Labor Supply and Directed Technical Change: Evidence from the Termination of the Bracero Program in 1964

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Research Question and Motivation

- Does labor scarcity increase technological innovation?
  - Labor scarcity in the 19th-century induced the rapid US technological progress (Habakkuk 1962)
  - Similar arguments for other countries and periods (Hayami and Ruttan 1970; Allen 2009; Alesina et al. 2018)
  - Long-run Implications of AI technology
- The direction of the effect is theoretically unclear
  - Scarcity of a factor spurs invention directed to economizing the use of that factor (Hicks 1932; Zeira 1998)
  - A low number of workers reduces the number of potential users of new technologies (Kremer 1993; Acemoglu 1998)

Overview of the Paper

- Study the termination of the "bracero" agreements on December 31, 1964
- Use variation in the exposure to the shock at the crop level
- Use patents data to measure technological innovation
- Find a significant, large and persistent positive effect
- Effects are stronger for technologies related to labor-intensive tasks
- Negative impact on land values

Related Literature

- Scarcity or a high price of a production factor affect the direction of innovation (Newell et al. 1999; Popp 2002; Hanlon 2015)
- Labor scarcity increases the adoption of labor-saving technology (Lewis 2011; Hornbeck and Naidu 2014)
- The termination of the bracero program did not affect local employment and wages (Clemens et al. 2018)
- The impact of high-skilled immigration on technological change (Kerr and Lincoln 2010; Borjas and Doran 2012; Moser et al. 2014; Moser and San 2020)

Outline

1. Historical Background and Data
2. Effects of Labor Scarcity on Invention
3. Robustness: IV and Synthetic Exposure
4. Adding Another Dimension: the Technological Class
5. Effects on Land Values

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Historical Background

Table 1: Timeline of Events

Date	Event
August 1942	Wartime program started
January 1948	Postwar era: Braceros contracted directly with US employers
August 1951	Congress approved Public Law 78, which served as the statutory basis for the program until its end
March 1962	US government required farmers to offer Braceros at least the statewide average wage
December 1964	Termination of the program

Notes: The table is based on Craig (1971).

