Agricultural supply response to international food prices and price volatility: a cross-country panel analysis

Mekbib G. Haile[1], Matthias Kalkuhl, Joachim von Braun

Center for Development Research (ZEF), Bonn University
Walter-Flex Str. 3, 53113 Bonn, Germany
mekhaile@uni-bonn.de

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Abstract

This article estimates global supply response for key agricultural commodities. The findings reveal that, while higher output prices are incentives to improve global crop supply, output price volatility plays otherwise. Depending on respective crop, the results indicate that own price supply elasticities range from about 0.05 to 0.35. The findings suggest that output price-risk has negative correlations with crop supply, implying that farmers shift land, other inputs and yield improving investments away to crops with less volatile prices. The recent output price volatility seems to significantly reduce production of wheat and – to a lesser extent – rice.

Key words: food prices, price volatility, supply response, price expectation

1. Introduction

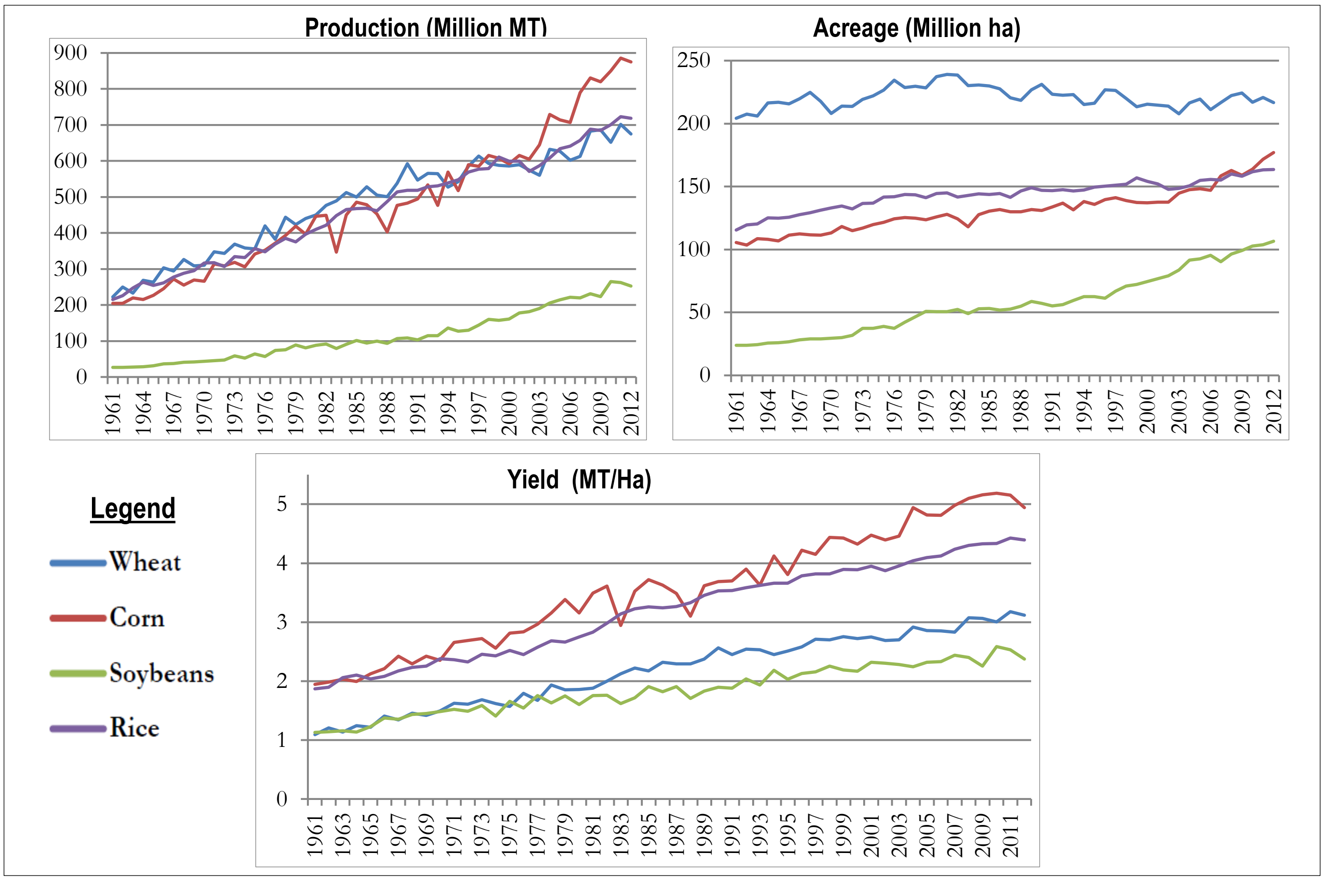
After about three decades of low and relatively stable level of prices, the world has experienced a dramatic surge in the price of many staple food commodities since 2005. Such high prices are expected to bring about a supply response that results in more land allocated to the agricultural sector and greater investment to improve yield growth (OECD, 2008). The (recent) increase in prices is, however, attended with higher volatility (Gilbert & Morgan, 2010). Price volatility introduces output price-risk, which has detrimental implications for producers' resource allocation and investment decisions (Moschini & Hennessy, 2001; Sandmo, 1971). Since agricultural producers in many developing countries are neither able to deal with (Binswanger & Rosenzweig, 1986) nor protected from (Miranda & Helmberger, 1988) the consequences of price volatility, they are substantially exposed to the effects of international agricultural market price instability. Given this backdrop, this study analyses the supply responsiveness of key world staple food commodities namely, wheat, corn, soybeans and rice, to changes in output prices and the latent uncertainty. Understanding how global food commodity producers allocate cropland and how their decisions about crop production are affected by changes in prices and their volatility is fundamental for designing policies related to global agriculture and food supply.

