Identifying Supply and Demand Elasticities of Agricultural Commodities:
Implications for the US Ethanol Mandate

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Why are Commodity Prices High?

- Demand growth in Asia.
- Weather shocks.
- Ethanol.

- Climate Change?
- Goldman Sachs?

This Talk

1. Statistics on world agriculture and US role.

2. Supply, demand & the identification problem

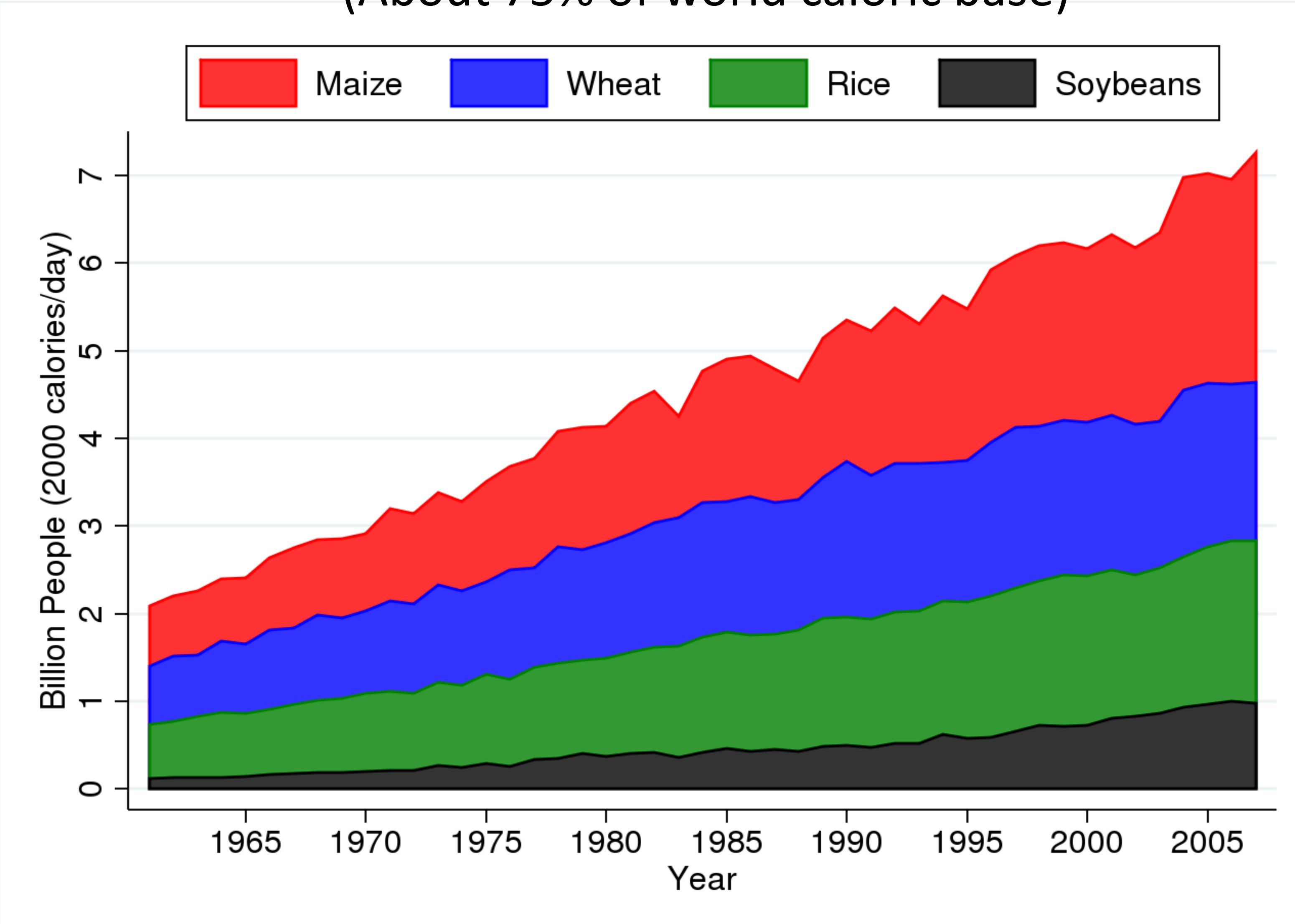
3. Our econometric estimates

One

Statistics on world agriculture and US role.

Four Key Crops

(About 75% of world caloric base)