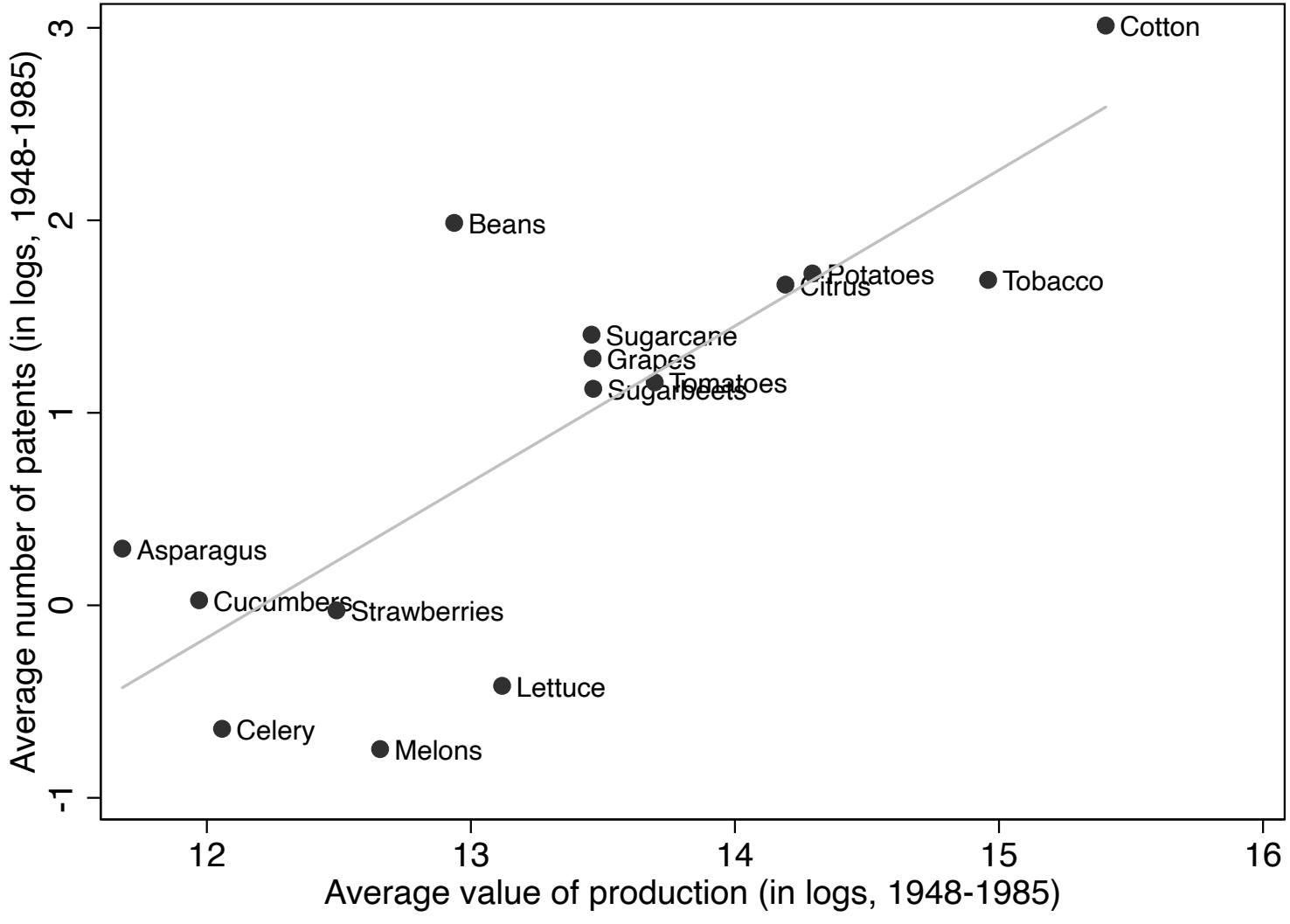
Data: Outcome

- Innovation measure: number of patents per crop, possibly scaled by forward citations
- Focus on technological innovations related to picking and harvesting tasks (CPC class A01D) CPC Definitions
- Allocate patents to crops by searching the text of patents for crop names (e.g., "tomato", "lettuce")

Data: Treatment

- Exposure measure: share of foreign seasonal workers in the total seasonal employment in 1964
- In 1948-1964, 94.5% of the foreign workers admitted for temporary employment in U.S. agriculture were Mexican
- Sample: 16 crops which used 4,000 or more man-months of foreign labor in 1964

Validity Check of the Outcome Measure: Correlation with Market Size



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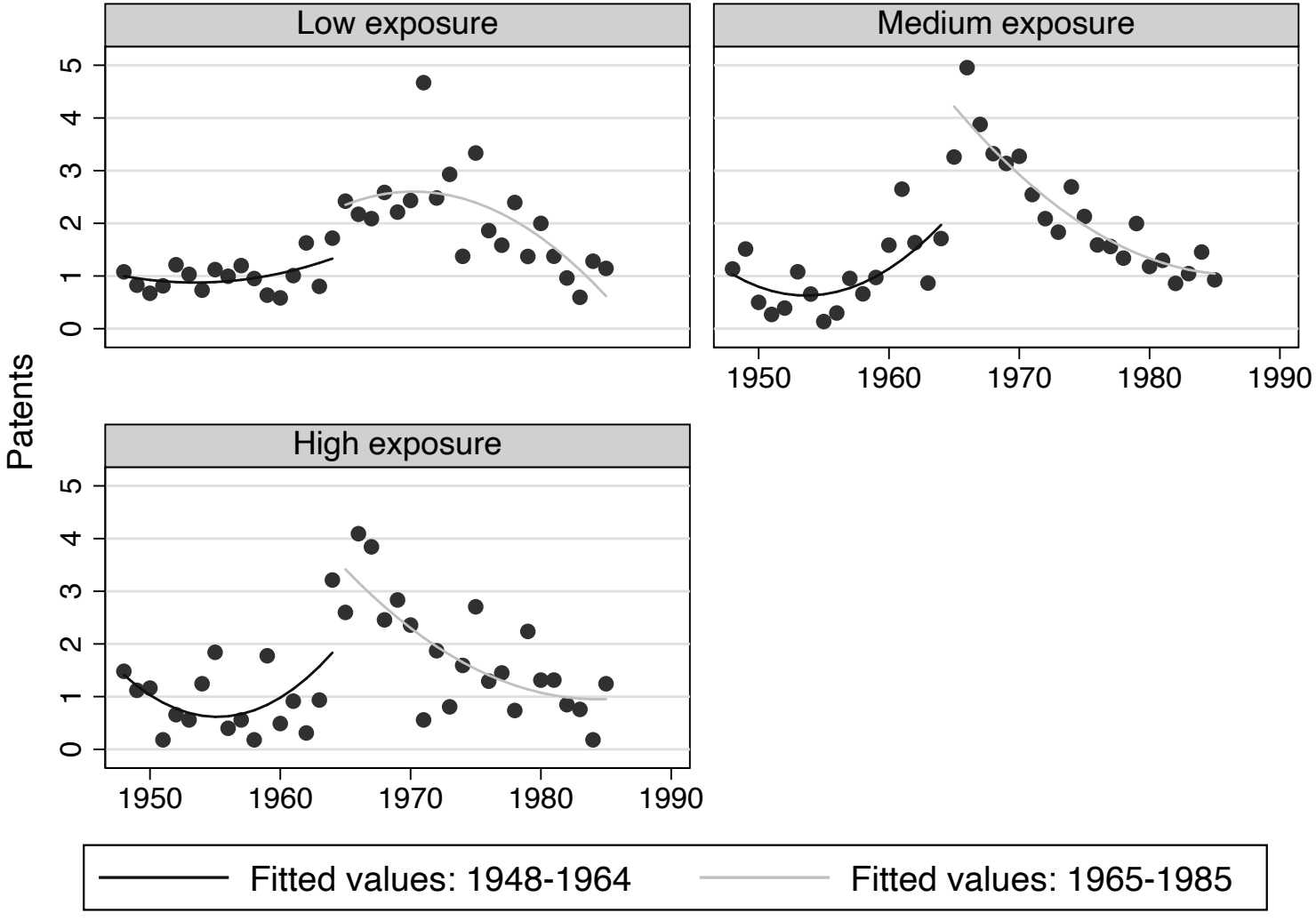
Innovation by Groups of Crops



