The impacts of production uncertainties on world food prices

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Abstract

Purpose – Because of large time lags between the production decision, completion and sale of output, any uncertainty during the process of production, such as bad weather, disease or financial crisis, can affect the prices within food markets systematically. Therefore, the paper aims to analyze the influence of production uncertainties on world's wheat and corn prices.

Design/methodology/approach – In a specially designed two-step method, at first, the contributions of deterministic and uncertainty factors to wheat and corn production in around 100 countries are decomposed. Then, a panel model is applied to estimate the combined impact of each type of factors on the prices. Furthermore, the authors decompose the explained variances of the panel models in order to determine the importance of each type of factors for price adjustments.

Findings – The uncertainties in wheat production do significantly affect both wheat and corn prices on a global scale, whilst those of corn do not. Moreover, the variance decompositions reveal that deterministic factors contribute much more to the explanation of world food prices than indeterministic factors.

Practical implications – As deterministic factors are much more important than uncertainty factors for explaining market price movements, farmers should organize themselves to coordinate production in order to stabilize world food prices.

Originality/value – The paper proposes a simple methodology, which enables scholars to integrate production uncertainties into food price analyses.

Keywords WTO, Wheat, Corn, Indeterministic factors, World food prices

Paper type Research paper

1. Introduction

Huge spikes in world food prices in 2006-2008 and recent so-called food crises have triggered a lot of research in this field. Many institutes, such as FAO (2008), OECD (2008), USDA (Trostle, 2008), the World Bank (Mitchell, 2008) and IFPRI (von Braun, 2007) have published numerous research papers in which an attempt to provide explanations to such a price "explosion" is made. On the one hand, scholars discussed supply events, which could have been responsible, such as weather effects, reduced stocks or changes in input prices (e.g. fertilizer or labor). On the other hand, demand-side factors could also have been influential. For instance, rising biofuel production, rapid urbanization and fast income growth in transition countries (especially China and India) could have increased the demand for agricultural products (von Braun, 2007). Other explanations include the role of intermediaries and speculations in commodity markets as well as political interventions into food markets, such as subsidies and trade restrictions (e.g. export embargoes).

In this study we concentrate on the investigation of the production uncertainties which mainly affect supply, and their impact on food prices. Even though a lot

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of researches state that production uncertainties significantly affect the price volatility, there is little literature to quantify the impact, and these uncertainties were often neglected in food price analysis. Most of the current literature makes the assertion that prices of inputs and outputs are deterministic, which in fact for farmers (and for economists as well) is not true. In particular, the price of output is often uncertain and indeterministic. Lags exist between the decision to produce and realization and sale of the output (Tomek and Robinson, 2003). Any uncertainties during the process of realization, such as bad weather, disease or financial crisis, can affect the market price systematically and are very difficult for farmers to predict or for economists to capture. Therefore, it is very important to decompose the total quantity effects, which can affect the final food price, into deterministic and uncertainty parts.

This article will develop a two-step method to fulfill the aforementioned objective, to decompose the total effects of production into two parts: a deterministic part and an uncertainty part. If there are no production uncertainties (or indeterministic factors) and we assume that farmers know the production function and the demand function (more precisely, inverse demand function) based on the historical observations, as economists do, farmers can predict the output price based on their inputs (deterministic factors). That is, farmers, like a central planner, first use the production function to predict the total output, which is then substituted into the inverse-demand function to obtain the final market price.

However, uncertainties during food production may undermine the predictability of the markets. Production uncertainties are the factors, which are not observed by farmers or economists at the beginning of production and can finally affect outputs, which as a result affect market prices. Agricultural production processes are exposed to the weather, political risks, and financial market uncertainties. For instance, good weather may increase the output and lowers the output price, and vice versa. Weather effects are the most salient uncertainty factors, because they are in a constant state of flux. Previous studies (Schnepf, 2008; Trostle, 2008) have summarized the effects, which adverse weather conditions have had on the largest grain producing countries.

There are important policy implications in distinguishing the deterministic and uncertainty factors of production in food price analysis. If the impacts of production uncertainty factors on food prices are not significant, governments, or generally a central planner, such as a farmers' cooperative, can coordinate food production in advance in order to stabilize the food price. Otherwise, the government should provide more counter-production-risk measures to stabilize the food price, such as increasing government stocks, to increase the welfare of both farmers and consumers. Many studies have shown that food price volatility can have a negative effect on the welfare of both farmers and consumers (von Braun, 2007).