The literature on estimation of supply response to prices has a long history in agricultural economics (Nerlove, 1956). Nevertheless, there are various reasons to reconsider the research on supply response. The majority of the previous empirical literature investigating supply response is concentrated on a few countries. The effect of price and its volatility is usually considered as a microeconomic problem for producers. However, there are several factors such as foreign direct investment in agriculture that make the global and country-level agricultural production equally sensitive to prices and their volatility as is the case at the individual producer level. Another reason for the renewed research interest in the topic is the growing demand for biofuels and the financialization of agricultural commodities, which are suspected to have contributed to the high and volatile food prices that in turn affect the global food supply (Tadesse et al., forthcoming).

Furthermore, existing econometric analyses focus on supply response to domestic prices. This study, on the other hand, investigates the supply response of the key world staples to international market prices. In doing so, the study makes the following major contributions: (i) It provides updated short- and long-term supply elasticities that indicate how major agricultural commodity producers respond to the recent increase in global food prices and volatility. (ii) It provides answers whether the recent increase in prices is an opportunity or a challenge to agricultural producers and to the sector in general. (iii) Given some empirical evidence suggesting that the major proportion of the supply response to output price, in the short-run, is via acreage changes (e.g. Roberts & Schlenker, 2009), estimation of both acreage and yield responses to prices is important to contest or affirm this finding.

2. Production, Acreage and Yield: An Overview

Agricultural productivity and competition for land are the major drivers of global food and farming in the future (Smith et al., 2010). Since the beginning of human history, there have been land cover changes involving clearing of natural ecosystems for agriculture, pasture, urbanization and other purposes. While total cropland constituted less than a tenth of the global land cover in the 18th century (Beddow et al., 2010), about one third of the global land area is currently devoted to agricultural use (Hertel, 2011). There have been several changes in crop acreage allocation all over the world due to several factors. This cropland expansion along with increased productivity has been (and will be) needed in order to sustain the associated population growth. While there is little room for extensification (bringing in more land for crop cultivation) in South and East Asia, the Middle East, North Africa, and many advanced economies, extensification does have substantial potential to increase crop production in many other regions such as Sub-Saharan Africa, Latin America and the Caribbean (Bruinsma, 2003). The recent rise in agricultural commodity prices has also resulted in more competition for agricultural land. For instance, there have been large foreign agricultural investments in many developing countries, primarily focusing on growing high-demand crops including corn, soybeans, wheat, rice and many other biofuel crops (von Braun & Meinzen-Dick, 2009). Rising agricultural commodity prices are also incentives for larger agricultural investments of yield improving technologies.



