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

Introduction

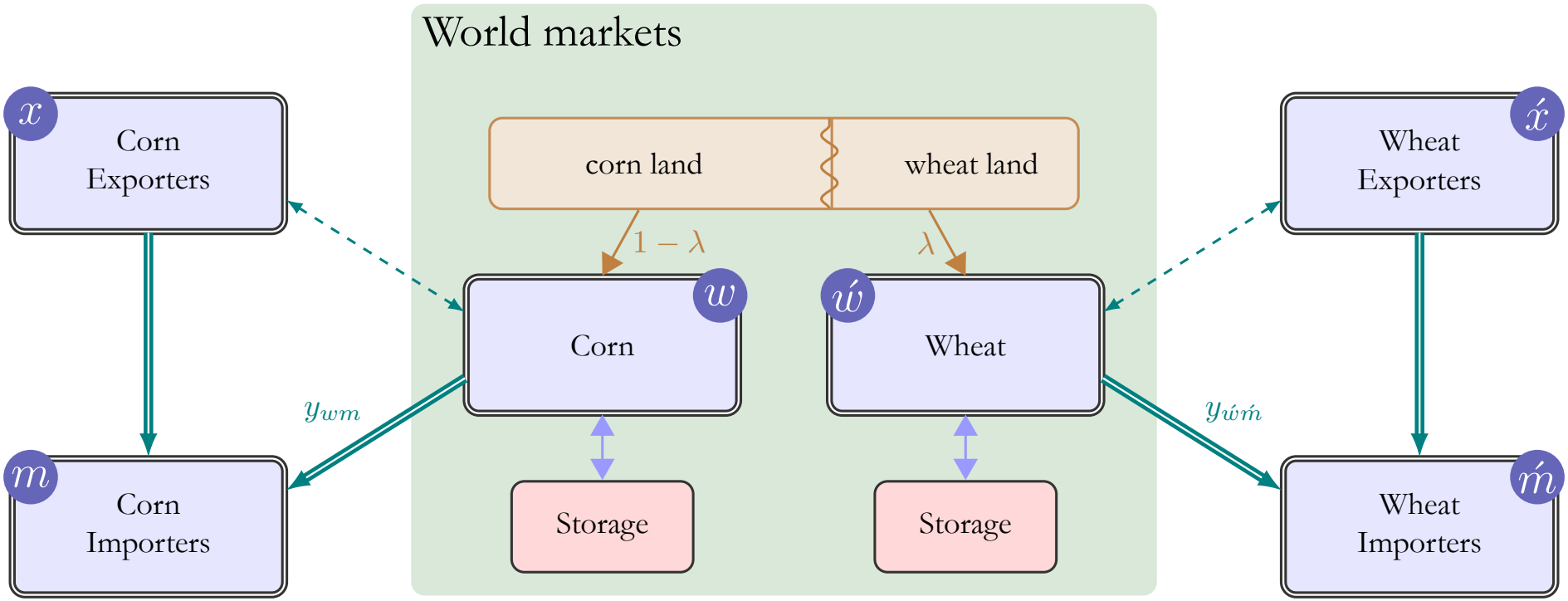
We build a model to examine some proposed drivers of the 2007-2009 World Food Price Crisis:

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

Outline

The Model

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



Supply, demand, production, consumption

Supply and demand:

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

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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Trade and private storage

Trade:

$$0 \leq \underbrace{y_{jk}}_{\text{export j to k}} \leq \underbrace{\bar{y}_{jk}}_{\text{capacity}} \perp \begin{cases} P_k - \underbrace{\tau_{jk}}_{\text{transport cost}} - P_j & \text{unrestricted} \\ \min[P_k - \tau_{jk}, \ \bar{P}_j \ ] - P_j & \end{cases}$$

