Volatility in the international food markets: implications for global agricultural supply and for market and price policy

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Abstract
Agricultural countries usually produce multiple crops, but a particular area of land is allocated to the production of a certain crop. Understanding how producers make decision to allot acreage among crops and how decisions about land use are affected by changes in prices and their volatility is fundamental for both policy design and for estimation models of the behavior of agricultural producers. The profitability of a land allocated to a certain crop is affected by the volatility of the crop's price that in turn affects the acreage allocation decision of the producer. To address this, the present paper estimates global acreage response equations for major agricultural commodities (wheat, maize, soybeans and rice) using two related databases: globally aggregated time series and cross-country panel databases. The paper addresses the debate of agricultural market regulation from the perspective of agricultural producers. The findings of this study reveal that, while higher output prices are incentives to improvements in the global crop supply, output price volatility, on the other hand, discourages agricultural investment in terms of cropland expansion. Depending on respective crop, short-run acreage elasticities range between 0.05 and 0.25 whereas price volatility tends to reduce acreage response of all crops except of soybeans. Thus, price volatility management tools, which could include market regulation but also other market based tools like futures contracts or contract farming, need to be customized to specific crops and countries.

1. Introduction

Prices of agricultural commodities are inherently unstable. The variability of prices is mainly caused by the stochasticity of weather and pest events that influence harvest and that are exacerbated by the inelastic nature of demand and supply. Besides these traditional causes for price fluctuations, agricultural commodities are increasingly connected to energy and financial markets, with potential destabilizing impacts on prices (von Braun & Tadesse, 2012).

The aim of this paper is to better understand the global supply dynamics of the four basic staple crops, namely wheat, corn, soybeans and rice. These commodities are partly substitutable at the margin in production and demand, and constitute a substantial share of the caloric substance of world food production (Roberts & Schlenker, 2009). Abstracting from the 'external' weather and pest shocks that are hardly predictable some months in advance, we focus on the acreage allocation decision as one important determinant of short-term supply. For these and other unpredictable conditions that usually occur after planting, the agricultural economics literature favored acreage over output response in order to estimate crop production decision (Coyle, 1993).

The literature on estimation of supply response to prices has a long history in agricultural economics (Houck & Ryan, 1972; Lee & Helmberger, 1985; Nerlove, 1956). Nevertheless, there are various reasons to reconsider the research on acreage allocation. The majority of the previous empirical literature investigating supply response focuses largely on particular crops and is concentrated in a few countries. The effect of price 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. Given that previous analyses showed the supply effects of output price and price volatility at the micro and national levels (Bakhshi & Gray, 2012; Binswanger & Sillers, 1983; Fafchamps, 1992; Newbery & Stiglitz, 1981), it is rational to ask whether this effect ensues at the global scale as well. The analysis at global scale appears to be even more important as the global food supply impacts have strong implications for food security in several countries. 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 (Gilbert & Pfuderer, 2013; von Braun & Tadesse, 2012).

