

# Drivers of the World Grain Price Crisis in the Short- and Long-Run: A Spatial-Temporal Rational Expectations Equilibrium Approach

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# Outline

## 1 Introduction

## 2 The Model

- The model equations
- Solving the model

## 3 Results

- Long-term results
- Short-term results

## 4 Conclusions

# Introduction

We build a model to examine some proposed drivers of the 2007-2009 World Food Price Crisis:

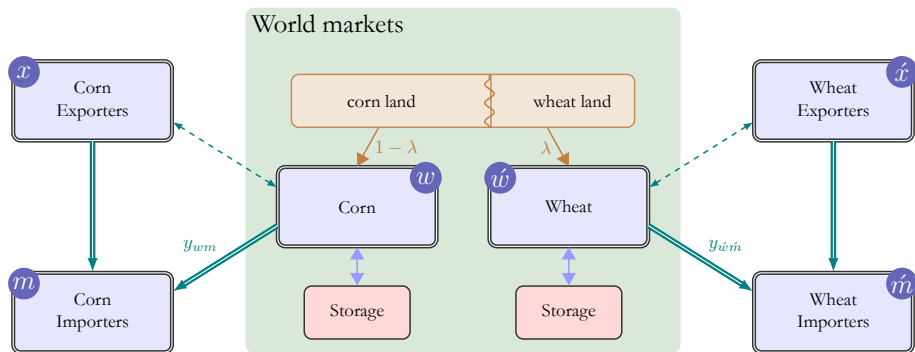
- low grain stock levels;
- trade restrictions by wheat exporters;
- public storage by wheat importers; and
- diversion of corn production to biofuels.

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# The Model

- Two commodities: wheat and corn
- One fixed input: land
- International trade
- Storage



# Supply, demand, production, consumption

Supply and demand:

$$\tilde{Q}_i + Z_{i,-1} \equiv \underbrace{A_i}_{\text{availability}} = C_i + Z_i + Y_i$$

Production

$$\tilde{Q}_i = q_{i,-1} \cdot \tilde{\epsilon}_i$$

Consumption demand

$$C_i = \alpha_i P_i^{-\beta_i}$$

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Production

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Consumption demand

$$C_i = \alpha_i \underbrace{P_i}_{\text{price}}^{-\beta_i}$$

# Trade and private storage

Trade:

$$0 \leq \mathcal{Y}_{jk} \leq \bar{\mathcal{Y}}_{jk} \quad \perp \quad \begin{cases} P_k - \tau_{jk} - P_j & \text{unrestricted} \\ \min[P_k - \tau_{jk}, \bar{P}_j] - P_j \end{cases}$$

export j to k      capacity  
transport cost

Private storage

$$0 \leq Z_i \leq \bar{Z}_i \quad \perp \quad \delta \mathbb{E} P'_i - P_i - K$$

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$$0 \leq Z_i \leq \underbrace{\bar{Z}_i}_{\text{capacity}} \quad \perp \quad \delta \underbrace{\mathbb{E} P'_i}_{\text{expected price}} - P_i - \underbrace{K}_{\text{storage cost}}$$

# Public storage

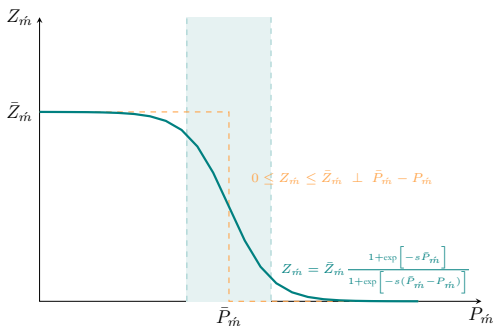
Public storage

$$0 \leq Z_i \leq \bar{Z}_i \quad \perp \quad \bar{P}_i - P_i$$

interv. price

alternative:

$$Z_i = \bar{Z}_i \frac{1 + \exp[-s\bar{P}_i]}{1 + \exp[-s(\bar{P}_i - P_i)]}$$



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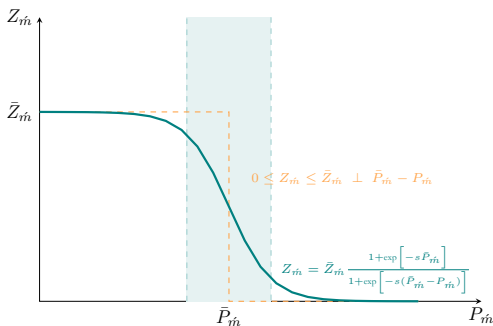
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# Acreage

