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Did the Fertilizer Cartel Cause the Food Crisis?

H. Gnutzmanna | Faculty of Economics and Management, Leibniz Universität Germany
P. Spiewanowskib | Institute of Economics, Polish Academy of Sciences | Warsaw | Poland

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ABSTRACT

Food commodity prices escalated during the 2007/2008 food crisis, and have scarcely fallen since. We show that high fertilizer prices, driven by the formation of an international export cartel as well as high energy prices, explains the majority of the recent price spikes. In particular, we estimate the pure fertilizer cartel effect explains up to 50% of crisis food price increases. While population growth, biofuels, high energy prices and financial speculation doubtlessly put stress on food markets, our results help to understand the severity and sudden emergence of the crisis and suggest avenues to prevent its repetition.

Keywords: food crisis, fertilizer, cartel, competition policy JEL: F10, L40, Q02

PAPER

1. Introduction

During the 2007–2008 food crisis, commodity prices escalated leading to food insecurity and political instability in the developing world (Timmer, 2010). Simultaneously an export cartel for fertilizer, an essential input to industrial crop production, established itself and fertilizer prices tripled (Jenny, 2012). This paper estimates that the cartel directly led to a 40-50% overcharge in the fertilizer market, which

– through cost passthrough to agriculture – translated into up to a 20% increase in food prices. Since food prices rose on average by 40% during the crisis, we can attribute nearly 50% of the price increase to the formation of the fertilizer cartel. Moreover, while the cartel channel has apparently been overlooked in the literature so far, it can explain not only the severity but also sudden emergence of the food crisis which other explanations – such as population growth or high energy prices – do not. More generally, our results indicate an urgent need to better understand the role of export cartels in addressing future challenges to food security (Grote, 2014).

Commensurate to the importance of the food crisis, a large literature is developing to estimate its causes[2]. On the demand side, analysts emphasize population growth and rising per capita meat consumption (Trostle, 2010). Mitchell (2008) focuses on the role of biofuel subsidies in raising demand for crops, although subsequent research is ambiguous at best (Serra and Zilberman, 2013). Adverse supply shocks due to high energy prices are a potential explanation (Harri et al., 2009), although challenged by Zhang et al. (2010). Bad weather in some regions certainly did not help (Headey and Fan, 2010, chapter 2), although harvests were not unusually poor during the crisis period. Synchronous low grain stocks, or more precisely low stockto-use ratios is also frequently blamed (Bobenrieth et al., 2013). Current research and debate largely focuses on determining the relative importance of these causal factors to the food crisis[3]. Additionally, a growing body of research investigates the role of financial speculation in the food crisis, e.g. Irwin and Sanders (2012); Fattouh et al. (2013); Sanders and Irwin (2010), although there is considerable evidence against herd behaviour (Steen and Gjolberg, 2013). Finally, trade shocks (Headey, 2011) may have been a factor.

Email addresses: hinnerk@gnutzmann.info (Hinnerk Gnutzmann), piotr.spiewanowski@gmail.com (Piotr Spiewanowski)

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[2] Headey and Fan (2010) provide a very comprehensive survey

[3] One view is succinctly expressed by then-President George W. Bush in a White House press conference on 29.04.2008: "I thought it was 85 percent of the world's food prices are caused by weather, increased demand and energy prices ... 15 percent has been caused by ethanol"

Fertilizer has so far been at best at the sidelines of the discussion. While high fertilizer prices during the crisis are sometimes noted, they are often attributed to high energy prices (e.g. Headey and Fan (2010, p. 25)). Mitchell (2008) notes that "energy–intensive" components of total production costs account for 6.7%–13.4% in USDA farm survey data; but we know from economic theory that prices depend on marginal cost in a competitive industry. According to USDA (2014a), the average fertilizer cost share in years 1975-2013 accounted for 32% of the marginal cost of wheat and 37% of the marginal cost of maize.[4] High fertilizer prices can also have adverse impacts on the government budget of developing countries; e.g. Dorward and Chirwa (2011) point out that high fertilizer prices increased Malawi's fertilizer subsidy expenditures in 2008/2009. Yet we are not aware of previous literature taking fertilizer seriously as a driver of the food crisis, or estimating a formal econometric model in this direction.

An appreciation of the role of fertilizer may be crucial to understanding the past food crisis and mitigating future ones. Given the large share of agricultural marginal cost accounted for by fertilizer, strong price passthrough from fertilizer to food is predicted by standard economic theory[5]; careful econometric analysis is thus needed. Second, fertilizer prices are at times determined by an international export cartel (Hoekman and Saggi, 2007) or the degree of market concentration (Hernandez and Torero (2013)) and not market forces. Understanding the extent of the cartel overcharge is crucial to estimating the potential effects international competition enforcement against such cartels could have on food markets– particularly on developing countries, where households spend roughly half their income on food (Mitchell, 2008).

Contribution: We contribute to the literature in three ways. First, using established time series methodology (cf. Baffes (2010); Nazlioglu and Soytas (2011); Zhang et al. (2010)), we establish the strong cost passthrough from fertilizer to food. Second, we estimate the cartel overcharge (Connor and Bolotova, 2006; Connor, 2010) in the fertilizer market during the crisis period. Finally, we conduct a simulation of food prices in the counter–factual case that no cartel would have been formed and show that the majority of the crisis food price increase can be explained by the fertilizer cartel alone.

This paper proceeds by briefly presenting the role of fertilizers in modern agriculture and describing the fertilizer market. Subsequently, data and methods are introduced in section 3, succeeded by a discussion of the economic motivation of the regression equation and our the estimation strategy. We present results in section 4, and place them in the context of the literature. Section 5 simulates the development of food prices had no cartel been in place. Robustness checks are collected in section 6. Finally, we conclude.