Continuous DD Specification

- My estimating equation relates crop c's output in year t to characteristics of c:

$$\mathbb{E}(y_{ct}|X_{ct}) = exp\left[\beta \cdot ForeignShare_c \cdot post_t + \gamma_c + \delta_t\right]$$

where:

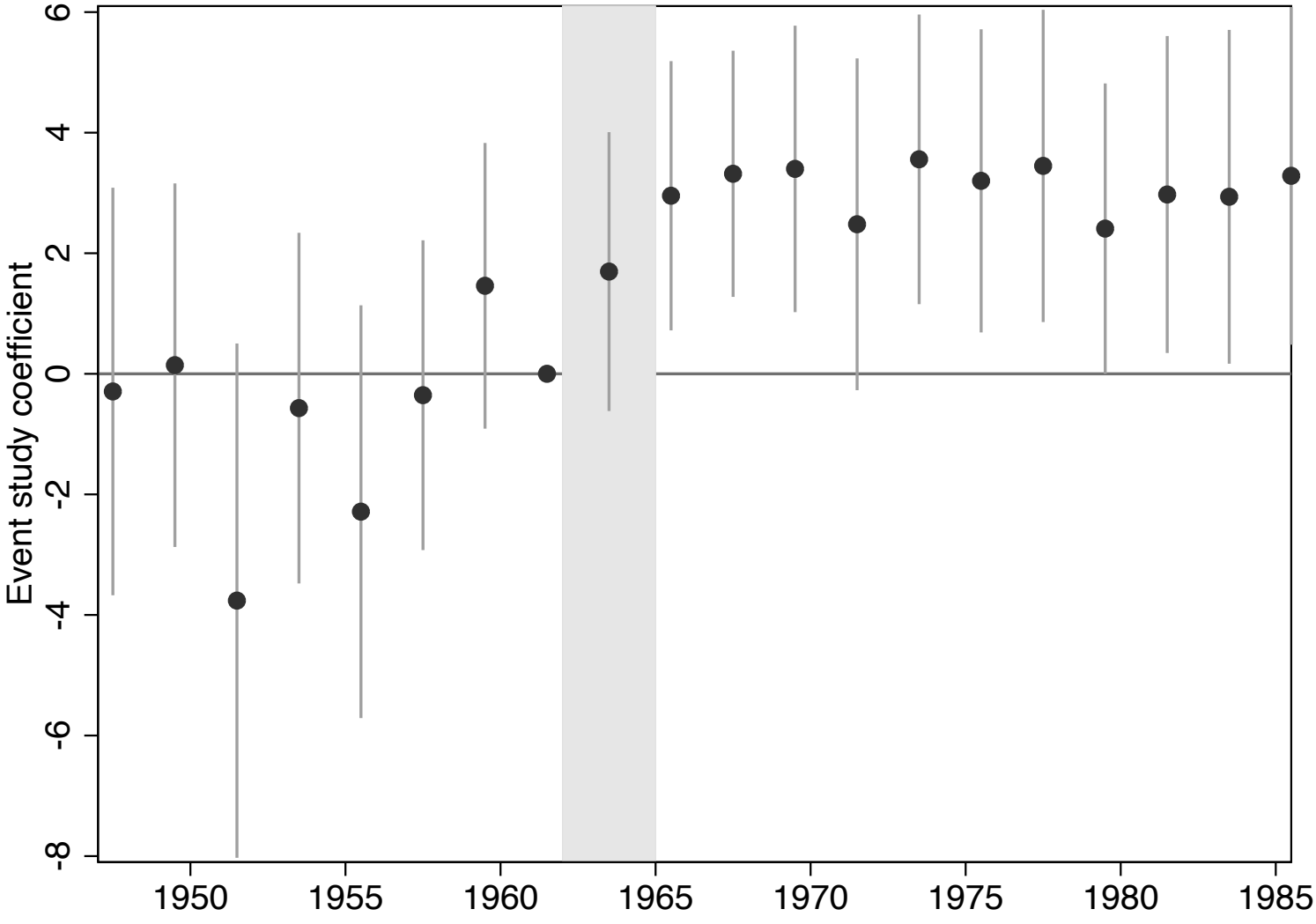
  - y: patents/citations
  - *ForeignShare*: share of foreign workers in the total number of seasonal workers in 1964
  - *Post*: an indicator variable that switches to one after 1965
  - γ_c: crop fixed effects
  - δ_t: year fixed effects