Based on the logic of production and market realization mentioned above, we propose a two-step model and use a panel dataset of almost 100 countries between 1995 and 2007 to study the impacts of deterministic and uncertainty factors of production on the volatility of world corn and wheat prices after the foundation of WTO, given the fact that corn and wheat are the two most important food products. The reason that we pick the period after WTO foundation is that WTO substantially changed the structure of the world food market[1]. In addition, analysis of the post-WTO market can provide more policy implications for ongoing WTO negotiation and agricultural policy making for many countries.

The rest of the article is organized as follows: first, we introduce the two-step model; then introduce the data sources, which is followed by the presentation of empirical results; and finally, provide policy implications and conclusions.

2. The model

Following the logic of production and market realization, our first step is to separate the uncertainty factors (the random components) from the deterministic factors in the production function. In the current literature, weather shock is considered one of the most important uncertainty factors in agricultural production. Most studies use the deviation of the yield to measure it. For instance, a seminal work by Wright (1928) calculated the deviation from the yield with a trend and used it as a proxy variable for weather shock; and the recent analysis by Roberts and Schlenker (2009) estimated the impact of weather by a non-parametric time trend for the yield. However, most of the existing studies do not use structural forms and therefore neglect possible inputs, such as the deterministic factors mentioned in this study. This methodology makes it possible to more precisely model weather and other production uncertainties. For instance, during the financial crises of Argentina from 2000 to 2002 and 2007 to 2008, there were reductions of farm labor and increases in fertilizer prices (due to exchange rate depreciation), which reduced the yields and can be captured by the deterministic factors of a production function[2]. Furthermore, possible changes in the quality of the labor, which result from rural exodus are not observable for farmers are captured by the deviation from the expected production.

After dividing the total quantity effect into deterministic factors and uncertainty factors, we plug them into the inverse demand function to estimate their impacts on prices, respectively. By this, we can study the impact of uncertainties in production on final market price. The model is set as follows.

2.1 The production function

Following the discussions of Tian and Yu (2012) and Yu (2012) about the production functions, we specify the production:

$$Y_{it} = F(X_{it}, t_{it}, e_{it}), \tag{1}$$

where Y_{it} is the total output for country i at time t; X_{it} is a vector of inputs and t_{it} is the technology, and these are deterministic factors; e_{it} represents the uncertainty factors including weather, disease and other variables which can affect production but cannot be observed, controlled or predicted by farmers.

Dividing equation (1) by land input L_{it} in both sides, we have:

$$y_{it} = f(X_{it}, t_{it}, e_{it}), \tag{2}$$

where $y_{it} = Y_{it}/L_{it}$ which is the yield and $f(X_{it}, t_{it}, e_{it}) = F(X_{it}, t_{it}, e_{it})/L_{it}$.

If we specify the production function of equation (2) as a Cobb-Douglas form, and labor, land, and fertilizers are used as the inputs, we have:

$$\ln y_{it} = \beta_0 + \beta_1 \ln l_{it} + \beta_2 \ln c_{it} + \beta_3 \ln L_{it} + \gamma_1 t + \gamma_2 t^2 + e_{it} \tag{3}$$

where l_{it} and c_{it}, respectively, are the labor and fertilizer chemicals per unit of harvest area for country i at time t; L_{it} is the harvested land; and we use a quadratic form of time trend to capture the technological changes.

With the additional assumption of constant returns to scale for harvest area we can exclude the variable L_{it} from equation (3). In the empirical part, we estimate models both with and without the assumption of constant returns to scale for the sake of comparison.

Suppose the parameters in equation (3) can be observed or estimated by historical data. We estimate equation (3) for each country separately to obtain the production function for each country. If the production functions are known and there are no uncertainties, farmers can predict their outputs based on the inputs used. Suppose the predicted yield is $\hat{y}_{it}$, and the uncertainty factor $e_{it} = \ln y_{it} - \ln \hat{y}_{it}$.

We can define $YSI_{it} \equiv \exp(e_{it}) = y_{it}/\hat{y}_{it} = Y_{it}/\hat{Y}_{it}$ as the Yield Shock Index. YSI_{it} is positive and measures the impact of uncertain factors in production. If YSI_{it} equals to one, there is no uncertainty and farmers (and economists as well) can predict the output perfectly; if YSI_{it} is less than one, the real output is less than the predicted output and the uncertainty factors are unfavorable; and if the YSI_{it} is greater than one, the real output is greater than the predicted output and the uncertainty factors are favorable.

Now, we have:

$$Y_{it} = \hat{Y}_{it} * YSI_{it} \tag{4}$$

which decomposes the real outputs into deterministic and uncertainty factors for wheat and corn, respectively, which will be substituted into the inverse demand function in the second step to predict the output prices.

