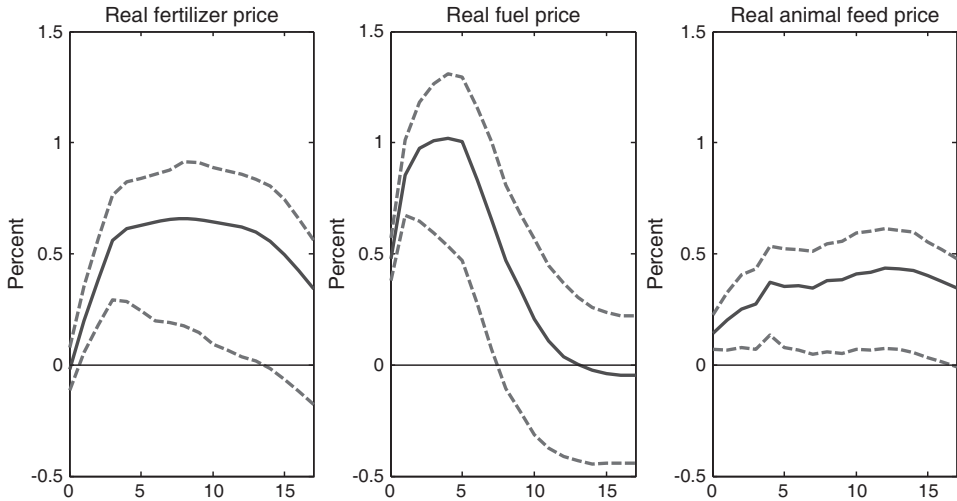


Figure 16. Response to a 1% real oil price shock, 2006:5–2013:5

Notes: Estimates from monthly bivariate vector autoregressions under the identifying assumption that the real price of oil is predetermined with 90% bootstrap confidence bands.

To the extent that higher oil prices inflate crop prices, they also directly increase the cost of animal feed. Finally, higher demand for agricultural products may be associated with higher fertilizer prices.

Fitting VAR(6) models for the real price of oil and the real prices of fertilizer, farm fuel and animal feed, respectively, on data since May 2006, allows us to investigate the responses of the real price of fertilizer, fuel, and animal feed to a 1% real oil price shock. Figure 16 confirms that all three real cost measures have tended to increase significantly in response to oil price shocks after May 2006.

5.3. Revisiting the identification problem

An obvious concern is that unanticipated changes in the real price of oil may simply reflect higher demand for oil in a booming economy (see Kilian and Murphy, 2014). Such a situation complicates the interpretation of the responses to such shocks because higher demand for oil is often followed by higher demand for agricultural and food commodities, as discussed earlier. Even though our estimates do not control for the effects of shifts in global demand on crop prices and oil prices, it is clear that doing so would only diminish the already very small responses of consumer food prices associated with unexpected variation in the real price of oil. In this sense, it seems safe to ignore this issue in the context of our empirical analysis. This argument does not apply to the response of crop prices, however, which indeed may reflect global demand shocks for commodities as much as or more than other explanations.

To gauge the role of global demand shifts in explaining the responses of crop prices to real oil price shocks we turn to a different source of identifying

information. As discussed in Section 5.2, we know that the production of nitrogen fertilizer relies on natural gas rather than crude oil. We also know that the real price of natural gas at the wellhead has fallen dramatically in recent years. Hence, the cost-push effect from higher oil prices on the real price of fertilizer must be negligible. Figure 16, nevertheless, shows a statistically significant positive response of the real price of fertilizer to a 1% real oil price shock, which can only be explained by a shift both in the demand for agricultural commodities and for oil. This fact in turn suggests that the positive responses of the real fuel price and of the real price of animal feed also reflects in large part the same demand shift, as do the responses of the agricultural prices in Figures 14 and 15. This observation is furthermore consistent with the fact that the response of the real price of rice in Figure 14 is quite similar to that of the real price of corn, even though the production of rice should be largely unaffected by shifts in the demand for corn because rice production is water-intensive and highly concentrated in a few areas of the US.

In other words, there is no compelling evidence that unexpected changes in the real price of oil alone and all else equal would have caused a change in agricultural product prices after May 2006. This conclusion is consistent with the evidence in Figure 6 based on data prior to May 2006. We defer further investigation of this point to Section 6. The following subsection focuses on an alternative channel by which real oil price shocks may affect retail food prices.

5.4.. Quantifying the effect of a higher cost of food marketing on retail food prices

One of the main reasons why retail food prices are considered sensitive to the price of oil is that consumer prices for food are thought to depend on the cost of food processing, packaging, advertising, storage, transportation and distribution (collectively referred to as food marketing). One would expect the spread between retail prices for food and the prices received by farmers to be responsive to oil price shocks, most importantly, because the transportation and distribution of fresh food by truck requires diesel fuel.

Our analysis of this question differs from earlier work including Leibtag (2009), Berck *et al.* (2009), and Roeger and Leibtag (2011) in that we quantify these dynamic effects using semi-structural vector autoregressions estimated on data since May 2006. One way of capturing the response of this spread to oil price shocks is to match specific food items in the CPI and in the PPI. We focus on dairy products including whole milk, butter, cheese, and ice cream, which require refrigeration and hence are particularly energy intensive in transportation. Our analysis involves fitting for each food item models of the form

$$\begin{pmatrix} p_t^{CPI \text{ dairy food item}} - p_t^{crude/CPI} \\ p_t^{PPI \text{ dairy food item}} - p_t^{CPI \text{ dairy food item}} \end{pmatrix} \sim \text{VAR}(6)$$

Because these dairy products are already processed, this exercise primarily tells us about how sensitive the cost of transportation and distribution is to oil price shocks. Figure 17 shows that in no case an unanticipated 1% increase in the real price of oil is associated with an increase in the spread of consumer over producer prices, contradicting the notion that higher energy costs in transportation and distribution are being passed on from producers to consumers.

Figure 18 focuses on the corresponding spread between the retail price of processed dairy products paid by consumers and the price of milk received by US farmers. Unlike Figure 17, this exercise also incorporates the cost of producing these dairy products from the raw milk sold by the farmer. Figure 18 shows that even in this case there is no evidence that the cost of processing dairy food is increasing in response to real oil price shocks. Rather there is evidence of a significant decline in this spread in the short run. Subsequent increases are small and statistically insignificant.

Even more specific data on the components of food prices is available from the US Department of Agriculture (USDA), which keeps track of the farm-to-wholesale price spread and the wholesale-to-retail price spread for pork and for beef sold in the US. Rather than relying on the spread data provided by the USDA, we recompute the spreads in question as log deviations of the raw price indices provided by the USDA to ensure the stationarity of the spread data. Figure 19 shows that, if anything, the farm-to-wholesale spread declines in response to a real oil price shock, as does the

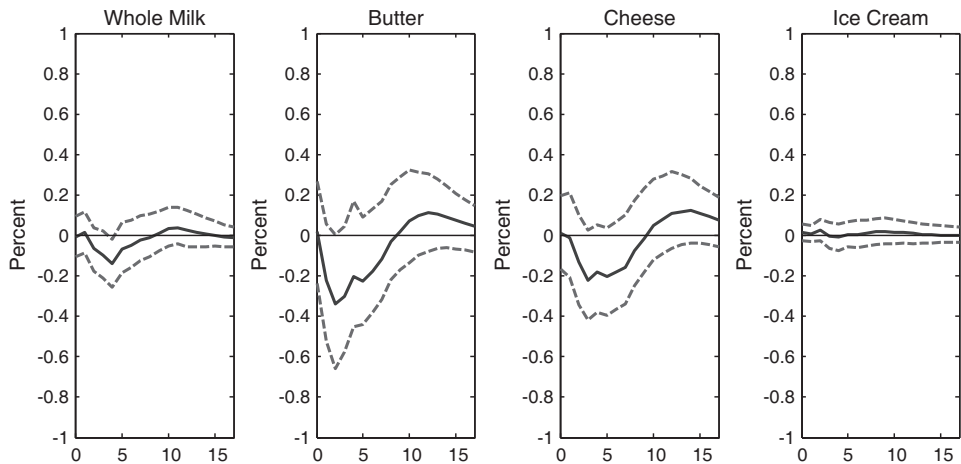


Figure 17. Response of CPI/PPI spread to a 1% real oil price shock by dairy product, 2006:5–2013:5

Notes: Estimates from monthly bivariate vector autoregressions under the identifying assumption that the real price of oil is predetermined with 90% bootstrap confidence bands.