More Patents After 1965 for Crops with Higher Labor-Supply Shock

Table 2: Effects of Bracero Exclusion on Invention: Baseline Estimates

	(1) Patents	(2) Citations
Foreign share × post	3.258*** (0.474)	2.271*** (0.497)
Average response	2.87	10.79
N (crops × years)	608	608
Mean patents/citations before 1965	4.06	23.90
Treatment mean	0.19	0.19
Treatment sd	0.16	0.16
Year FE	Yes	Yes
Crop FE	Yes	Yes

Dynamics of the Effect



Robustness Checks

- Treatment go
- Text-search algorithm go
- Crops sample go
- Years of the analysis go

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Instrumental Variables Strategy

- Two instruments: distance from Mexico and Mexican population in 1940

$$d_c = \sum_k d_k w_{ck}$$

where

  - d_c: IV of crop c (distance/population share)
  - d_k: minimal distance between Mexico border and the centroid of county k/ Mexican population share in the 1940 US census of population
  - w_{ck}: acreage share of crop c in county k in the total acreage of crop c in 1964

Instrumental Variables Estimation

Table 3: Effects of Bracero Exclusion on Invention: Instrumental Variables

	Patents			Citations		
	(1)	(2)	(3)	(4)	(5)	(6)
Foreign share × post	4.853***	2.968*	4.467***	5.273***	4.272**	4.968***
	(1.566)	(1.622)	(1.500)	(1.587)	(1.742)	(1.538)
Instruments	Distance	Population	Both	Distance	Population	Both
N (crops × years)	608	608	608	608	608	608
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Crop FE	Yes	Yes	Yes	Yes	Yes	Yes