2.2 The inverse demand function

We also assume that farmers know the (inverse) demand function in their own countries and there are no transportation costs within a country, different from the assumption of Li *et al.* (2012). So that price is homogenous within a specific country. Then the price function is specified as:

$$P_{it} = \tilde{G}(Q_{it}, GNI_{it}, Pop_{it}, t) \tag{5}$$

where P_{it}, GNI_{it}, Q_{it} and Pop_{it}, respectively, are price, per capita income, food quantity and population size in country i at time t. Food quantity in the market may be determined by country i's production Y_{it}, stock change ΔS_{it} and net import ΔT_{it}, so that:

$$Q_{it} = Y_{it} + \Delta S_{it} + \Delta T_{it} \tag{6}$$

Equations (5) and (6) state that the changes in the stocks are endogenous variables in the system as well. In order to identify its impact, we can assume that the changes of stock are determined by the current production Y_{it}. Nevertheless, its impact is ambiguous for an aggregate effect. Because the government will increase or decrease their strategic reserves if the unexpected production factors are positive or negative, respectively. However, farmers or intermediaries behave oppositely. They may increase their stocks in order to make more profits whenever the Yield Shock Index is above one. Additionally the ratio of population to agricultural land size $Pop_{it}/\tilde{L}_{it}$ also could determine stock changes. It reflects the capacity of food supply in the country. That is:

$$\Delta S_{it} = S(Y_{it}, Pop_{it}/\tilde{L}_{it}). \tag{7}$$

The domestic and imported goods are assumed to be perfect substitutes which means we can determine net imports of food for country i (ΔT_{it}) by the current production Y_{it}, population-to-agricultural-land-ratio $Pop_{it}/\tilde{L}_{it}$, income per capita GNI_{it}, and possibly the stock change ΔS_{it}. In particular, the ratio of population to agricultural land size determines the potential of the country to be an exporter or importer, and the income per capita shows the food purchase ability for a country in the world market. We have:

$$\Delta T_{it} = T(Y_{it}, Pop_{it}/\tilde{L}_{it}, GNI_{it}, \Delta S_{it}) \tag{8}$$

Substituting equations (4) and (6)-(8) into equation (5) gives:

$$P_{it} \approx G(\hat{Y}_{it}, YSI_{it}, Pop_{it}/\tilde{L}_{it}, Pop_{it}, GNI_{it}, t) \tag{9}$$

Then equation (9) can be specified a log-linear form which can be seen as a first-order approximation for equation (9):

$$\ln P_{it} = \alpha_0 + \alpha_1 \ln \hat{Y}_{it} + \alpha_2 \ln Pop/\tilde{L}_{it} + \alpha_3 \ln Pop_{it} + \alpha_4 \ln GNI_{it} + \theta * YSI_{it} + \lambda_1 t + \lambda_2 t^2 \tag{10}$$

In equation (10) we add a linear and a quadratic trend to capture the price changes over time. θ captures the effects of uncertainty factors on food prices.

We use a panel dataset consisting of almost 100 countries. The price units of the currencies are different. In order to overcome this difficulty, we take first-order differences of equation (10):

$$\begin{aligned} d\ln P_{it} = {} & \alpha_1 d\ln \hat{Y}_{it} + \alpha_2 d\ln Pop/\tilde{L}_{it} + \alpha_3 d\ln Pop_{it} + \alpha_4 d\ln GNI_{it} + \theta * dYSI_{it} \\ & + \lambda_1 dt + \lambda_2 dt^2 \end{aligned} \tag{11}$$

In equation (11), the dependent variable $d\ln P_{it} = \ln(P_{it}/P_{i,t-1})$ becomes the log of price index which is consistent in units across countries.

Furthermore, this paper studies the two important agricultural products: wheat and corn. Because of the substitution effects between them, we should include both quantities in each price function. The final functions for world corn and wheat, respectively, are:

$$\begin{aligned} d\ln P_{it}^{w} = {} & \alpha_1^{w} d\ln \hat{Y}_{it}^{w} + \alpha_1^{c} d\ln \hat{Y}_{it}^{c} + \alpha_2 d\ln Pop/\tilde{L}_{it} + \alpha_3 d\ln Pop_{it} \\ & + \alpha_4 d\ln GNI_{it} + \theta^{w} * dYSI_{it}^{w} + \theta^{c} * dYSI_{it}^{c} + \lambda_1 dt + \lambda_2 dt^2 \end{aligned} \tag{12a}$$

$$\begin{aligned} d\ln P_{it}^{c} = {} & \alpha_1^{c} d\ln \hat{Y}_{it}^{c} + \alpha_1^{w} d\ln \hat{Y}_{it}^{w} + \alpha_2 d\ln Pop/\tilde{L}_{it} + \alpha_3 d\ln Pop_{it} \\ & + \alpha_4 d\ln GNI_{it} + \theta^{c} * dYSI_{it}^{c} + \theta^{w} * dYSI_{it}^{w} + \lambda_1 dt + \lambda_2 dt^2. \end{aligned} \tag{12b}$$

Here the superscripts w and c, respectively, are indicating wheat and corn.

