Farm Acreage Shocks and Food Prices:
An SVAR Approach to Understanding the Impacts of Biofuels

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All views are those of the authors and do not represent those of the Energy Biosciences Institute

Motivation

- BBC (2007): "It is one of the most hotly debated environmental topics … whether the drive to produce alternative so-called green fuels will take food from the mouths of the hungry."
- The question: Can we anticipate how food prices will react to further increasing biofuels production?
- How does this depend on the feedstock used for the biofuel and on where that feedstock is grown?

Motivation

- No consensus has been reached on the magnitude of the effect of corn ethanol policies.
- Little research has been done on the price effects of non-food crops (ie miscanthus or switchgrass) for biofuels production.

Two Scenarios

- Biofuels are grown on land that had been:
  1. Planted with corn, soybeans, or other food crops
  2. Non-crop farmland (includes pasture, idle land, etc)

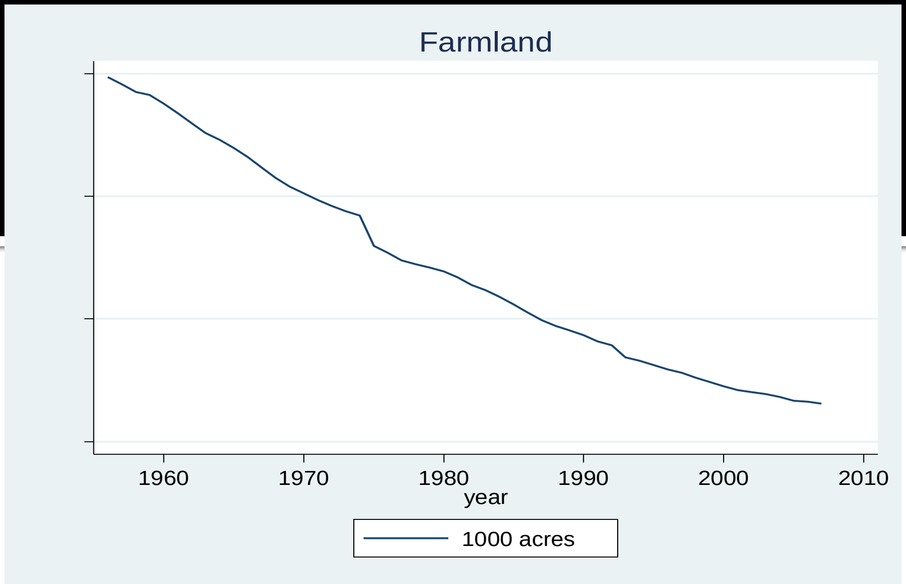
Main Results

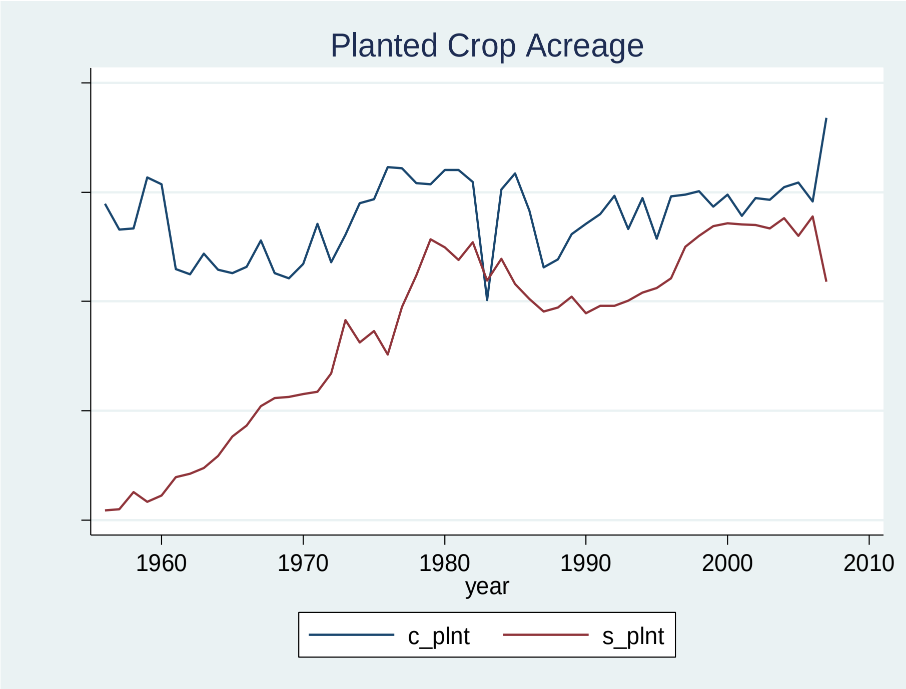
- Scenario 1:
- $0.05 increase in corn price for every 1 million corn acre shock
  - From 2006 to 2007, acreage of corn going to ethanol increased by 6 million
  - Price increased $0.80
  - Then around 40% of the price increase is explained by 2007 ethanol production, in our model
- Small price decrease predicted by scenario 2 (non-crop farmland)