2. Fertilizers and Market

Mineral fertilizers - nitrogen, potassium and phosphorus are the key nutrients crucial for plant growth and hence modern agriculture. The increase in use of commercial fertilizers was the main component of the so called green revolution and at least 30 to 50% of crop yield is attributable to commercial fertilizer nutrient inputs (Stewart et al., 2005). Currently the world fertilizers market is worth approximately $170 billion annually.

The fertilizer industry is conducive to cartelization, for individual nutrients and all three nutrients together. This feature of the fertilizer industry is based on heavy concentration of the essential mined inputs - potassium and phosphorus - where reserves are being exploited only in few countries and by few firms. Together with the high investment required in mining operations and the presence of export associations such as e.g. PhosChem and Canpotex, the fertilizer industry provides favorable conditions for collusion; indeed, cartel episodes have been documented since the late 19th century (see Taylor and Moss (2013) for a detailed study of the industry). Since the main input for nitrogen fertilizer is energy (used to convert atmospheric nitrogen to a nutritionally available form via the Haber-Bosch process), one would expect a higher degree of competitiveness on that market. However, many of the major phosphorus producers also manufacture nitrogen fertilizer, partly because a source of nitrogen is required to stabilize phosphorus, and partly because many fertilizer manufacturers sell blended nitrogen-phosphorus-potash fertilizer at wholesale and retail (Taylor and Moss (2013).

Furthermore, producers of fertilizers are often central to their local economies – e.g. PotashCorp for the Sasketchewan region of Canada – or indeed leading national exporters, as in the case of Office Cherifien des Phosphates (OCP) in Morocco or the Belarusian Potash Corporation, they are politically entrenched and backed by legal or de facto exemptions from usual antitrust enforcement.

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[4] Those figures represent the share of marginal costs. For total costs one must add an overhead – largely the rental cost of capital and land, since US agriculture is not labor intensive. These overheads can be interpreted as a largely fixed cost, which should not affect competitive market prices.

[5] See section 3 for details

Dating the Cartel: The propensity of the fertilizer industry to establish cartels is well known (al Rawashdeh and Maxwell, 2014). However, competitive periods – after breakdown of a cartel – also occur. This makes it imperative to precisely date cartel periods for empirical analysis. Taylor and Moss (2013) conduct a detailed micro–level study to distinguish different phases of market competition in fertilizers. They conclude, based on qualitative and quantitative evidence, that the cartel exercised in market power in the 2008–2012 period[6].

Furthermore, there exists evidence suggesting a successful attempt to form a Moroccan–lead phosphates cartel in 1974. In that period, Morocco's share of the international market was 40 percent, and with the other African and Middle Eastern producers, Morocco controlled 55 percent of world trade in phosphates (Johnson, 1977). However, due to significant decrease in exports (by 30 percent) during 1975, Morocco was forced to announce a price reduction in January, 1976. Later that year the Afro-Arab Phosphate Commission (APC), an export group to which Morocco, Tunisia, Senegal, and Jordan belong, announced that they would not further tighten the supply highlighting that they only pursued price stabilization and a guaranteed minimum price.

3. Data and Methods

Model Specification: Our interest is in determining the price passthrough from fertilizer and energy indices on food prices. Thus, based on annual time series data, we estimate reduced form regressions explaining food commodity prices as a function of fertilizer and energy indicies, controlling for inflation and allowing a linear time trend. This yields the regression model:

$$\begin{aligned} log(X_t) &= \mu + \beta_1 log(\mathrm{FERTILIZERS}_t) + \beta_2 log(\mathrm{ENERGY}_t) \\ &+ \beta_3 log(\mathrm{MUV}_t) + \beta_4 log(\mathrm{USD}_t) + \tau t + \epsilon_t \end{aligned} \quad (1)$$

where t denotes a year between 1960 and 2013, $\mathrm{FERTILIZERS}_t$ is the index of fertilizer prices and ENERGY_t the index of energy prices; moreover, a price deflator, denoted MUV_t, US dollar exchange rate USD_t and linear time trend *t* are a ded as controls. The dependent variable is denoted X_t; in our analysis, we consider a general food price index FOOD as well as prices for main agricultural commodities, wheat and maize, soybeans, barley, sorghum and rice. To facilitate comparison with the existing literature, we also estimate a reduced model where the restriction 1 = 0 is imposed. Furthermore, similarly to Nazlioglu and Soytas (2011) we present a specification without MUV and similarly to Baffes (2010) a model without the exchange rates.

Finally, we estimate the reduced model with the fertilizer index as the dependent variable. Throughout, we follow Engle-Granger methodology, i.e. we use OLS as our estimation method and carefully check for non-stationarities using appropriate versions of the Augmented Dickey Fuller (ADF) test. We assume that unobserved variables (e.g. other cost–push factors such as wages) are uncorrelated with the error term; further properties of the error time series will be subjected to statistical testing below. Specifying the model as in equation 1 we implicitly assume existence of a single cointegration relation between all variables in the equation. We find no evidence to reject this hypothesis if the residuals of the regression from equation 1 are stationary, as non-stationarity of the error term invalidates the OLS approach. If we can't reject the hypothesis about residuals non-stationarity, we reject the hypothesis of a single cointegrating and are unable to interpret the model parameter estimates.

This statistical model can be given a structural economic interpretation. Consider a competitive industry, where each firm produces according to a constant returns to scale Cobb–Douglas production function. Then, the unit marginal cost function has the functional form of (1), allowing for a time trend in total factor productivity and possibly non–neutrality of money (unless $\beta\ 3 = \beta 1\ \beta 2$). Coefficients 1 and 2 can thus be interpreted as the factor weights in the production function; moreover, the predicted cost share of each factor corresponds to the coefficients i. For proof see the appendix.