In the rest of the paper we will use a panel dataset with almost 100 countries from 1995 through to 2007 from FAO to empirically study the determinants of food price after the foundation of WTO.

3. The dataset

In the first step, we assume that the production function for each country is different, so that, in order to construct the Yield Shock Index for each country, we estimate equation (3) by OLS for each country separately. The productions and harvest areas for wheat and corn, respectively, are directly obtained from the FAOStat database. Because FAO does not have labor input and fertilizer input for each product, we use the rural population as a proxy for labor input, and per hectare fertilizer inputs as a proxy for fertilizer input for corn and wheat, respectively. Fertilizer chemicals include nitrogen (N), phosphate (P) and potash (K), which together are included in the production function. In order to obtain more degrees of freedom for each country, we use the data after 1990 rather than after 1995 for each country to get the predicted production and the Yield Shock Index[3].

In the second step, the variables of agricultural land size $\tilde{L}_{it}$, corn price P_{it}^{c}, and wheat price P_{it}^{w} are also obtained from FAOStat. The prices in FAOStat are the farm-gate prices, which are the mean price of all "grades, kinds and varieties" (FAOStat, 2010) for a particular crop in a country.

However, FAO only reports the price for each country using the current value of that country's currency. Some EU countries changed their currencies during this period, and we integrate the old currencies into the new ones. Inflation also affects the real prices, so we also use the CPI for each country to adjust the current price to the price in 2007.

The variables of CPI, and population Pop_{it}, and income per capita GNI_{it} are obtained from the World Development Index of the World Bank.

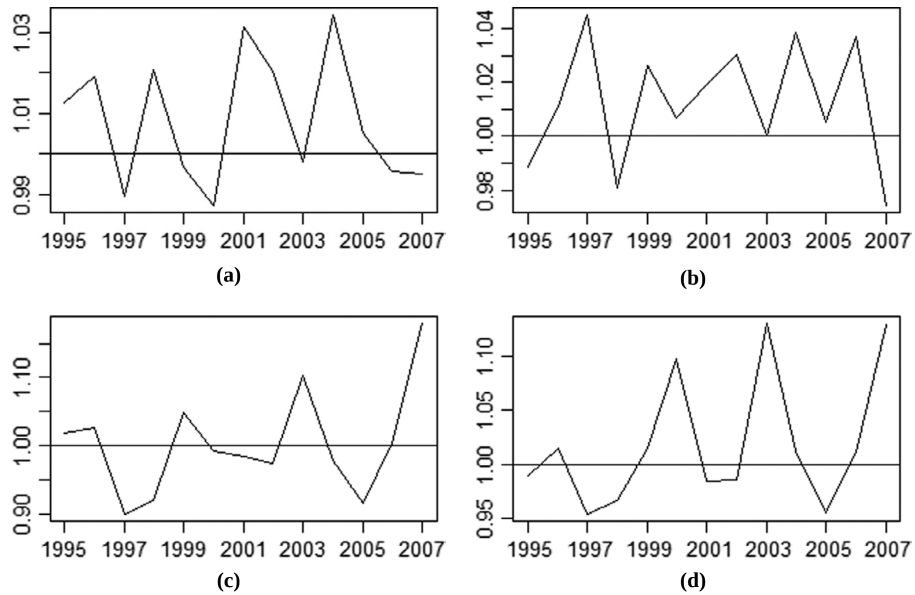
The WTO was founded in 1995, hence the data used in the second step dates from 1995 onwards. The food price in each country would be more relevant because of less-barrier trade under the WTO, which implies that the WTO causes structural changes in demand function. If we include the data between 1990 and 1994, it might bias the final results. The countries used in this study are producers of wheat or corn. The number of countries for the two commodity datasets are different, and more countries produce corn than wheat. Table I shows that the countries in the sample are equally distributed over the world.