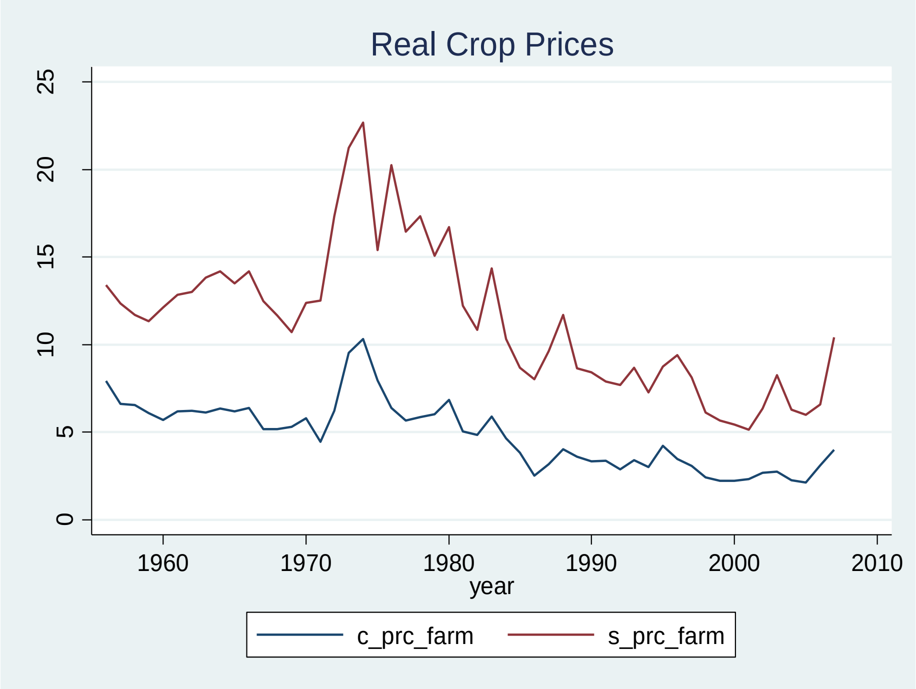
Data

- US production of corn and soybeans
- Yearly observations from 1956 to 2007
- Farmland, cropland, farmgate crop prices, futures crop prices
- Input prices, foreign production, and loan prices

Data


Farmland
1960
1970
1980
1990
2000
2010
year
1000 acres


Planted Crop Acreage
1960
1970
1980
1990
2000
2010
year
c_plnt
s_plnt


Real Crop Prices
0
5
10
15
20
25
1960
1970
1980
1990
2000
2010
year
c_prc_farm
s_prc_farm

The Model

- The dynamic nature of agricultural production makes this question ideally suited for a vector auto-regression framework.
- Structural VAR: leveraging the timing of the process so that contemporaneous shocks are orthogonalized
- Our system is a generalization of traditional agricultural production frameworks (for instance, Nerlovian acreage response models)

Why an SVAR?

- We haven't started mass production of ethanol from switchgrass…

- So a structural model isn't possible. We are left with teasing out what has happened following past acreage shocks.