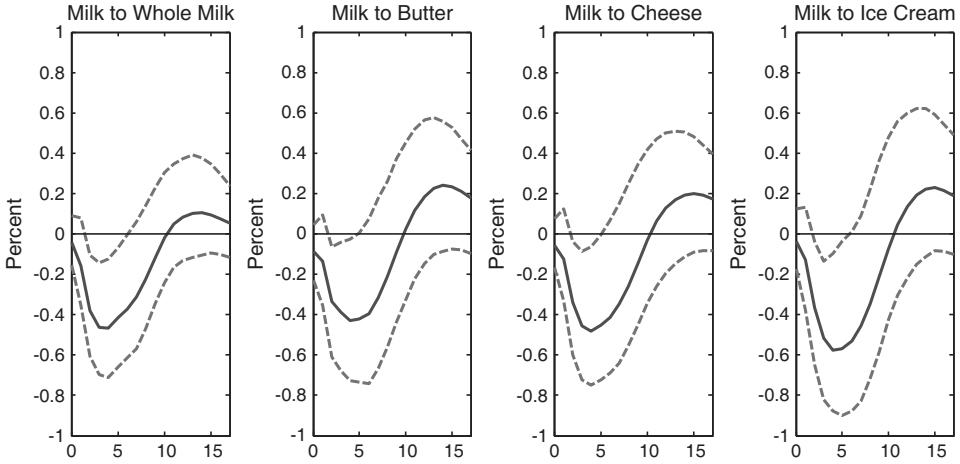


Figure 18. Response to a 1% real oil price shock of farm to retail price spread by dairy product, 2006:5–2013:5

Notes: Estimates from monthly bivariate vector autoregressions under the identifying assumption that the real price of oil is predetermined with 90% bootstrap confidence bands.

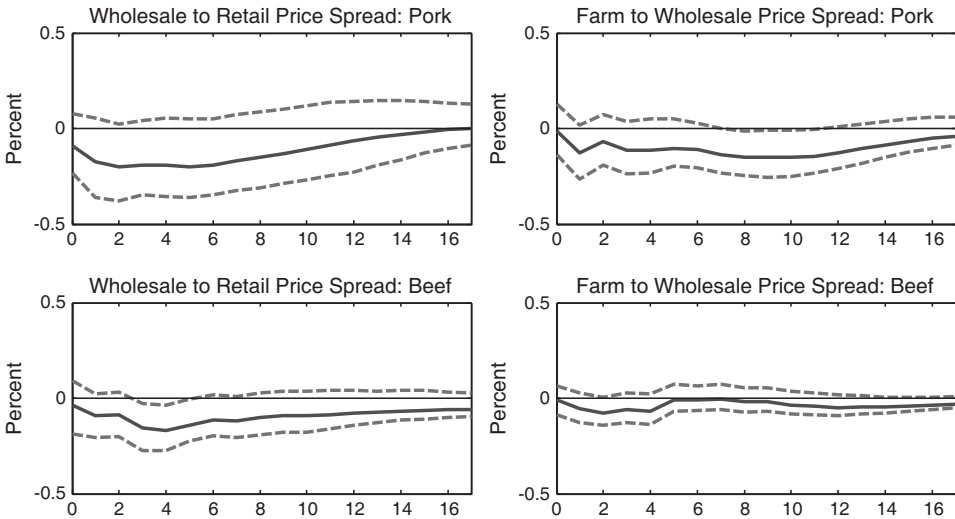


Figure 19. Response of pork and beef price spreads to a 1% real oil price shock, 2006:5–2013:5

Notes: Estimates from monthly bivariate vector autoregressions under the identifying assumption that the real price of oil is predetermined with 90% bootstrap confidence bands.

wholesale-to-retail spread. There is no evidence that positive shocks to the real price of oil are associated with increases in the retail price of beef or pork associated with higher costs of processing, transportation or distribution.

Figure 20 shows results of a complementary exercise focusing on the spread between the consumer price for a whole fresh chicken and the price US farmers

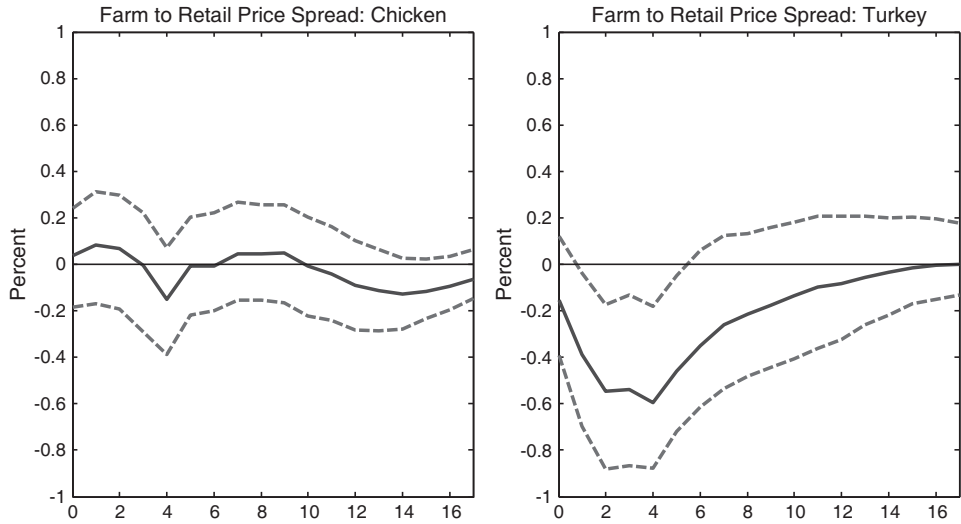


Figure 20. Response of chicken and turkey price spreads to a 1% real oil price shock, 2006:5–2013:5

Notes: Estimates from monthly bivariate vector autoregressions under the identifying assumption that the real price of oil is predetermined with 90% bootstrap confidence bands.

receive for a broiler chicken, according to the USDA. There is no statistically significant increase in this spread in response to a real oil price shock. We also examined the spread between the price a consumer pays for *poultry other than chicken* (which includes turkey) and the price US farmers receive for a live turkey. These responses again show a statistically significant decline rather than increase.

Figure 21 examines the same question in a different manner. We evaluate the response to a real oil price shock of consumer prices for flour, for bread, and for breakfast cereal measured relative to the price of wheat received by US farmers. Because wheat is one of the main agricultural inputs in producing flour, bread and breakfast cereal, one would expect higher processing, transportation and distribution costs driven by higher oil prices to translate into higher spreads. Figure 21 shows no evidence of such an increase in the spread in response to real oil price shocks, confirming the earlier results.

We conclude that there is no evidence to support the notion that oil price shocks are associated with increased food prices driven by higher costs of food processing, packaging, advertising, transportation and distribution. This result is not unexpected because we already showed that food prices have been remarkably unresponsive overall to oil price shocks even after May 2006. To the extent that there is any response at all, it appears to be driven by higher crop prices.

A final question that is not so much related to the price of food, but to the price of serving food is whether a real oil price shock drives up the cost of eating out compared with eating at home. Figure 22 presents results based on the model

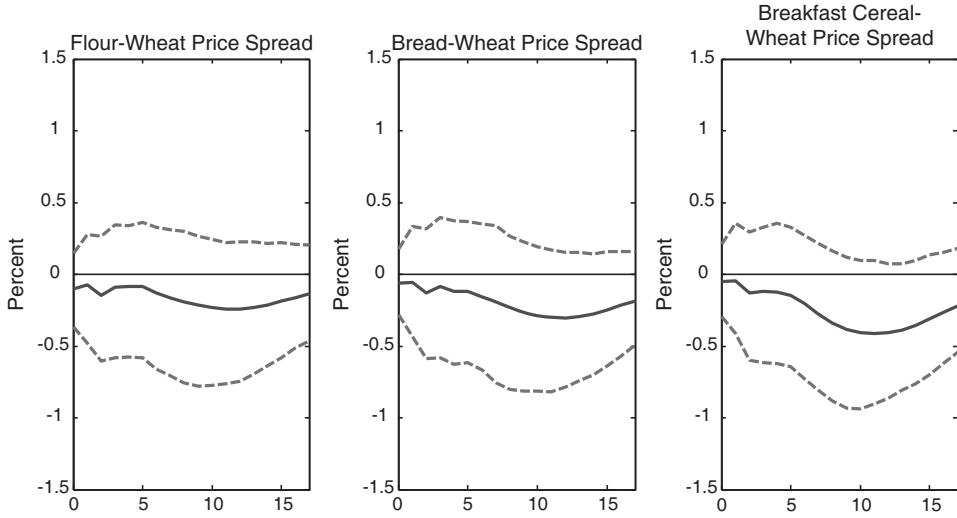


Figure 21. Response to a 1% real oil price shock of wheat-related products, 2006:5–2013:5

Notes: Estimates from monthly bivariate vector autoregressions under the identifying assumption that the real price of oil is predetermined with 90% bootstrap confidence bands.