4. Empirical results

Because the separation of production into a deterministic and an uncertainty factor cannot be reported in detail for all countries, Figure 1 documents the mean of the two Yield Shock Indices during the period of our study. The production of wheat for example was negatively influenced by uncertainty factors in the years 2006 and 2007, which is consistent with the findings of Trostle (2008) in as much as it might result from an unexpected decline in the output of wheat in some important production countries such as Australia and Ukraine as a result of drought. Besides, we can ascertain that the Yield Shock Indices of wheat and corn are, as expected,

Table I.
Distribution of the wheat and corn producing countries by continents

Commodity	Africa	America	Asia	Oceania	Europe	Total
Wheat	18	14	30	1	34	97
Corn	27	23	28	2	22	102



Notes: (a) YSI wheat; (b) YSI corn; (c) price wheat; (d) price corn

Figure 1. Average YSI^w, YSI^c and relative commodity prices

uncorrelated ($\rho = 0.05$), so that the uncertainties impact on the production of the two products can be assumed independent. In addition, Figure 1 also shows the changes in the price indices.

In the second step of the method, a panel of countries is used. Variables like expected production ($\hat{Y}_{it}$) and income (GNI_{it}) are adjusted for population size to make their effects comparable at the country level. The changes in the mean of all variables used in this study over the time are displayed in Tables II and III for the inverse demand functions of wheat and corn, respectively. The tables show the differences

Year	$\hat{Y}^w$ hg/1,000 people	YSI^w	GNI \$/1,000 people	Pop 1,000 people	$\tilde{L}$ 1,000 ha	$\hat{Y}^c$ hg/1,000 people	YSI^c
1995	291,463	1.013	6,916	50,653	44,699	217,860	0.9886
1996	307,721	1.019	7,345	51,328	44,699	255,723	1.010
1997	328,640	0.9897	7,537	52,092	44,676	250,820	1.055
1998	312,631	1.021	7,278	52,753	44,755	236,876	0.9948
1999	321,293	0.9968	7,223	53,411	44,834	227,938	1.029
2000	304,200	0.9872	7,329	54,063	44,893	239,354	0.9870
2001	302,489	1.031	7,208	54,712	44,947	244,588	1.012
2002	316,963	1.020	7,185	55,357	44,761	267,087	1.038
2003	306,401	0.9980	7,991	56,000	44,573	301,918	0.9886
2004	314,601	1.034	9,537	56,640	44,609	327,227	1.034
2005	310,659	1.005	10,977	57,280	44,723	341,461	0.9941
2006	309,369	0.9957	12,004	57,919	44,981	321,329	1.040
2007	271,099	0.9949	13,022	58,557	44,585	301,731	0.9889

Table II. Mean dataset used to estimate equation (12a)

Table III.
Mean dataset used to estimate equation (12b)

Year	$\hat{Y}^c$ hg/1,000 people	YSI^c	GNI \$/1,000 people	Pop 1,000 people	$\tilde{L}$ 1,000 ha	$\hat{Y}^w$ hg/1,000 people	YSI^w
1995	183,164	0.9885	5,132	47,918	41,505	225,704	1.010
1996	207,663	1.011	5,423	48,593	41,513	236,437	1.013
1997	208,043	1.045	5,480	49,323	41,505	247,813	0.9823
1998	206,064	0.9807	5,257	49,984	41,587	237,570	1.029
1999	195,740	1.026	5,197	50,639	41,550	248,706	1.006
2000	201,523	1.007	5,204	51,290	41,610	230,374	0.9842
2001	206,053	1.019	5,119	51,937	41,677	231,084	1.030
2002	225,539	1.030	5,171	52,581	41,510	243,477	1.017
2003	244,722	1.000	5,651	53,221	41,492	223,764	0.9961
2004	259,162	1.038	6,657	53,861	41,534	226,889	1.042
2005	272,973	1.006	7,596	54,499	41,543	226,409	1.001
2006	263,150	1.037	8,283	55,137	41,465	229,495	0.9997
2007	247,256	0.9744	8,962	55,775	41,426	196,679	0.9920

between the wheat and corn producing countries in terms of population, income and acreage. Interestingly, the incomes in wheat producing countries are higher than corn producing ones, mainly resulting from the fact that the main wheat producing countries are located in the colder northern hemisphere and they are the most developed countries.

The estimated results of equation (12a) for wheat and equation (12b) for corn are reported in Tables IV and V, respectively. In particular, Models 1.1 and 2.1, which assume non-constant returns to scale in the first step, are the full models which we are interested in, and on which the following discussion will be based. In order to conduct a comparison and check for robustness, we also reported the results of different models for either product. For instance, Models 1.2 and 2.2 assume constant returns to scale in the first stage.