The United States Production

39% of corn

38% soybeans

9% of wheat

2% of rice

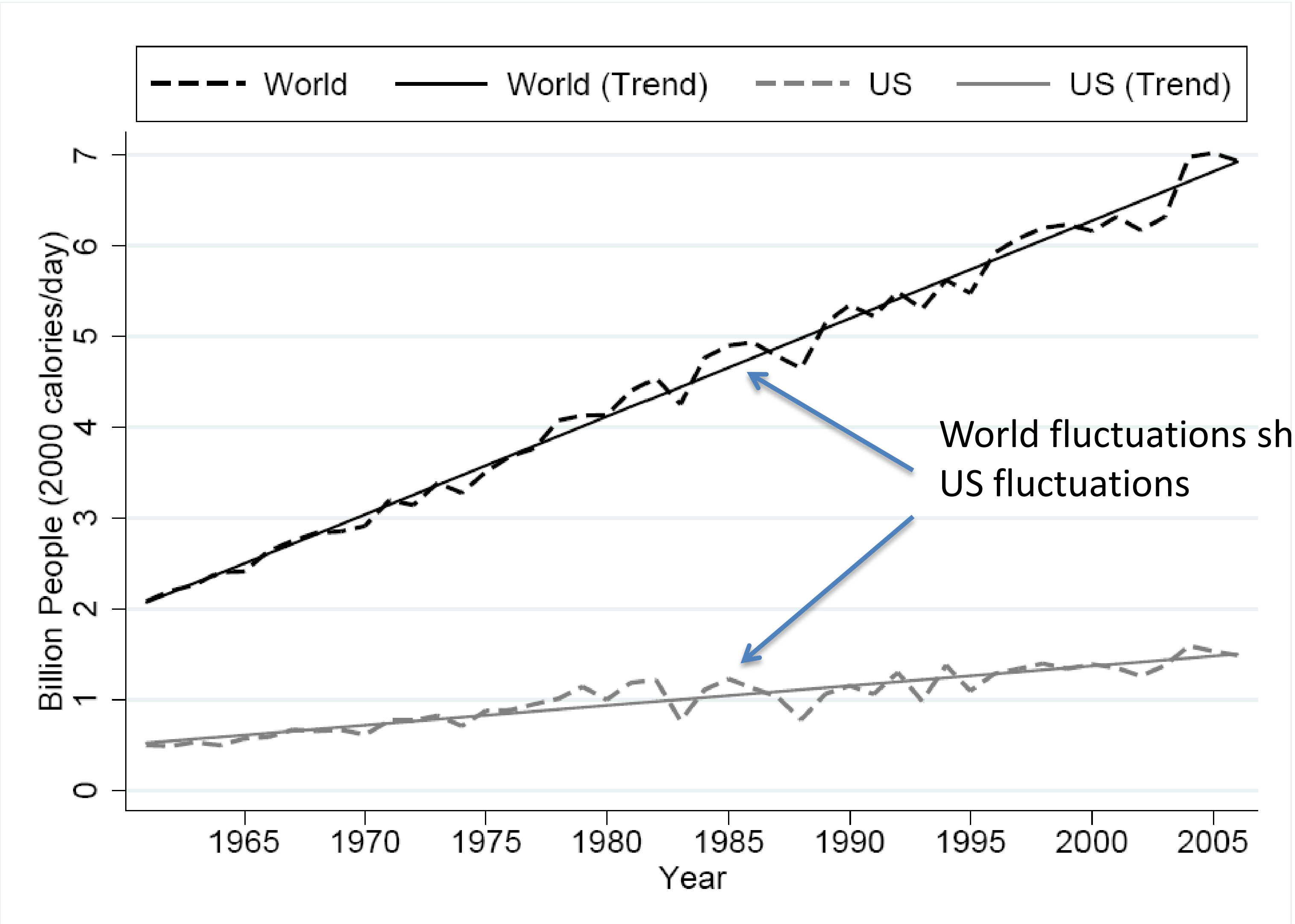
Much larger shares of world exports

United States Ethanol

40% of US corn production

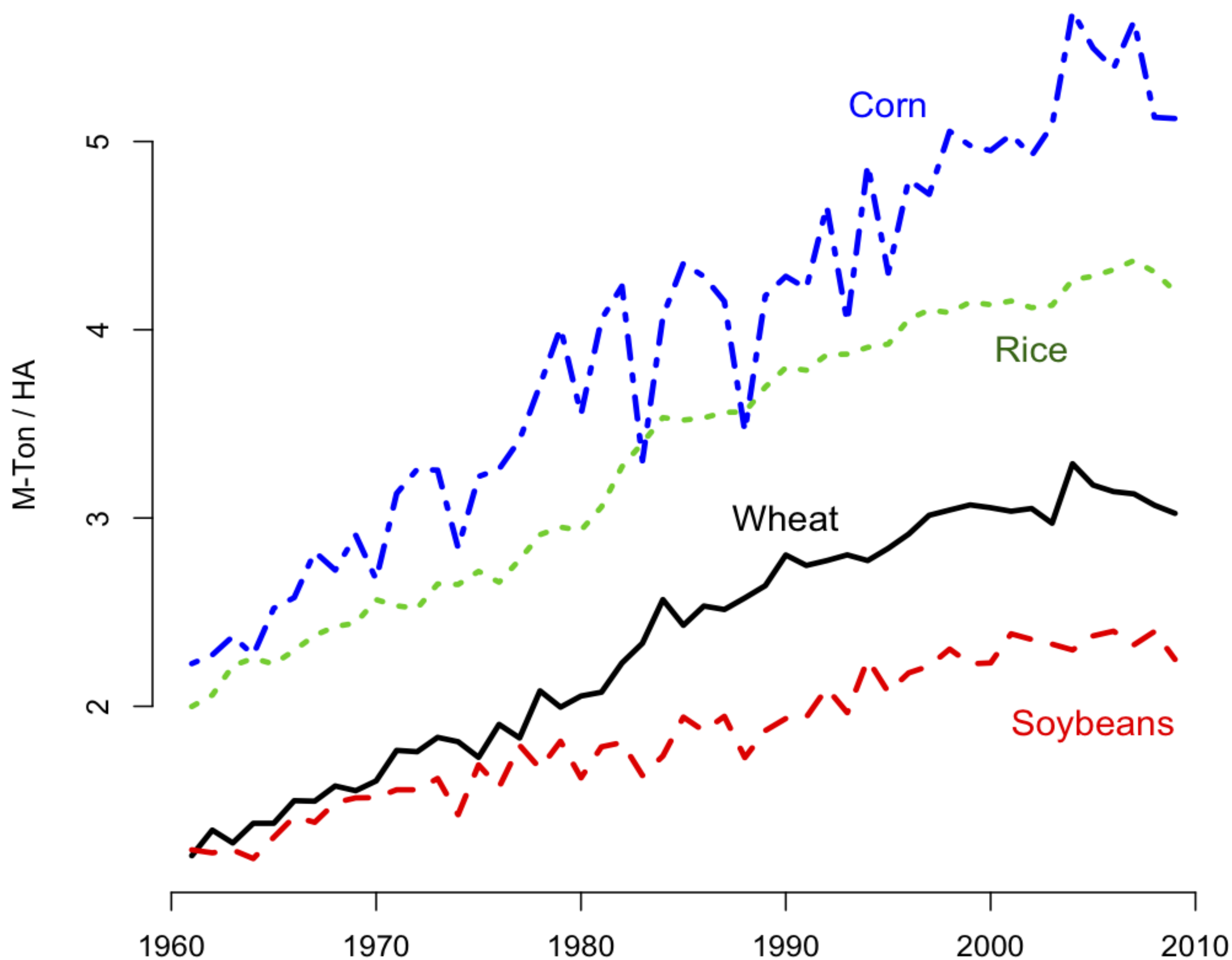
5% of world caloric base

US caloric share is about 23%