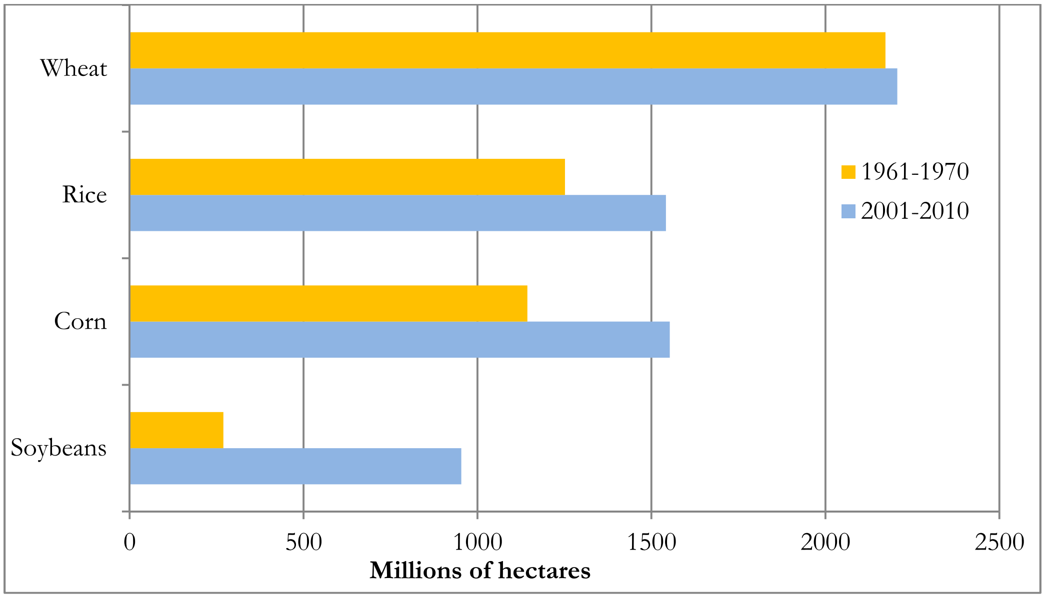
This study, therefore, investigates the responsiveness of global cropland to changes in output prices and the uncertainty therein. The econometric approach of the present study is in line with a partial supply adjustment framework updated, among others, with dynamic response, alternative price expectation assumptions and introduction of price risk variables. The study applies time series and panel econometric methods to estimate global acreage response equations for the key agricultural commodities. While upward output price trends are incentive for agricultural producers to make agricultural investments such as expanding acreage, output price volatility introduces risks that affect a risk-averse agricultural producer (von Braun & Tadesse, 2012). Since evidence shows that the recent increase in price trends is accompanied by higher volatility (Gilbert & Morgan, 2010), simultaneous investigation of the supply impacts of output price level and volatility is crucial in order understand whether the price incentive is fully counterbalanced. This way, the paper addresses the debate of agricultural market regulation from the perspective of the agricultural producers.

The rest of the paper is organized as follows: the following section presents a brief overview of global acreage and output price dynamics. Section 3 provides the theoretical framework and the state-of-the-art on the empirical acreage response model. Section 4 presents and discusses the econometric results, and the last section concludes.

2. Global cropland and price dynamics

Competition for land is one of the drivers that affect 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 recently been remarkable 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).

Figure 1 shows that global average area cultivation has increased for all the four crops during the past 50 years. While the acreage increase is small for the case of global wheat (less than 2%), it has been substantial for soybeans (254%), corn (36%), and rice (23%). Moreover, global average corn acreage, which was about 90% of the global rice acreage over the decade 1961-1970, has surpassed the latter by about a million hectares during the recent decade. 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 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). It is likely that total cropland supply will be even more inelastic in the future due to population pressure, desertification and other climatic factors.



Source: Data from FAO (2012) and several national sources

Figure 1. Changes in global average acreage for the four crops, 1961-1970 versus 2001-2010

The levels of agricultural investment have been low for about three decades since the early 1970s. This has been attributed to the prevailing low international agricultural commodity prices. However, agricultural commodity prices have shown dramatic upward movement since the middle of the previous decade. 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. The world price volatility of selected crops, as measured by the moving standard deviation of monthly logarithmic prices, has been higher in the recent decade relative to earlier periods (Table 1).

Table 1. Volatility of international prices for selected crops

Period	***Wheat***	***Corn***	***Soybeans***	***Rice***
1961-1970	0.06	0.07	0.08	0.10
1971-1980	0.16	0.12	0.18	0.19
1981-1990	0.09	0.13	0.12	0.13
1991-2000	0.13	0.13	0.08	0.14
2001-2011	**0.17**	**0.15**	**0.15**	**0.13**
2006-2011	**0.21**	**0.19**	**0.16**	**0.16**

Note: Price volatility is measured by the standard deviation of logarithmic monthly prices using the World Bank international prices. The figures in each row refer to average values over the respective decade.

Table 1 also shows that the volatility of soybean and rice prices was slightly higher in the 1970s. Moreover, the literature indicates that international agricultural commodity prices have been more volatile over the past three decades than during the pre-1973 periods (Dehn et al., 2005). Thus, the main contribution of this study is to investigate the effect of international price volatility on crop production, with an emphasis on cropland allocation at the global level. The study involves global time series and cross-country panel data and recent developments in panel econometrics in order to test for several assumptions on variable acreage responses to prices and volatility, as well as to control for a time trend.