Data Sources: Our commodity price series is based on the World Bank Global Economic Monitor Commodities database (World Bank, 2014). We study the broad–based food price index (series IFOOD), which includes grains, cereals and oils among other food items as our dependent variable of interest; furthermore, key commodities – maize, wheat, soybeans, barley, sorghum and rice – are studied separately. Our explanatory variables are the fertilizer index (series IFERTILIZER), which includes all widely used fertilizer types: potassium, nitrogen and phosphate rock, and energy prices (IENERGY index). More detailed description of the composition of each of the indices is presented in the appendix.

Individual commodity prices are given in nominal USD; indices are also of nominal prices, with 2010 as the base year. The Manufactured Unit Value (MUV) index, also provided by the World Bank, is included in the regressions as a deflator.

[6] Since the fertilizer export cartel is not constrained by usual anti–trust enforcement, the cartel is relatively transparent. For example, according to the Potash Investing News, potassium producers simultaneously announced in 2009 an intention to further reduce output (Toovey, 2009). Following a rapid collapse in fertilizer prices, Uralkali Chief Executive Officer Vladislav Baumgertner was detained in a prison in Belarus in August 2013 after talks on restoring the cartel were apparently unsuccessful (Fedorinova and Kudrytski, 2013)

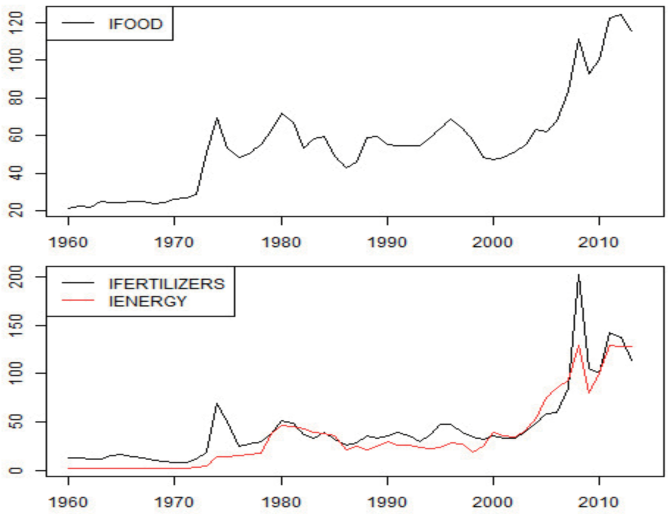
Furthermore, we account for USD real exchange rates, based on Breugel Institute's monthly data series[7] (Darvas, 2012). Data were current as of December 2014. The dataset is closely related to Baffes (2010), who studies the 1960-2008 period; however, his analysis omits consideration of fertilizer prices as an explanatory variable.

Descriptive Analysis: The starkness of the ongoing food crisis is illustrated in figure 1. Food prices are drawn in the top panel; in 2010, they were 40% higher than two years previously; moreover, after a brief recovery in 2009, prices at the end of the sample period exceed the peak of the crisis level. Simultaneously with the food crisis, energy prices also rose – yet more mildly, by merely 25% over the same period. But by far the most drastic change in the crisis period took place in the fertilizer market: by 2010, fertilizer prices *more than tripled* compared to 2006 levels.

All time series are trending upwards; this includes those in the data set that are not drawn in the figures. By visual inspection, one may suspect nonstationarity in the form of a unit root; this intuition is supported through autocorrelation functions. Below, we conduct an ADF test to test this view against the alternative hypothesis of a trend stationary process.

Fertilizer-Energy Link: Fertilizer and energy price indices are closely linked. This is apparent from visual inspection: from the mid-1970s to 2005 or so, energy and fertilizer indices move almost entirely in parallel. This is explained by the fact that fertilizer production is highly energy-intensive, be it due to mining (potassium, phosphate rock) or as a direct input (e.g., natural gas in the Haber-Bosch process). Yet there is independent variation in fertilizer prices: in both 1973/1974 and 2007/2008, fertilizer prices are much higher than one would expect from energy prices. Moreover, in both of these periods food prices were abnormally high – indeed, at crisis levels. It is this variation that underlies the more formal analysis below and allows us to estimate the direct impact of fertilizer prices on food commodities.

Figure 1 - Trends in food and energy/fertilizer prices



4. Fertilizer Matters

Unit Root Tests: We use the Augmented Dickey-Fuller (ADF) test testing the null hypothesis of a unit root against the alternative of a stationary autoregressive process. The optimal lag order is determined through the Akaike Information Criterion (AIC); results are presented in table 1. It is evident that for the levels series – displayed in the left panel – the ADF test largely fails to reject the unit root hypothesis. For the fertilizer and USD, there is weak evidence for stationarity at the 10% level; we consider this significance level insufficient to reject the null. Thus, all levels series are considered to have a unit root. In the right panel, the corresponding ADF test for the first-differenced series is displayed. Here, results are rather straightforward: the null hypothesis is rejected at the 1% level for all series. Hence, the evidence suggests that our data follows an *I*(1) process.

The *I*(1) finding has profound implications for our econometric analysis of model (1). On the one hand, standard errors and the R2 statistic are biased towards excessive significance (the "spurious regression" problem); hence significance tests need to be interpreted with care. On the other hand, as we show below, the model in fact provides a *cointegrating regression*; hence the error term t will be stationary and, importantly, OLS parameter estimates are super consistent, i.e. they converge to the population at a faster rate than in an *I*(0) regression with the same sample size.

[7] Official FED USD exchange rates are reported only since the collapse of the Bretton Woods system in 1971.