The Model

(scenario 1: biofuels feedstock grown on corn acreage)

$$y_t \equiv \begin{bmatrix} corn\ futures_t \\ soy\ futures_t \\ corn\ acreage_t \\ corn\ harvest\ price_t \\ soy\ harvest\ price_t \end{bmatrix}$$

$$Ay_t = A_1 y_{t-1} + A_2 y_{t-2} + ... + A_k y_{t-k} + Cx_t + B\varepsilon_t$$

where $\varepsilon_t \sim N(0, I_K)$ and $E(\varepsilon_s \varepsilon_t = 0), s \neq t$

$$y_t = A^{-1}A_1 y_{t-1} + A^{-1}A_2 y_{t-2} + ... + A^{-1}A_k y_{t-k} + A^{-1}Cx_t + u_t$$

where $u_t = A^{-1}B\varepsilon_t$ implying that u_t follows a white noise process.

The Model

$$Ay_t = A_1 y_{t-1} + A_2 y_{t-2} + ... + A_k y_{t-k} + Cx_t + B\varepsilon_t$$

$$A = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ a_{13} & a_{23} & 1 & 0 & 0 \\ a_{14} & a_{24} & a_{34} & 1 & 0 \\ a_{15} & a_{25} & a_{35} & 0 & 1 \end{bmatrix}, \ B = \begin{bmatrix} b_{11} & 0 & 0 & 0 & 0 \\ 0 & b_{22} & 0 & 0 & 0 \\ 0 & 0 & b_{33} & 0 & 0 \\ 0 & 0 & 0 & b_{44} & 0 \\ 0 & 0 & 0 & 0 & b_{55} \end{bmatrix}$$

Modeling Each Scenario

- Curse of dimensionality – better to have fewer variables, as long as identification is achieved
  1. **Food acreage:** futures prices, corn acreage, total farmland, farmgate prices
  2. **Non-crop farmland:** futures prices, corn acreage, non-crop farmland, farmgate prices

Estimation

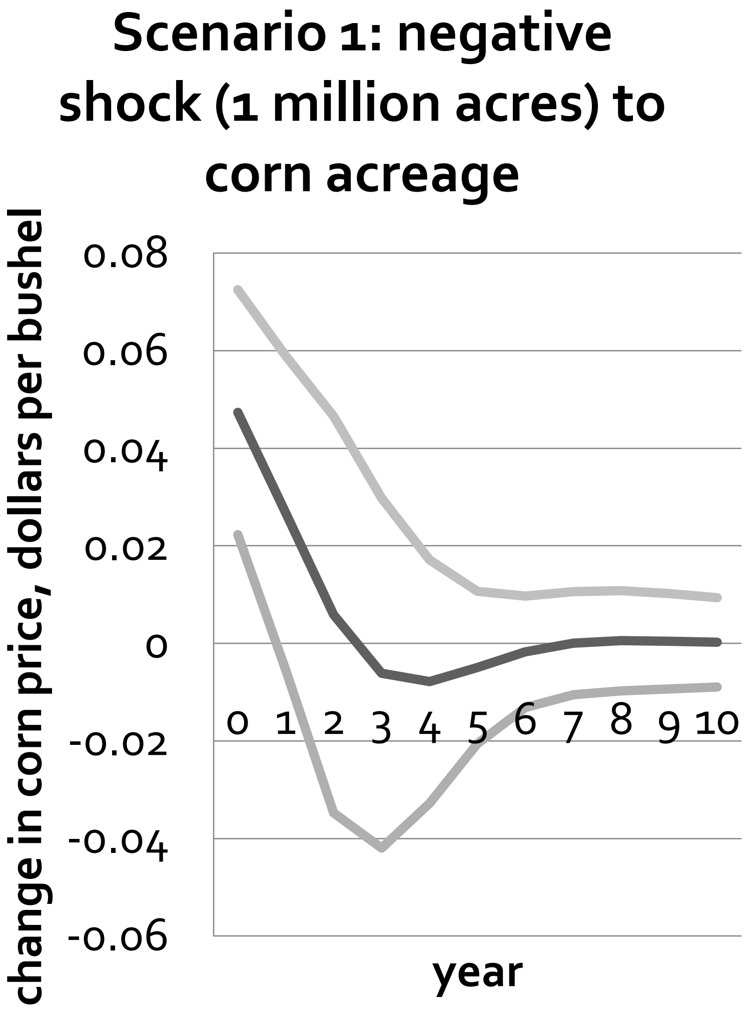
- Coefficients themselves are difficult to interpret.
- But we can look at:
  - Granger Causality Tests
  - Forecast Error Variance Decompositions
  - Impulse Response Functions
- These all tell us what happens initially as well as how the system behaves in the long run.