Source: Data from FAOSTAT, FAO (2012)

Figure 1. Global production, harvested acreage and yield trends since the 1960s

Although with different degrees, Figure 1 shows that global production, acreage and yield have increased for all the four key staple crops during the past 50 years. As a result of acreage expansion and yield improvements, global production has shown significant increase for all the four crops during this period. Comparing the 1960s and the most recent decade, for instance, global production has increased more than six times for soybeans, tripled for corn, and more than doubled for wheat and rice. While the majority of the increase in wheat production comes from higher yield, acreage expansion is the primary source of the significant increase in the case of soybean production. The global soybean acreage has more than tripled followed by a 40% increase of global corn acreage over the past five decades. Some studies indicate that the emerging biofuel markets and Chinese soybean imports are the major drivers of the acreage increases for corn and soybeans (Abbott et al., 2011). The crop acreage changes have been met both by adding marginal land into cultivation and by bidding land away from low-demand crops. To this end, a recent study has shown that over a quarter of the increase in area of the high-demand crops for the period 2004/2005 to 2010/2011 was composed of displaced low-demand crop area while the rest came from the expansion of marginal land (Haile et al., 2013).

Although production, acreage and yield of all these four crops have increased during the past five decades, Figure 1 shows that the changes have not always been smooth upward trends. Several factors play a role for the changes of these variables. This study examines how the supplies of the four staple food commodities have responded to international prices and price volatility. The study involves cross-country panel data and recent developments in panel econometrics in order to test for several hypotheses on crop supply responses to prices and volatility.

3. Model

3.1. Conceptual Framework

The supply response literature has gone through several important empirical and theoretical modifications, out of which two major frameworks have been developed. The first approach is the Nerlovian partial adjustment model, which allows analyzing both the speed and the level of adjustment from actual towards desired output. The second is the supply function approach, derived from the profit-maximizing framework. This latter approach requires detailed input prices and simultaneous estimation of input demand and output supply equations. However, input markets, in particular land and labor markets, are either missing or imperfect in several developing countries. Moreover, our main interest lies in the output supply function. Thus, the econometric approach of the present study is in line with the partial adjustment framework, enhanced with dynamic response, alternative price expectation assumptions and the introduction of price-risk variables.

There have been a wide variety of applications of the Nerlovian model with certain modifications of the original framework. Alternative expectation assumptions such as futures prices as additional information used for price expectation formation (Gardner, 1976), expected net returns rather than prices alone (Chavas & Holt, 1990), and output/land value rather than prices or returns (Bridges & Tenkorang, 2009) have been used. Risk variables have also been included to capture the behavioral aspects of farmers (Lin & Dismukes, 2007). Furthermore, econometric developments have allowed more recent work to use panel data while time series data have often been used to capture the dynamics of agriculture production in earlier studies.

Models of the supply response of a crop can be formulated in terms of output (Q), area (A) or yield (Y) response. For instance, the desired output of a certain crop in period *t* is a function of expected output prices, and a number of other exogenous factors (Braulke, 1982):

$$Q_t^d = \beta_1 + \beta_2 p_t^e + \beta_3 Z_t + \varepsilon_t \tag{1}$$

where Q^d is the desired output in period t, p^e is the expected price of the crop under consideration and of other competing crops, Z is a set of other exogenous variables including fixed and variable input prices, climate variables, and technological change, ε_t accounts for unobserved random factors affecting crop production with zero expected mean, and β_i are the parameters to be estimated.

Usually there is a delayed output (area and yield) adjustment in agricultural production due to resource availability within one or two agricultural production cycles. It is therefore important to apply a dynamic approach to account for such time lags in agricultural supply response. Supply response is usually a two-stage process. Since the harvest time prices are not realized during the time of planting, producers, in the first stage, decide cropping acreage conditional on expected prices. Similar to the production equation above, the desired area to be cultivated for a certain crop at time *t* is determined by expected own and competing crop prices and other non-price factors:

$$A_t^d = \alpha_1 + \alpha_2 p_t^e + \alpha_3 Z_t + \varepsilon_t \qquad (2)$$

Given the acreage allocation for each crop, farmers then determine crop yield based on other inputs and climate conditions. During the growing period, they may make revisions to their production practices by adjusting input quantity, quality and crop protection. Hence, the desired yield of each crop is defined similarly as equations (1 or 2) except that the output price vector only includes the crop's own price.

3.2. Data

The econometric model relies on a comprehensive database covering the period 1961-2010. The empirical model utilizes global and country-level data in order to estimate global production, acreage and yield responses for the world's key crops. While data on planted acreage are obtained from several relevant national statistical sources[1], harvested acreage, production, and yield for all countries are obtained from the Food and Agricultural Organization (FAO) of the United Nations. Area harvested serves as a proxy for planted area if data on the latter are not available from the relevant national agricultural statistics. International spot market output prices as well as different types of fertilizer prices and price indices are obtained from the World Bank's commodity price database. All commodity futures prices are from the Bloomberg database. Table 1 reports the countries or regions included in this study.