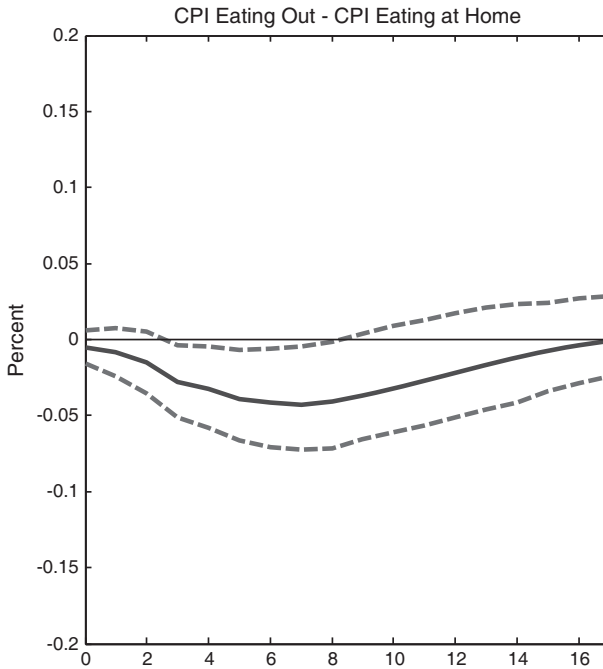


Figure 22. Response to a 1% real oil price shock of the cost of eating out compared to at home, 2006:5–2013:5

Notes: Estimates from monthly bivariate vector autoregression under the identifying assumption that the real price of oil is predetermined with 90% bootstrap confidence bands.

$$\begin{pmatrix} \dot{p}_t^{crude/CPI} \\ \dot{p}_t^{CPI\ food\ away/CPI\ food\ at\ home} \end{pmatrix} \sim \text{VAR}(6)$$

If higher oil prices were associated with higher costs of running restaurants, one would expect this spread to increase in response to a 1% real oil price shock. Figure 22 shows that the response instead appears to be significantly negative, allowing us to rule out this interpretation.

6. A GLOBAL PERSPECTIVE

Our results are in striking contrast with the literature and public debate on the emergence of global food shortages. It has been common in this debate simply to equate food prices with the prices of key agricultural commodities such as wheat, corn and soybeans. For example, Bruno *et al.* (2013) discuss the evidence for speculation ‘in food markets’. A casual observer might associate their work with retail food prices, when this study is actually concerned with the prices of grains and livestock traded on futures exchanges. Our analysis shows that care must be exercised in drawing a distinction between the prices of raw agricultural products and the retail price of food.

Whereas the response of real retail food prices to real oil price shocks has been negligible even after May 2006, as shown in Figure 10, we documented much larger responses of the real price of food crops such as corn, wheat, soybeans and rice in Figure 14. To the extent that consumers in developing countries eat less processed food than US consumers, the real price of crops is likely to be more representative for food prices in developing countries than in the US. This observation suggests that we examine in more detail how sensitive real grain prices in particular are to real oil price shocks.

In this context, it is important to remind ourselves that the response estimates in Figure 14 need not represent the causal effects of real oil price shocks. A causal interpretation would require that shocks to the real price of oil are exogenous with respect to agricultural markets and occur all else equal. This premise seems unlikely, given the consensus in the literature that recent fluctuations in the real price of oil mainly arose because of unexpected variation in the global business cycle. Kilian and Hicks (2013), Kilian and Murphy (2014) and Kilian and Lee (2014), among others, demonstrate that the real oil price shocks since 2003 have reflected primarily global shocks to the flow demand for oil associated with unexpected industrial growth in emerging Asia. The same growth is likely to be followed by higher incomes in emerging Asia and hence by higher demand for high-quality food. Thus, an alternative interpretation is that increases in the real price of oil and increases in real crop prices in recent years have shared a common component that is associated with fluctuations in the global real activity and incomes.

6.1. Are crop price increases associated with shifts in global real activity?

We examine this question by relating changes in the real price of crops to flow demand shocks for crude oil and other industrial raw materials. An unanticipated expansion in global industrial activity, for example, is associated with increased demand for industrial raw materials to be used in the production of industrial goods. Estimates of such flow demand shocks may be recovered from structural oil market models such as the models used in Kilian and Murphy (2014) or Kilian and Lee (2014).¹⁵ Below we relate the per cent change in the real price of corn, wheat, soybeans and rice to the historical evolution of these flow demand shocks. Our objective is to separate the component of price changes that is associated with unexpected variation in the global business cycle from the component that is driven by other shocks. Given that the global business cycle as measured in these studies relates to industrial activity, there is no reason to expect the effect of flow demand shocks on the real price of crops to be as large as their effect on the real price of oil or on other industrial commodity prices. Moreover, one would expect changes in real income and in food consumption in emerging economies to follow fluctuations in industrial activity only with a delay.

We quantify this effect by fitting a distributed lag model with intercept α to the per cent change in the real price of corn:

$$\Delta p_t^{corn/CPI} = \alpha + \beta_0 u_t + \beta_1 u_{t-1} + \dots + \beta_{12} u_{t-12} + \varepsilon_t$$

where the mean zero regression error ε_t may be heteroscedastic and serially correlated, and where the regressor u_t denotes the flow demand shock recovered from an updated estimate of the structural oil market model used in Kilian and Lee (2014). In estimating the distributed lag model, we restrict the sample to the period since May 2006 to allow for a structural change in May 2006 in the relationship between flow demand shocks and real crop prices. The response of the real price of corn to a flow demand shock may be constructed by cumulating the regression coefficients $\partial \Delta p_{t+h}^{corn/CPI} / \partial u_t = \beta_h$, $h = 0, 1, 2, \dots, 12$. Similar regressions are fit for the real prices of wheat, soybeans and rice.

Figure 23 shows that all four real crop prices respond positively to a global flow demand shock, but only the responses of the real prices of corn, soybeans and rice are statistically significant based on pointwise one-standard error bands obtained using

¹⁵ These studies rely on a fully structural VAR model of the per cent change in global crude oil production, an index of fluctuations in the global business cycle developed in Kilian (2009), the real price of crude oil, and the change in above-ground crude oil inventories. The model differentiates between flow supply shocks, flow demand shocks, speculative demand shocks and a residual shock that captures idiosyncratic demand shocks. These structural shocks are jointly identified based on a combination of sign restrictions on the structural impulse responses and bounds on the impact price elasticities of oil demand and oil supply.

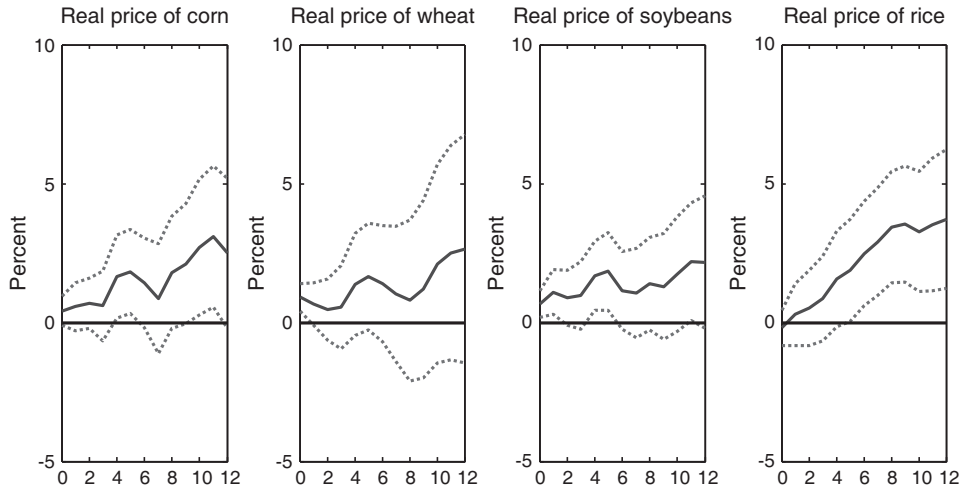


Figure 23. Responses of grain prices to global flow demand shocks, 2006:5–2013:5

Notes: Estimates from distributed lag models relating the growth rate in each real grain price to exogenous flow demand shocks obtained from an update of the model of Kilian and Lee (2014) with 1-standard error bootstrap confidence bands.

the block bootstrap. Given the short sample, this low level of statistical significance is expected.