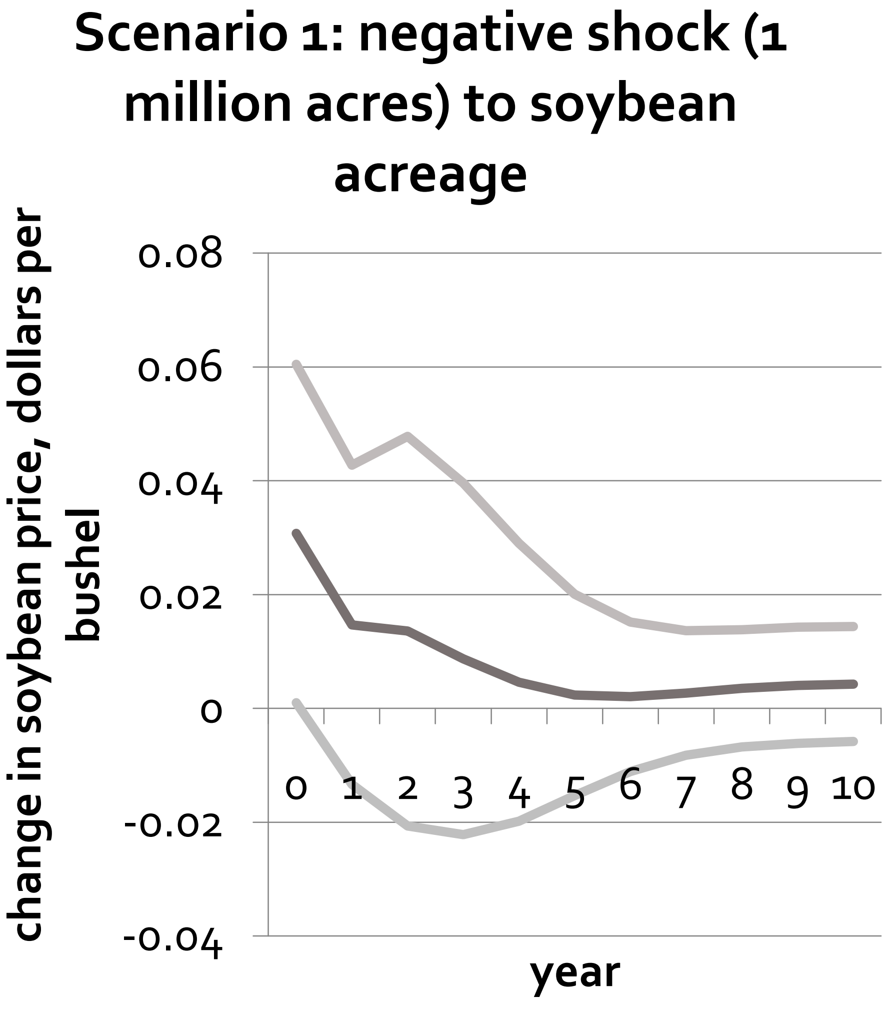
Impulse Response Functions

$$y_t = A^{-1}A_1 y_{t-1} + A^{-1}A_2 y_{t-2} + ... + A^{-1}A_k y_{t-k} + A^{-1}Cx_t + u_t$$