Building Synthetic Crops

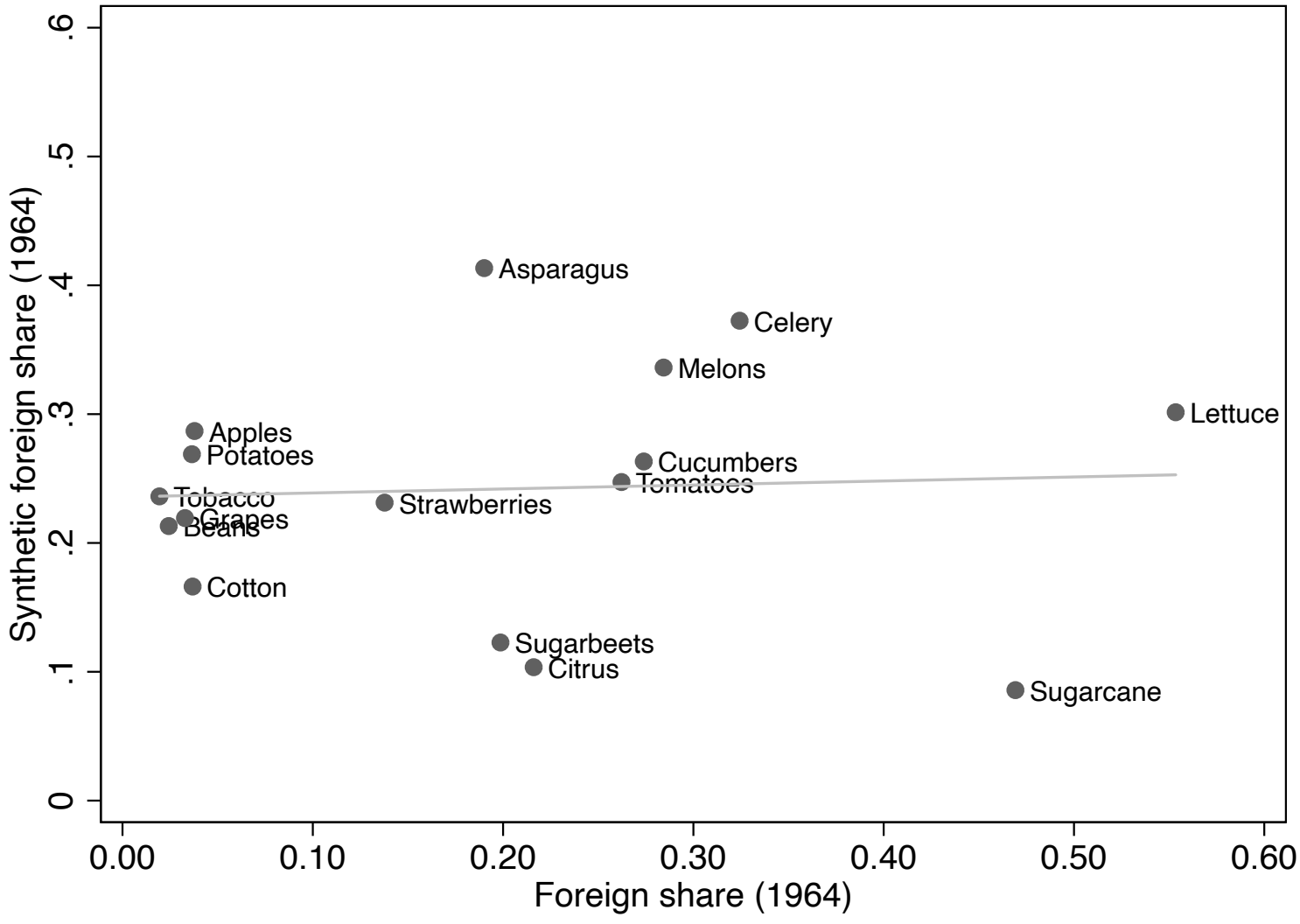
- Threat: exposure is explained by technical properties of the crops.
- Build a similarity matrix based on patents mention more than one crop
- Synthetic exposure:

$$ForeignShare_c^{syn} = \sum_{c' \neq c} w_{c,c'} ForeignShare_{c'}$$

where

- $w_{c,c'}$: share of patents mention crops c and c' in the total patents mention crop c and another crop

Correlation between Actual and Synthetic Exposure



Regressions with Synthetic Treatment

Table 4: Effects of Bracero Exclusion on Invention: Continuous Difference in Differences with Synthetic Treatment

	(1) Patents	(2) Citations
Foreign share × post	3.588***	2.474***
	(0.517)	(0.557)
Synthetic foreign share × post	2.392**	1.377
	(0.981)	(1.188)
N (crops × years)	608	608
Mean patents/citations before 1965	4.06	23.90
Year FE	Yes	Yes
Crop FE	Yes	Yes

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Triple Difference

- Using archival data on labor requirements by task and crop, I build a measure of labor intensity by crop-class
- Triple differences specification:

$$\mathbb{E}(y_{cst}|x_{cst}) = exp[\beta \cdot ForeignShare_c \cdot ClassShare_{cs} \cdot Post_t + \gamma_{cs} + \delta_{ct} + \epsilon_{st}]$$