Table 1 - Unit Root Tests

Levels			First Differences		
	ADF	lags		ADF	lags
FERTILIZERS	-3.29*	1	D.FERTILIZERS	-6.16***	1
ENERGY	-2.78	5	D.ENERGY	-4.77***	1
FOOD	-2.16	3	D.FOOD	-6.48***	1
MUV	-1.59	1	D.MUV	-4.05***	1
USD	-3.20*	1	D.USD	-4.04**	1

Note: *p<0.1; **p<0.05; ***p<0.01

Estimation Results: Table 2 collects estimation results. Given the I(1) data, universally high values of adjusted R^2 are expected, therefore the statistics are not reported in the regression tables; encouragingly, we are able to reject statistical significance of some parameters. In particular, there appears to be essentially no time trend in commodity prices. Moreover, the deflator MUVt is mostly insignificant, reaching the 5% level only in few specifications. In regressions (1-3), which include the fertilizer index, there is robust evidence in favor of cointegration. The Augmented Dickey Fuller test, computed on residuals of the estimated equation, is able to reject the null hypothesis of a unit root in all cases at the 5% level. There is mixed evidence regarding cointegration in the restricted model which omits the fertilizer index (specifications 4-6). The no cointegration null hypothesis cannot be rejected even at the 10% level in specification (4), in which as in Baffes (2010) only energy and price index are included. In specification (5), as in Nazlioglu and Soytas (2011), i.e. with energy and exchange rate indexes the no cointegration null hypothesis can be rejected only at the 10% level. Once both USD exchange rate and the price index are included the no cointegration null hypothesis can be rejected at the 5% level. Relatedly, Zhang et al. (2010) also reject both cointegration and Granger causality from fuel to food in a different dataset. Baffes (2010) found cointegration for a similar dataset to ours, but with a shorter time period. In line with Harri et al. (2009), our results indicate lack of a robust cointegration relationship between energy and food across different commodities.

Fertilizer is a consistently statistically and economically significant price driver in food markets. Estimates for $\beta 1$ range from 0.28 to 0.42 depending on the specifi cation; this implies that a doubling in fertilizer prices would be predicted to lead to at least a 28% increase in food prices. The estimates may, at first, seem surprisingly high, but they indeed stay very much in line with the fertilizer cost shares in variable costs from the USDA farm cost surveys as shown on figure 2. We compare cost share coefficients from the reduced form regressions (see appendix for the regressions tables) and the average fertilizers share in the variable production cost using USDA data for years 1975-2013[8] (USDA (2014a)). The data points on figure 2 lay along the 45, which indicates that a nearly perfect match is achieved, thereby confirming the validity of the approach.[9]

There is mixed evidence supporting statistically significant effect of energy on food prices once fertilizer is included. This finding is especially striking in light of the spurious regression problem: due to biased standard errors, it may be difficult to reject truly insignificant parameters. The estimates at around 5-13% stay in line with USDA survey suggesting that the combined costs for "fuel, lube and electricity" account for 9% to 12% of operating costs for the main crops (USDA, 2014a). Note that since commodity prices are generally quoted "free on board", the bulk of transportation costs does not enter directly in the data.

The energy–food price link reappears once fertilizer prices are excluded. Our estimates suggest an cost elasticity in the range 0.3 of food prices with respect to the energy index; these findings are close to earlier estimates in the literature[10].

Combined with the lack of cointegation between energy and food, this suggests that earlier studies – which omitted fertilizer – may have identified only the *indirect* impact of energy on food, channeled through higher fertilizer prices.

At an estimated 38-62% cost share (specifications 7-9 of table 2), energy prices have a very strong cost passthrough to fertilizer prices. Due to the energy–intensive production of fertilizers – with energy costs accounting for up to 90% of nitrogen fertilizer cost (Headey and Fan, 2010, p. 25) – the estimate is plausible.

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[8] The estimates are based on producer surveys conducted about every 4-8 years for each commodity and updated each year with estimates of annual price, acreage, and production changes. Estimates for non-survey years use the actual survey year as a base and use price indexes and other indicators to reflect year-over-year changes. The cost estimates include both cash expenditures and non-cash costs that constitute an economic cost. The USDA cost classification was changing over time. To reconstruct a cost category "Total, variable cash expenses" available only for the older series, hired labor costs were added to category "Total, operating cost".

9For the analysis all food commodities for which data are available in both USDA and GEM databases except for rice. The exclusion of rice from the analysis is on both on econometric and economic grounds. The former are due the the fact that we can't reject the hypothesis that rice price is I(0). From more economic perspective, rice markets are very thinly traded and the market price is often driven by import and export regulations and not by the cost factors (see e.g. (Timmer, 2010)).

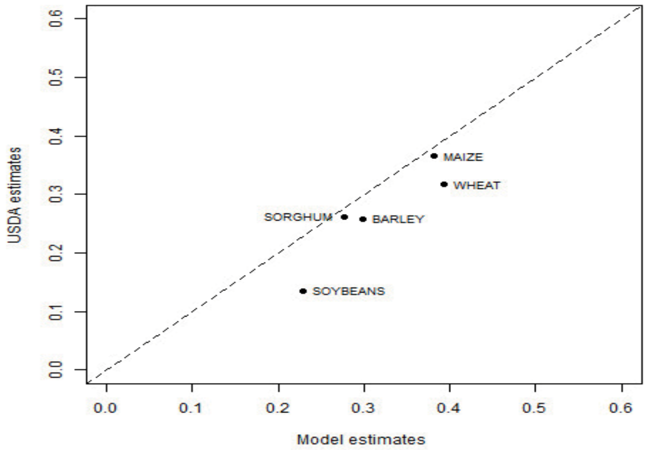
[10] Baffes (2010), using a similar data set until 2008, estimates an elasticity of 0.28; due to persistently high energy and food prices, the correlation appears to be stronger in the extended sample used in the present analysis. Relatedly, Gilbert (1989) estimates an elasticity of 0.25 using quarterly data from 1965.Q1 to 1986.Q2