6.2. How much of the change in crop prices is accounted for by the global business cycle?

Having established a tentative link between the global business cycle and real grain prices, it is natural to ask how much of the evolution of real crop prices on the basis of these estimates may be attributed to flow demand shocks. It can be shown that the explanatory power of flow demand shocks for real crop prices is far from dominant, but not negligible. The fitted values of the distributed lag regressions imply that 17% of the variation in the growth rate of the real price of wheat is explained by flow demand shocks, 19% of the variation in the growth rate of the real price of soybeans, 27% of the variation in the growth rate of the real price of corn and 24% of the variation in the growth rate of the real price of rice. These effects are larger than conjectured in Wright (2014), for example, but not overwhelmingly large.

Figure 24 plots the component of these growth rates that is not explained by global flow demand shocks. Much has been made of the possibility of speculation driving agricultural crop markets. If the residual variation in Figure 24 reflected speculation in agricultural crop markets, we would expect real price changes to be highly correlated across different crops. Table 2 shows that the residual growth rates of the real prices of corn and wheat have a correlation of only 0.50. The correlation of 0.61 between corn and soybeans is only slightly higher, whereas the correlation between

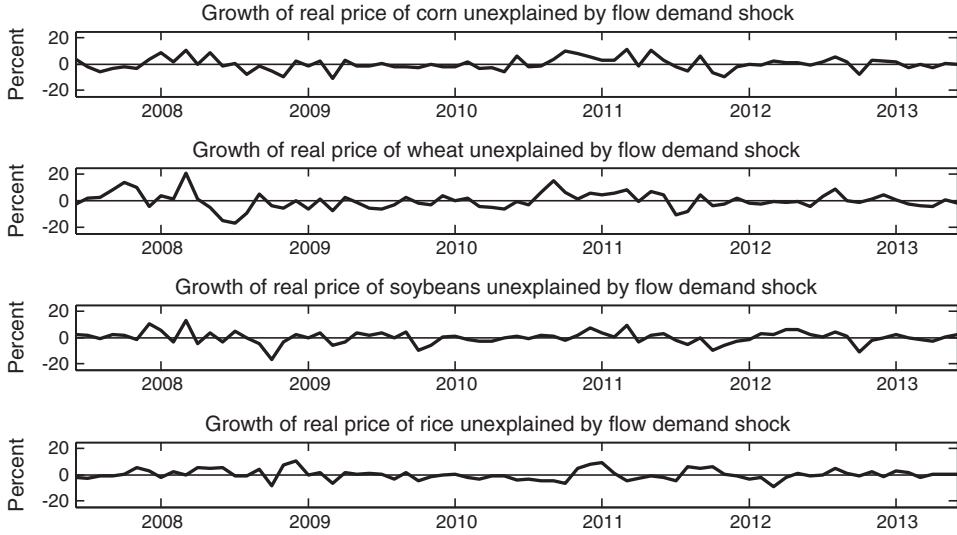


Figure 24. Growth rate in grain prices unexplained by flow demand shocks, 2006:5–2013:5

Notes: Residuals from distributed lag models relating the growth rate in each real grain price to exogenous flow demand shocks obtained from an update of the model of Kilian and Lee (2014).

Table 2. Correlation of Residual Growth Rates in Real Grain Prices after Controlling for Cumulative Effect of Flow Demand Shocks, 2006.5–2013.5

	Real price of corn	Real price of wheat	Real price of soybeans	Real price of rice
Real price of corn	1	0.50	0.61	0.06
Real price of wheat	–	1	0.40	–0.04
Real price of soybeans	–	–	1	0.08
Real price of rice	–	–	–	1

Notes: Authors’ computations based on residuals from distributed lag models relating the growth rate in each real price to exogenous flow demand shocks obtained from an update of the model of Kilian and Lee (2014).

wheat and soybeans is much lower with an estimate of 0.40.¹⁶ These estimates cast doubt on explanations of the residual variation in the data based on speculation in agricultural crops. This impression is reinforced by inspection of Figure 24. For example, the increases in the real price of wheat in 2007 are not mirrored by similar increases in the real price of corn or soybeans, suggesting an idiosyncratic supply or demand shock in the wheat market in 2007 and 2008 (including domestic supply shocks as well as fluctuations in foreign demand for US crops and in foreign supplies of crops competing with US crops).

¹⁶ This pattern is consistent with the fact that in many US states soybeans and corn are substitutes in production.

There are many other potential reasons for the residual comovement in Table 2. Apart from droughts or floods that may affect more than one crop at the same time, another possible explanation of a positive residual correlation would be competition for land and water in response to US biofuel policies, amplified by the use of both corn and soybeans as biofuels. For example, Wright (2014), when explaining how increased demand for biofuels raised grain crop prices after 2005 notwithstanding increased production, emphasizes the substitution of biofuels for petroleum based fuels together with the substitution in food consumption and animal feed between wheat and corn (as well as wheat and rice in some regions of the world) and the stockpiling of grains in anticipation of rising demand for biofuels.

The latter interpretation is consistent with the higher correlation in Table 2 of corn with soybeans, which is also used in the production of US biofuel, compared with wheat, which by and large is not. It is also consistent with a substantial increase in the residual correlations between corn and wheat and between wheat and soybeans compared with the pre-May 2006 data. It is inconsistent, however, with a largely unchanged residual correlation between corn and soybeans, compared with the pre-May 2006 data. The most striking feature of Table 2 is the low residual correlations of rice with respect to the other food commodities. In fact, these correlations are even lower than prior to May 2006, suggesting that the causes of increases in the real price of rice are unrelated to those underlying the real price of corn, soybeans and wheat.

We conclude that, after controlling for the global business cycle, none of the standard explanations of higher crop prices including the shift in US biofuel policies by itself seems to provide a good fit for the agricultural crop price data. In particular, it is difficult to attribute increases in the real price of corn, wheat and soybeans simply to biofuel mandates, given the heterogeneity in results across crop prices. This conclusion is especially evident for the real price of rice, which is perhaps the single most important food commodity for many developing countries. On the basis of our evidence, it appears that increases in the real price of rice were largely unrelated to US biofuel policies and to oil-market specific events. Figure 25 illustrates the latter point without the help of a formal model. It shows that the real price of rice continued to increase even as the real price of oil collapsed in the second half of 2008, and declined in 2009 and 2010, while the real price of oil recovered. Moreover, the persistent decline in the real price of rice after 2009 underscores that the shift in US biofuel policies had no relevance for the evolution of this price, which appears to be due to a combination of idiosyncratic factors and a shift in global real incomes. This finding is not surprising perhaps, as there is no competition between rice and corn in production, limiting substitution effects to the consumption side of the market.