Triple differences results

Table 5: Effects of Bracero Exclusion on Invention in Labor Intensive Tasks: Triple-difference Estimates

	(1) Patents	(2) Citations	(3) Patents	(4) Citations	(5) Patents	(6) Citations
Foreign percentage × labor-class × post	2.036**	2.045**				
	(0.931)	(1.023)				
Foreign percentage × cost-class × post			1.988**	1.967**		
			(0.916)	(1.003)		
Foreign percentage × class × post					1.684***	1.769***
					(0.474)	(0.576)
N (crops × classes × years)	2,486	2,486	2,486	2,486	4,096	4,096
Mean patents/citations before 1965	1.54	10.25	1.54	10.25	1.22	8.46
Crop-Class FE	Yes	Yes	Yes	Yes	Yes	Yes
Crop-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Class-Year FE	Yes	Yes	Yes	Yes	Yes	Yes

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Farm Values: County-level Analysis

- I use the agricultural censuses to examine the effect of the termination of the Bracero program on agricultural land values
- The exposure measure of a county k is

$$Exposure_k = \sum_c ForeignShare_c \cdot AcreageShare_{ck}$$

where $AcreageShare_{ck}$ is the share of crop c in the total acreage of county k.

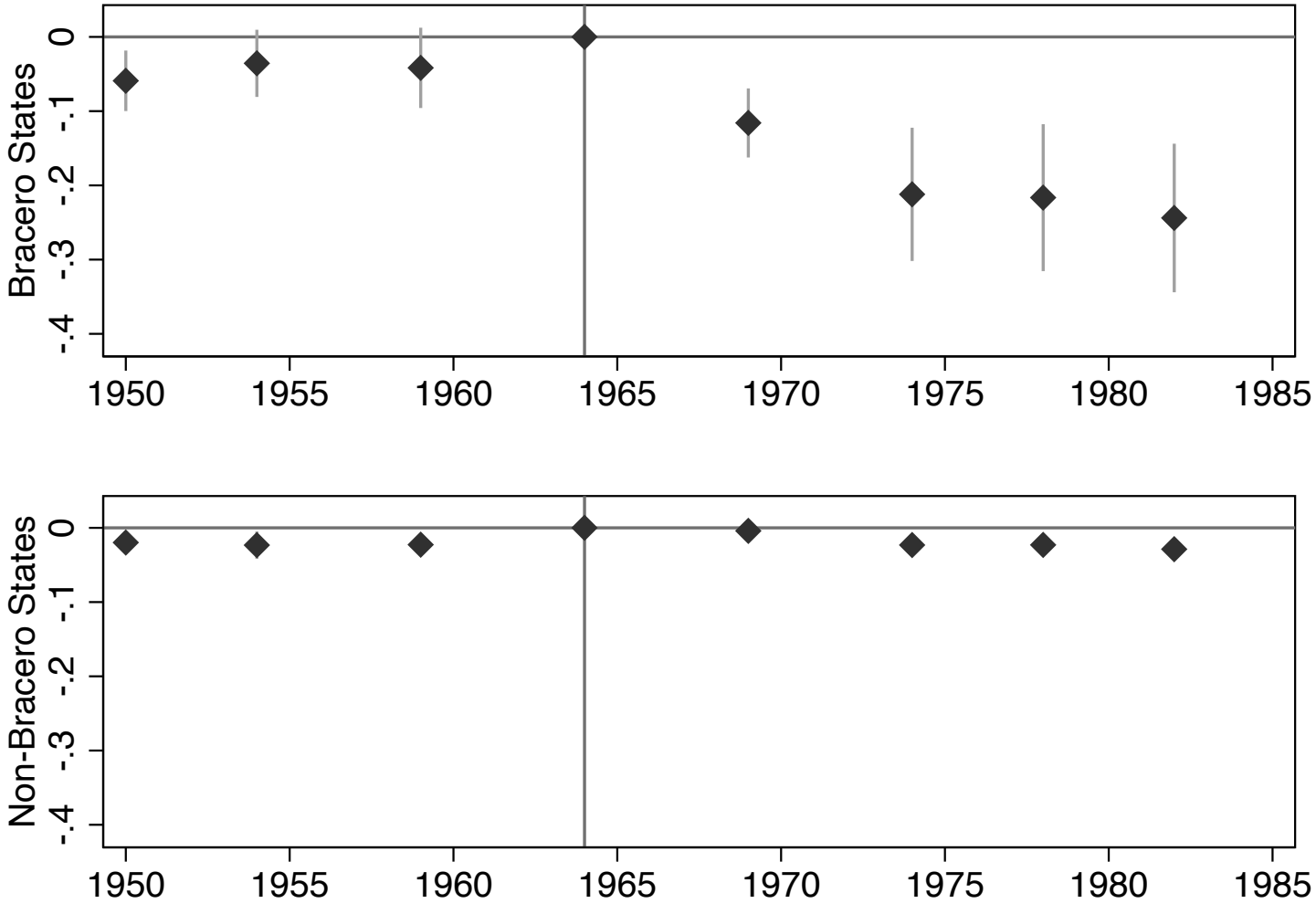
- The regression equation is

$$ln\left(Value_{kt}\right) = \sum_{\tau=1950}^{1982} \beta_\tau \cdot \mathbb{I}(t = \tau) \cdot Exposure_k + \gamma_k + \delta_t + \epsilon_{kt}$$

where ϵ_{ts} is a year-state fixed effect

- Separate regressions for Bracero and non-Bracero states

Farm Values per Acre



Thank You

Robustness Checks: Various Definitions for the Treatment Variable

Table 6: Effects of Bracero Exclusion on Agricultural Invention: Alternative Definitions of the Treatment

	Baseline		Binary		Peak season		Post=1962		Change 64-65	
	(1) Patents	(2) Citations	(3) Patents	(4) Citations	(5) Patents	(6) Citations	(7) Patents	(8) Citations	(9) Patents	(10) Citations
Foreign share × post65	3.258***	2.271***								
	(0.474)	(0.497)								
Binary exposure × post65			0.925***	0.603***						
			(0.146)	(0.163)						
Peak season × post65					2.718***	1.848***				
					(0.402)	(0.426)				
Foreign share × post62							3.324***	2.539***		
							(0.509)	(0.540)		
(Foreign share change 64-65 × post65									2.858***	1.620**