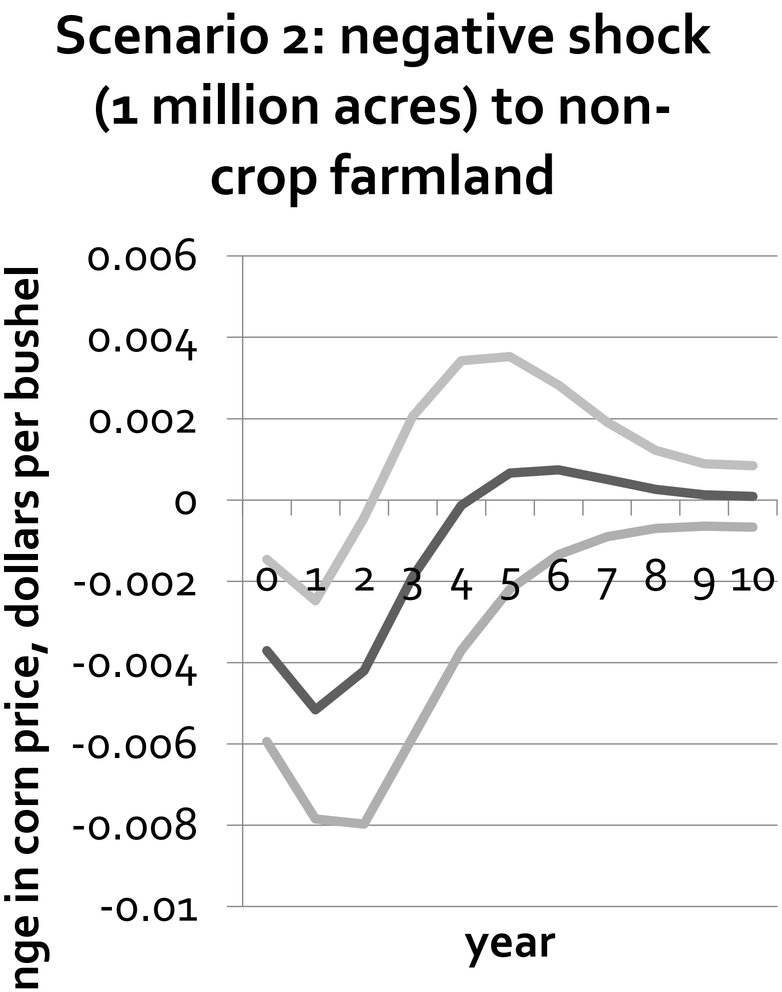
$$\begin{aligned} y_t &= \mu + \textstyle\sum_{i=0}^{\infty}(A^{-1}A_1)^i u_{t-i} \\ &= \mu + \textstyle\sum_{i=0}^{\infty}(A^{-1}A_1)^i A^{-1}B\varepsilon_{t-i} \\ &= \mu + \textstyle\sum_{i=0}^{\infty} \Psi_i \varepsilon_{t-i} \end{aligned}$$