Share of land cultivated with wheat

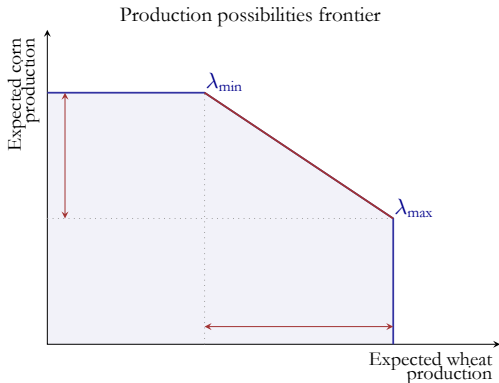
$$\lambda_{\min} \leq \lambda \leq \lambda_{\max} \quad \perp \quad \mathbb{E} P'_{w'} - \varphi \mathbb{E} P'_{c'}$$

share wheat
wheat
corn

Acreage

$$q_w = (1 - \lambda) L$$

$$q_w' = \lambda L$$





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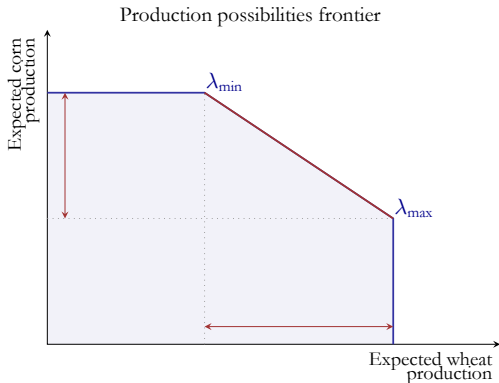
share wheat
wheat
corn

Acreage

$$q_w = (1 - \lambda) L$$

land available

$$q_{\dot{w}} = \lambda L$$



# Numerical solution strategy

- Dynamic model, with state variable  $A$ .
- Given  $A_i$ , model can be reduced to a mixed-complementarity problem with unknowns  $P, Z, \lambda, y$ ; 17 or 18 variables.
- $\mathbb{E} P'_i$  is unknown  $\Rightarrow$  collocation methods:  $p_i \approx \hat{p}_i = \sum_b c_b \phi_b(A)$
- Inner loop iteration to solve MCP, using  $A^i$  and numerical integration to evaluate

$$\mathbb{E} P'_i \approx \mathbb{E} \sum_{b=1}^H c_b \phi_b(A^i) \approx \sum_j \omega_j \sum_b c_b \phi_b(Z + q\epsilon'_j)$$

- Outer loop iteration to solve for collocation coeffs  $c_b$

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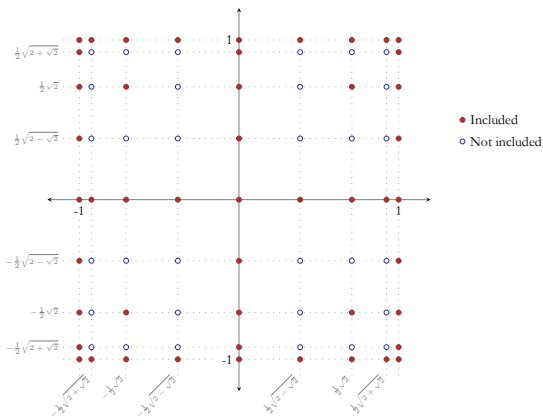
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# Dealing with the “curse of dimensionality”

- Collocation with Chebyshev polynomials, 9 nodes per dimension.
- $\mathcal{A}$  has 6 dimensions  $\Rightarrow 9^6 = 531\,441$  nodes and basis functions if using tensor product.



- Use Smolyak's method to choose nodes and bases.
- Result: only 1409 nodes and 389 polynomials.

## Data sources and regions

Most parameters calibrated with historical data from PSD database (USDA).

PSD region	Corn			Wheat		
	World	Exporter	Importer	World	Exporter	Importer
North America	✓			✓		
Former Soviet Union		✓			✓	
Oceania					✓	
South America		✓				
East Asia			✓			✓
Southeast Asia			✓			✓
Middle East			✓			✓
North Africa			✓			✓
Sub-Saharan Africa						✓
European Union			✓		✓	



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# The Policy Scenarios

We consider these scenarios

- 0: baseline
- 1: wheat exporters set price ceiling at baseline average
- 2: wheat importers set public storage, price around baseline average
- 3: wheat exporters and importers apply policies simultaneously
- 4: ethanol production increases corn demand by 20%

## Long-term prices: mean and standard deviation

Scenario	Corn			Wheat		
	World	Exporter	Importer	World	Exporter	Importer
<b>Mean</b>						
0: Baseline	100.00	100.00	108.91	100.00	100.05	112.22
1: Price ceiling	101.68	101.68	110.50	102.45	93.80	114.66
2: Public storage	101.63	101.63	110.41	98.28	98.34	110.51
3: Ceiling + storage	103.22	103.22	111.87	99.17	94.69	111.43
4: High demand	118.18	118.18	126.22	115.19	115.23	127.41