First, the results of the estimation reveal a clear and consistent picture about the impact of uncertainty factors on food prices. The Yield Shock Index of wheat is statistically significant both for wheat and corn prices, while the Yield Shock Index of corn is not statistically significant either for wheat or for corn prices. This implies that the uncertainty factors in wheat production can significantly influence both prices in the inverse demand function, while those in corn production cannot. For instance, an unexpected negative shock in wheat harvest (e.g. caused by bad weather) can push up both commodity prices, while shocks on corn production have no impact on both prices. The asymmetric relation implies that wheat is a strong substitute for corn and not vice versa. Furthermore, the cross-price elasticity in terms of the indeterministic factors of wheat is:

$$\frac{d\ln(P^w)}{d\ln(P^c)} = \left.\frac{d\ln(P^w)/dYSI^w}{d\ln(P^c)/dYSI^w}\right|_w = \frac{-0.0909}{-0.1365} = 0.67 \tag{13}$$

Interestingly, the impact of uncertainty factors of wheat on corn prices is greater than the impact on the price of wheat itself.

The findings of the importance of uncertainty factors in wheat production are consistent with the results of recent research. For instance, through the use of a partial

Table IV. Estimated results for various demand functions of wheat

Wheat	Model 1.1 Non-constant return to scale		Model 1.2 Constant return to scale		Model 1.3 Non-constant return to scale		Model 1.4 Non-constant return to scale		Model 1.5 Non-constant return to scale		Model 1.6 Non-constant return to scale	
	Coef.	t-ratio	Coef.	t-ratio	Coef.	t-ratio	Coef.	t-ratio	Coef.	t-ratio	Coef.	t-ratio
YSI^w	−0.091	−2.57***	−0.095	−2.73**	–	–	−0.091	−2.53*	−0.067	−2.20**	−0.087	−2.29**
$\log(\hat{Y}^w)$	−0.065	−2.91***	−0.064	−2.86***	–	–	−0.071	−3.16***	−0.061	−3.06***	−0.079	−3.29***
$\log(Y^w)$	–	–	–	–	−0.003	−3.06***	–	–	–	–	–	–
YSI^c	0.014	0.48	0.003	0.10	−0.001	−0.05	0.006	0.21	–	–	0.004	0.14
$\log(\hat{Y}^c)$	−0.006	−0.22	0.002	0.06	−0.014	−0.58	−0.006	−0.24	–	–	0.025	0.83
$\log(GNI)$	−0.315	−4.12***	−0.315	−4.13***	−0.312	−4.07***	−0.179	−2.48**	−0.321	−4.56***	−0.319	−3.90***
$\log(Pop)$	−0.457	−0.76	−0.464	−0.77	−0.460	−0.76	−0.490	−0.81	0.233	0.45	0.595	0.91
$log(Pop/\tilde{L})$	0.173	0.67	0.173	0.67	0.187	0.72	0.202	0.77	0.006	0.20	−0.26	0.97
t^2	0.005	4.90***	0.005	4.89***	0.005	4.89***	–	–	0.005	5.46***	0.002	1.55
t	−0.111	−4.51***	−0.111	−4.50***	−0.111	−4.48***	−0.004	−0.38	−0.119	−5.47***	−0.072	−2.49**
R^2	0.0529		0.0533		0.0468		0.0272		0.0503		0.0486	
Sample size	892		892		892		892		1,076		747	
Time period	1995-2007		1995-2007		1995-2007		1995-2007		1995-2007		1995-2005	