It is possible for the producer to choose cultivating a different crop at planting time (Just & Pope, 2001). Therefore, it is worthwhile to consider price, price-risk and other information during the planting season. Accordingly, we gather crop calendar information to identify the major planting seasons of each country in order to construct country-specific spot and futures prices, measures of price-risk and yield shocks, and input prices. While the crop calendar for emerging and developing countries is obtained from the General Information and Early Warning System (GIEWS) of the FAO, information from the Office of the Chief Economist (OCE) of the USDA is used for the advanced economies.

Since actual prices are not realized during planting, we model farmers' price expectations using relevant spot and futures world price information available during planting. Since they contain more recent price information for farmers, own and competing spot prices observed in the month before the start of planting are used in the empirical model. Harvest-time futures prices quoted in the months prior to planting are alternatively used. The use of these two price series to formulate producers' price expectations makes our supply response models adaptive as well as forward-looking. Since the planting pattern varies across countries and crops, both the futures and spot prices of each crop are country-specific. For countries in the rest-of-world (ROW), we use the annual average spot and generic futures prices.[2]

We include own and cross volatility of international spot prices in order to capture output price-risk. Price volatility is measured, as is customary in agricultural economics, as the standard deviation of logarithmic prices. We calculated price volatility as the standard deviation of price returns, i.e. the standard deviation of changes in logarithmic prices in order to use the de-trended price series. The price-risk measures are country-specific referring to the output price variability in the twelve months preceding the beginning of the planting season of each country.

[1]Data sources are available in Haile et al. (2013)

[2] Countries with a global acreage share of less than half a percent are grouped in the 'rest-of-world' (ROW) category.

Table 1. Study countries and regions

Asia		***Africa***	***South America***	***Europe***
Bangladesh	Myanmar	Egypt	Argentina	EU-27
Cambodia	Pakistan	Ethiopia	Brazil	Russia
China	Philippines	Nigeria	Mexico	Ukraine
India	Sri Lanka	South Africa	Paraguay	***Australia***
Indonesia	Thailand	***Middle East***	Uruguay	Australia
Japan	Uzbekistan	Iran	***North America***	***Other***
Kazakhstan	Viet Nam	Turkey	Canada	ROW
			USA	

Notes: While production and acreage data are pooled across the 27 member countries for the EU and across all the remaining countries for the ROW group, yield is the average over these countries. Post-1991 data are applicable for the former Soviet Union countries.

We include yield shocks calculated as deviations from country and crop-specific trends in our empirical supply models. Our presumption is that these deviations from the respective yield trends, which may be as a result of weather shocks, pest infestations or other factors, could serve as proxy for producers' yield expectations. Following Roberts & Schlenker (2009), the yield shocks are the jackknifed residuals from separate yield-on-trend regressions for each crop in each country. A positive deviation implies good yield expectations, implying a positive effect on crop supply. For countries in the ROW, we pool the crop yields across the remaining countries to generate yield shocks for each crop.

Fertilizer price indices are used as proxies for production costs in this study. Given the weights used by the World Bank, the fertilizer price index contains the prices of natural phosphate rock, phosphate, potassium and nitrogenous fertilizers. The fertilizer prices indices are also crop and country-specific depending on the planting pattern of each crop in each country. The fertilizer price index in the month prior to the start of planting is used.

3.3. Econometric Model

Given the above theoretical model and assuming there are *K* countries observed over *T* periods, the supply functions of the four crops can be specified most generally as:

$$Q_{ikt} = \pi_i Q_{ik,t-1} + \sum_{j=1}^{4} \alpha_{ij} p_{jk,t_k} + \sum_{j=1}^{4} \varphi_{ij} vol(p)_{jk,t_k} + \lambda_{i1} w_{ik,t_k} + \lambda_{i2} YS_{ik,t_k} + \mu_{it} + \eta_{ik} + u_{ikt} \tag{3}$$