6.3. Implications of higher crop prices for industrialized countries

Our evidence shows that retail food price increases in the United States were modest. There were no large spikes or surges in US retail food prices. This means that there is

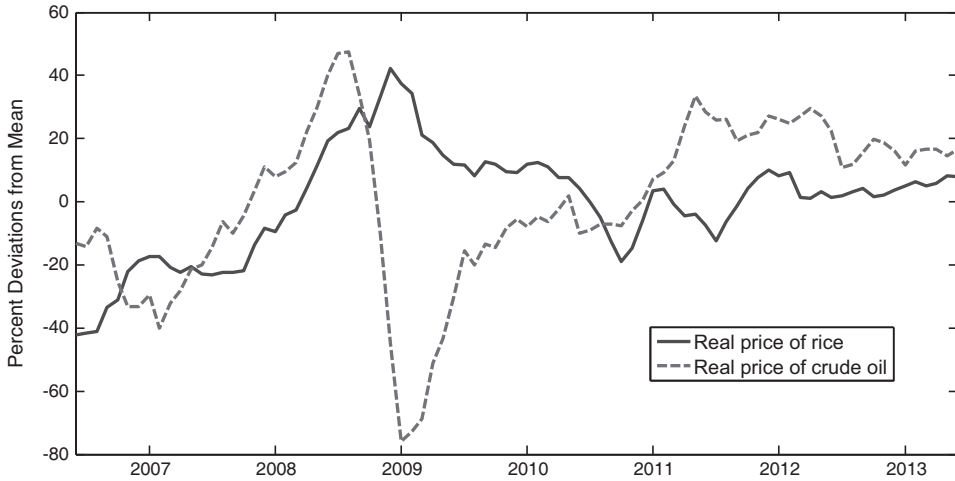


Figure 25. Real prices of rice and crude oil, 2006:5–2013:5

Notes: Authors' computations based on the data described in the appendix.

no reason to expect a significant negative impact of higher crop prices on consumers in the United States. In other words, there is no reason to be concerned about the welfare implications of higher crop prices in the United States. One would expect similar results for other industrialized economies (and increasingly for emerging economies), in which food consumption consists mainly of processed foods.

We already showed that a low share of agricultural commodities in the cost of producing processed foods means that even large price swings in agricultural commodity markets have little effect on retail consumer prices for food. We provided evidence that this share is low for the United States, taking advantage of the availability of detailed data on US consumer prices and prices paid and received by farmers. Such detailed data are not readily available for other industrialized countries, but one can show that consumer food price inflation is not a major problem in other industrialized countries either by comparing the food price inflation rates in leading industrialized countries.

Table 3 shows the cumulative and average rates of food price inflation in the United States, Canada, the eurozone, France, Germany, Italy, the United Kingdom, and Japan since May 2006. Because data on the CPI excluding all food items are not readily available for many of these economies, we deflate the CPI for food by the overall CPI. For countries such as the United States it can be shown that this normalization makes little difference, given the relatively small share of food in overall consumer expenditures (see Table 1). Table 3 confirms that consumer food price inflation adjusted for overall inflation has been low not just in the United States. In fact, in the eurozone and in Japan food price inflation has been even lower, and in Canada only slightly higher. By far the highest real food price increases are observed in the United Kingdom, but even there the average rate of increase has been only 2% per year. These increases are so modest that there is no apparent reason to be

Table 3. Percent Change in Consumer Food Prices Relative to the Overall CPI, 2006.5–2013.5

	Cumulative Growth	Average Annual Growth
United States	6	0.8
Canada	9	1.2
Euro area	3	0.4
France	2	0.2
Germany	7	1.0
Italy	3	0.4
United Kingdom	15	2.0
Japan	2	0.3

Notes: The data sources are described in the appendix. Food price inflation is computed by adjusting inflation in the food CPI by inflation in the overall CPI, given the lack of data for the CPI excluding food for many industrialized economies. It can be shown that this normalization makes little difference for countries such as the United States where the CPI excluding food exists because the share of food in the overall CPI tends to be small for industrialized countries (see Table 1).

concerned with the welfare implications of higher crop prices for these industrialized countries.

6.4. Implications of higher crop prices for developing countries

The evidence in Table 3, of course, does not mean that higher crop prices are not a problem for many developing countries. One reason is that consumers in poor countries do not eat as much highly processed food. One would expect the prices of staple foods such as wheat, corn, and rice in poor countries to track the prices of agricultural commodities much more closely than they track the corresponding retail food prices in industrialized countries. To illustrate this point consider a country in which the diet consists mainly of rice. Figure 26 plots the price of processed rice, as measured by the US consumer price index, and the price of rice received by US farmers. The plot shows that over the period from 2006:5 until 2008:5, for example, the price of unprocessed rice received by US farmers increased by an additional 50% compared with the price of processed rice faced by consumers in the United States. The real price of rice in global food commodity markets increased by an additional 100% compared with the US consumer price of processed rice. This evidence suggests that the population of countries consuming less processed rice is likely to have been disproportionately affected by rising rice prices in global markets.

Despite the importance of this question, there is little systematic evidence on how the real price of staple foods has evolved in poor countries worldwide. Documenting changes in the real price of staple foods in poor countries over time is a difficult task because it requires detailed and reliable data on consumer prices, which do not in general exist in developing countries, it requires information about local diets, and it requires data on nominal exchange rates. Without such time series data one is forced to rely on survey data, which is indeed what many academic studies have done (e.g.,



Figure 26. Alternative measures of the real price of rice, 2006:5–2013:5

Notes: Authors' computations based on the data described in the appendix. The IMF commodity price refers to the Thai wholesale price index (US\$/metric ton); the US crop price refers to the price received by US farmers; the US consumer price to the price of processed rice. All price series have been deflated by the US CPI and normalized to 0 in May 2006.

Ivanic *et al.*, 2012). Other studies work directly with time series of global agricultural commodity prices (e.g., Giordani *et al.*, 2012).

As the review of the literature in the introduction illustrates, there is rightly great concern about the welfare implications of large increases in the real price of staple foods in developing countries. The concern is not only that poor countries are more exposed to increases in food commodity prices for the reasons discussed above, but that a price increase of the same magnitude has a greater impact on the welfare of the average household, because households in poor countries spend a higher fraction of their income on food than consumers in industrialized countries and because they are more likely to live close to subsistence levels. For example, the food share in US consumer expenditures is about 13%, while estimates put the expenditure share of food for poor people in developing countries somewhere between 40% and 70% (see de Hoyos and Medvedev, 2011).

While these points are well taken, there also are reasons to be cautious about accepting the usual presumption in the policy debate that higher global crop prices, inflicted on developing economies by market forces or by the actions of industrialized economies, are responsible for political strife, malnutrition and food riots in poor countries. One reason is that the US dollar has been fluctuating with respect to many foreign currencies, so the real price of food in the consumption units of developing countries may be much lower or much higher than the real price in US consumption units. For example, the Central African Currency Unit appreciated against the US dollar by nearly 20% from mid-2006 to mid-2008, during the surge in global wheat and rice prices, presumably offsetting some of that real price increase measured in

domestic consumption units. At the same time, food riots in poor countries that are usually attributed to higher crop import prices may also be associated with rapidly depreciating local currencies unrelated to agricultural markets. For example, between May 2006 and 2013, the US dollar appreciated by 40% relative to the currency of Uganda and by 50% relative to the currency of Botswana, amplifying the impact of higher international crop prices. This means that we have to be careful to distinguish between global crop prices and domestic food prices in developing countries.

Another reason for scepticism is that higher crop prices may be bad news for urban consumers in developing countries, but tend to be good news for farmers in rural areas. It is by no means self-evident from a welfare point of view whether developing countries overall are worse off or better off as a result of higher crop prices. Ivanic and Martin (2008) emphasize that the overall impact on poverty in developing countries depends on whether the gains to poor net food producers in rural areas outweigh the losses incurred by poor urban consumers. Answering this question requires detailed household survey data. Whether higher food commodity prices improve or worsen the welfare of a particular household depends on the products involved, how integrated the poor are into the cash economy, their pattern of incomes and expenditures, other economic changes potentially associated with higher commodity food prices (such as higher real wages for unskilled labour in the context of a booming economy), and, most importantly, the domestic and trade policies pursued by the governments in poor countries. In related work, Ivanic *et al.* (2012) conclude that the 2010–11 increase in food commodity prices was associated with approximately a 1% increase in poverty in low income countries on average with enormous variation across countries. The statistical significance of this estimate is not assessed, however.

It is indeed ironic that for decades declining real prices of crops have been held responsible for the economic plight of many developing countries, but now a reversal of this trend is considered equally detrimental to their welfare. Undoubtedly, an important determinant of the effects of higher food commodity prices on the poor in low income countries is government policies. Ivanic and Martin's (2008) empirical analysis confirms that an increase in the real price of rice, for example, raises welfare in countries such as Vietnam, given the relatively egalitarian land distribution in that country, while lowering welfare in countries such as Pakistan with a higher fraction of poor urban consumers. This evidence suggests that we need to be careful not to attribute the effects of long-standing government policies to higher food commodity prices. Given that in some developing countries mismanagement and government restrictions have stunted the agricultural sector to the point of food imports being the only option available to the government to pacify the urban poor, it seems especially misleading to hold higher global crop prices responsible for the effects of these countries' earlier government interventions.