Note: Significant at: *10, **5 and ***1 percent

Table V. Estimated results for various demand functions of corn

Corn	Model 2.1 Non-constant return to scale		Model 2.2 Constant return to scale		Model 2.3 Non-constant return to scale		Model 2.4 Non-constant return to scale		Model 2.5 Non-constant return to scale		Model 2.6 Non-constant return to scale	
	Coef.	*t*-ratio	Coef.	*t*-ratio	Coef.	*t*-ratio	Coef.	*t*-ratio	Coef.	*t*-ratio	Coef.	*t*-ratio
YSI^c	0.038	0.62	0.026	0.43	–	–	0.028	0.46	−0.002	−0.04	0.014	0.24
$\log(\hat{Y}^c)$	−0.042	−0.73	−0.025	−0.45	–	–	−0.037	−0.65	−0.015	−0.33	0.011	0.21
$\log(Y^c)$	–	–	–	–	−0.0006	−1.60	–	–	–	–	–	–
YSI^w	−0.137	-1.79^{*}	−0.131	-1.76^{*}	−0.082	−1.15	−0.139	-1.81^{*}	–	–	−0.147	-2.22^{**}
$\log(\hat{Y}^w)$	0.044	0.92	0.043	0.87	0.043	0.92	0.033	0.68	–	–	0.030	0.71
$\log(GNI)$	−0.717	-4.22^{***}	−0.716	-4.22^{***}	−0.683	-4.18^{***}	−0.489	-3.06^{***}	−0.586	-4.12^{***}	−0.371	-2.47^{**}
$\log(Pop)$	0.839	0.65	0.804	0.62	0.914	0.72	0.791	0.60	0.583	0.55	2.457	2.14^{**}
$\log(Pop/\tilde{L})$	0.202	0.37	0.205	0.37	0.084	0.16	0.250	0.45	0.125	0.27	0.117	0.25
t^2	0.008	3.72^{***}	0.008	3.74^{***}	0.008	3.52^{***}	–	–	0.006	3.57^{***}	0.006	2.49^{**}
dt^t	−0.203	-3.77^{***}	−0.204	-3.79^{***}	−0.190	-3.58^{***}	−0.026	−1.02	−0.159	-3.64^{***}	−0.190	−3.69
R^2	0.0329		0.0326		0.0321		0.0172		0.0219		0.302	
Sample size	857		857		873		857		1,088		720	
Time period	1995-2007		1995-2007		1995-2007		1995-2007		1995-2007		1995-2005	

Note: Significant at: *10, **5 and ***1 percent equilibrium model; Saunders *et al.* (2009) find that wheat prices react on a greater level to weather effects, while corn prices do not; moreover, in congruence with these findings Headey and Fan (2008) propose weather effects in wheat production as an explanation for price fluctuation.

In addition, the predicted output of wheat has a significantly negative influence on its own price, but not a cross-market effect on corn prices. As anticipated, a higher expected output of wheat results in falling prices. However, the impact of the expected output of corn has no significant effect either on wheat prices or on corn prices itself.

Second, the coefficients for per capita income are negative and statistically significant at 1 percent level in both wheat and corn price functions. The elasticity of wheat prices with respect to per capita income is -0.315, and the elasticity of corn prices with respect to per capita income is -0.717. It implies that food prices within a country can decrease when a country is richer, which is consistent with our prediction. As predicted in our theory, per capita income is a proxy for purchase power in the world market, so that a richer country can purchase more food in the world market when the domestic supply is not sufficient.

Third, other variables, like population-to-agricultural-land-ratio and population size are not statistically significant, which indicates that these factors are not so important in determining food prices.

Furthermore, the time trends are statistically highly significant both in first and in second order, either in corn equation or in wheat equation. In particular, the coefficients for the time trend are 0.005 and -0.111 respective for the first-order and the second-order term in the wheat equation. It implies that the world wheat prices moved in a U-shape after 1995, reaching their lowest point between 2005 and 2006. The coefficients for the time trend are 0.008 and -0.203 for the first-order and the second-order term in the corn equation, respectively. It implies that the world corn prices also moved in a U-shape after 1995 and reached their lowest point between 2006 and 2007.

For each of the two models the R^2 is low, which means that there are also other market uncertainty factors which influence the prices.

Tables IV and V also report the results of other models with different specifications and different time periods, and we find that the results are quite consistent with those in Models 1.1 and 2.1. For instance, even though we put a constraint of constant return to scale in the production functions, the results in the second stage reported as the results of Models 1.2 and 2.2 are quite close to those in Models 1.1 and 2.1, respectively. This implies that our econometric models are fairly robust.

In order to reveal further details about the impact of the indeterministic factors on food prices, we specifically investigate the effect of extreme production uncertainties on the markets. Therefore, we estimate Models 1.1 and 2.1 by only including observations, which belong to either the 3 percent largest or 3 percent smallest Yield Shock Indices (Table VI).

The results show that there are significantly negative relationships between quantity effects and prices. For both commodities, we can confirm that if there is an unforeseen large harvest the prices are, as expected, significantly decreasing. However, the prices are not directly rising if the crop is especially bad. This might be a consequence of the strategic reserves of the governments, which are smoothing the prices quite well. Nevertheless, the coefficients of the expected quantities are significantly negative. Therefore, if the expected production of farmers is large and coincides with extreme negative events, the prices are significantly decreasing in both markets.