Private storage

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

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Private storage

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

Public storage

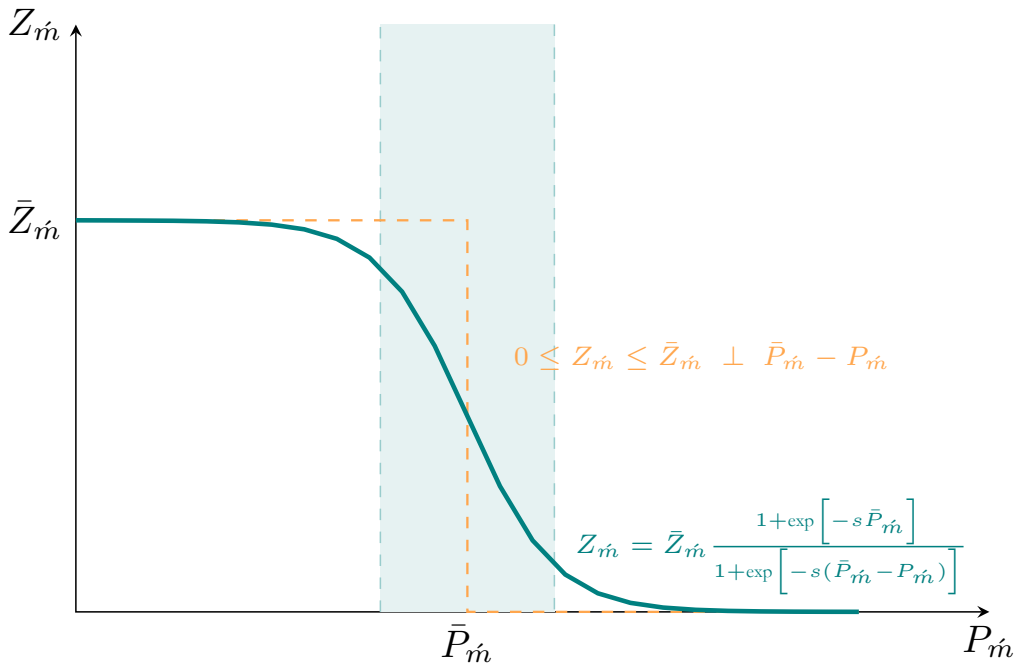
Public storage

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

interv. price

alternative:

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



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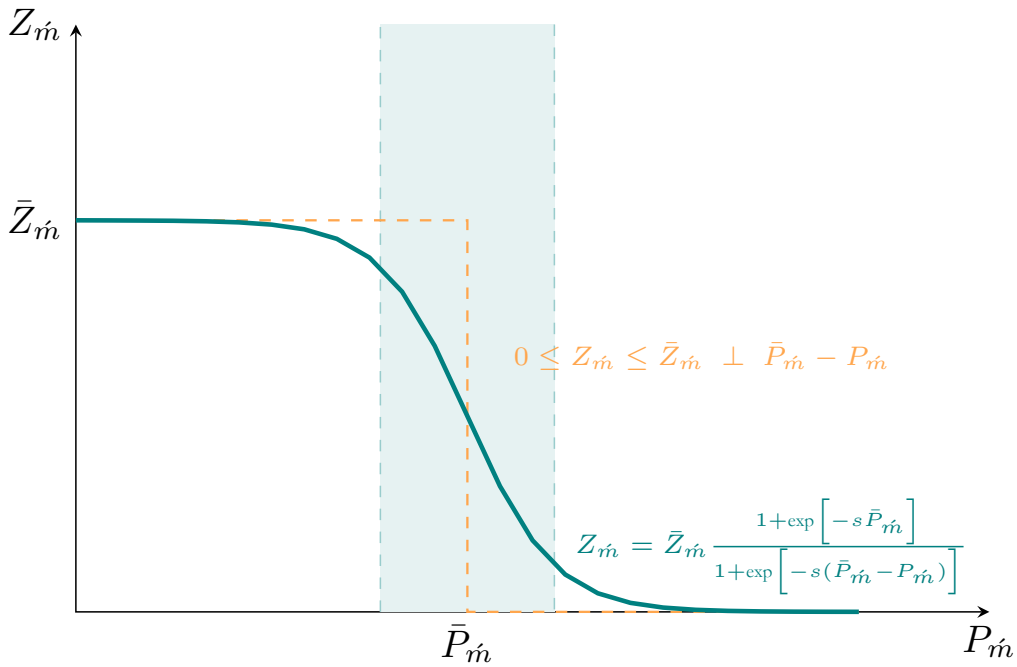
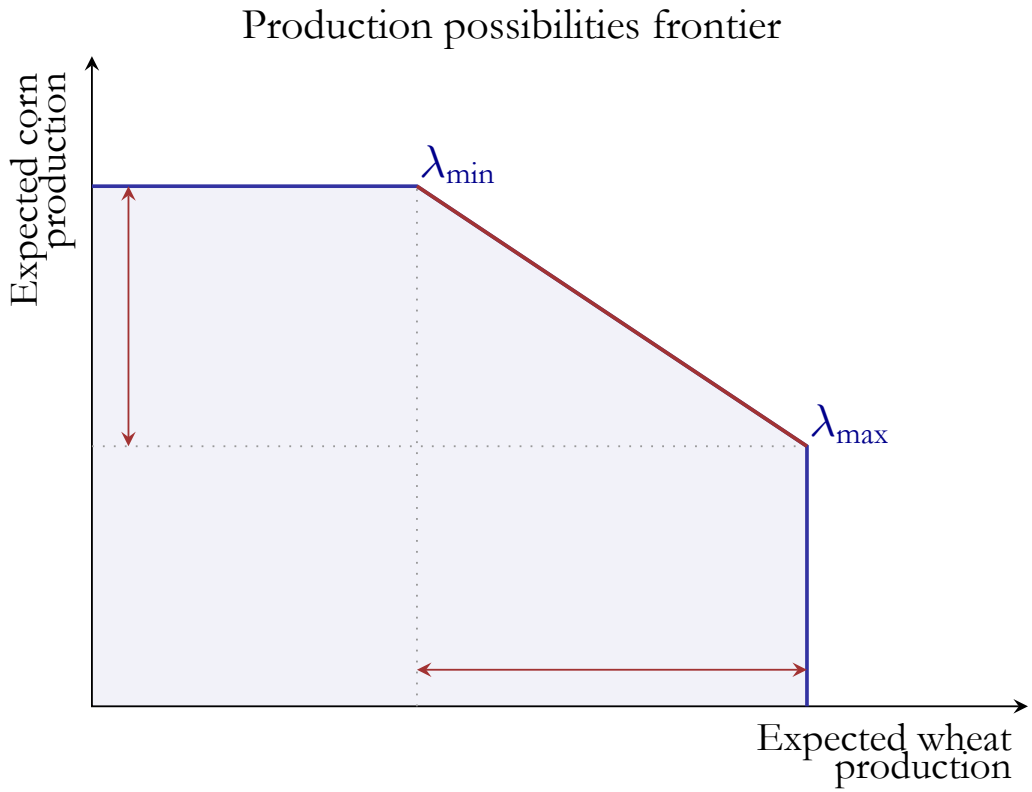