where Q_i denotes the total production (or area under cultivation) of the *i-th* crop (1=wheat 2 = corn, 3 = soybeans, and 4 = rice), *p* denotes a vector of either spot or futures prices that are used as a proxy for expected own and competing crop prices at planting time, $vol(p)_i$ is a vector of the volatility measures for own and competing crop prices, *w* refers to prices of variable inputs (e.g. fertilizer), *YS* refers to a yield shock for each crop, μ captures time dummies to account for some structural changes or national policy changes, η denotes country-fixed effects to control for all time-invariant heterogeneities across countries, and *u* denotes the idiosyncratic shock. The subscript *k* denotes the country: this implies that the lag lengths of the relevant futures and spot price, output price volatility, input price and yield shock variables are country-specific. As mentioned above, the seasonality of agricultural cultivation in different countries enables us to construct such country-specific price variable, which is more precise than assuming all countries to face the same yearly output price. This is in particular problematic when planting decisions in the early months of the calendar year (or US marketing year) in some countries affects the annually averaged price, causing endogeneity problem in the supply model. Likewise, if planting decisions take place at a later stage of the calendar or US marketing year, an average annual price will contain many past prices that dilute the information signal that more recent planting-time prices could convey. Taking the lagged annual average price is not a good remedy since producers adjust their price expectations with more recent information ((Just & Pope, 2001).

As described in the conceptual model section, the yield equation is specified similar with equation (3) except that the output price and price volatility vectors do not include price and volatility of competing crops. There is a subtle difference between the yield deviation measures that we use in the production/acreage and yield response models in order to proxy yield expectations. While, for the former, they are derived from the harvest period prior to planting, they are derived from the harvest of the previous year for the latter. Accordingly, the deviations in the yield response models are lagged whereas they need not be lagged in the former if the prior harvest was in the year of planting. We, therefore, exclude these variables from the regressions of the production and yield response functions as they are by definition correlated with the respective lagged dependent variables. All quantity, output and input price variables (except for price volatilities, which are rates) are specified as logarithms in the econometric models of the proceeding discussion. Hence, the estimated coefficients can be interpreted as short-run elasticities.

Applying Ordinary Least Squares (OLS) estimation to a dynamic panel data regression model such as in equation (3) above results in a dynamic panel bias due to the correlation of the lagged dependent variable with the country-fixed effects (Nickell, 1981). Arellano and Bond (1991) developed an efficient estimator, called differenced GMM, in order to estimate a dynamic panel difference model using all suitably lagged endogenous and other exogenous variables as instruments in the GMM technique (Roodman, 2009a). Blundell and Bond (1998) further developed a strategy named system GMM to overcome dynamic panel bias. Instead of transforming the regressors to purge the fixed effects and using the levels as instruments, the system GMM technique transforms the instruments themselves in order to make them exogenous to the fixed effects (Roodman, 2009a). The estimator in the differenced GMM model can have poor finite sample properties in terms of bias and precision when applied for persistent series or random-walk type of variables (Roodman, 2009b). The system GMM estimator allows substantial efficiency gains over the differenced GMM estimator provided that initial conditions are not correlated with fixed effects (Blundell & Bond, 1998). Thus, we use the system GMM method to estimate our dynamic supply models.

Several statistical tests are done to check the consistency of our preferred GMM estimator. First, the Arellano-Bond test for autocorrelation is used in order to test for serial correlation in levels. The test results, reported in the next section, indicate that the null hypothesis of no second-order autocorrelation in residuals cannot be rejected for nearly all production, acreage and yield models, indicating the consistency of the system GMM estimators. Second, the Hansen test results cannot reject the null hypothesis of instrument exogeneity. We also conduct a test for the validity of the Blundell-Bond assumption using the Difference-in-Hansen test of the two-step system GMM. The test statistics give p-values greater than 10% in all cases, suggesting that past changes are good instruments of current levels and that the system GMM estimators are more efficient. Furthermore, the standard error estimates for all specifications are robust in the presence of any pattern of heteroskedasticity and autocorrelation within panels. The Windmeijer (2005) two-step error bias correction is incorporated. Following Roodman (2009a, 2009b), we also "collapsed" the instrument set in order to limit instrument proliferation.