Table 2: Estimation Results

	Dependent variable:								
	FOOD	FOOD	FOOD	FOOD	FOOD	FOOD	FERT	FERT	FERT
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
FERTILIZERS	0.419***	0.276***	0.278***						
	(0.057)	(0.052)	(0.063)						
ENERGY	0.047	0.129***	0.126**	0.308***	0.233***	0.293***	0.624***	0.377***	0.601***
	(0.052)	(0.032)	(0.051)	(0.054)	(0.031)	(0.039)	(0.093)	(0.068)	(0.075)
MUV	0.256**		0.008	0.005		−0.273**	−0.598**		−1.012***
	(0.107)		(0.116)	(0.146)		(0.114)	(0.253)		(0.219)
USD		−0.927***	−0.917***		−1.363***	−1.563***		−1.582***	−2.322***
		(0.200)	(0.246)		(0.225)	(0.231)		(0.491)	(0.444)
t	−0.004	0.002	0.002	0.001	0.004	0.008***	0.012*	0.006	0.022***
	(0.003)	(0.002)	(0.003)	(0.004)	(0.003)	(0.003)	(0.007)	(0.006)	(0.006)
Constant	1.391***	6.833***	6.759***	2.968***	9.482***	11.210***	3.761***	9.609***	16.007***
	(0.362)	(1.002)	(1.474)	(0.419)	(1.074)	(1.254)	(0.724)	(2.343)	(2.415)
ADF	−3.598**	−3.957**	−3.951**	−2.831	−3.312*	−3.814**	−3.385*	−3.203*	−3.946**
Observations	54	54	54	54	54	54	54	54	54

Note: *p<0.1; **p<0.05; ***p<0.01

Figure 2 - Cost share estimates: model fit vs. USDA (2014a) survey data



5. Did the Fertilizer Cartel cause the Food Crisis?

During the "perfect storm" of 2007/2008, the food crisis coincided not only with an energy crisis but also the establishment of a fertilizer cartel. Given our estimation results above, we are interested in isolating the effect of the cartel formation on fertilizer prices, and hence, ultimately on food. To this end, we first seek to date the recent cartel period in the fertilizer industry and then we estimate an augmented fertilizer pricing equation in the spirit of model (1). Based on predicted fertilizer prices in the counter–factual case of no cartel formation, we then simulate what food prices would have been had a cartel not been formed.

Estimating Cartel Overcharges: We seek to estimate a model that disentangles the impact of energy prices and cartel formation on fertilizer prices. To this end, we augment the version of model (1) already used to estimate potash prices with the cartel variables. To accommodate for the non-competitive periods in the fertilizer industry described in section 2 we introduce a new dummy variable CARTEL0812t, which takes value 1 in those years and zero otherwise (i.e. 1960–2007 and 2013). To account for the Morocco-lead phosphates cartel from the 1970s we introduce a dummy variable CARTEL7475t, which takes value 1 in year 1974 and 1975 and zero otherwise. The cartel impact on fertilizer prices is very strong, as shown in table 3. According to the model, the 2008 cartel formation was associated with a 42-51% overcharge in the fertilizer market. The previous attempt to form a cartel resulted in slightly higher overcharge at approximately 51-65%. Statistical significance at the 1% level, in spite of only few years of observations with the cartel in place, is a reflection of the magnitude of the economic effect. Such large overcharges are not uncommon: in a meta–study of cartel overcharges, Connor and Bolotova (2006, table 3) report an average overcharge of 54.2% for international cartels based on a sample size of 365 cartel episodes. Allowing for the cartel reduces the earlier estimate of energy passthrough on fertilizers; this is intuitive, since the cartel period coincided with high energy prices.

A possible threat to the estimation strategy is the impact of the oil crises on the relation between energy and fertilizer prices and the market turbulences in the aftermath. Therefore, to check the robustness of the results we introduce dummy variables for the 1973-74 and 2007-08 oil crises years (DUMMY7374 and DUMMY0708 respectively). The inclusion of additional out-of-the-sample information affects the results only marginally reassuring that strong fertilizer price spike was not caused only by the increase in energy prices.

Impact on the Food Crisis: The fertilizer cartel can potentially explain up to a halve of food price increases during the crisis time. According to our earlier estimates, the 42-51% fertilizer cartel overcharge would be expected to lead to a 12-21% [11] increase in food prices. Given the observed increase in the food price index of 40%, our model attributes 29-53% of the crisis price hike to the fertilizer cartel. Figure 3, based on specification (1) in table 3, shows the counter–factual food and fertilizer prices without cartel formation side–by–side with actual values: it is apparent that, according to our estimates, food prices could have remained nearly stable over recent years in the absence of the cartel.

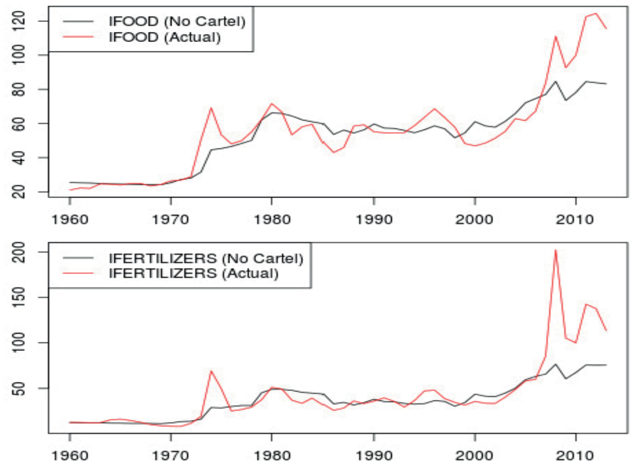
[11] The lower bound is given by the lowest estimates from tables 2 and 3 (0.276*0.423=11.7%) while the upper bound calculated based on the highest estimates (0.419*0.508=21.3%)