Acreage

Share of land cultivated with wheat

$$\lambda_{\min} \leq \underbrace{\lambda}_{\text{share wheat}} \leq \lambda_{\max} \quad \perp \quad \underbrace{\mathbb{E}\, P'_{\acute{w}}}_{\text{wheat}} - \varphi \underbrace{\mathbb{E}\, P'_{w}}_{\text{corn}}$$



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

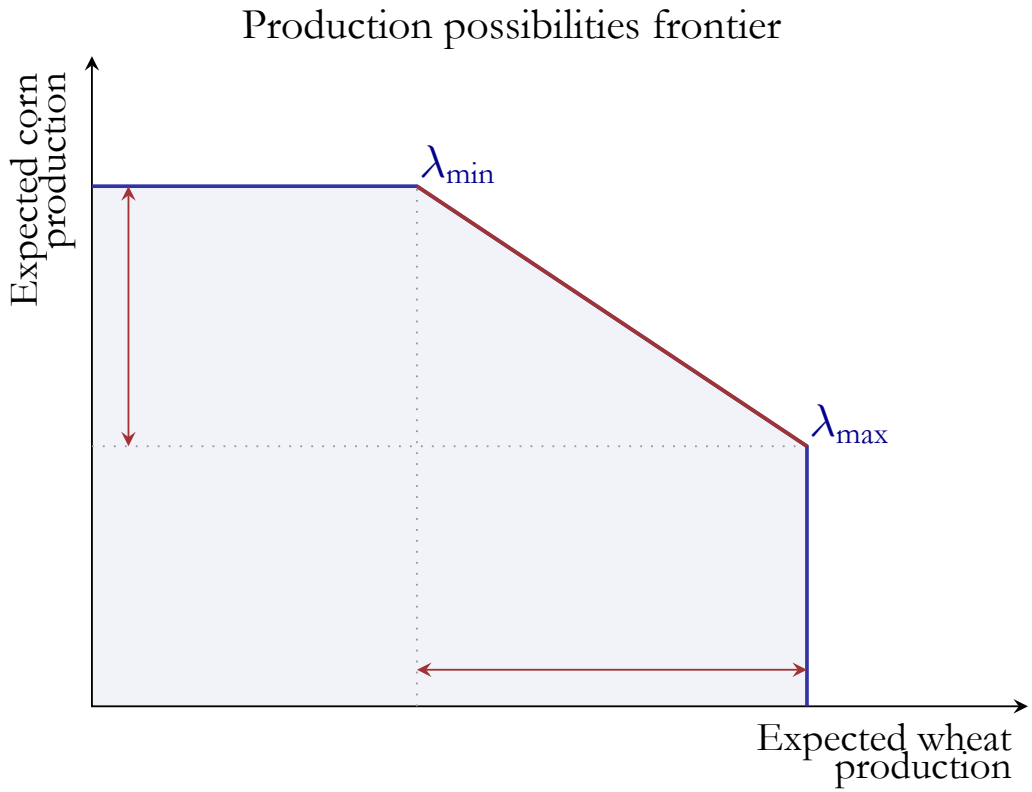
λ: share wheat; $\mathbb{E}\, P'_{\acute{w}}$: wheat; $\varphi\, \mathbb{E}\, P'_{w}$: corn