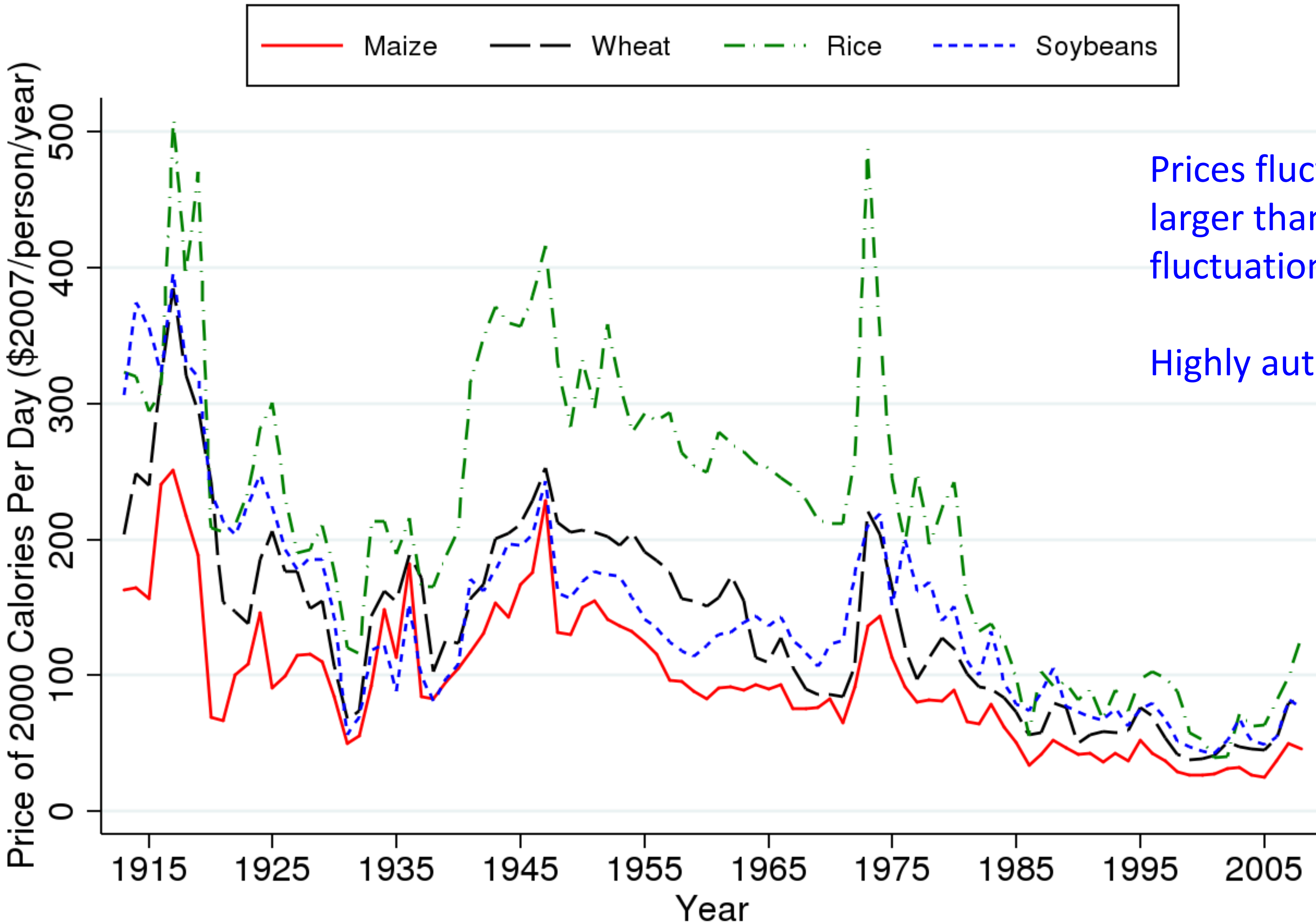


World fluctuations shadow US fluctuations

World Crop Yields



Prices Fluctuate Together



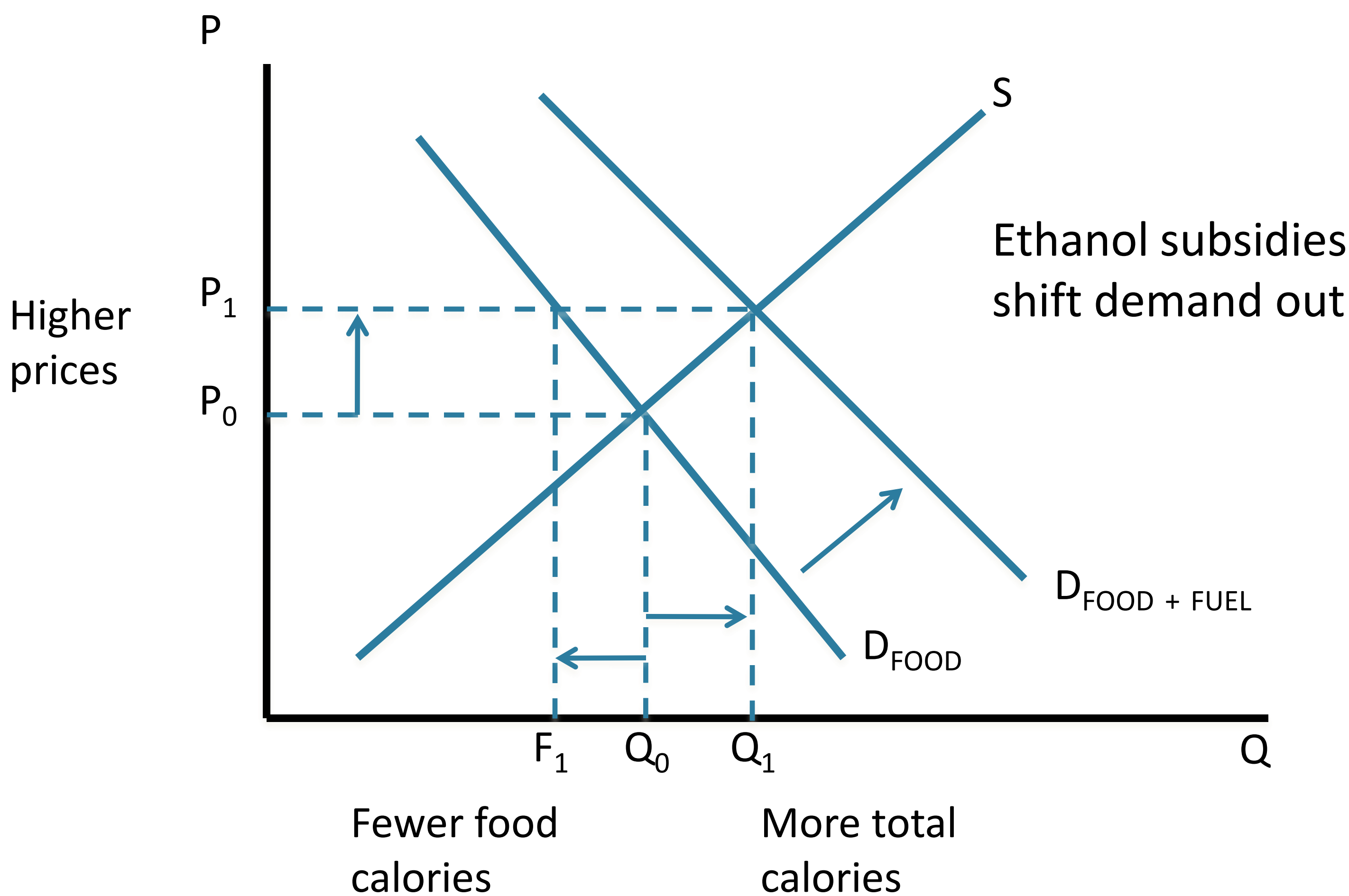
Prices fluctuations larger than quantity fluctuations

Highly autocorrelated

Two

Supply, Demand & the Identification Problem.