A third point to consider is that it does not seem warranted to view higher price volatility in food commodity markets as necessarily exogenous with respect to poor countries. Martin and Anderson (2012), for example, stress that trade barriers intended to

shield poor countries from fluctuations in food commodity prices may in fact have magnified the international price instability associated with exogenous shocks. They estimate that 45% of the increase in the global price of rice and 30% of the increase in the global price of wheat during 2005–2008 can be explained by changes in border protection rates (also see Ivanic and Martin, 2014). In related work, Giordani *et al.* (2012) estimate that a 1% increase in the share of exports covered by export restrictions is associated with an increase in global agricultural commodity prices by 1.1%. It is important to stress that trade policies in this context are not the impulse triggering food price increases; rather they help propagate and amplify rising food prices. Hence, we must be careful not to attribute to other shocks the welfare consequences of restrictive trade policies. Anderson *et al.* (2013), for example, conclude that the net effect of policies intended to insulate poor consumers from food commodity price shocks on global markets may actually have been to increase global poverty in 2008.

Finally, it is easy to forget that it is in part the economic success of emerging economies that has contributed to a substantial increase in oil prices as well as agricultural crop prices in the first place. Surely, one would not want to deny developing countries pursuing sensible economic policies the right to industrialize because other developing countries pursuing harmful economic policies have a hard time coping with higher food import prices as a result. A more sensible policy approach would be to insist that all developing countries with food shortages including countries in Africa and in the Middle East implement economic policies that facilitate the development of their agricultural sector if they find themselves unable to pay for food imports.

None of these caveats diminish the economic plight of the urban and rural poor in many developing countries and the fact that higher food commodity prices may worsen their economic situation, but they suggest that a more nuanced view than the testimony of Rosegrant (2008), for example, is important in developing policy solutions to these problems. It may seem that the precise cause of higher agricultural crop prices would be secondary, when these price increases are viewed from the perspective of a developing country without a significant industrial sector. This is not the case because the causes of higher food prices matter for the design of appropriate policy responses. We stressed, for example, that a good case can be made that inappropriate agricultural and trade policies in many developing countries helped amplify the observed food shortages. Moreover, our evidence suggests that calls for an end to biofuel programmes may not have the desired effect of lowering global food prices.

7. CONCLUSION

There is substantial evidence that US biofuel policies have been associated with sizeable increases in the real price of corn since 2006, as the production of ethanol began to compete for the production of food. In this paper, we examined the complementary question of the transmission of oil price shocks to food prices both prior to and after this change in US policy. One concern is to what extent higher oil prices cause higher

food prices. A related concern is how this transmission takes place in practice. These questions have taken on a new importance, as policymakers are growing increasingly concerned about the prospect of a global food shortage.

A common perception among academics and policymakers is that oil price increases in recent years have been associated with higher food prices. We showed that there is no evidence that US retail food prices closely tracked oil prices before or after the change in US biofuel policies in May 2006. Notwithstanding substantial variation in the real price of crude oil, indices of the real retail price of food faced by US consumers remained remarkably stable over time even after the shift in US biofuel policies. This is not true, in contrast, for the real prices of major agricultural commodities produced in the United States such as corn, wheat, soybeans and rice. Corn and soybeans experienced average real price increases of between 12% and 15% per year after May 2006, while the real prices of wheat and rice grew at an annual rate of 7%.

The distinction between retail food prices and the prices received by farmers for grain crops and livestock is important. Policy concerns about a looming food shortage appear to be based on rising real crop prices received by farmers as opposed to rising real food prices faced by US consumers. Although US consumer food prices have increased substantially in nominal terms, the cost of food measured in terms of other consumer goods has increased only by 7% cumulatively since May 2006 (or 1% per year). The discrepancy between the slow growth in real consumer food prices and the more rapid growth in the crop prices received by farmers is explained by the small cost share of agricultural products in the food prices paid by US consumers. For example, the farm value of wheat in the price of bread is only about 5%, so even substantial wheat price increases are associated with only small increases in the price of bread.

We provided evidence that after May 2006 unexpected increases in the real price of oil have indeed been followed by systematic increases in some US crop prices. For example, a 1% real oil price shock tends to be followed by a persistent and statistically significant increase in the real price of corn that peaks at 0.5% one year later. The same real oil price shock is followed by much smaller increases in US consumer prices for food (measured relative to the CPI excluding food and energy) with a peak response of only 0.05%. We emphasized that these responses should not be interpreted as the causal effects of higher oil prices, however, because the real oil price shocks that took place after May 2006 mainly reflected broad-based shifts in the demand for industrial commodities.

There are two main channels for oil price shocks to affect food prices. One channel is through an increase in crop prices; the other is through an increase in the cost of processing agricultural crops and of delivering the processed foods to the retail consumer. An increase in crop prices may arise because oil price shocks raise the cost of producing crops or because oil price shocks are associated with higher demand for crops. We showed that the latter explanation fits the data better because the real price of fertilizer (the production of which does not depend on the price of crude oil but on

the price of natural gas) responds significantly to real oil price shocks after May 2006 much like other agricultural prices. Given the divergence of the prices of oil and natural gas in recent years, this evidence can only be explained by a shift in the demand for agricultural products. In fact, 27% of the variation in the growth rate of the real price of corn since May 2006 can be explained by changes in demand associated with shifts in global real economic activity. The remaining price variation is by no means due to corn-ethanol mandates alone. Our analysis suggests that the evolution of the real prices of corn, wheat, soybeans and rice, while sharing a common component, is determined by a variety of factors that can differ from one crop to the next.

With regard to the effect of oil price shocks on the cost of food marketing, we found that, contrary to prevailing wisdom, there is no evidence that unexpected increases in the real price of oil are associated with higher food prices because of the increased cost of processing, transporting and distributing food. To the extent that there is any pass-through from oil to food prices, it reflects higher crop prices only.

Our results are in striking contrast with a growing literature and public debate on the emergence of global food shortages. It has been common in this debate to attribute hunger and malnutrition among the poor in developing countries to increased food price volatility in recent years. Our analysis showed that there has been no systematic increase in food price volatility. Only for wheat is there any evidence of a noticeable increase in price volatility and the reasons appear idiosyncratic rather than systematic. We emphasized that the real problem for consumers, if there is one, is one of rising food prices, not of volatile prices. The effect of increases in crop prices on consumers may differ greatly across countries.

We stressed, for example, that because of the absence of pass-through from crop prices to US retail food prices, a significant negative impact on consumers in the United States can be ruled out. One would expect similar results for other industrialized economies (and increasingly for emerging economies), in which food consumption consists mainly of processed foods. This conjecture is consistent with evidence of low food price inflation in many industrialized economies.

A different matter is to what extent increases in the real price of food commodities affect the welfare of poor households in the least industrialized countries which tend to consume less processed food and spend a larger share of their income on food. The answer is not obvious, because poor farmers in developing countries are likely to be producers as well as consumers of food commodities. Providing a reliable answer to this question requires detailed household survey data for extended periods. Recent studies show enormous variation in the effects of higher food commodity prices on poverty in developing economies. Our interpretation of this evidence is that, whether a country benefits from rising food commodity prices or not, in important part appears related to the agricultural, exchange rate, and trade policies it pursues and that these policies tend to predate recent food commodity price increases. We made the case that a more nuanced analysis is called for than is embodied in some recent policy statements.

Discussion

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There has been quite some talk about the potential adverse effects of higher oil prices for the prices of food. The background is a 2006 policy change in the US, which promoted the use of crop for the production of ethanol. Coincident with that policy change, the prices of many cultural commodity products have been on the rise. And as often happens, some commenters and policymakers were quick to draw conclusions from this observation.

The paper by Baumeister and Kilian subjects the matter to a serious analysis and debunks the myth that higher oil prices are responsible for the increase in food prices. The key insight is that one needs to distinguish between *commodity* prices and *retail* food prices. While there is some evidence that commodity prices have increased post-2006, there is no convincing evidence that this has also fed through to higher retail prices, which are the prices that should matter from a policy perspective. After all, this is to be expected since commodities only constitute a small share of overall food prices (the share of wheat in the price of bread, for instance, is only 5%). In hindsight, the results are thus not surprising, but this argument was clearly missing in the public debate. So the paper makes an important point.