Acreage

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

L: land available

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



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, λ, 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' and numerical integration to evaluate

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

- Outer loop iteration to solve for collocation coeffs c_b

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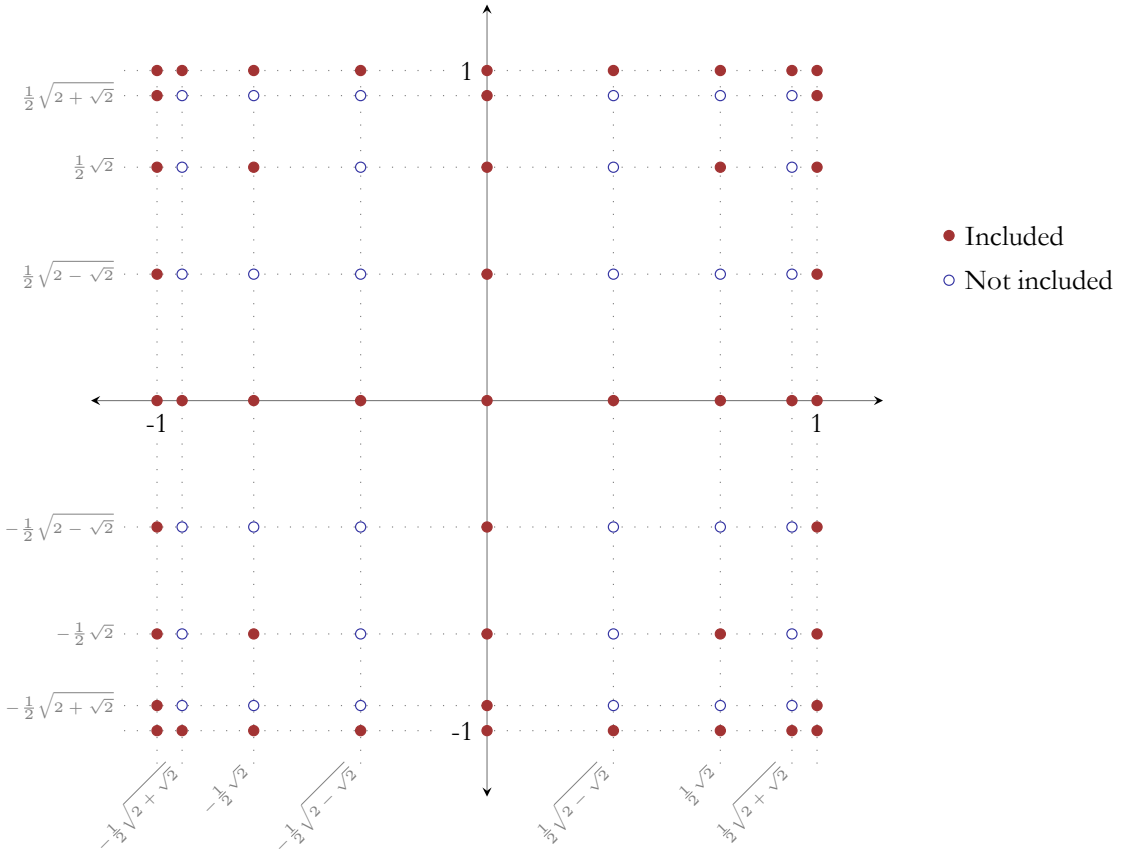
Dealing with the "curse of dimensionality"

- Collocation with Chebyshev polynomials, 9 nodes per dimension.
- 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).

	Corn			Wheat		
PSD region	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			✓		✓	