4. **Results**

Tables 2 and 3 present the GMM results of the production/acreage and yield response functions respectively. For each respective crop, we estimate the supply models using pre-planting month spot prices and harvest period futures prices (except for rice) as proxy for expected prices at planting time.[3] We failed to find a significant supply-price relationship using futures prices (except for soybeans), which could imply

[3] Rice futures markets have relatively shorter time series.

that several agricultural producers do not make use of futures prices information in forming their price expectations. Indeed, futures prices are good proxy for expected prices for those producers in countries where the domestic price is strongly linked to the futures prices, i.e. where the maturity basis is constant. Although the farmers in advanced economies widely participate in the futures markets and the futures prices are linked to the cash prices, this is not the case in several developing countries. Thus, we reported the results obtained from the specifications with spot prices.

In general, production, acreage and yield responses to own prices are positive and statistically significant, consistent with economic theory. The results indicate that higher output prices induce producers to increase acreage and to invest in crop yield improvement, implying that global food supply response to prices appears to occur via both acreage and yield changes. The production response to own prices are larger than the respective acreage and yield responses (with the exception of wheat yield response). The acreage and yield responses to prices are mostly in similar order of magnitude.

Table 2. Estimates of production and acreage response[4,5]

Variable	**Production**				**Acreage**			
	Wheat	*Corn*	*Soybeans*	*Rice*	*Wheat*	*Corn*	*Soybeans*	*Rice*
Lagged dep. var	0.96***	0..96***	0.93***	0.99***	0.99***	0.97***	0.93***	0.99***
	(0.01)	(0.04)	(0.04)	(0.02)	(0.01)	(0.03)	(0.03)	(0.00)
Wheat price	0.09**	-0.03	-0.21***		0.08***	0.01	-0.03***	
	(0.04)	(0.06)	(0.06)		(0.03)	(0.01)	(0.01)	
Corn price	0.08	0.24**	-0.04		-0.002	0.07***	-0.12***	
	(0.06)	(0.11)	(0.06)		(0.03)	(0.02)	(0.02)	
Soybean price	-0.02	0.06	0.36**		-0.05	-0.04*	0.15**	
	(0.05)	(0.06)	(0.16)		(0.03)	(0.02)	(0.07)	
Rice price	-0.01	-0.14**	-0.07	0.05***				0.03**
	(0.03)	(0.07)	(0.06)	(0.01)				(0.01)
Wheat price volatility	-0.69**	0.16	0.44**		-0.37**	0.12	-0.07	
	(0.29)	(0.28)	(0.17)		(0.14)	(0.15)	(0.16)	
Corn price volatility	0.49	0.30	-0.44**		0.25*	0.14	0.11	
	(0.45)	(0.23)	(0.17)		(0.13)	(0.09)	(0.15)	
Soy price volatility	0.36	-0.66	0.18		0.28**	-0.11	0.22**	
	(0.24)	(0.57)	(0.41)		(0.11)	(0.13)	(0.09)	
Rice price volatility				-0.25**				-0.11**
				(0.11)				(0.05)
Fertilizer price	-0.08**	-0.01	0.05**	-0.01	-0.01	-0.02	0.02	-0.01*
	(0.03)	(0.02)	(0.02)	(0.01)	(0.01)	(0.01)	(0.03)	(0.01)
N	1174	1444	1371	1342	1162	1418	1350	1342
No. of Instruments	246	246	242	146	296	296	296	197
F- test of joint significance: p-value	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Test for AR(2): p-value	0.15	0.15	0.07	0.09	0.89	0.29	0.98	0.14
Hansen J- test: p-value	1.00							
Diff-Sargan test: p-value	0.99	0.99	0.98	0.99	1.00	0.99	0.99	0.98

Notes: All regressions are two-step System GMM. Two-step standard errors clustered by country, incorporating the Windmeijer (2005) correction, in parenthesis. Yield deviations are included in the acreage response models as additional control variables. *, **, and *** represent the 10%, 5% and 1% levels of significance.

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4 All the production and area response models are weighted by the global crop acreage share of each country. Moreover, sensitivity analyses where we estimated elasticties using panels excluding countries in the ROW group provide consistent results.

5 Rice price and volatility are excluded in the acreage response model since land for rice cultivations is not usually suitable for the other crops; however, competition in production is possible through input substitution.