Key for examining the potential link between oil prices and food prices is of course proper identification. The relationship between the two variables is rife with reverse causality and simultaneity problems. For instance, oil and food prices may simply jointly react to the business cycle and there may hence not be any causality at all. The main empirical exercise in the paper is a VAR that includes two variables, the relative price of oil and the relative price of food. This allows disentangling causality between the two variables. In addition, the paper provides a discussion of endogeneity with respect to global demand shifts, exploiting the price of nitrogen fertilizer (production of this fertilizer relies on natural gas rather than crude oil). This discussion clearly alleviates endogeneity concerns. However, it would have been preferable to tackle endogeneity head-on in the econometric exercise – so in my view concerns about identification remain.

One way to bolster causal interpretation would be to exploit heterogeneity. The paper finds noticeable differences in the response of food prices to oil prices for different types of foods. Can this be reconciled with a different importance of oil prices for various food products? Products that are more dependent on oil should display more pronounced responses to oil prices. Evidence of heterogeneity linked to oil dependence would corroborate the idea of a causal effect.

A curious detail in the empirical specification is the definition of relative prices: food prices are measured relative to consumer prices *excluding* food, while oil prices are measured relative to consumer prices. Two questions arise in this respect. First, it is not clear that we are interested in relative prices at all. Suppose oil prices do raise food prices, but the prices of non-food items as well, and do so in a proportional fashion. In this case, no impact on food prices will be identified by the specification. Is this what we want? I am not sure. It is not clear that policymakers would only worry in case food prices go up relative to other prices. If oil prices raise consumer costs across the board, this is arguably also a concern. The second issue is that because different denominators are used for relative prices (one time CPI, and the other time CPI excluding food), relative prices can change even if neither crude nor food prices change (to see this, consider an increase in non-food CPI). While there may be technical reasons for choosing this specification, it opens up the possibility of the relationship capturing unintended effects.

Deren Unalmis

Central Bank of the Republic of Turkey

The paper is on a timely and important subject, and has striking findings. Baumeister and Kilian aim to quantify the impact of changes in oil prices on food prices. They question whether the links from the price of oil to the prices of agricultural commodities and their retail prices have strengthened recently, after a policy shift in the US in 2006. The study sheds light on the causes of the recent increases in the prices of various food items and their impacts on the consumer welfare in developed and developing countries, hence providing important policy implications.

Although the authors find some impact of the price of oil on agricultural commodity prices, the effects on retail prices are found to be relatively limited. Besides, they show that the observed comovement between oil and food prices is partially driven by global business cycles. They conclude that the negative effects of the environmental policy shift on welfare in industrialized and developing countries are so far limited.

The underlying problem is simple. The real prices of food commodities had been on a declining trend since mid-1970s, but this trend was reversed around mid-2000s. Since food prices are highly related to consumer welfare (food has a large share in the consumption basket in many countries), it is quite important for the policymakers to understand the reason for the recent increases in food prices and to know whether this shift is transitory or permanent.

In fact, some food items seem to be more seriously affected. For example, when we compare the developments in an aggregate real food price index to the developments in the real price of corn (which is extensively used in the US for ethanol production), we observe that the recent increases in the real price of corn and its volatility are more evident compared to the aggregate food index. As stated in this paper, one possible (plausible) explanation of the increases in food prices is the major shift in the US

policies in favour of using more biofuel, which became effective after May 2006. This type of policy change is expected to increase the dependency on agricultural commodities, due to an additional demand created by the biofuel production.

Food and energy prices had already been linked through the stages of production, food processing, food packaging and distribution. The policy change mentioned above has created a new link between the price of oil and the prices of agricultural commodities. This new link is expected to strengthen over time as the substitutability between oil and biofuel increases. Higher substitutability can be caused by two developments. The first one is advancement of the biofuel production technology, leading to an increase and standardization in the biofuel quality. The second one is the development of machines and vehicles which are more compatible with the use of biofuel. Higher substitutability between oil and biofuel implies a stronger comovement between the prices of oil and food commodities. The paper also stresses the fact that agricultural commodities are linked by many channels. Hence, if oil, corn and other agricultural commodities that are used in fuel production become substitutes, this should also increase the comovement in the prices of other agricultural commodities, even if they are not used in fuel production.

In fact, many recent studies in the literature find that the causality from the price of oil to the prices of food commodities has increased after the policy change. This is bad news, because oil prices are historically much more volatile than the food prices and since global oil reserves are running out, oil prices are expected to increase further in the medium to long run. The danger is that all the unrest in the oil market might now be felt in the food market amplifying the effects of the oil market specific shocks. However, Baumeister and Kilian warn that the studies in the literature tend to use atheoretical methods, like Granger non-causality tests, reduced form VAR impulse responses, and reduced form VAR or VECM coefficients as measures of causal impacts.

Authors also indicate that the link between the prices of oil and food is driven largely by macroeconomic developments. Besides, they say that it is necessary to take into account not only the causality running from oil prices to food prices, but also the causality running in the other direction. Hence, different from the related literature, Baumeister and Kilian instead use a structural econometric framework to examine the issue.

Before moving onto my comments, I would like to state that this discussion needs to be regarded as suggestions for future work rather than a criticism of the current paper. Given the short sample size and data availability I believe that the authors do a great job providing answers to a recently important issue.

I have three major comments. First, I argue that such policy changes do not necessarily create a strong comovement since there are two clashing effects. Given a positive level of substitution between oil and food as alternative sources of energy, all else equal, the two prices are expected to be positively related. However, news about a

change in the substitutability between these two types of commodities could create an effect in the opposite direction.

Imagine news is spread in the markets about a policy shift that encourage or require the use of more biofuels. The market participants will interpret this as the economy being less dependent on oil and more dependent on agricultural products in the future. This is relieving for the oil market and hence the response of the price of oil has to be downwards. On the other hand, the same development will have the opposite effect on the prices of agricultural commodities that are used in biofuel production, that is, the prices of agricultural commodities will rise. In fact, looking closer to the data around and since mid-2006, it is possible to see that, after around the policy shift towards the use of more ethanol, the prices of corn and oil moved in opposite directions for some time (see Figure 27). Figure 27 also shows that, when prices are indexed to 1 in May 2006, the corn price seems to be persistently higher than the price of oil since 2006. If this effect was one-off (only in May 2006 for example) it would not constitute much of a problem. Because the only thing to do in this case would be to separate the sample into two (as pre-policy change period and post-policy change period) and carry out the analysis in two separate subsamples as this study did. However, many other countries follow with similar policy changes with subsidies and quantitative targets for biofuel (for example, Europe in 2009).

This behaviour in oil and food prices in opposite direction is likely to be observed every time there is a policy shift encouraging the use of more biofuel. Since many countries are in the process of developing their own biodiesel programmes (see Avalos, 2014 for a list of countries), the markets are faced with such news from time to time. Moreover, not only policy shifts but also news about increases in the efficiency of

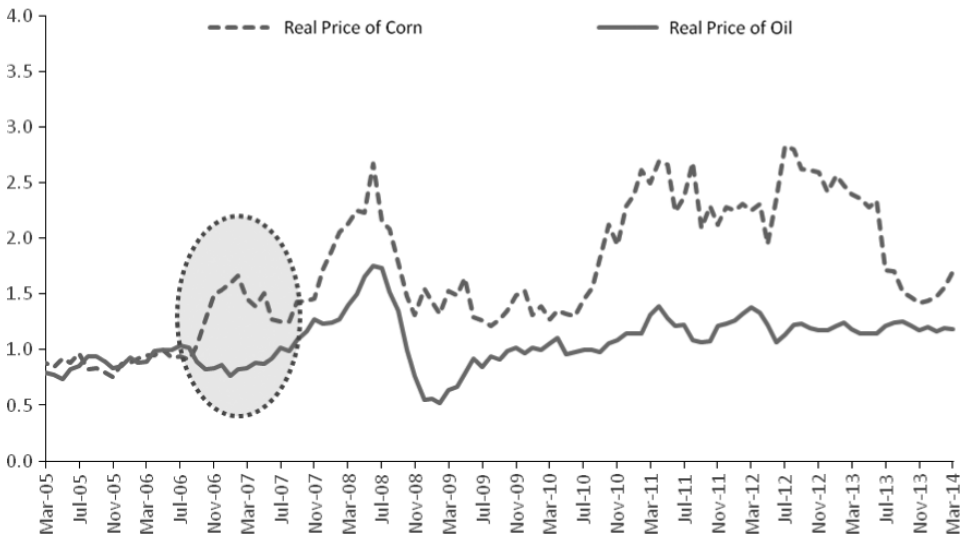


Figure 27. Real price of corn and oil since 2005 (May 2006=1)

Source: Bloomberg, author's calculations.

biofuel production or consumption can decrease the dependency on oil. In addition, the fact that the biofuel market is currently too small compared to the oil market can be another reason why it is early to see a strong positive relationship between oil and food prices due to the substitution effect.