Outline

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
Mean						
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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Standard Deviation						
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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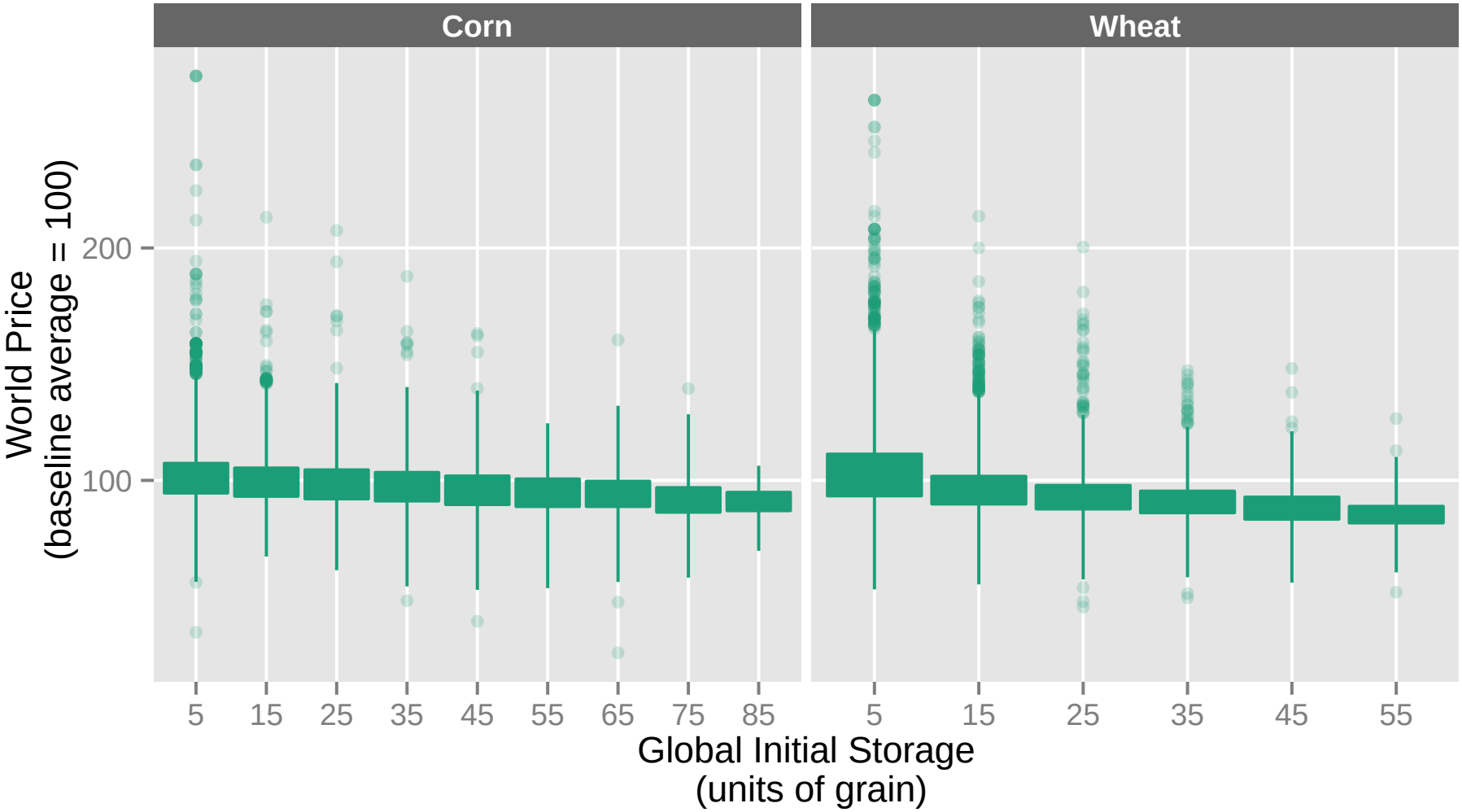
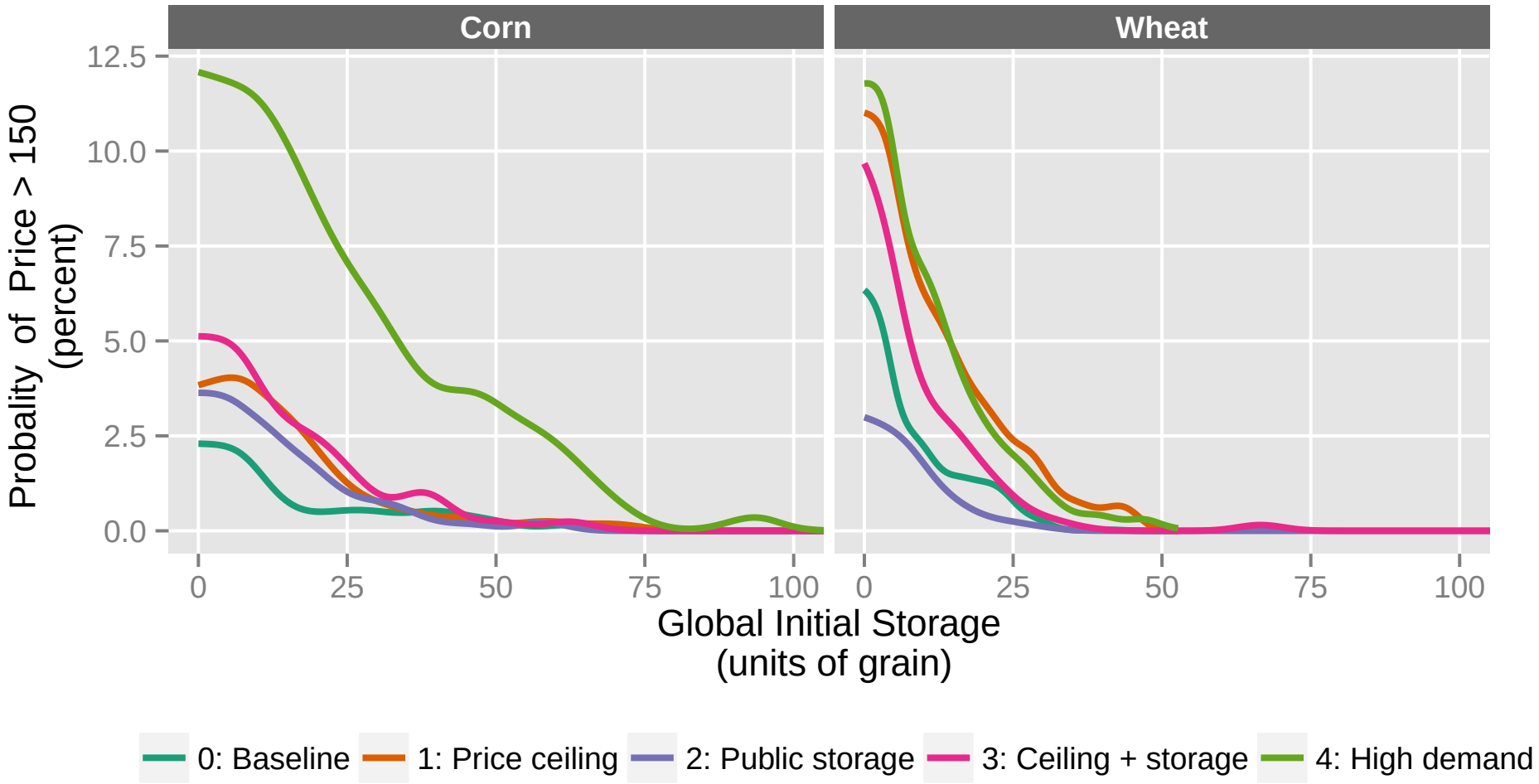
Normalized prices: World baseline mean=100