Food VS Fuel

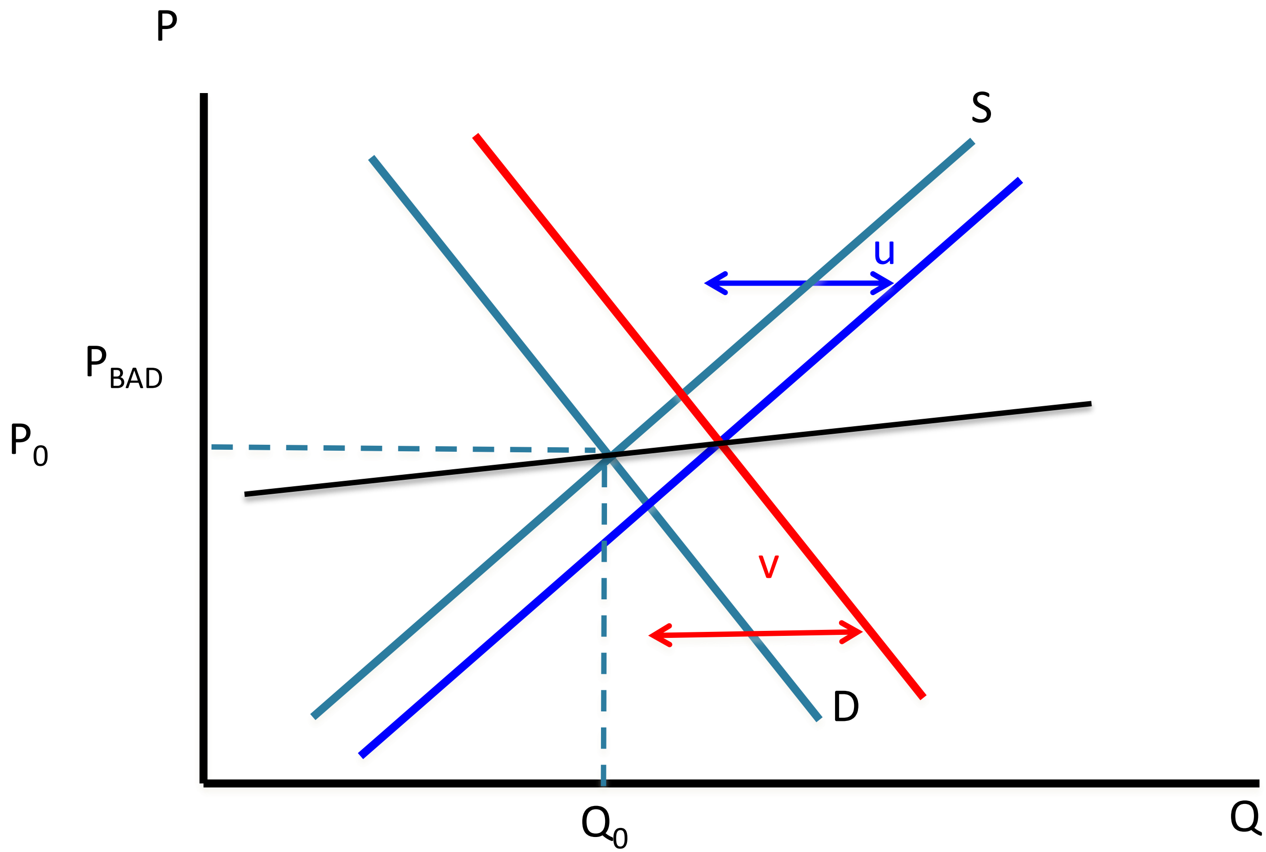


P
S
Ethanol subsidies
shift demand out
Higher
prices
P_1
P_0
$D_{FOOD + FUEL}$
D_{FOOD}
F_1
Q_0
Q_1
Q
Fewer food
calories
More total
calories

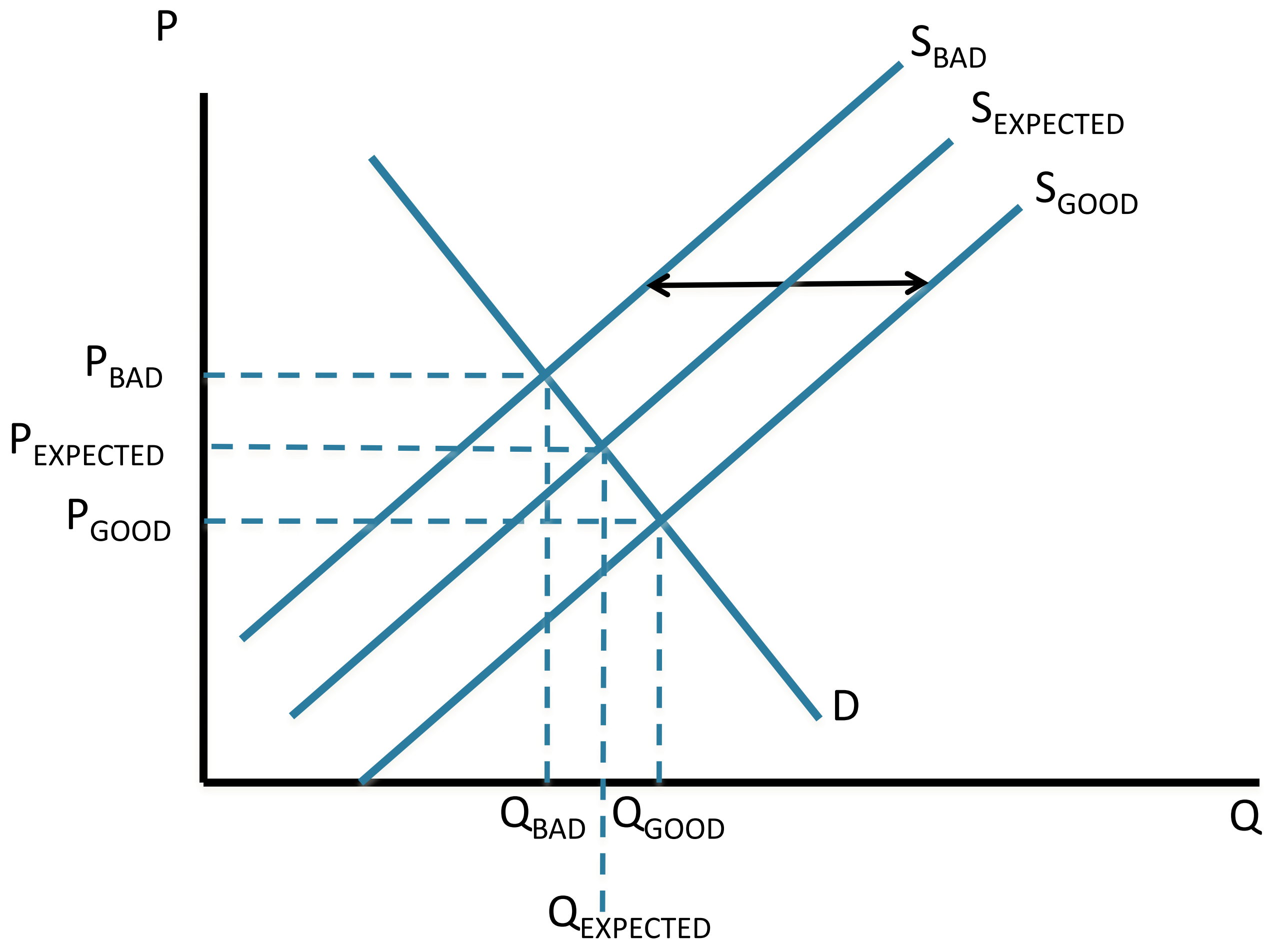
The Price Effect of Ethatnol

$$\%\Delta P = \frac{\%(\text{shift in demand})}{-\xi_D + \xi_S}$$

Identifying Supply and Demand



Weather Shocks Identify Demand



Identification of Supply

- Traditional approach (Nerlove, 1958)