Table VI.
Estimated results for extreme production uncertainty

Commodity (i)	Wheat				Corn			
	+		−		+		−	
Direction	Coef.	t-ratio	Coef.	t-ratio	Coef.	t-ratio	Coef.	t-ratio
YSI^i	−0.197	−2.21**	0.077	0.95	−0.169	−1.88*	0.11	1.46
$\log(\hat{Y}^i)$	−0.341	−1.86*	−0.237	−4.7***	−0.029	−0.36	−0.113	−1.76*
YSI^j	−0.037	−0.39	−0.016	−0.21	−0.231	−1.66	−0.113	−1.43
$\log(\hat{Y}^j)$	0.388	1.57	0.046	0.77	−0.099	−1.09	0.097	1.23
$\log(GNI)$	−1.419	−2.56**	−0.39	−0.8	1.619	3.78***	0.568	2.74**
$\log(Pop)$	1.672	0.41	−6.031	−2.46**	9.507	2.59**	3.925	1.43
$\log(Pop/\tilde{L})$	−2.337	−0.64	1.903	0.93	2.459	0.52	−3.354	−0.84
t^2	0.002	0.2	0.0004	0.1	0.01	1.26	−0.001	−0.13
dt^t	0.055	0.23	0.126	1.13	−0.318	−1.62	0.043	0.36
R^2	0.474		0.638		0.649		0.574	
Sample size	27		27		26		26	

Notes: Significant at: *10, **5 and ***1 percent; $i \neq j \forall i, j \in \{Wheat, Corn\}$

5. Variance decomposition

In order to measure the importance of the production uncertainty factors, we apply a variation analysis to decompose the total variances of food prices into different factors. Usually, adding an explanation variable in a regression model can decrease the variance of residuals due to the explanation power, so that we can decompose the total variance into different factors. The results of the variance analysis are reported in Table VII.

The benchmark models are Models 1.1 and 1.2 in Tables II and III, respectively. First, we exclude YSI^w to reveal its explanatory power. Then, we remove all other quantity variables (YSI, $\hat{Y}$) to obtain the explanatory power of total quantitative effects. The numbers of observation are kept constant to ensure compatibility.

We find that the uncertainty factors in production function can explain 18.7 and 15.4 percent, respectively, for wheat and corn in total quantity effect. Surprisingly, the numbers are not so high. It implies that farmers could predict more than 80 percent of the price changes caused by production.

Furthermore, we also find that uncertainty factors in production function only explain 3.2 and 1.6 percent, respectively, for wheat and corn in total explained effects for price functions. It implies that uncertainty factors in wheat production have significant but small effects on world food prices.

Table VII.
Variation analysis discovering the impact of YSI^w on both, wheat and corn prices

Prices	*Wheat*	*Corn*
Equation	*Variance*	*Variance*
Equations (12)	0.0443	0.2048
Equations (12) without YSI^w	0.0446	0.2054
Equations (12) without all quantity effects	0.0458	0.2083
Total variation of price	0.0474	0.2132
Explication	*%*	*%*
YSI^w in total quantity effect	18.7	15.4
YSI^w in total explained variation	3.2	1.6

6. Conclusions

Agricultural production involves a lot of uncertainties, comprising natural risks and market risks, resulting from time lags between the planning, realization and sale of output. A shock during production can, of course, affect the outputs of agricultural products, which in turn may impact the final market price in a region or a country. As many scholars have argued, the recent food crisis might be partially caused by the uncertainty factors in agricultural production, such as adverse weather conditions in agricultural countries. However, few quantitative studies investigating the impacts of uncertainties in production on final market prices in the world have been conducted.

This study develops a two-step method to study the impacts of uncertainties in production on world food prices, and then empirically analyzes the price of wheat and corn, the two most important staple foods, for almost 100 countries from 1995 to 2007.

The results of our econometric model show that uncertainty factors of wheat, denoted by the Yield Shock Index, have significant impacts on both wheat and corn prices, while that of corn is not significant either for wheat or for corn prices. It may be explained by the fact that wheat is a strong substitute for corn, but not vice versa. The results also indicate that food prices can decrease as per capita incomes increase in a country, mainly due to higher purchase power in the world market. Additionally, we find that in years of extreme uncertainty in the production the quantity effects are more obvious.

Finally, we also use variance analysis to decompose the total quantity effects in production into deterministic and uncertainty factors, and we find that more than 80 percent of the total quantity effects can be explained by deterministic factors. This study concludes that the uncertainty factors in wheat production have significant but small impacts on world food prices, and the uncertainty factors in corn production have even smaller effects. The policy implication is that farmers should be organized by themselves or by governments to coordinate production to stabilize the final market price.

Notes

1. In addition, the time between 1990 and 1995 is too short to conduct an analysis.
2. This example was mentioned by an anonymous referee.
3. FAO changed the standard of fertilizer statistics after 1990, so that we use the data after 1990, not earlier.

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