3. Theoretical and empirical model

3.1. Theoretical 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 a 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 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 acreage 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 has 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; Davison & Crowder, 1991), and acreage 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 (Liang et al., 2011; Lin & Dimukse; 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 crops can be formulated in terms of yield, area, or output response. For instance, the desired area to be planted for a certain crop in period t is a function of expected output prices, and a number of other exogenous factors (Braulke, 1982):

$$A_t^d = \beta_1 + \beta_2 P_t^e + \beta_3 Z_t + \varepsilon_t \quad (1)$$

where A^d is the desired cultivated area 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 the area under cultivation with zero expected mean, and β_i are the parameters to be estimated.

Usually there is a delayed area adjustment in agricultural production due to resource availability within one or two agricultural production cycles. The harvest time prices are not also observed during the time of planting and hence the farmers make expectations about output prices based on their knowledge of past and present prices as well as other relevant observable variables and make some expectation adjustments.

3.2. The econometric model

As stated earlier this study employs both time series and panel econometric techniques to estimate global crop supply. The acreage demand equations for the time series model can be specified most generally as:

$$A_{i,t} = \alpha_{i,t} + \pi_i A_{i,t\text{-}1} + \sum_{j=1}^{4} \beta_{ij} P_{j,t} + \sum_{j=1}^{4}\sum_{i\geq j}^{4} \varphi_{ij} vol(p)_{j,t} + \theta_i Z_{i,t} + u_{i,t} \quad (2)$$

where A denotes the acreage planted to the i-th crop (1=wheat 2 = corn, 3 = soybeans, and 4 = rice), A_{t-1} is lagged acreage used as a proxy for soil conditions or land constraints, p_j is the expected price for the j-th crop, *vol(p)* is a matrix of the price (co)variances that serves as volatility measures for own and competing crop prices, Z_i denotes other explanatory variables (e.g. a time trend t, dummy variables d, production costs w), and the error term ε.

Using the panel database, on the other hand, assuming there are K countries observed over T periods, the acreage demand equations of the four crops can be specified most generally as:

$$A_{k,t}^{i} = \sum_{p=1}^{p} \pi_i A_{k,t-p}^{i} + \sum_{j=1}^{4} \alpha_{ij} P_{k,t_k}^{j} + \sum_{j=1}^{4} \varphi_{ij} vol(p)_{k,t_k}^{j} + \lambda_1 w_{k,t_k}^{j} + \lambda_2 YS_{k,t_k}^{i} + \lambda_3 f^{i}(t) + \mu_{t}^{i} + \eta_k^i + u_{k,t}^{i} \quad (3)$$

where A^i denotes the cultivated acreage of the *i-th* crop (1=wheat 2 = corn, 3 = soybeans, and 4 = rice), A^i_{t-p} is lagged acreage used as a proxy for soil conditions or land constraints, P denotes either spot or futures prices that are used as a proxy for expected own and competing crop prices at planting time, $vol(p)^j$ is a matrix 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, potentially capturing producers' expectations of weather conditions, *f(t)* is a time trend which may vary across countries or continents and captures trends in area cultivation stemming from technological change and population growth, μ captures year-fixed effects to account for some structural changes or national policy changes with global influence, η denotes country-fixed effects, and u denotes the error term. The subscript k denotes the country: this implies that the lag lengths of the relevant futures and spot prices to form price expectations as well as the 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 variables. All variables (except the price volatility measures, which are rates; and yield shock measures, which are negative as well as positive) are in logarithmic form.

Since actual prices are not realized during planting, we model farmers' price expectations using price information available during planting. We alternatively use two price variables, spot and futures prices, to proxy producers' expected harvest period prices. Just and Pope (2001) noted that it is possible for the producer to choose cultivating a different crop at planting time. Therefore, it is worthwhile to consider the price and price-risk information during the planting season. Accordingly, we gathered crop calendar information to identify the major planting seasons of each country. The spot prices are the crop prices in the month immediately before planting, containing more recent price information for farmers. They are also closer to the previous harvest period, possibly conveying new information about the future supply situation. The futures prices refer to the harvest period futures prices quoted in the months prior to planting. Since the crop calendar varies across countries, both the futures and spot prices of each crop in the above panel model specification are country-specific. For countries in the rest of the world, we use the annual average spot prices and annual average generic futures prices, respectively. We also include own and cross price volatility in order to capture price-risks. Price volatility is measured, as is customary in agricultural economics, as the standard deviation of logarithmic prices. We alternatively calculate price volatility as the standard deviation of price returns, i.e. the standard deviation of changes in logarithmic prices as suggested by Gilbert & Morgan (2011). The price-risk measures are also country-specific referring to the crop price variability in the twelve months preceding the beginning of the planting period for each country[2].