									(0.758)	(0.759)
N (crops × years)	608	608	608	608	608	608	608	608	608	608
Mean patents/citations before 1965	4.06	23.90	4.06	23.90	4.06	23.90	4.06	23.90	4.06	23.90
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Crop FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

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Robustness Checks: Sensitivity to the Text-Search Algorithm

Table 7: Effects of Bracero Exclusion on Agricultural Invention, Robustness to the Text-search Algorithm

	First crop		Maximal crop		All crops		Equal weights		Proportional weights	
	(1) Patents	(2) Citations	(3) Patents	(4) Citations	(5) Patents	(6) Citations	(7) Patents	(8) Citations	(9) Patents	(10) Citations
Foreign share × post	3.258***	2.271***	3.223***	2.163***	3.028***	2.220***	3.046***	2.128***	3.182***	2.178***
	(0.474)	(0.497)	(0.467)	(0.500)	(0.449)	(0.498)	(0.443)	(0.464)	(0.457)	(0.483)
N (crops × years)	608	608	608	608	608	608	608	608	608	608
Mean patents/citations before 1965	4.06	23.90	4.06	23.90	4.37	26.74	4.06	23.90	4.06	23.90
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Crop FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

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Robustness Checks: Extending the Sample of Crops

Table 8: Effects of Bracero Exclusion on Agricultural Invention, Robustness to the Sample of Crops

	Baseline crops		Baseline + Field		Baseline + California		All crops	
	(1) Patents	(2) Citations	(3) Patents	(4) Citations	(5) Patents	(6) Citations	(7) Patents	(8) Citations
Foreign share × post	3.258***	2.271***	2.848***	1.481***	3.137***	2.329***	2.765***	1.545***
	(0.474)	(0.497)	(0.414)	(0.442)	(0.445)	(0.470)	(0.399)	(0.423)
N (crops × years)	608	608	988	988	988	988	1,368	1,368
Mean patents/citations before 1965	4.06	23.90	3.59	21.53	2.65	16.17	2.70	16.50
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Crop FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

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Robustness Checks: Changing the Years of the Analysis

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Table 9: Effects of Bracero Exclusion on Agricultural Invention, Changing the Period of the Sample