  Regress quantity on <u>expected</u> price

  1. Autoregressive prediction
  2. Futures price

- Problem: Prices still endogenous to market-anticipated supply shifts

  Consider what the error is in the supply equation

  Consider what drives variation in futures prices

Identification of Supply

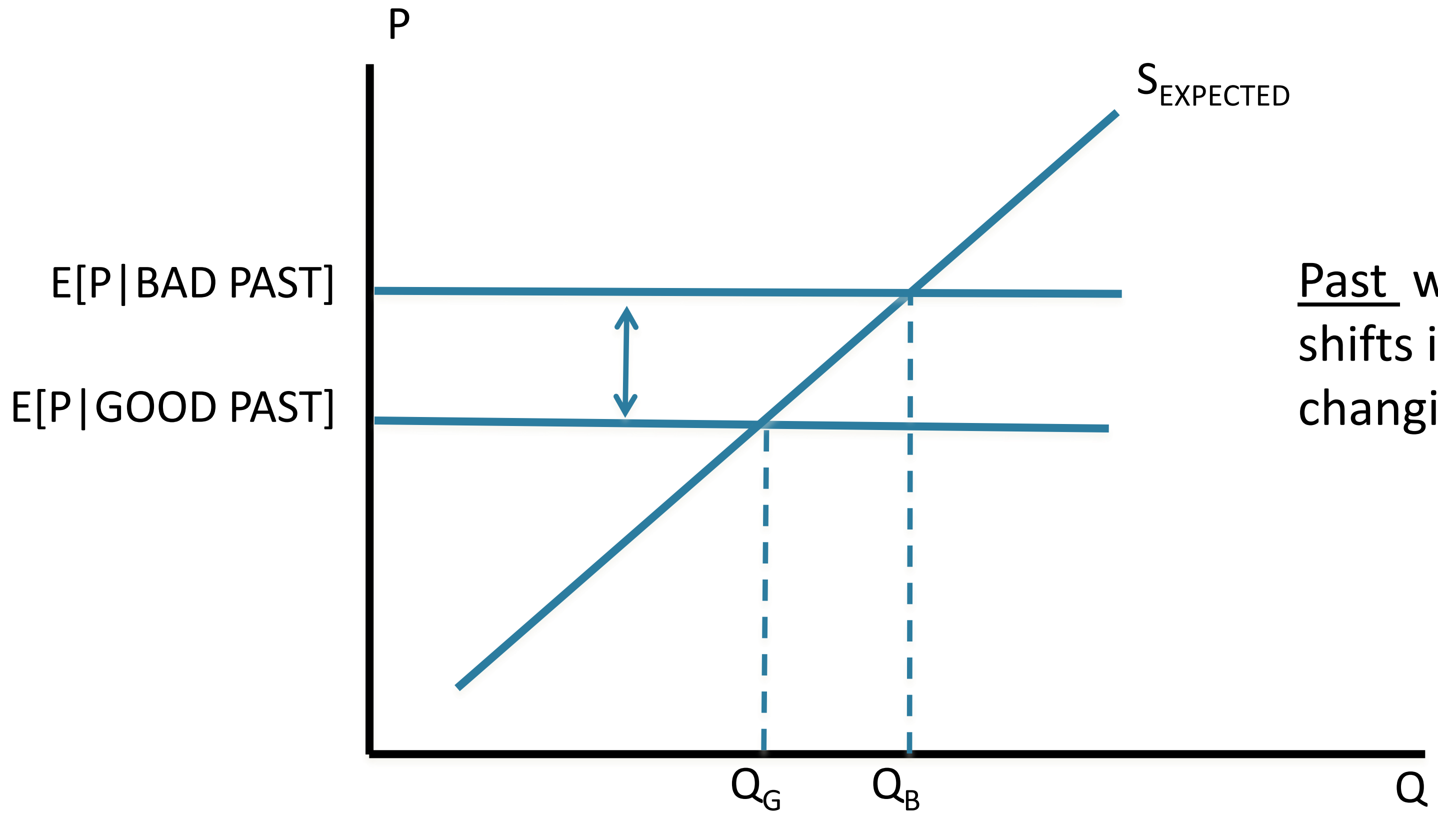
- Storage buffers weather shocks.

- Quantity-consumed shock is smaller than quantity-produced shock.

  $\otimes\ Q_{CONSUMED} = \otimes\ Q_{SUPPLED} + \otimes$ Inventories

- Transmits current weather shocks to future expected prices.

Using weather shocks to identify supply



Past weather variation shifts inventories, changing expected price

Estimated Equations

Supply

$$\log(s_t) \quad = \quad \alpha_s + \beta_s \log(\widehat{E_{t-1}[p_t]}) + \gamma_s \omega + f(t) + u_t$$

Demand

$$\log(c_t) \quad = \quad \alpha_d + \beta_d \widehat{\log(p_t)} + g(t) + v_t$$

$$c_t = s_t - \text{ change in inventories}$$

First Stage Equations

Supply

$$\log(E_{t-1}[p_t]) = \text{ current and past shocks} + \text{polynomial time trend}$$

Demand

$$p_t = \text{ current and past shocks} + \text{polynomial time trend}$$

Three

Our Econometric Estimates

Estimating Shocks

Two approaches:

1. Yield shocks

   Sum jackknifed residuals from country-by-crop trends

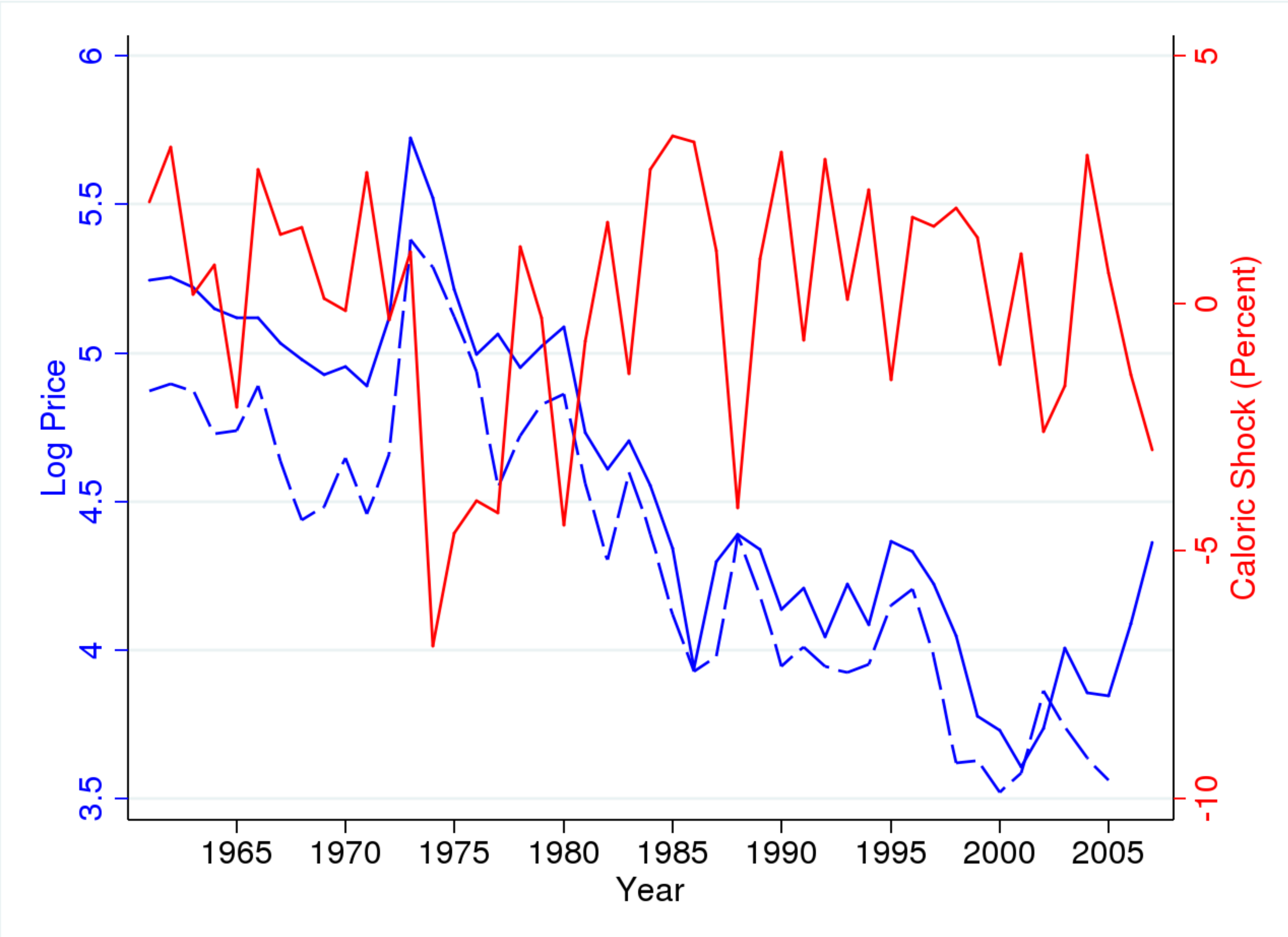
2. Weather

   Good for United States

   Not so good for rest of world

   Large standard errors

Worldwide Caloric Yield Shocks Drive Price Fluctuations



Results for Demand

	Model					
	2SLS	**3SLS**	**2SLS**	**3SLS**	**2SLS**	**3SLS**
β_d	-0.0505***					
(s.e.)	(0.0190)					
β_s						
(s.e.)						
Δp						
(95%)						
p_t	-5.05e-02***					
	(1.90e-02)					
t	4.26e-02***					
	(8.32e-04)					
t^2	-4.18e-04***					
	(2.34e-05)					
t^3						
N	42					
I	2					
K	1					