The results show that soybeans and corn have larger production responses to own crop prices followed by wheat and rice. Conditional on other covariates, a 10 percent rise in the expected own output price induces a production increase of about 4% for soybeans, 2% for corn, 1% for wheat and 0.5% for rice in the short-run. These production responses are typical reflections of the acreage and yield adjustments. An equivalent increase in the respective international crop prices induces farmers to increase their land allocated to soybean and corn cultivation by about 1.5% and 0.8% respectively. Moreover, the yields of both soybeans and corn respond by an increase of about 1% following akin increases in international own output prices. Global wheat acreage and yield also respond to output prices, with short-run elasticities of 0.08 and 0.17, respectively. In line with the production response results, rice has relatively weaker acreage and yield responses to own prices. Rice cultivation requires capital investment (canals, sluices etc.) to ensure flooding at the time of planting. These investments are long-term decisions, implying that short-run price responses are inevitably low.

Additionally, the statistically significant cross-price elasticities have negative signs consistent with economic theory. While soybean production has negative correlations with higher wheat prices, corn producers respond to higher international rice prices by lowering their corn production. The cross-price elasticities show that corn and soybeans compete for land, with a stronger corn price effect on soybean acreage. Besides, higher wheat international prices lead to less land for soybean production.

Table 3. Estimates of yield response

Variable	*Wheat*	*Corn*	*Soybeans*	*Rice*
Lagged dep. var	0.92***	0.96***	0.93***	0.98***
	(0.03)	(0.02)	(0.04)	(0.01)
Own crop price	0.17***	0.09**	0.15***	0.06***
	(0.05)	(0.04)	(0.04)	(0.01)
Own price volatility	-0.34**	-0.37**	-0.47**	-0.17**
	(0.16)	(0.17)	(0.23)	(-0.06)
Fertilizer price	-0.07**	-0.01	-0.05**	-0.03*
	(0.03)	(0.02)	(0.02)	(0.01)
N	1174	1444	1371	1363
Number of instruments	167	166	168	167
F- test of joint significance: p-value	0.00	0.00	0.00	0.00
Test for AR(2): p-value	0.05	0.43	0.08	0.13
Hansen J-test : p value		1.00		
Diff-Sargan test: p-value	0.96	0.74	0.93	0.84

Notes: All regressions are two-step System GMM. Two-step standard errors clustered by country, incorporating the Windmeijer (2005) correction, in parenthesis. *, **, and *** represent the 10%, 5% and 1% levels of significance.

Unlike the effect of own crop price levels on supply responses of the respective crop, own price volatility does not have uniform effect on the supply of all crops. Wheat producers seem to be affected most by internationals output price volatility. The results reveal that an increase in the volatility of international wheat price leads to a decline in the average wheat production, resulting from less land allocated for wheat production as well as lower yield improving investments. To some extent the negative wheat acreage response to own-price fluctuations could be offset if prices of competing crops such as corn and soybeans also exhibit such fluctuations. The negative corn supply impact of output price volatility is mainly due to declining yield. While producers react to rising corn prices by putting more input to improve corn productivity, corn price-risk induces risk-averse producers to shift input away from corn production.

Considering the soybean supply response results, on the other hand, the estimated coefficients on the volatility of all crop prices are statistically insignificant, with a statistically positive sign for own price volatility of the acreage response model. What this means is that own output price-risk does not have any impact on soybean supply and if at all, it is a positive one. This is consistent with previous national level studies that find either insignificant or positive effects of price variability on soybean acreage supply (e.g. de Menezes & Piketty, 2012). The majority of soybean producers in the world are large and commercialized holders who are likely to be more informed about price developments. Thus, they are likely to be willing to take price-risks in order to acquire the associated higher returns of agricultural investments.

In addition to output prices, input price is also an important factor in farmers' production decision as shown by the fertilizer price elasticities. Besides its negative effect on wheat production and rice acreage, higher international fertilizer price is detrimental to improving the yields of nearly all crops. More specifically, doubling of international fertilizer price indices brings about 1% to 7% reduction in crop productivity.

The lagged dependent variables were both statistically and economically relevant in all crop supply models. The estimated coefficients indicate producers' inertia that may reflect adjustment costs in crop rotation, crop specific land (and other quasi-fixed and fixed inputs), technology and soil quality requirements. However, the coefficients of the lagged dependent variables might also reflect unobservable dynamic factors and interpretation should be made with caution (Hausman, 2012). The estimated coefficients of the lagged dependent variables are close to one indicating that agricultural supply is much more responsive to international output prices in the longer term than in the short-term.