My second comment is on the structural VAR (SVAR) model used in the paper. The authors criticize the existing literature for using atheoretical methods. Although going a step further, in my view, the authors cannot fully address two problems in their SVAR estimation. First, they cannot directly include variables to capture the macroeconomic developments, due to the fact that the sample sizes are too short for any model larger than a bivariate model. But they do show afterwards that the commodity prices worldwide are dependent on variations in global flow demand shocks. Second, Baumeister and Kilian use a recursive identification approach where it is assumed that there is no contemporaneous effect running from food to oil prices. In other words, the authors assume that food market specific shocks do not have an impact on the price of oil within a month. This assumption seems reasonable for the SVAR estimation in Baumeister and Kilian since they are looking at agricultural commodity prices received by US farmers. However, for global food commodity prices, I think this assumption may be less valid recently and it can be even less valid in the future. The oil market may be becoming more sensitive to the food market specific shocks (for example, unexpected extreme weather conditions in cultivated regions) as the share of biofuel in the total energy usage increases.

Figure 28 presents the behaviour of the prices of corn and oil during a recent food market specific event. The US Department of Agriculture released its 'World Agricultural Supply and Demand Estimates' report of the year on 9 May 2014 at 12 noon, which had predicted record corn and soybean harvests for 2014/2015 (see USDA, 2014). This announcement was regarded as a surprise in the financial markets, since expectations regarding the agricultural supply performance were much weaker. Hence, when this report was out, the markets immediately responded with a sharp drop in the price of corn (a decline of 3% in half an hour). Although this shock is not specific to the oil market, the price of oil as well responded with a significant decline (of 0.7% within half an hour). Hence, high frequency data in this case indeed suggests that oil prices respond immediately to food market specific shocks. Obviously, this point deserves investigation in the future using a formal statistical analysis with satisfactorily large set of recent events.¹⁷

Thirdly, as future work, I would like to stress that a suitable theoretical model could complement the empirical work in this study. Although theoretical models often are incapable of measuring the quantitative importance of relevant channels, they can help us provide some policy recommendations for the future.

¹⁷ Admittedly, observing high frequency comovement does not necessarily establish comovement at the monthly frequency, which is relevant for the analysis in Baumeister and Kilian.

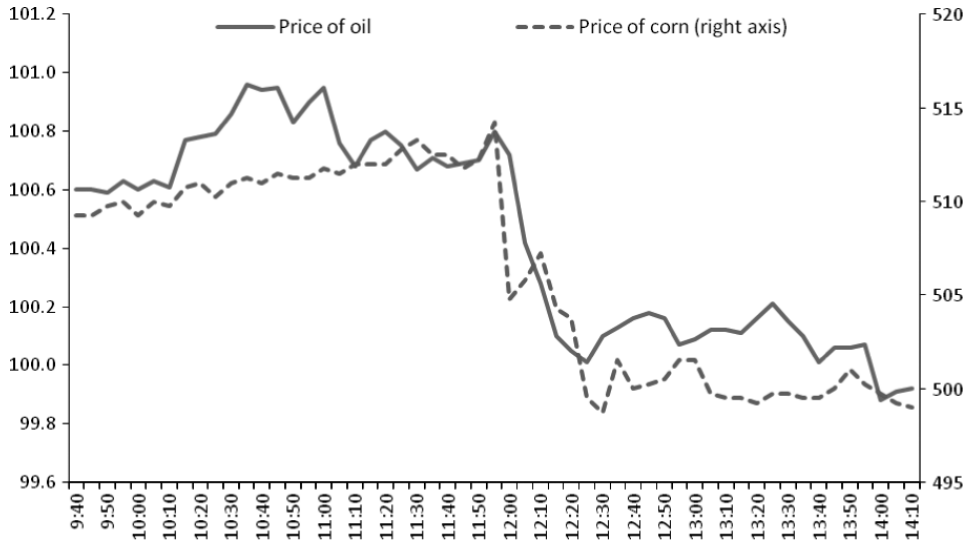


Figure 28. The release of USDA report 'World Agricultural Supply and Demand Estimates' on 9 May 2014 at 12.00 p.m. US time (data for 5 minute intervals)

Source: Bloomberg.

Although the paper is great in the sense that it attempts to answer important recent questions, it cannot go into the issue of future policy recommendations. One concern is that if the industrialized countries continue pursuing these types of policies, the substitutability between oil and agricultural commodities will increase, driving the food prices up even further. After some time, the cost share of agricultural commodities in retail prices might come up to levels that the retailers will be less reluctant to reflect the increases in the prices of agricultural commodities.

A general equilibrium model would be useful, which allows for substitutability between oil and biofuel. In the context of such a model, it would be possible to carry out a sensitivity analysis for higher degrees of substitution. In the model, the existence of storage/inventory behaviour for both oil and agricultural commodities would be key to understand the role of speculative motives in driving prices in commodity markets. Unalmis *et al.* (2012) model competitive oil storage in the US, in the context of a general equilibrium model, and show that ignoring the speculative motive amplifies or mitigates the effects of oil price shocks depending on the source of the shock. Moreover, an analysis of different monetary policy environments, including the case of zero lower bound would help us understand what would happen (in a relative sense) in a conventional monetary policy environment. In order to derive useful policy implications for the global economy, a detailed welfare analysis in a model with at least two country blocks (developed and developing countries) would be extremely useful. For example, it would be interesting to look at the implications of trade barriers, food subsidies and capital control policies in developed and developing countries. These issues

might be too much to tackle in a single paper but could be the subjects of a PhD thesis or a comprehensive research project. The findings of such a work would have quite valuable implications for the environmental policy issues.¹⁸

To conclude, this is an inspiring paper, which asks an important question and has striking findings. There is substantial information for policymakers. However, my view is that further work is needed on the subject. On the empirical front, the structural models on the issue could be enriched to include macroeconomic factors and could allow for a two way contemporaneous relationship between the prices of food and oil. As future work, it would also be interesting to carry out event studies to analyse the impacts of news on biofuel policies or market specific events on prices of various commodities including oil. Besides, policy simulations under a suitable theoretical framework would be extremely useful in order to create policy recommendations for the future.

Panel discussion

Georges de Menil asked about the relation of the paper with changes in ethanol requirements and the supply of agricultural land available for corn used in food production. Michalis Haliassos wondered whether the authors could make use of changes in the minimum requirements of ethanol content in gasoline to trace the effect on food prices. Replying to discussants and comments, Lutz Kilian addressed the problem of endogeneity of the real price of food. He explained that this was not a major issue, pointing out that the share of food in the CPI is so small that there cannot be any bias. In response to the suggestion to use different countries for the analysis, he added that this sounds like a good idea at first but that suitable data for countries other than the US are not readily available.

DATA APPENDIX

The nominal price of crude oil is obtained from the *Monthly Energy Review* of the US Energy Information Administration. We follow the literature in using the US refiners' acquisition cost for crude oil imports as a proxy for the global price of oil. The same source also provides the US refiners' price of No. 2 diesel fuel to end users excluding taxes.

¹⁸ The data required for the direct estimation of such a two-country model may not exist currently, hence, the model parameters may need to be calibrated and a detailed sensitivity analysis may need to be carried out for unknown parameters.

All consumer price index (CPI) and producer price index (PPI) data are obtained from the Bureau of Labor Statistics. The aggregate and disaggregate indices refer to prices paid by all urban consumers and are seasonally adjusted.

Monthly prices received by US farmers for corn, wheat, soybeans, rice, cattle, hogs, live broiler, and live turkey are provided by the US Department of Agriculture, which also makes available indices of the cost of fuel, fertilizer and animal feed paid by US farmers. Additional monthly price data for farm inputs issued at quarterly frequency were obtained from the National Agricultural Statistics Service for January 1988 to October 1995.

The international CPI data were obtained from Eurostat, Statistics Canada, and the Japanese Ministry of Internal Affairs and Communications. All global commodity prices are from the International Financial Statistics of the IMF.

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