Table 3 - Regression Results: Cartel

	Dependent variable: FERTILIZERS					
	(1)	(2)	(3)	(4)	(5)	(6)
CARTEL0812	0.434***	0.423***			0.508***	0.505***
	(0.136)	(0.133)			(0.116)	(0.110)
CARTEL7475			0.562***	0.508***	0.650***	0.600***
			(0.168)	(0.186)	(0.144)	(0.150)
ENERGY	0.527***	0.502***	0.550***	0.551***	0.455***	0.424***
	(0.073)	(0.072)	(0.070)	(0.070)	(0.064)	(0.061)
MUV	−0.625**	−0.537**	−0.877***	−0.865***	−0.405*	−0.270
	(0.235)	(0.235)	(0.204)	(0.205)	(0.204)	(0.199)
USD	−1.860***	−1.789***	−1.926***	−1.877***	−1.325***	−1.147***
	(0.433)	(0.425)	(0.421)	(0.429)	(0.384)	(0.370)
t	0.012*	0.010	0.024***	0.023***	0.012**	0.009*
	(0.006)	(0.006)	(0.005)	(0.005)	(0.005)	(0.005)
DUMMY0708		0.298*				0.344**
		(0.164)				(0.134)
DUMMY7374				0.126		0.172
				(0.181)		(0.145)
Constant	12.776***	12.202***	13.717***	13.441***	9.583***	8.363***
	(2.438)	(2.403)	(2.300)	(2.347)	(2.178)	(2.109)
ADF	−4.018**	−3.925**	−3.575**	−3.519**	−3.606**	−3.111
Observations	54	54	54	54	54	54

Note: *p<0.1; **p<0.05; ***p<0.01
ADF stands for ADF test statistic on residuals of the long run model.

Figure 3 - Actual and counter–factual food and fertilizer prices without cartel formation



6. Robustness Checks

To assert a robust impact of fertilizer prices on food commodities we replace the food price index with the main food commodities as the dependent variable in equation 1. More specifically, we test the following commodities: wheat, maize, soybeans, barley, sorghum and rice. Similarly as in section 4 we proceed with stationarity tests reported in the appendix. As we can't reject the hypothesis about stationarity of the rice price time series we limit our attention to the remaining commodities in the cointegrating regression. The regression results suggest a strong impact of fertilizer consistent across specifications and commodities. In all specifications the coefficient on fertilizer is highly significant and in line with the USDA cost survey data presented on figure 2. The fertilizer cost share for soybeans is significantly lower than for other crops due to legumes' nitrogen-fixing abilities. The ADF test on residuals suggests the existence of a cointegrating vector between the commodities. Results of specification (1) from table 2 are presented in columns (1-5), specification (2) in columns (6-10) and specification (3) in columns (11-15) of the table in the appendix.

The availability of storing technology distorts the standard Marshallian supplydemand cross (Wright, 2011). To control for the possible impact of storage on price dynamics, stock-to-use ratios for each of the commodities have been added to the regression. Although, the stationarity of commodity prices suggests that food stocks are not used as an investment device for arbitrage opportunity seeking investors, the distortions caused by state buffer stocks cannot be excluded. Therefore, similarly to Baffes and Dennis (2013) we include the stock-to-use ratio directly in the regression framework[12]. The estimates on stock-to-use ratio are potentially biased due to endogeneity problems, however good instruments were not available to us. Except for wheat, stock-to-use ratios for all commodities are *I*(1) so we include them in the cointegrating regression. Results presented in specifications (16-20) in the appendix show that while being highly significant and negatively correlated with commodity prices, stock-to-use ratios do not affect the coefficients on fertilizers. This suggests that any endogenity problems in the stock-use-ratio do not affect our estimates of the fertilizer effect.

[12] We calculate stock-to-use ratio following the methodology and data (USDA, 2014b) as suggested by Bobenrieth et al. (2013)

The broad range of regressions performed robustly show the importance of fertilizers in determining food prices. For each of the five food commodities, in each of the four regression specifications, fertilizers persistently prove to be a major cost contributor of food commodity prices. Importantly, the changes in the specifications do not significantly affect the estimates of the fertilizer effect.

7. Conclusion

Since the Green Revolution, the increased application of fertilizer has been instrumental in raising crop yields worldwide. But, as this paper shows, this dependence on fertilizer is not merely technological, but economic: high fertilizer prices directly translate into high food prices. This link is crucial to our understanding of the recent food crisis, during which prices rose by 40% on average. We estimate this was largely caused by the formation of an international export cartel for fertilizers. According to our model, the cartel overcharge in the fertilizer market amounted to nearly 50%. his directly led to a 26% increase in the food price index. In other words, the formation of the fertilizer cartel explains up to a halve of the crisis price increase.

While many factors doubtlessly contributed to the food crisis, we believe the role of fertilizer should be taken seriously. First, while our results are stark, they are in line with the related literature. We estimate fertilizer cost passthrough from aggregate time series data running many years; but the share of fertilizer in marginal cost implied by our model is close to estimates obtained from production budgets and farmer surveys. Our estimated cartel overcharge of 42-51% is typical for international export cartels. Finally, we control for energy prices; according to our estimates, food prices would certainly have been high in 2007/2008 – due to the simultaneous energy crisis – but they would not have reached crisis levels. These results highlight the importance of addressing fertilizer cartel – the "OPEC of world potash markets" (Scherer, 1996) – in combating food crises. In recent history, various export cartels have at different times dominated the fertilizer market (cf. al Rawashdeh and Maxwell (2014); e.g. Newman (1948) discusses the role of the German potassium cartel in the Nazi economy). These cartels flourished, with either explicit or implicit state backing, because of the absence of effective international competition authorities and enforcement (Marquis, 2014)[13]. Sokol (2008) discusses possible institutional reforms to mitigate export cartels; Taylor and Moss (2013) make the case for global antitrust enforcement in the fertilizer industry. Perhaps above all, this paper is a call for further research. Since the "fertilizer hypothesis" is new, it is in need of further corroboration for additional food commodities and from other datasets. The recommended steps include data disaggregation. The analysis performed on the indices may miss some important subtleties of the fertilizer and energy markets. It would be very valuable for the agricultural policy to understand the co-movement of prices of nitrogen, potassium and phosphorus fertilizers. Furthermore, the recent dramatic shocks to the fertilizers markets caused by the cartel formation and the significant decrease of natural gas prices may help to identify the links between the different fertilizer types. Furthermore, a focus on the oil and natural gas prices rather than the analysis compound index would allow to separate the effect of cartel formation from the recent processes that change the shape of the relation between food, energy and fertilizer prices - the introduction of the fracking technology and the recent increase in the use of biofuels. Finally, we treated fertilizer cartel formation as exogenous; but a better understanding of the reasons for success and breakdowns in fertilizer cartels over time is sorely needed.