Long-term World prices: conditional on initial stock



Baseline scenario

Probability of crisis: conditional on initial stock

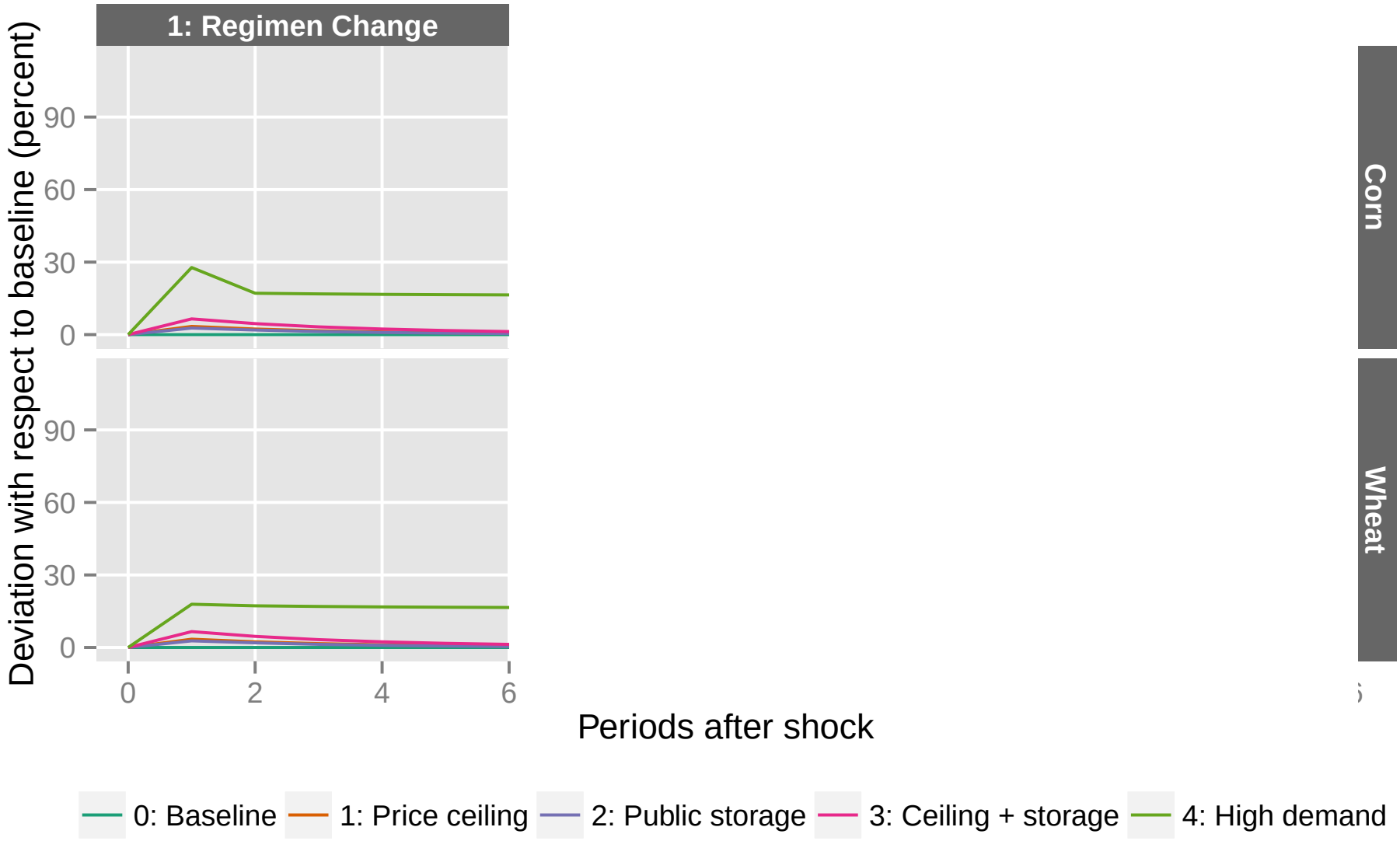


Short-term prices: Impulse response function