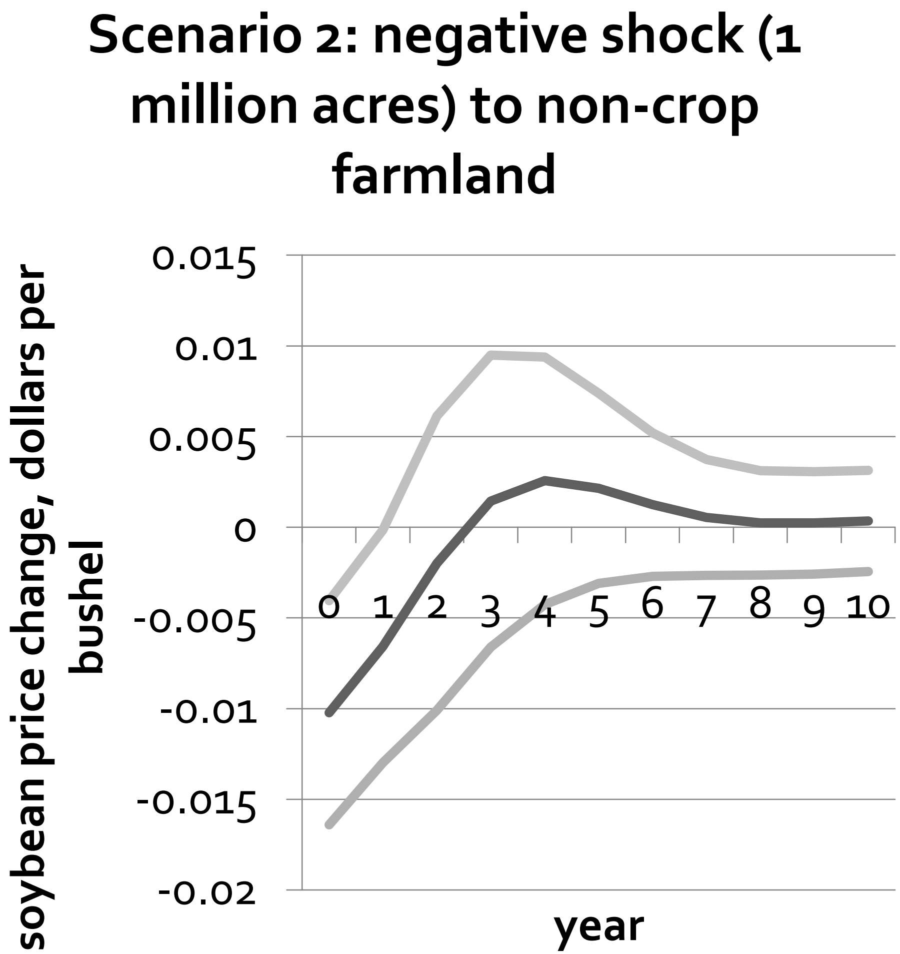
Scenario 1: Shock to Food Acreage



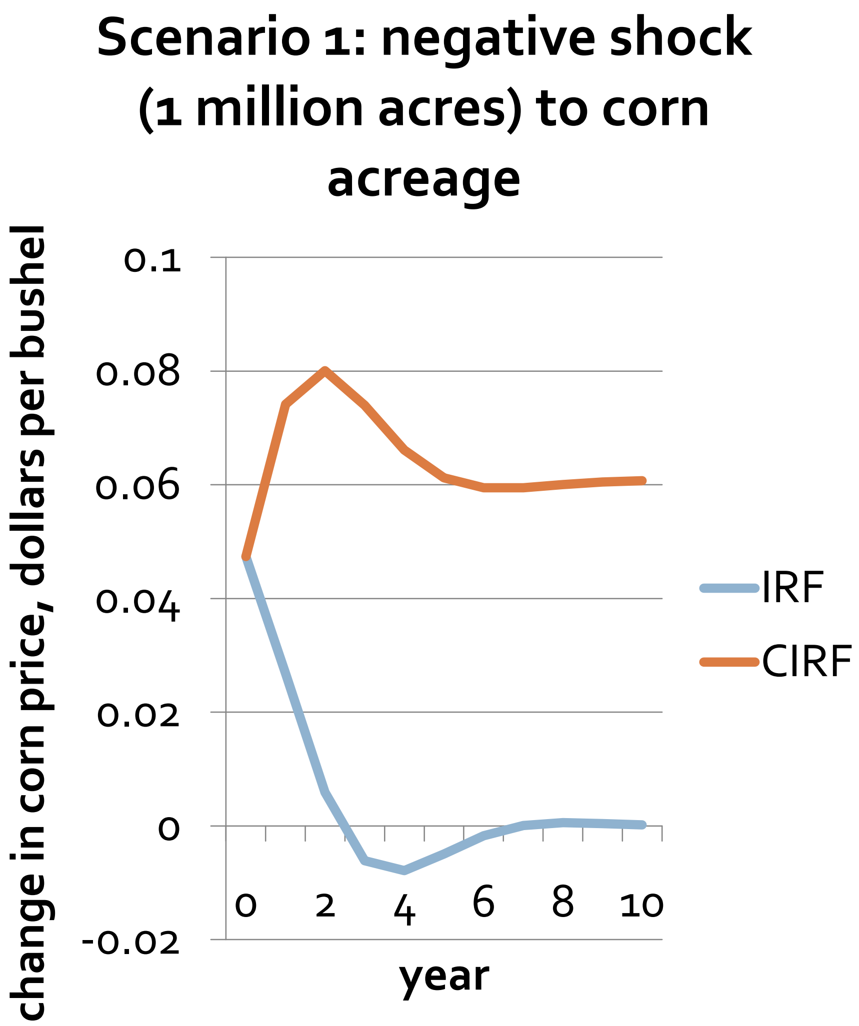


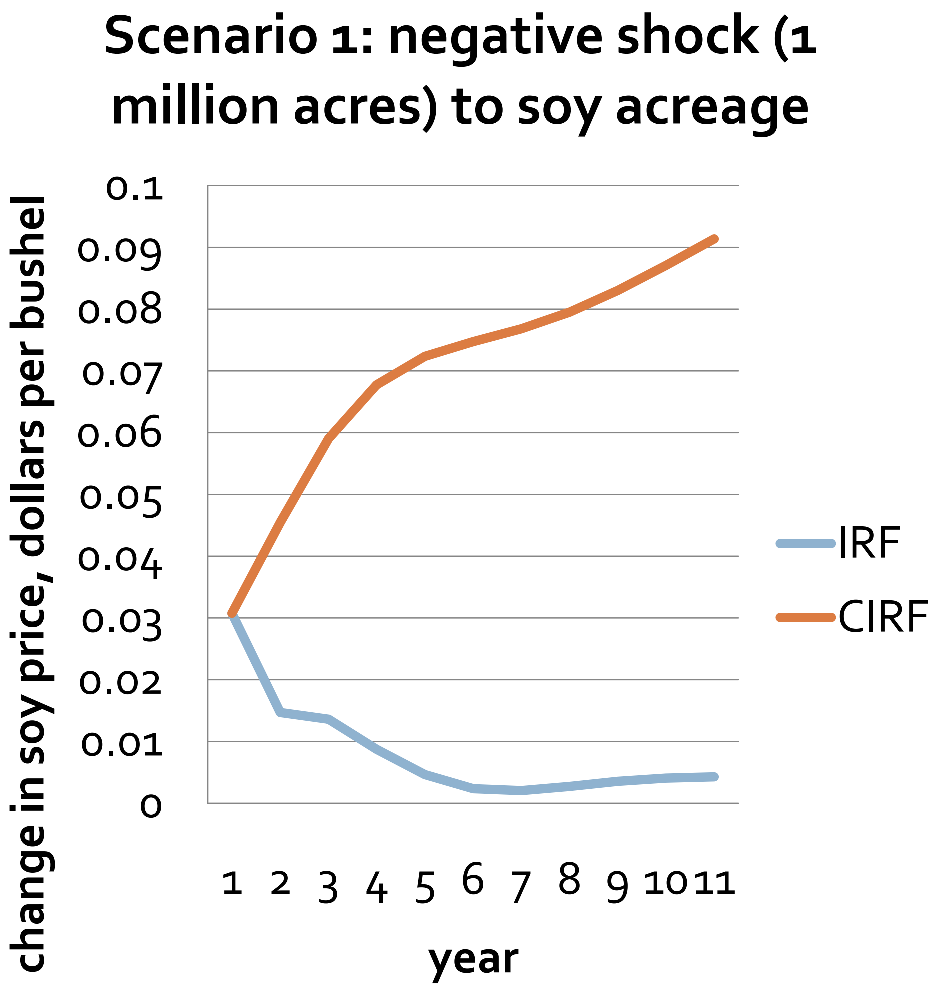
Scenario 2: Shock to Non-Crop Farmland





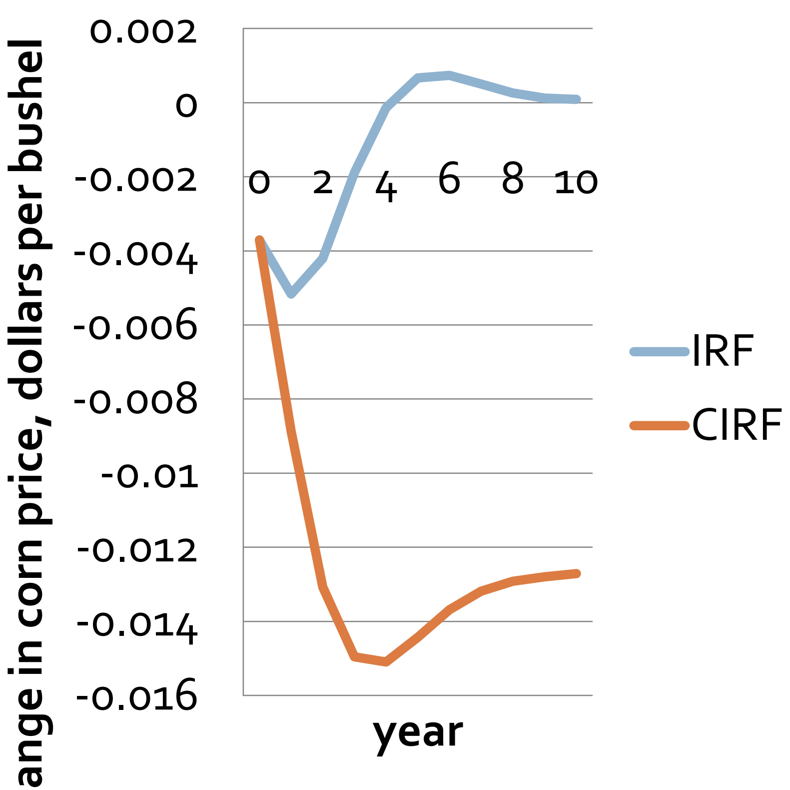
Cumulative IRF



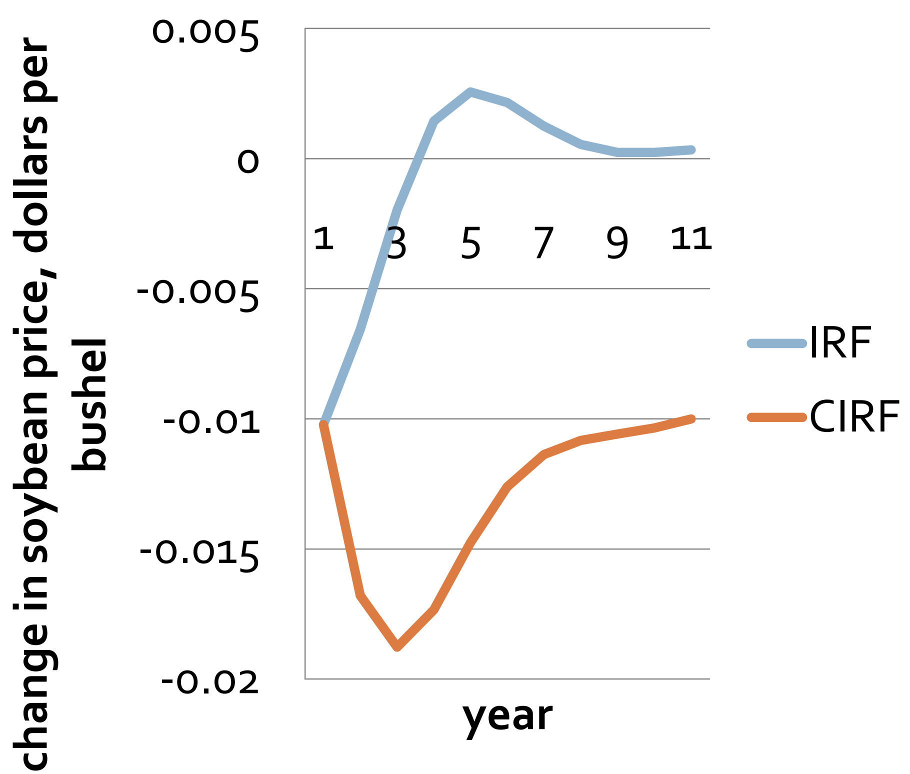


Cumulative IRF

Scenario 2: negative shock (1 million acres) to non-crop farmland



Scenario 2: negative shock (1 million acres) to non-crop farmland



Robustness Checks

- Linear vs Log/log
- Additional lags
- Yields
- Time period
- Diffusion Indices
- Curse of dimensionality!

Diffusion Indices

- Stock and Watson (2002)
- Summarizing a large number of time series variables with a few indices
- Nonparametric estimation so that the index incorporates as much of the variation in the original series as possible.
- Supply (US) side variables: input prices (automobiles, USDA-calculated indices of producer prices paid, building materials, oil price, and farm wages) and loan rates
- Demand side variables: US GNP, corn and soybean production from southern hemisphere countries (Argentina and Brazil)

Main results

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Other findings

- Shocks to own acreage lead to otherwise unpredicted variation in crop prices.
- If the shock is one-time, the system will return to a similar long-run equilibrium. But for cumulative shocks, the long-run equilibrium will be different.

Caveats and Future Work

- The magnitudes we see depend on the US share of world production. If this were to change substantially, we might expect a different multiplier.
- Time series methods mean few observations
- Better standard error estimation
- Pathways for the observed responses are only hypothesized
- Repeated shocks: CIRFs won't capture changes in expectations

Suggestions welcome!