Normalized prices: World baseline mean=100

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<b>Standard Deviation</b>						
0: Baseline	14.72	14.72	13.98	18.02	18.08	18.02
1: Price ceiling	16.07	16.07	14.93	24.54	6.92	24.54
2: Public storage	17.23	17.23	16.11	11.45	11.54	11.44
3: Ceiling + storage	19.26	19.26	17.50	14.64	4.73	14.53
4: High demand	21.31	21.31	16.88	18.09	18.13	18.09

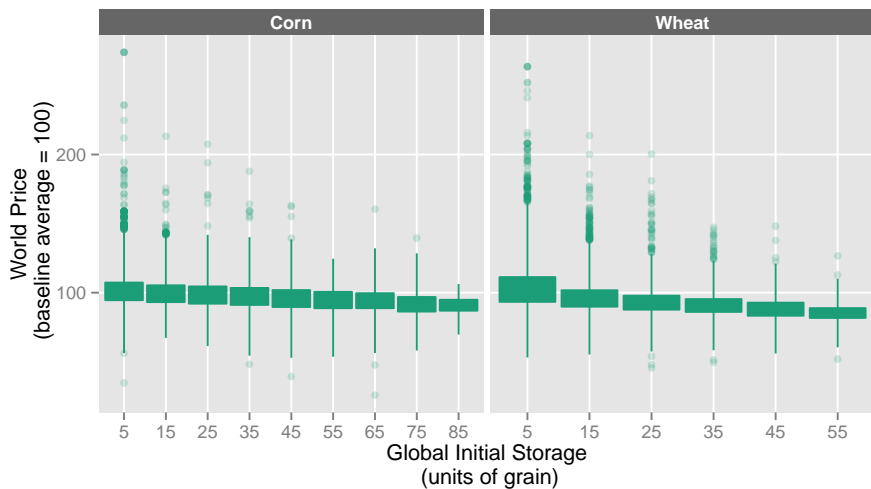
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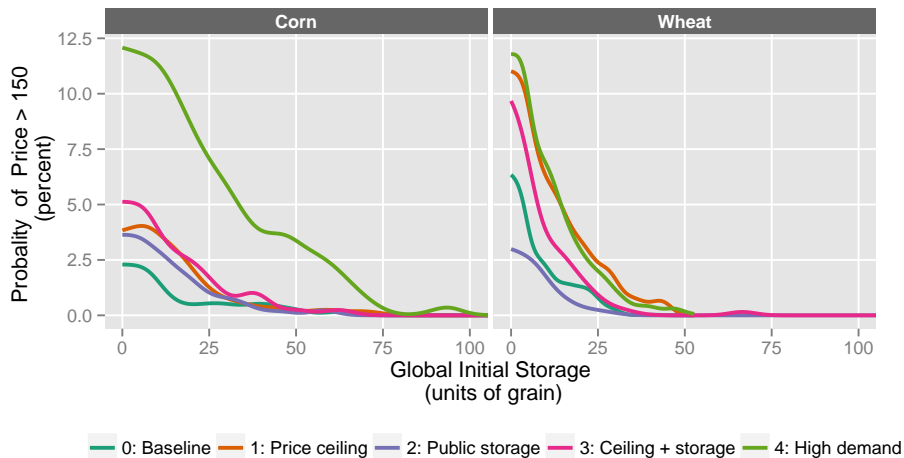
Normalized prices: World baseline mean=100

# Long-term World prices: conditional on initial stock



Baseline scenario

# Probability of crisis: conditional on initial stock



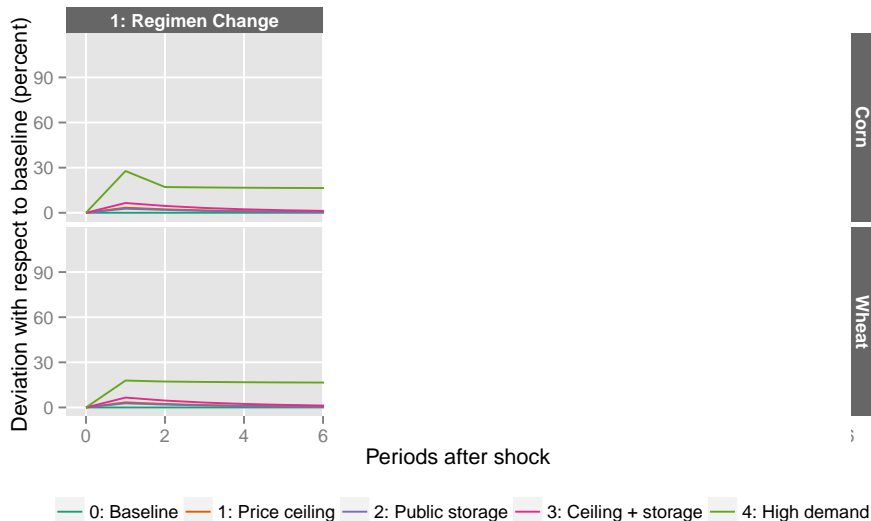
## Short-term prices: Impulse response function