-Basic two-stage least squares

-Quadratic time trend

-One yield-shock lag

Results for Demand

	Model					
	2SLS	**3SLS**	**2SLS**	**3SLS**	**2SLS**	**3SLS**
β_d	-0.0505***	-0.0554***				
(s.e.)	(0.0190)	(0.0167)				
β_s						
(s.e.)						
Δp						
(95%)						
p_t	-5.05e-02***	-5.54e-02***				
	(1.90e-02)	(1.67e-02)				
t	4.26e-02***	4.26e-02***				
	(8.32e-04)	(8.57e-04)				
t^2	-4.18e-04***	-4.23e-04***				
	(2.34e-05)	(2.28e-05)				
t^3						
N	42	42				
I	2	2				
K	1	1				

Same except 3SLS

Results for Demand

	Model					
	2SLS	3SLS	2SLS	3SLS	2SLS	3SLS
β_d	-0.0505***	-0.0554***	-0.0641**			
(s.e.)	(0.0190)	(0.0167)	(0.0243)			
β_s						
(s.e.)						
Δp						
(95%)						
			Demand			
p_t	-5.05e-02***	-5.54e-02***	-6.41e-02**			
	(1.90e-02)	(1.67e-02)	(2.43e-02)			
t	4.26e-02***	4.26e-02***	4.56e-02***			
	(8.32e-04)	(8.57e-04)	(2.50e-03)			
t^2	-4.18e-04***	-4.23e-04***	-6.12e-04***			
	(2.34e-05)	(2.28e-05)	(1.53e-04)			
t^3			2.93e-06			
			(2.26e-06)			
N	42	42	42			
I	2	2	3			
K	1	1	1			

-2SLS

-cubic time trend

Results for Demand

	Model					
	2SLS	3SLS	2SLS	3SLS	2SLS	3SLS
β_d	-0.0505***	-0.0554***	-0.0641**	-0.0797***		
(s.e.)	(0.0190)	(0.0167)	(0.0243)	(0.0215)		
β_s						
(s.e.)						
Δp						
(95%)						
			Demand			
p_t	-5.05e-02***	-5.54e-02***	-6.41e-02**	-7.97e-02***		
	(1.90e-02)	(1.67e-02)	(2.43e-02)	(2.15e-02)		
t	4.26e-02***	4.26e-02***	4.56e-02***	4.77e-02***		
	(8.32e-04)	(8.57e-04)	(2.50e-03)	(2.81e-03)		
t^2	-4.18e-04***	-4.23e-04***	-6.12e-04***	-7.34e-04***		
	(2.34e-05)	(2.28e-05)	(1.53e-04)	(1.63e-04)		
t^3			2.93e-06	4.56e-06*		
			(2.26e-06)	(2.37e-06)		
N	42	42	42	42		
I	2	2	3	3		
K	1	1	1	1		

-3SLS

-cubic trend

Results for Demand

	Model					
	2SLS	3SLS	2SLS	3SLS	2SLS	3SLS
β_d	-0.0505***	-0.0554***	-0.0641**	-0.0797***	-0.0668***	
(s.e.)	(0.0190)	(0.0167)	(0.0243)	(0.0215)	(0.0241)	
β_s						
(s.e.)						
Δp						
(95%)						
			Demand			
p_t	-5.05e-02***	-5.54e-02***	-6.41e-02**	-7.97e-02***	-6.68e-02***	
	(1.90e-02)	(1.67e-02)	(2.43e-02)	(2.15e-02)	(2.41e-02)	
t	4.26e-02***	4.26e-02***	4.56e-02***	4.77e-02***	4.69e-02***	
	(8.32e-04)	(8.57e-04)	(2.50e-03)	(2.81e-03)	(3.03e-03)	
t^2	-4.18e-04***	-4.23e-04***	-6.12e-04***	-7.34e-04***	-6.74e-04***	
	(2.34e-05)	(2.28e-05)	(1.53e-04)	(1.63e-04)	(1.77e-04)	
t^3			2.93e-06	4.56e-06*	3.78e-06	
			(2.26e-06)	(2.37e-06)	(2.57e-06)	
N	42	42	42	42	41	
I	2	2	3	3	3	
K	1	1	1	1	2	

-2SLS

-cubic trend

-two lags of shocks

Results for Supply

	Model					
	2SLS	**3SLS**	**2SLS**	**3SLS**	**2SLS**	**3SLS**
β_d	-0.0505***	-0.0554***	-0.0641**	-0.0797***	-0.0668***	-0.0634***
(s.e.)	(0.0190)	(0.0167)	(0.0243)	(0.0215)	(0.0241)	(0.0226)
β_s	0.1165***	0.1337***	0.0826***	0.0951***	0.0957***	0.0979***
(s.e.)	(0.0286)	(0.0241)	(0.0217)	(0.0189)	(0.0208)	(0.0189)
Δp	31.41	27.01	36.10	29.31	32.14	32.16
(95%)	(21.32,50.14)	(20.69,36.62)	(23.75,60.31)	(22.01,40.80)	(22.23,50.00)	(22.79,48.40)
			Supply			
$\mathbb{E}[p_t \mid_{t-1}]$	1.17e-01***	1.34e-01***	8.26e-02***	9.51e-02***	9.57e-02***	9.79e-02***
	(2.86e-02)	(2.41e-02)	(2.17e-02)	(1.89e-02)	(2.08e-02)	(1.89e-02)
ω_t	2.46e-01***	2.62e-01***	2.61e-01***	2.72e-01***	2.71e-01***	2.73e-01***
	(3.37e-02)	(2.94e-02)	(2.65e-02)	(2.38e-02)	(2.56e-02)	(2.35e-02)
t	4.46e-02***	4.46e-02***	5.41e-02***	5.40e-02***	5.27e-02***	5.26e-02***
	(9.34e-04)	(8.74e-04)	(2.04e-03)	(1.89e-03)	(2.32e-03)	(2.14e-03)
t^2	-3.54e-04***	-3.44e-04***	-9.23e-04***	-9.11e-04***	-8.48e-04***	-8.43e-04***
	(2.66e-05)	(2.40e-05)	(1.12e-04)	(1.04e-04)	(1.26e-04)	(1.16e-04)
t^3			8.45e-06***	8.37e-06***	7.52e-06***	7.46e-06***
			(1.68e-06)	(1.55e-06)	(1.81e-06)	(1.68e-06)
N	42	42	42	42	41	41
I	2	2	3	3	3	3
K	1	1	1	1	2	2