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.

Short-term adjustment



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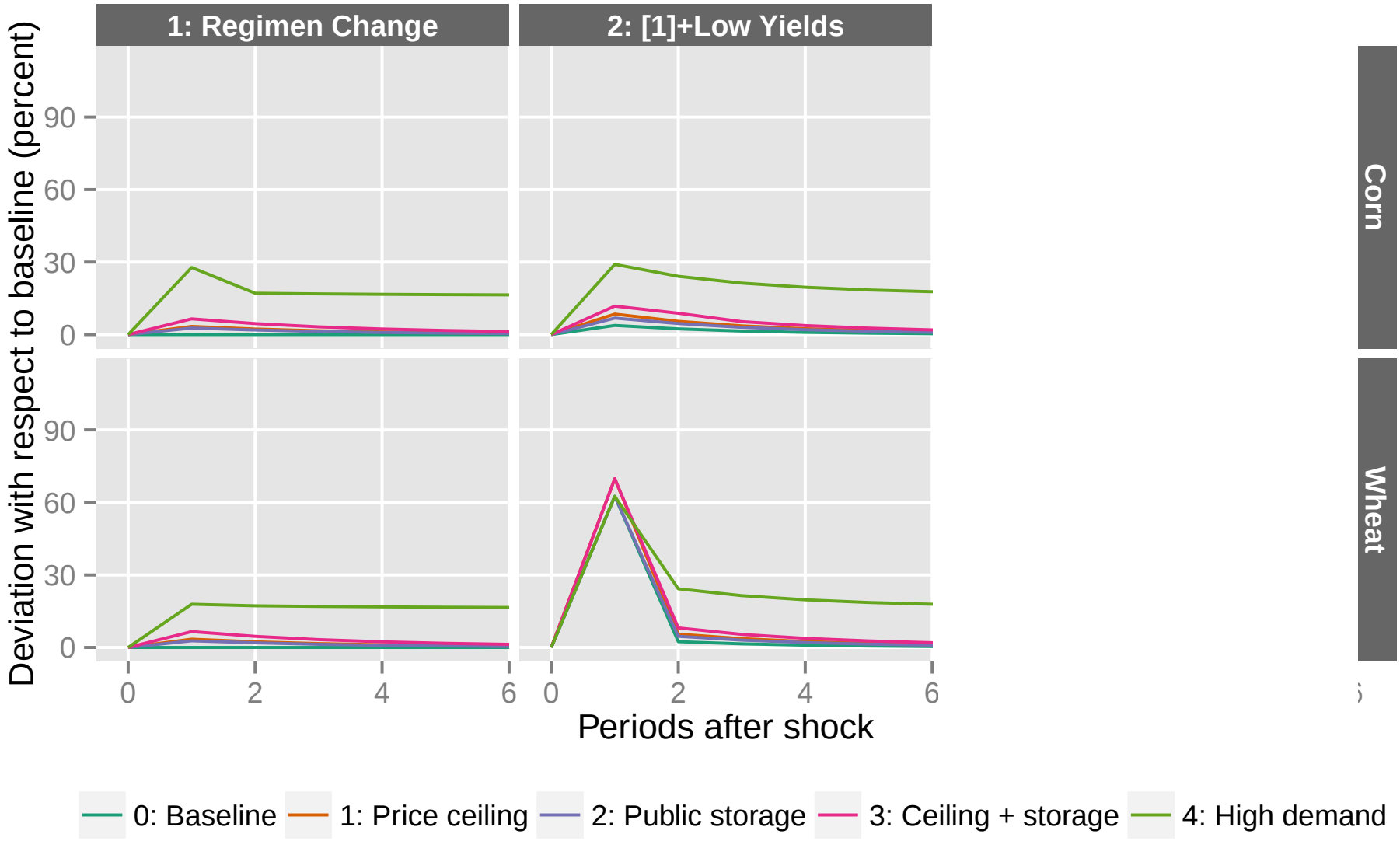