We next consider the short-term adjustment to 3 different shocks

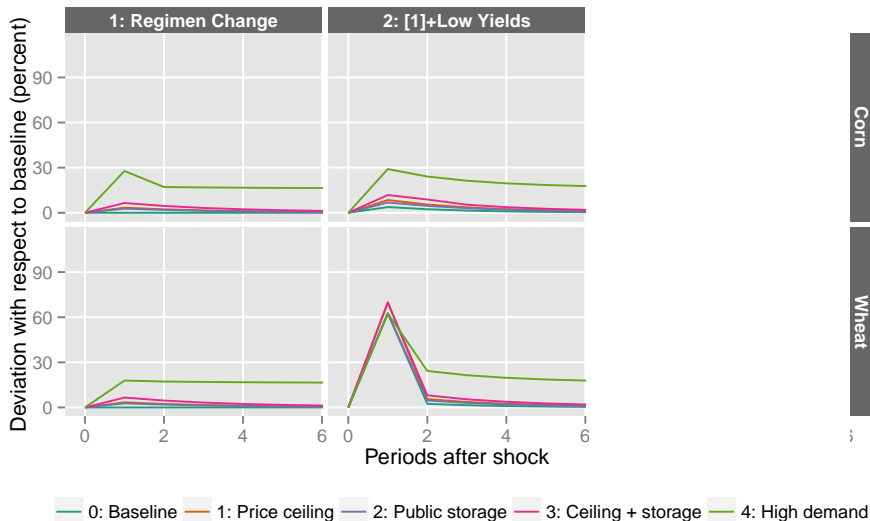
- 1 change of policy regime;
- 2 change of regime while 20% drop in Exporter wheat production; and
- 3 change of regime, production shock, when initial wheat stocks are low.



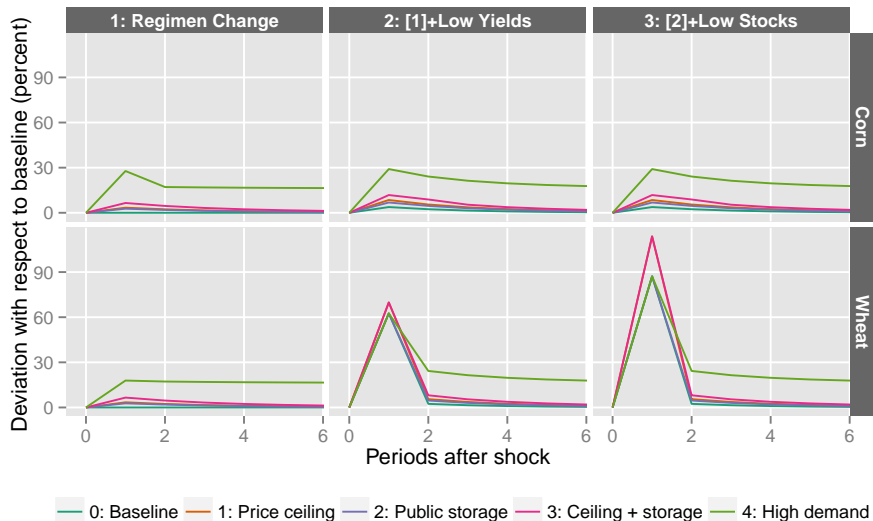
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## Conclusions: Long-term prices

- Ethanol mandate:
  - only policy with large effect on long-term price (both grains)
  - greatly increases price volatility of both grains, in all regions
- Wheat Exporter price ceiling increases wheat price volatility in other regions
- Public storage in Wheat Importer, despite displacing private storage, reduces wheat price volatility in all regions

## Conclusions: Short-term prices

- By itself, introducing price ceiling or public storage have small impact in short-term prices
- Initial grain storage is a key determinant of *likelihood* of crisis
- An export price ceiling can worsen a crisis originated in production shock & low stocks

## Some limitations of the model = Opportunities to improve

- No disincentive to farmers from price ceiling
- Stationary model: no productivity growth, no population growth
- No “panic” purchases from importers
- Ethanol shock as one-time permanent demand increase on corn demand