First Stage Results--Demand

	Model					
	2SLS	3SLS	2SLS	3SLS	2SLS	3SLS
			Demand			
ω_t	-1.19e+00***	-1.16e+00***	-1.12e+00***	-9.92e-01***	-1.04e+00***	-1.07e+00***
	(2.62e-01)	(2.47e-01)	(2.93e-01)	(2.65e-01)	(2.97e-01)	(2.57e-01)
ω_{t-1}					-3.99e-01	-3.30e-01
					(2.95e-01)	(2.02e-01)
t	-8.43e-03	-6.49e-03	4.64e-03	2.03e-02	7.05e-04	2.32e-02
	(9.73e-03)	(1.01e-02)	(2.64e-02)	(2.84e-02)	(3.22e-02)	(3.28e-02)
t^2	-5.49e-04**	-5.88e-04***	-1.32e-03	-2.10e-03	-1.08e-03	-2.12e-03
	(2.24e-04)	(2.28e-04)	(1.47e-03)	(1.53e-03)	(1.72e-03)	(1.71e-03)
t^3			1.22e-05	2.32e-05	8.68e-06	2.26e-05
			(2.27e-05)	(2.33e-05)	(2.60e-05)	(2.54e-05)
N	42	42	42	42	41	41
I	2	2	3	3	3	3
K	1	1	1	1	2	2

First Stage Results--Supply

	Model					
	2SLS	3SLS	2SLS	3SLS	2SLS	3SLS
			Supply			
ω_{t-1}	-8.60e-01***	-7.52e-01***	-9.18e-01***	-8.17e-01***	-8.33e-01***	-8.45e-01***
	(2.14e-01)	(1.91e-01)	(2.26e-01)	(1.98e-01)	(2.20e-01)	(1.96e-01)
ω_{t-2}					-3.53e-01	-3.41e-01*
					(2.21e-01)	(1.89e-01)
ω_t	-6.10e-01***	-6.35e-01***	-6.82e-01***	-6.75e-01***	-6.39e-01***	-6.45e-01***
	(2.10e-01)	(1.97e-01)	(2.27e-01)	(2.09e-01)	(2.20e-01)	(1.99e-01)
t	-1.04e-02	-9.64e-03	-3.01e-02	-2.54e-02	-2.14e-02	-2.17e-02
	(8.15e-03)	(7.64e-03)	(2.46e-02)	(2.26e-02)	(2.77e-02)	(2.51e-02)
t^2	-4.39e-04**	-4.57e-04***	6.72e-04	4.25e-04	2.55e-04	2.76e-04
	(1.85e-04)	(1.73e-04)	(1.32e-03)	(1.21e-03)	(1.43e-03)	(1.30e-03)
t^3			-1.69e-05	-1.34e-05	-1.07e-05	-1.11e-05
			(1.99e-05)	(1.83e-05)	(2.10e-05)	(1.91e-05)
N	42	42	42	42	41	41
I	2	2	3	3	3	3
K	1	1	1	1	2	2

The Punchline

$$\%\Delta P = \frac{\%\Delta D}{-\xi_D + \xi_S} \approx \frac{5\%}{0.05 + 0.10} \approx 33\%$$

$$\%\Delta Q \approx (33\%)(0.10) = 3.3\%$$

$$\%\Delta F \approx 3.3\% - 5\% = -1.7\%$$

(Food for about 120 million)

Source of Ethanol

2/3: New production

1/3: Less food

Growing Area Response to Price

World

Shock ω_{t-1}	-0.0599***	-0.0620***				
	(0.0147)	(0.0186)				
$\mathbb{E}[p_t\|_{t-1}]$			0.0725***	0.0634***	0.0756***	0.0750***
			(0.0146)	(0.0148)	(0.0130)	(0.0140)
Time Trend I	2	3	2	3	2	3
Shock Lags K	n.a.	n.a.	1	1	2	2

Growing Area Response to Price

Brazil

Shock ω_{t-1}	-0.3111***	-0.2304**				
	(0.0731)	(0.0897)				
$\mathbb{E}[p_t\|_{t-1}]$			0.3768***	0.2356**	0.3681***	0.2233**
			(0.1096)	(0.0947)	(0.0986)	(0.0877)
Time Trend I	2	3	2	3	2	3
Shock Lags K	n.a.	n.a.	1	1	2	2

Growing Area Response to Price

United States

Shock ω_{t-1}	-0.2642***	-0.2512***				
	(0.0654)	(0.0826)				
$\mathbb{E}[p_t\|_{t-1}]$			0.3200***	0.2569***	0.3350***	0.2967***
			(0.0562)	(0.0566)	(0.0504)	(0.0527)
Time Trend I	2	3	2	3	2	3
Shock Lags K	n.a.	n.a.	1	1	2	2

Growing Area Response to Price

China

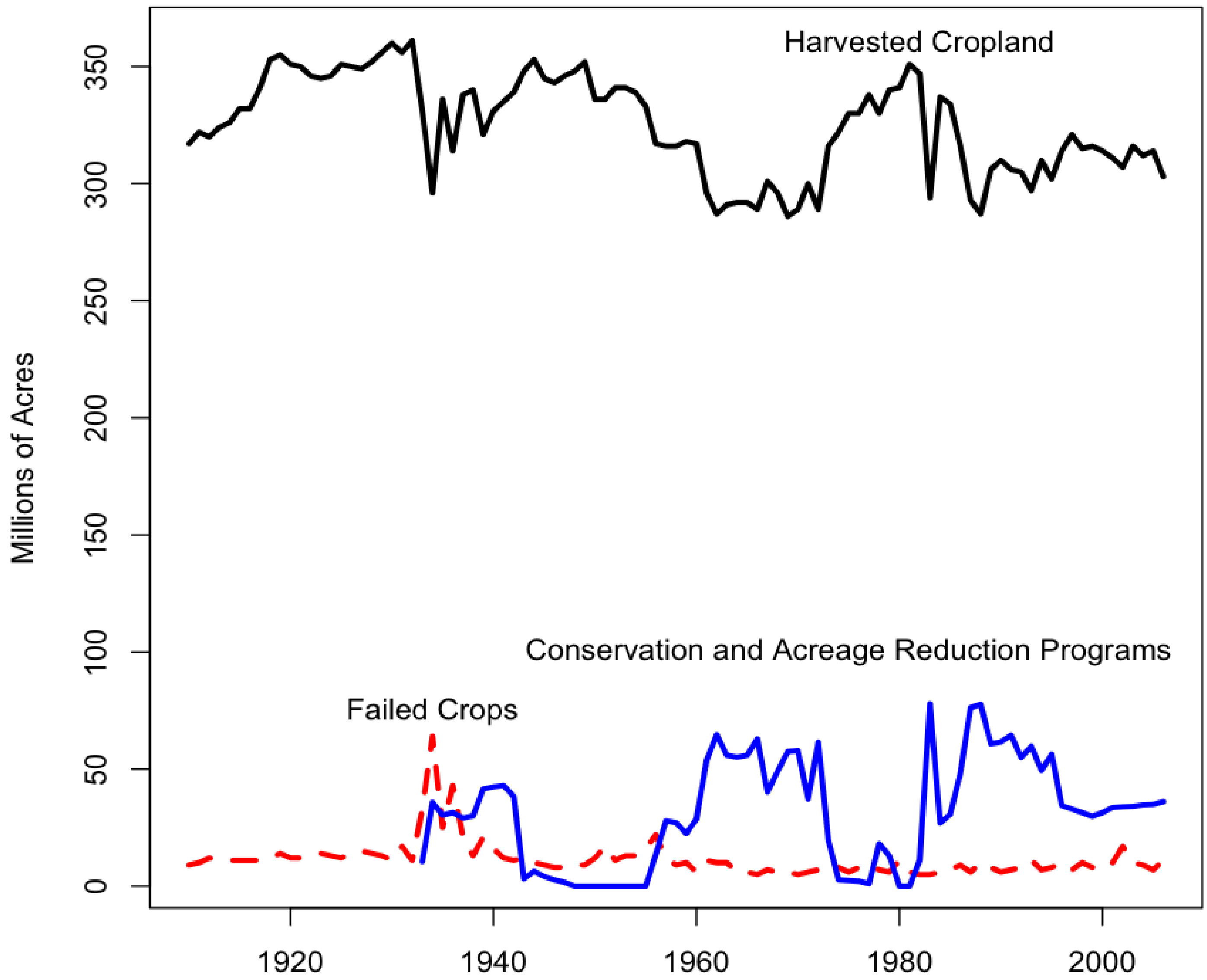
Shock ω_{t-1}	-0.0256	-0.0424				
	(0.0272)	(0.0340)				
$\mathbb{E}[p_t\|_{t-1}]$			0.0311	0.0434	0.0371	0.0713**
			(0.0299)	(0.0311)	(0.0265)	(0.0277)
Time Trend I	2	3	2	3	2	3
Shock Lags K	n.a.	n.a.	1	1	2	2