Table 4. Summary of existing own-price supply elasticities

Countries	Wheat	Corn	Soybeans	Rice
Egypt	0.25	0.09	0.03	0.16
South Africa	0.09	0.28	0.03	0.03
China	0.09	0.13	0.45	0.16
India	0.29	0.21	0.36	0.11
Pakistan	0.23	0.28	0.29	0.29
Argentina	0.41	0.7	0.32	0.24
Brazil	0.43	0.42	0.34	0.07
Turkey	0.2	0.14		0.47
Iran	0.08	0.01	0.01	0.01
EU	0.12	0.08	0.19	0.24
Russia	0.19	0.31		
Canada	0.39	0.18	0.32	
United States	0.25	0.17	0.3	0.35
Australia	0.33	0.23		0.17
Weighted average (weighted by area share)	***0.18***	***0.14***	***0.31***	***0.07***
Roberts & Schlenker (2013), Global	0.10	0.27	0.55	0.03
Haile et al, 2013, Global	0.09	0.18	0.37	0.02
This study	***0.10***	***0.23***	***0.34***	***0.05***

Source: Food and Agricultural Policy Research Institute (FAPRI). Since FAPRI does only report rice acreage elasticties for the United States, we took elasticties from Lin & Dimuskes (2007) for the other crops. We also took average acreage elasticties for other Africa for non-reported elasticties for Egypt and South Africa.

In summary, our empirical results align with previous work that shows agricultural supply is inelastic in the short-run. Table 4 above gives a summary of supply elasticities for selected countries estimated by FAPRI and other literature. Apart from the soybean supply elasticties that are of the same order of magnitude, our estimated elasticities are smaller than the weighted average of the national level estimates.

Albeit the positive response of national crop supply to international prices, this may hint that supply responses to domestic prices are relatively stronger.

5. Conclusions

Uncertainty is a quintessential feature of agricultural commodity prices. Besides the traditional causes for price fluctuations, agricultural commodities are increasingly connected to energy and financial markets, with potentially destabilizing impacts on prices (Tadesse, et al., forthcoming). In addition to the effects of climate changes, the unpredictable nature of output prices results in notable variations in supply. Factors such as ongoing developments in bio-technology, fluctuations in corn and soybean prices due to the rising demand for ethanol, and changes in production costs affect farmers' production decisions. These changes have substantial implications for global food supply as well as for the agribusiness sector such as input supply industries.

Using cross-country panel data for the period 1961-2010, this study investigates the global supply impacts of world-level output prices and their volatility. Estimation of supply response to input and output prices as well as output price volatilities is a necessary step in predicting the global food supply effects of possible developments in output prices and their volatility. In addition to the acreage allocation response that agricultural producers make towards price changes, they also react to expected changes in terms of yield response. Thus, besides via acreage changes, the global food supply response to expected prices comes from yield changes.

The results underscore the relevance of output price volatility for the supply of the key global agricultural staple crops. Although higher risk in prices is usually associated with higher return, it is a well-known finding in economic theory that output price-risk is detrimental to producers (Sandmo, 1971). Coefficients for the price-risk variables are statistically and economically significant in all wheat supply response models and for corn yield response model. Besides inducing wheat producers to shift land away from wheat cultivation, higher output price volatility also weakens the incentive to invest in yield improvement. Having little or no acreage allocation impact, own output price volatility has a negative impact on corn yield. Consequently, reducing agricultural price volatility is likely to increase food supply in the world and more importantly in developing countries. However, there are agricultural producers who do not shy off from making investments in order to obtain higher returns associated with higher price-risks. Such producers need not be hurt by output price volatility. The findings of this article suggest that this is the case for the majority of soybean producers in the world. This is relevant for policy makers, suggesting that "one-size fits all" type of price volatility management tools would not benefit all producers.

This article provides answers to why the current high food prices do not bring about global agricultural supply increase as we would have expected. The estimated short-run supply elasticities are generally small. Agricultural supply does not, in the short-run, increase on a par with output price increases. In other words, agricultural producers need longer time in order to make necessary production adjustments and investments to increase supply. Agricultural supply is more elastic in the longer-term. Furthermore, the latent output price uncertainty weakens the positive supply response.

By aggregating data at country and regional levels, we may conceal the likely crop supply effects of farm and household level factors such as local transaction costs, farm and household characteristics. However, we are able to control for heterogeneities across countries and across time with greater transparency and parsimony than farm or household level supply response estimations. Our estimates serve both as complements to micro level supply models and as verifications of whether involved household and farm level estimations add up to patterns that are apparent in the aggregate national and regional data.

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