Given the dynamic nature of agricultural supply response, our empirical dataset may contain nonstationary variable series. Hence we conduct unit root tests (Dickey & Fuller, 1979; Maddala & Wu 1999), the results of which are available upon request. The test results suggest that unit roots exists in the levels of nearly all the time series variables whereas first order differences of these variables are stationary.

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). Anderson and Hsiao (1982) suggest instrumental variable (IV) method to estimate the first differenced model which can circumvent such problem. This technique eliminates the fixed effect terms by differencing instead of within transformation. Since the lagged dependent variable is correlated with the respective error term, this method uses the second lagged difference as an IV. Although this provides consistent estimates, Arellano and Bond (1991) argue that it is inefficient for it does not make use of all the available moment conditions. Thus we employ the Arellano-Bond technique, so-called feasible efficient GMM estimator method, in order to estimate our dynamic panel difference model using all suitably lagged endogenous and other exogenous variables as instruments in the GMM technique (Roodman, 2009). This GMM estimation retains the error component with panel-specific random terms. First differencing the variables does also remove the panel-specific effects and maintains purely random terms. In the process of first-differencing, the GMM estimation adjusts for unit root variable series and makes use of the stationary differenced series. Also, we use first-differenced variables to avoid spurious results due to unit root in the time series econometric model.

3.3. 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 acreage responses for the world's key crops. While data on planted acreage were obtained from several relevant national statistical sources[3], harvested acreages for all countries were obtained from the FAO and USDA. International spot market output prices, crude oil prices as well as different types of fertilizer prices and price indices were obtained from the World Bank's commodity price database. All commodity futures prices were obtained from the Bloomberg database. Table 2 reports the countries or regions and crops analyzed in this study.

We make use of the crop-calendar information of each country in order to construct country-specific spot and futures prices, measures of price-risk, and input prices. The crop-calendar information is obtained from the FAO GIEWS, for emerging and developing countries is obtained from the General Information, and from the Office of the Chief Economist (OCE) of the USDA, for the advanced economies. It is further modified with expert knowledge on planting and harvesting periods from Bayer CropScience AG. Area harvested serves as a proxy for planted area if data on the latter are not available from the relevant national agricultural statistics. Fertilizer price indices are used as proxies for production costs in this study. The

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[2] The standard devation of price returns are uses as price-risk measures in the econometric models.

[3] Data sources can be made available upon request.

fertilizer price index is constructed using the prices of natural phosphate rock, phosphate, potassium and nitrogenous fertilizers.

Table 2. Study countries and crops

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

Notes: Acreage data are pooled across the 27 member countries for the EU and across all the remaining countries for the ROW group. Post-1991 data are applicable for the former Soviet Union countries. [a]For these countries, either no acreage is devoted to wheat crop or data is not available and hence is not used for the empirical analysis in this paper.

4. Results and discussion

Tables 3 and 4 present the econometric results of the acreage response functions which use the aggregate time series and panel databases, respectively. The standard error estimates for all specifications are consistent in the presence of any pattern of heteroskedasticity and autocorrelation within panels (the Newey-West autocorrelation adjusted standard errors are employed for the time series model). The test results in the lower part of Table 4 indicate that the null hypothesis of no second-order autocorrelation in residuals cannot be rejected for all acreage models, indicating the consistency of the GMM estimators.

4.1. Time series crop acreage model

The annual regression gives a conventional estimate of supply elasticities that indicate how annual global acreage changes in response to changes in output price expectation. To our knowledge, this is a first study to estimate acreage elasticities at a global scale. Additionally, short-term price movement indicators are considered to assess the impact of price risk or unpredictability of prices.