Growing Area Response to Price

India

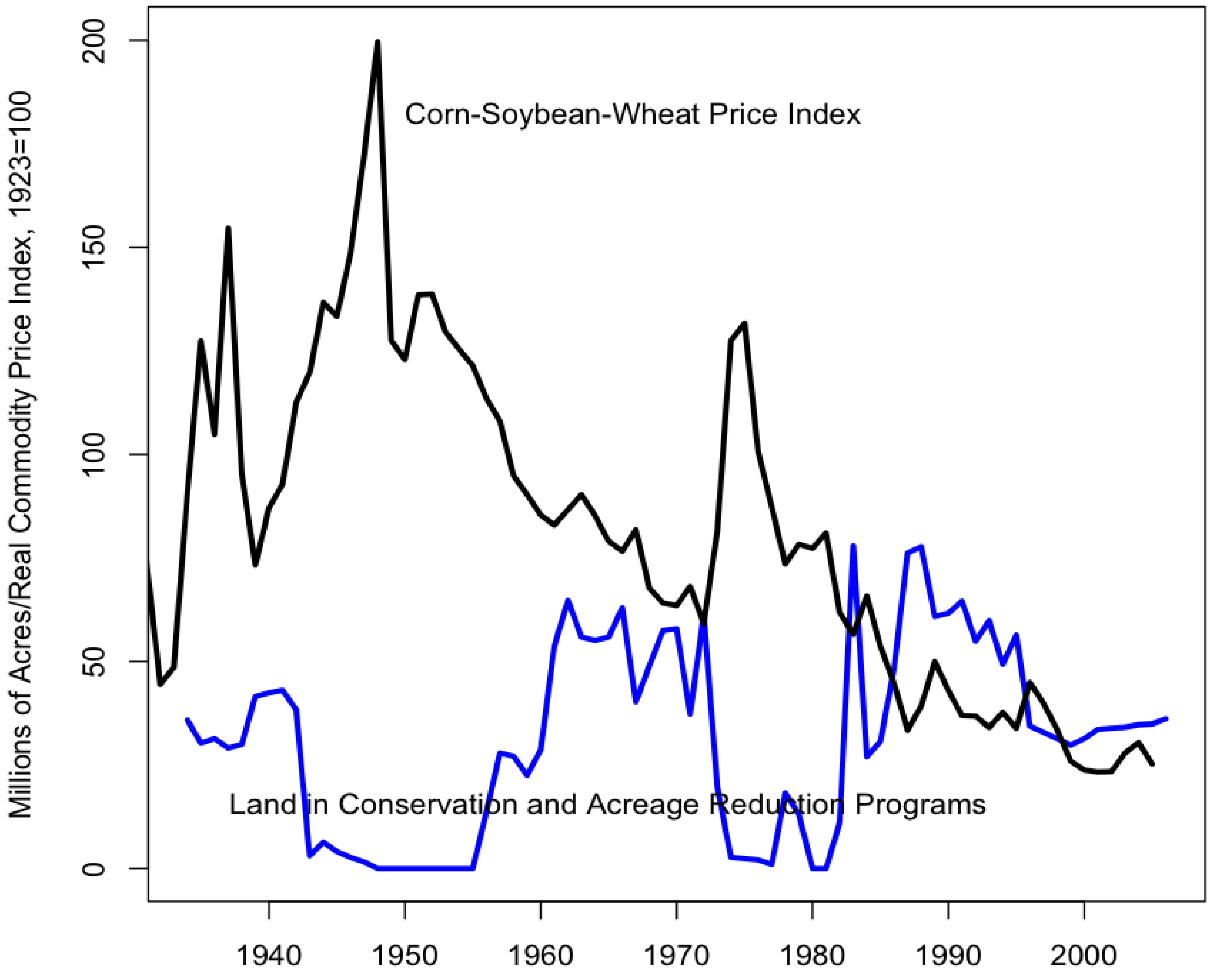
Shock ω_{t-1}	-0.0124	-0.0049				
	(0.0262)	(0.0331)				
$\mathbb{E}[p_t\|_{t-1}]$			0.0150	0.0050	0.0259	0.0065
			(0.0296)	(0.0315)	(0.0266)	(0.0287)
Time Trend I	2	3	2	3	2	3
Shock Lags K	n.a.	n.a.	1	1	2	2

Agricultural Policy Drives US Land Use



Prices Drive Agricultural Policy

(until recently…)



Some Robustness Checks & Extensions

1. Flexibility of country-specific trend used for yield shock estimates.
2. Use trend harvested acres rather than actual harvested acres in yield shock estimates.
3. Separate shocks for different crops—effects on aggregate price look similar.
4. Raw shocks and shocks relative to inventories
5. Different months for futures prices on the supply equation
6. Land area responses for major countries

FAQ

Q: Why aggregate calories?

A: (1) Simplicity.

(2) Value-weighted averages give the same estimates.

(3) Prices vary together so cross-price elasticities difficult to identify (but we are trying).

Q: What if yields or weather are autocorrelated?

A: We include <u>current</u> weather in the supply equation.

Q: Are FAO inventory estimates any good?

A: We think they are good for big countries and especially the United States. Errors do not have strong correlation with instruments. FAS numbers give similar results. Probably not good enough for country-level demand estimation.

Q: Why not structural estimates?

A: Good idea. But could the take home story be much different?

Some Extensions Underway

1. Replicate with USDA-FAS data rather than FAO data
2. Crop-specific estimates and cross-price elasticities
3. Model price transitions with calibrated storage model

Summary

- First-order approximation to food commodity supply and demand on a global scale.
- Prices are very sensitive to quantities.
- Supply somewhat more elastic than demand.
- About 15-60% higher world caloric price due to US ethanol expansion.
- About 1/3 of calories used in ethanol production come from food.
- Significant indirect land use effects.