	Total Patents										
Last Year:	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
First Year:											
1943	2.943***	2.924***	2.894***	2.939***	2.884***	2.886***	2.826***	2.761***	2.712***	2.702***	2.717***
	(0.460)	(0.451)	(0.445)	(0.442)	(0.439)	(0.434)	(0.431)	(0.430)	(0.428)	(0.422)	(0.422)
1944	2.965***	2.946***	2.916***	2.961***	2.906***	2.909***	2.849***	2.784***	2.735***	2.725***	2.740***
	(0.464)	(0.455)	(0.449)	(0.446)	(0.443)	(0.438)	(0.435)	(0.434)	(0.432)	(0.427)	(0.426)
1945	3.137***	3.116***	3.084***	3.129***	3.074***	3.076***	3.016***	2.951***	2.902***	2.890***	2.906***
	(0.472)	(0.463)	(0.457)	(0.454)	(0.450)	(0.446)	(0.443)	(0.442)	(0.440)	(0.434)	(0.434)
1946	3.145***	3.124***	3.091***	3.136***	3.080***	3.083***	3.022***	2.958***	2.908***	2.896***	2.912***
	(0.480)	(0.470)	(0.464)	(0.461)	(0.458)	(0.454)	(0.451)	(0.449)	(0.447)	(0.441)	(0.441)
1947	3.278***	3.255***	3.221***	3.265***	3.209***	3.212***	3.150***	3.085***	3.035***	3.022***	3.038***
	(0.492)	(0.482)	(0.475)	(0.473)	(0.469)	(0.465)	(0.462)	(0.460)	(0.458)	(0.452)	(0.452)
1948	3.326***	3.301***	3.267***	3.311***	3.255***	3.258***	3.196***	3.132***	3.082***	3.068***	3.084***
	(0.501)	(0.491)	(0.484)	(0.482)	(0.478)	(0.474)	(0.471)	(0.469)	(0.467)	(0.461)	(0.461)
1949	3.317***	3.292***	3.257***	3.301***	3.245***	3.248***	3.187***	3.122***	3.072***	3.058***	3.074***
	(0.515)	(0.504)	(0.497)	(0.495)	(0.491)	(0.487)	(0.484)	(0.482)	(0.480)	(0.473)	(0.474)
1950	3.313***	3.287***	3.252***	3.296***	3.240***	3.243***	3.181***	3.116***	3.066***	3.052***	3.068***
	(0.529)	(0.518)	(0.511)	(0.509)	(0.505)	(0.501)	(0.498)	(0.496)	(0.494)	(0.488)	(0.488)
1951	3.397***	3.369***	3.332***	3.376***	3.319***	3.321***	3.258***	3.193***	3.142***	3.127***	3.143***
	(0.543)	(0.532)	(0.525)	(0.522)	(0.518)	(0.515)	(0.512)	(0.510)	(0.508)	(0.501)	(0.501)
1952	3.270***	3.242***	3.205***	3.249***	3.192***	3.194***	3.132***	3.066***	3.015***	3.000***	3.016***

CPC Subclasses Definitions

Table 10: Plant-Agricultural Sub-Classes in the CPC Classification System: Definition of the Subclass, Number of Crop-Specific Patents by Period and Labor Requirements

Subclass	Definition	Number of patents			Seasonal Labor Requirements	
		Total	1948-1964	1965-1985	Mean	Sd
A01B	Soil Working In Agriculture Or Forestry; Parts, Details, Or Accessories Of Agricultural Machines Or Implements, In General	627	250	225	0.16	0.23
A01C	Planting; Sowing; Fertilising	785	233	410	0.01	0.02
A01D	Harvesting; Mowing	3080	1149	1414	0.69	0.26
A01F	Processing Of Harvested Produce; Hay Or Straw Presses; Devices For Storing Agricultural Or Horticultural Produce	236	64	130	0.00	0.00
A01G	Horticulture; Cultivation Of Vegetables, Flowers, Rice, Fruit, Vines, Hops Or Seaweed; Forestry; Watering	1401	270	930	0.13	0.12
A01H	New Plants Or Processes For Obtaining Them; Plant Reproduction By Tissue Culture Techniques	152	9	109	0.00	0.00
A01N	Preservation Of Bodies Of Humans Or Animals Or Plants Or Parts Thereof; Biocides, E.G. As Disinfectants, As Pesticides, As Herbicides Pest Repellants Or Attractants; Plant Growth Attractants; Plant Growth Regulators	11166	1719	8036	0.00	0.01

Notes: Sub-classes in the CPC A01 class (agriculture) that contain words related to plants or crops in the definition.

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