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[13] See in particular the discussion on pp. 65.

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Appendix

Food, Energy and Fertilizers Indices Composition

The main objective of this study is to understand the change of food prices. We use various World Bank's price indices, the composition of which may not be clear to the reader. Indeed, the information about how price indices are constructed is surprisingly scarce. Therefore, to inform about what is actually being measured in this paper we reconstruct the price indices used throughout the the text.

To reverse-engineer the indices we perform OLS regressions of indices against all commodities included in the database from the given commodity group. To solve the collinearity problem first differences of all variables of interest are taken. If constant weights were used throughout the sample period to construct the indices of interest, this approach allows for full index reconstruction.

The number of food commodities in the data base is close to the number of observations, which leaves few degrees of freedom for the estimation of food price index, therefore, we take a two stage approach. First, we identify the subindices also included in the GEM database that IFOOD is made of. Subsequently, we identify components of each of the subindices. Finally, we verify if , indeed all components of subindices are included in the IFOOD index.

The IFOOD index is built of three subindices - IFATS_OIL with over 40% and IGRAINS and IOTHERFOOD with approximately 30% share each. The detailed composition of IFOOD with it's shares (using 2010 prices) and weights with which particular prices enter the index presented in the table below.

Soybeans prices (beans, meal and oil) are by far the most important component of the IFOOD index with over 25% weight. Also changes in palm oil, maize and sugar prices can significantly affect the index with each commodity having an over 10% share in the index.

Similar analysis has been performed on the other two indices. Fertilizer price index has 4 components - potash, phosphate rock, TSP (triple superphosphate) with around 20% share each and urea with 40% share with details presented in table A.2. The energy price index is dominated by crude oil with 85% share equally divided between Brent, WTI and Dubai classifications. The remainder is coal (5%) and natural gas (10%) averaged over the European, US and Japanese prices, as shown in detail in table A.3.

Cost shares - a proof

Suppose that food production function is given by:

$$FOOD = A * FERT^{\beta}$$

Where A represents all other costs other than fertilizers. Cost share is given by:

$$\text{Cost } \% = \frac{p_{FERT}}{p_{FOOD}} * \frac{FERT}{FOOD}$$

Table A.1 - FOOD price index decomposition

	Food index share	Weights (OLS results)	t value
COCONUT_OIL	1.2540%	0.0011161	1176687707
GRNUT_OIL	1.1427%	0.0008140	993608721
PALM_OIL	12.3360%	0.0136940	5320371770
SOYBEAN_MEAL	10.7236%	0.0283396	3043535992
SOYBEAN_OIL	5.3270%	0.0053026	1811628597
SOYBEANS	10.0643%	0.0223752	1724849275
BARLEY	1.0448%	0.0065967	452387979
MAIZE	11.4777%	0.0617367	4811226064
RICE_05	8.4829%	0.0173508	7273502220
WHEAT_US_HRW	7.0982%	0.0317475	3411287726
BANANA_US	4.8652%	5.6029550	2520442216
BEEF	6.8377%	2.0402311	4176851463
CHICKEN	5.9577%	3.1483942	2030720627
ORANGE	3.6060%	3.4901202	2014492304
SUGAR_EU	1.2048%	2.7271556	1025261897
SUGAR_US	0.4595%	0.5798444	228419671
SUGAR_WLD	8.1178%	17.2960284	7604308883

Food index share is a product of OLS coefficient estimates and commodity prices in 2010

Table A.2 - Fertilizers price index decomposition

	Fertilizers index share	Weights (OLS results)	t value
PHOSROCK	16.8571%	0.1370264	218762956481
POTASH	20.1269%	0.0606479	401704526858
TSP	21.6704%	0.0567453	195088605142
UREA_EE_BULK	41.3455%	0.1432666	654964650625

Food index share is a product of OLS coefficient estimates and commodity prices in 2010 PHOSROCK - Phosphate rock (Morocco), 70% BPL, contract, f.a.s. Casablanca; POTASH - Potassium chloride (muriate of potash), standard grade, spot, f.o.b. Vancouver; TSP - triple superphosphate, up to September 2006 bulk, spot, f.o.b. US Gulf; from October 2006 onwards Tunisian, granular, f.o.b.; UREA_EE_BULK - Urea, (Black Sea), bulk, spot, f.o.b. Black Sea (primarily Yuzhnyy)

Table A.3 - Energy price index decomposition

	Fertilizers index share	Weights (OLS results)	t value
COAL_AUS	4.6574%	0.0470608	46850219932
CRUDE_BRENT	28.4024%	0.3566549	32423841898
CRUDE_DUBAI	27.8409%	0.3566549	27260655583
CRUDE_WTI	28.3275%	0.3566549	72265575737
NGAS_EUR	4.2439%	0.5120861	35603862442
NGAS_JP	0.7917%	0.0729780	3819604998
NGAS_US	5.7361%	1.3080540	94312595385

Food index share is a product of OLS coefficient estimates and commodity prices in 2010

Given producers optimal decisions setting marginal product to the marginal price the cost share equation simplifies to β.