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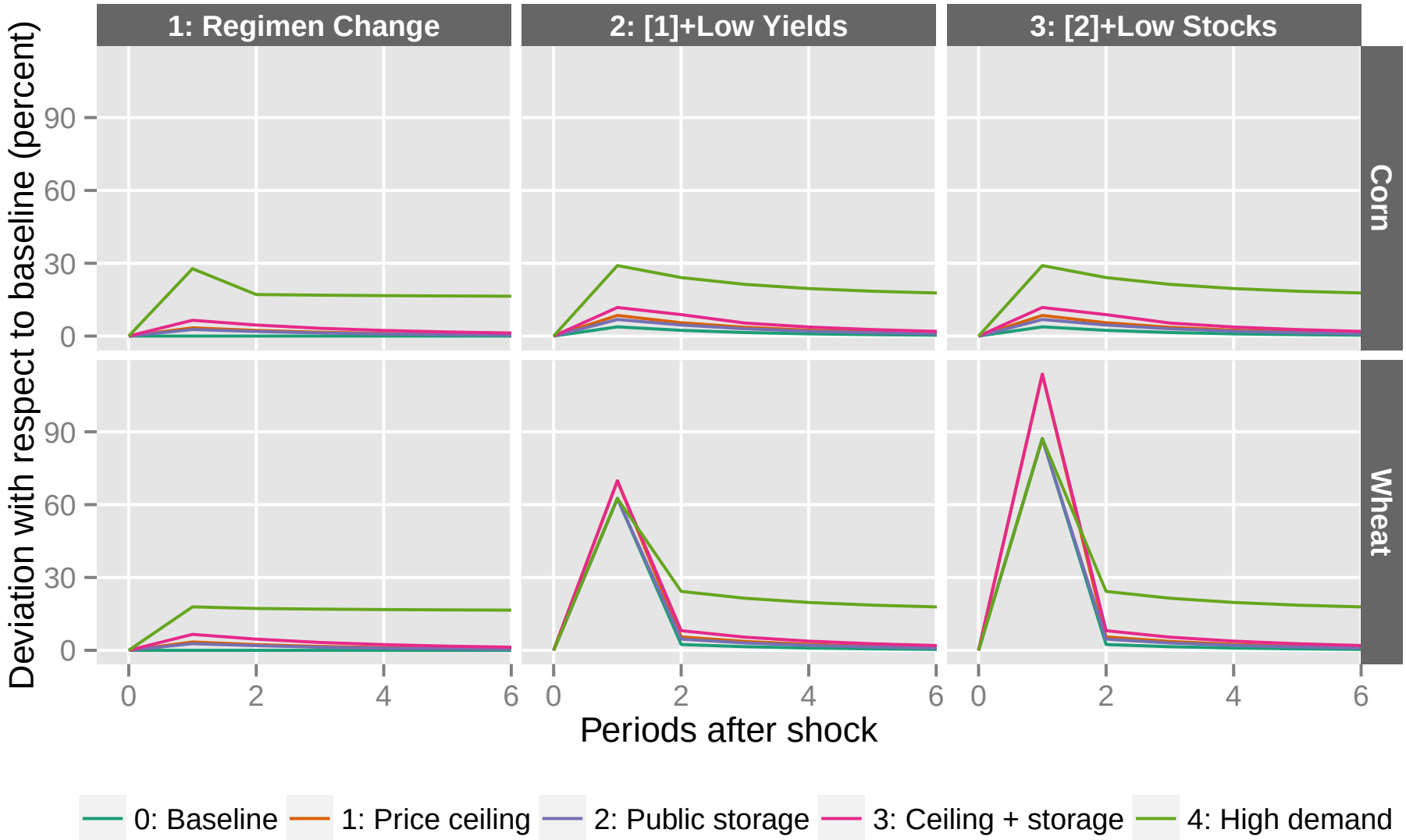

Outline

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