Table 3 shows the global annual acreage response results. For wheat, corn and soybeans, cash prices of the planting season before harvesting are considered as the expected harvest period prices. Since most of the sowing for the harvest of a specific year for these crops occurs during the spring of the same year or during the winter of the previous year, we lagged both spot prices and volatility. As rice is planted in most of the months throughout the year, we use the same-year values. The regression estimates show that all the acreage responses to own prices are statistically significant and consistent with economic theory. The short-run acreage responses to own prices range from 0.03 (rice) to 0.24 (soybeans), which is low but fairly consistent with other estimates: for instance, Roberts and Schlenker (2009) estimated supply elasticities for the caloric aggregate of the four staple crops between 0.06 and 0.11. The results also show that the statistically significant cross-price acreage coefficients are consistent with economic theory: a negative area response to competing crop prices. In this regard, expectations about wheat prices seem to be important for all but soybean crop acreages. Expectation of higher wheat prices encourages cultivation of more land for wheat production.

Table 3. Annual acreage response estimates

Variables	***Wheat***	***Maize***	***Soybeans***	***Rice***
Acreage (t-1)	-0.252**	-0.281**	-0.381*	-0.22
Wheat price	0.069**	-0.100***	0.036	-0.054*
Maize price	0.004	0.174***	-0.149*	0.039
Soybean price	0.012	-0.014	0.244***	0.004
Rice price				0.027*
Fertilize price index	-0.028**	0.012	-0.037	0.014
Own price volatility	0.015	-0.985**	-0.142	-0.283*
Time trend	0.0	0.0	0.0	0.0*
N		48		

*p<0.10, ** p<0.05, *** p<0.01

The cross price coefficients suggest that shifting away land from corn and rice cultivation contributes to this additional land for wheat production. Besides encouraging more land to corn cultivation, the results also show that higher corn prices lead to less land for soybean production. Own price volatility reduces global corn and rice acreages significantly, the respective estimated coefficients are -0.99 for corn and -0.28 for rice. Fertilizer prices are statistically significant only for the global wheat acreage in the annual model. As described above both the dependent variable, sown area, and its lagged independent variable are first-differenced to avoid spurious results due to unit root. The coefficients of the lagged acreage are statistically significant and negative for all crops except for rice. The interpretation is that a higher acreage growth in a certain year is associated by a lower growth in the coming year. This may be indicative of the cyclical (cobweb) nature of agricultural production.

4.2. Cross- country panel acreage model

The findings of the panel econometric model are, in most cases, consistent with the time series results above. For each respective crop, the first column uses pre-planting month spot prices whereas the second column (except for rice)[4] uses harvest period futures prices as proxy for expected prices at planting time. Crop acreage responses to own prices are positive and statistically significant, consistent with economic theory. The results are robust across the two specifications. Wheat acreage responds to competing crop futures prices besides the response to own output price. While the response of wheat acreage to corn futures prices has an unexpected positive sign, its response to soybean futures prices is negative and thus consistent with economic theory. Moreover, an increase in corn price, both spot and futures, tends to reduce the global soybean acreage. The proceeding discussion relies on the results obtained from the specifications with spot prices (reported under columns marked (1)), unless stated otherwise.

[4] Rice futures markets have relatively shorter time series data and local prices are unlikely to be strongly correlated with futures prices in several countries.

The results show that wheat acreage responds positively to own output price. When the expected price of wheat rises by 10 percent, farmers respond by increasing their land allocated to wheat cultivation by about 1 percent. However, the positive response of wheat acreage to a rise in own price levels may be overshadowed by own crop price volatility. The results reveal that higher volatility of wheat prices lead to a decline in the average global wheat acreage. Considering the specifications with futures prices, global wheat acreage tends to respond to the volatility of corn and soybean prices as well. More specifically, the negative wheat acreage response to own-price volatility could be offset by a similar increase in the volatility of the competing corn prices. Expectations about weather conditions, measured by yield shocks, also have the *a priori* expected statistically significant effect on wheat acreage.