$$\frac{\beta * A * FERT_t^{\beta-1} * FERT}{A * FERT^{\beta}} = \beta$$

Unit root test results

Table A.4 - Unit Root Tests

	tau3	sig	lags
WHEAT	-3.3	*	1.00
MAIZE	-1.75		2.00
SOYBEANS	-1.69		2.00
BARLEY	-2.43		2.00
SORGHUM	-2.79		1.00
RICE	-3.71	**	1.00
WHEAT_SUR	-4.18	***	2.00
MAIZE_SUR	-1.83		1.00
SOYBEAN_SUR	-1.75		4.00
BARLEY_SUR	-3.45	*	1.00
SORGHUM_SUR	-2.09		1.00

	tau3	sig	lags
D.WHEAT	-5.97	***	1.00
D.MAIZE	-6.24	***	1.00
D.SOYBEANS	-6.61	***	1.00
D.BARLEY	-7.24	***	1.00
D.SORGHUM	-6.1	***	1.00
D.RICE	-6.14	***	1.00
D.WHEAT_SUR	-5.75	***	5.00
D.MAIZE_SUR	-5.91	***	1.00
D.SOYBEAN_SUR	-6.34	***	3.00
D.BARLEY_SUR	-6.63	***	2.00
D.SORGHUM_SUR	-4.89	***	1.00

Robustness check - regression results

Table A.5 - Cost Share Estimation

	Dependent variable:				
	WHEAT	MAIZE	SOYBEANS	BARLEY	SORGHUM
	(1)	(2)	(3)	(4)	(5)
FERTILIZERS	0.474***	0.473***	0.400***	0.373***	0.396***
	(0.061)	(0.077)	(0.077)	(0.061)	(0.077)
ENERGY	0.051	0.063	0.068	0.038	0.094
	(0.055)	(0.070)	(0.070)	(0.055)	(0.069)
MUV	0.238**	0.082	0.221	0.165	0.076
	(0.115)	(0.145)	(0.145)	(0.114)	(0.144)
t	−0.005*	−0.003	−0.004	0.016***	−0.001
	(0.003)	(0.004)	(0.004)	(0.003)	(0.004)
Constant	2.253***	2.536***	3.077***	1.668***	2.632***
	(0.387)	(0.489)	(0.489)	(0.385)	(0.487)
ADF	−5.373***	−3.802**	−4.624***	−4.865***	−3.840**
Observations	54	54	54	54	54

	Dependent variable:				
	WHEAT	MAIZE	SOYBEANS	BARLEY	SORGHUM
	(6)	(7)	(8)	(9)	(10)
Fertilizers	0.364***	0.405***	0.252***	0.288***	0.316***
	(0.062)	(0.078)	(0.073)	(0.061)	(0.077)
Energy	0.129***	0.087*	0.138***	0.091**	0.117**
	(0.038)	(0.048)	(0.045)	(0.038)	(0.047)
USD	−0.642***	−0.499	−1.012***	−0.523**	−0.616**
	(0.236)	(0.299)	(0.278)	(0.234)	(0.293)
t	−0.0003	−0.001	0.001	0.019***	0.001
	(0.002)	(0.003)	(0.003)	(0.002)	(0.003)
Constant	6.215***	5.285***	8.833***	4.806***	5.952***
	(1.183)	(1.500)	(1.396)	(1.176)	(1.469)
ADF	−5.326***	−3.785**	−4.849***	−4.941***	−3.884**
Observations	54	54	54	54	54

Note: *p<0.1; **p<0.05; ***p<0.01

Table A.5 - cont'd: Cost Share Estimation

	Dependent variable:				
	WHEAT	MAIZE	SOYBEANS	BARLEY	SORGHUM
	(11)	(12)	(13)	(14)	(15)
FERTILIZERS	0.393***	0.381***	0.229**	0.299***	0.276***
	(0.074)	(0.095)	(0.088)	(0.074)	(0.092)
ENERGY	0.097	0.114	0.164**	0.079	0.162**
	(0.059)	(0.076)	(0.070)	(0.059)	(0.074)
USD	−0.526*	−0.594	−1.105***	−0.481	−0.778**
	(0.288)	(0.367)	(0.341)	(0.288)	(0.358)
MUV	0.096	−0.079	−0.077	0.035	−0.134
	(0.137)	(0.174)	(0.162)	(0.137)	(0.170)
t	−0.002	0.001	0.003	0.019***	0.004
	(0.003)	(0.004)	(0.004)	(0.003)	(0.004)
Constant	5.332***	6.010***	9.544***	4.485**	7.186***
	(1.730)	(2.201)	(2.048)	(1.728)	(2.147)
ADF	−5.390***	−3.804**	−4.885***	−4.940***	−3.968***
Observations	54	54	54	54	54

	Dependent variable:				
	WHEAT	MAIZE	SOYBEANS	BARLEY	SORGHUM
	(16)	(17)	(18)	(19)	(20)
FERTILIZERS	0.363***	0.408***	0.246***	0.275***	0.322***
	(0.071)	(0.083)	(0.089)	(0.061)	(0.087)
ENERGY	0.080	−0.001	0.177**	−0.037	0.157**
	(0.056)	(0.073)	(0.071)	(0.054)	(0.069)
USD	−0.304	0.364	−0.861**	−0.622**	−0.454
	(0.283)	(0.408)	(0.339)	(0.240)	(0.359)
MUV	0.193	0.669**	−0.047	0.090	−0.082
	(0.134)	(0.255)	(0.156)	(0.113)	(0.161)
t	−0.003	−0.015**	0.002	0.029***	−0.004
	(0.003)	(0.006)	(0.004)	(0.004)	(0.005)
SUR†	−0.314**	−0.406***	−0.145*	−0.489***	−0.117**
	(0.119)	(0.110)	(0.073)	(0.101)	(0.056)
Constant	3.708**	−1.370	7.952***	4.183***	5.306**
	(1.735)	(2.753)	(2.037)	(1.422)	(2.154)
ADF	−5.028***	−3.533**25	−4.879***	−6.384***	−3.895**
Observations	53	53	49	53	53

Note: *p<0.1; **p<0.05; ***p<0.01

† SUR - stock-to-use-ratio for each of the commodity respectively