Table 4. Results of the first- differenced GMM estimation

Variables	***Wheat***		***Corn***		***Soybeans***		***Rice***
	(1)	*(2)*	*(1)*	*(2)*	*(1)*	*(2)*	*(1)*
Lagged own area	0.856***	0.895***	0.981***	0.982***	0.922***	0.897***	0.682***
Wheat spot price	0.099***		-0.043		-0.145**		
Wheat futures price		0.112***		0		-0.092	
Corn spot price	-0.001		0.087**		-0.171*		
Corn futures price		0.119**		0.053		-0.223**	
Soy spot price	-0.019		0		0.319***		
Soy futures price		-0.129**		-0.062		0.294**	
Rice spot price							0.065**
Wheat price volatility	-0.411**	-0.433**	-0.194	-0.165	0.214	0.164	
Corn price volatility	0.416	0.602**	-0.443**	-0.332*	-0.258	-0.527	
Soy price volatility	-0.24	-0.236*	0.336*	0.362	0.208	0.569	
Rice price volatility							-0.19
Fertilizer price	-0.009	-0.029	-0.047*	-0.022	0.037	0.056	-0.021
Weather expectation	0.019**	0.014	-0.009	-0.016*	0.029*	0.026	0
Time trend	-0.001	-0.001	0.003*	0.003*	0	0.001	0.002
N	1130	1126	1155	1151	1100	1096	1332
Test for AR(1): p-value	0.001	0.001	0.076	0.075	0.007	0.006	0.018
Test for AR(2): p-value	0.423	0.413	0.419	0.390	0.235	0.241	0.313

Notes: * p<0.10, ** p<0.05, *** p<0.01. Columns marked (1) and (2) for the respective crop report results of which we use spot and futures prices, respectively.

Although we fail to find a significant relationship between corn area and competing crop price levels, global corn acreage does respond to own crop price and to international fertilizer prices. In addition, global corn area responds to own and competing crop (soybean) price volatilities. While producers react to rising corn prices by increasing land for corn cultivation, corn price-risk induces risk averse producers to bid land away from corn production. Considering the soybean acreage response results, on the other hand, the estimated coefficients on the volatility of all crop prices are statistically insignificant, with a positive sign for own price volatility. This may imply that output price risk does not have a negative impact on soybean acreage and that, unlike wheat and maize producers, soybean producers are less risk averse. 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 response of global soybean acreage to own price is stronger relative to the other crops, with a short run acreage elasticity of 0.32 and a corresponding long-run elasticity of 4.1. Global rice acreage also responds to its own international price, with elasticity of 0.07.

The lagged acreage variables were both statistically and economically relevant in determining all crop acreages. The estimated coefficients indicate producers' inertia that may reflect adjustment costs in crop rotation and crop specific land 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).

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 (von Braun & Tadesse, 2012). In addition to the effects of climate change, 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 producers' acreage allocation decisions. To this end, a recent study showed that land use changes as a result of expansion of biofuel significantly decreases global food supply mainly in developing countries (Timilsina et al., 2012). 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 and time series data for the period 1961-2010, this paper investigates the global supply impacts of output prices and their volatility. Besides providing updated estimates of supply responses to own and competing price expectations, it also estimates growth trends that are informative to policy in understanding the likely extensive and intensive margin changes because of crop price changes. Estimation of acreage response to input and output prices as well as output price volatilities is a necessary step to predict the global food supply effect of possible developments in output prices and their volatility. Generally, corn and soybean acreages are more responsive to prices with short-run own-price elasticities of 0.17 and 0.24, respectively, than wheat (0.07) and rice (0.03). The low acreage supply elasticities may be indicative of the need for productivity improvements to meet (growing) demand as area expansion is economically and environmentally limited.

The findings of this paper underscore the relevance of output price volatility on 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 for global wheat and corn acreages but less so to rice and soybean acreages. Thus, the hegemonic view that output price volatility is disincentive for pure agricultural producers relies on the behavioral assumption of risk aversion of the producers. This assumption is likely to hold for the majority of crop producers in developing and developed countries, albeit to a lesser extent in the latter case. Consequently, regulation of international markets in order to reduce agricultural price volatility is more likely to expand land for cultivation of staple crops and hence, 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 study suggest that this is the case for the majority of soybean producers in the world whereas risk-aversion is the foremost behavior among the majority of wheat and corn producers. This is relevant for policy makers, suggesting that "one-size fits all" type of price volatility management tools would not benefit all producers. Nevertheless, reducing agricultural price volatility is more likely to expand land for the cultivation of staple crops and hence, to increase food supply in many developing countries as it is likely that agricultural producers in such countries are averse to output price uncertainty

By aggregating area 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. Although the use of international instead of local farm gate prices as proxy for expected prices implies that the domestic market is less important, it is likely and empirically verified that international prices transmit to domestic prices even when countries are poorly integrated to the global agricultural market (e.g. Greb et al., 2012). 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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