# Appendices (for online publication)

## A Appendix Tables and Figures

**Table A1:** 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).

**Table A2:** Summary Statistics for Crops in the Sample, United States, 1948-1985.

| Crop | total labor | domestic labor | foreign labor | foreign share | acreage | production | value |
|---|---|---|---|---|---|---|---|
| Lettuce | 122,500 | 54,600 | 67,800 | 0.553 | 220,351 | 44,483 | 498,007 |
| Sugarcane | 105,700 | 56,100 | 49,600 | 0.469 | 588,511 | 491,619 | 698,747 |
| Celery | 44,400 | 30,000 | 14,400 | 0.324 | 34,434 | 15,389 | 172,452 |
| Melons | 64,700 | 46,300 | 18,400 | 0.284 | 426,346 | 41,421 | 313,727 |
| Cucumbers | 105,500 | 76,600 | 28,900 | 0.274 | 178,723 | 14,914 | 158,070 |
| Tomatoes | 345,100 | 254,600 | 90,500 | 0.262 | 474,035 | 131,244 | 887,708 |
| Citrus | 319,800 | 250,800 | 69,100 | 0.216 | . | 225,213 | 1,456,449 |
| Sugarbeets | 160,600 | 128,700 | 31,900 | 0.199 | 1,093,495 | 442,956 | 703,143 |
| Asparagus | 60,500 | 49,000 | 11,500 | 0.190 | 122,811 | 2,936 | 118,202 |
| Strawberries | 308,500 | 266,100 | 42,500 | 0.138 | 72,702 | 5,551 | 265,991 |
| Apples | 132,000 | 127,000 | 5,000 | 0.038 | . | . | . |
| Cotton | 1,769,400 | 1,704,200 | 65,200 | 0.037 | 14,420,034 | 61,122 | 4,898,662 |
| Potatoes | 246,600 | 237,700 | 9,000 | 0.036 | 1,422,176 | 292,770 | 1,613,069 |
| Grapes | 179,600 | 173,700 | 5,900 | 0.033 | 592,258 | 82,798 | 701,520 |
| Beans | 263,100 | 256,700 | 6,400 | 0.024 | 1,481,324 | 18,670 | 415,374 |
| Tobacco | 767,200 | 752,300 | 14,900 | 0.019 | 1,124,646 | 19,458 | 3,137,989 |

**Notes:** Seasonal hired labor, by crop and origin of worker, United States, 1964 and average acreage, production and value by crop, United States, 1948-1985. Data from Farm Labor Developments and USDA annual statistical bulletins (see Appendix C for details). Seasonal labor in person-months, acreage in acres, production in 1000 Cwt (100,000 pounds), and value of production in 1980 dollars. Crops listed in descending order of foreign seasonal hired labor relative to the total.

**Table A3:** Measures of Market Concentration

| | Sample | | Other patents | |
|---|---|---|---|---|
| | 1948-1964 | 1965-1985 | 1948-1964 | 1965-1985 |
| N. assignees | 637 | 800 | 210531 | 317974 |
| Av. patents per assignee | 1.7 | 1.7 | 3.7 | 4.4 |
| Herfindahl-Hirschman Index | 125.1 | 96.3 | 21 | 11.3 |
| Share patents by top 1 assignee | 7.3 | 6.3 | 2.9 | 1.3 |
| Share patents by top 3 assignees | 16 | 14 | 5.8 | 2.7 |
| Share patents by top 5 assignees | 21.1 | 18.5 | 7.6 | 3.9 |
| Share patents by top 10 assignees | 26.4 | 23.5 | 10.8 | 6.8 |
| Share patents by top 30 assignees | 35.7 | 31.9 | 17.3 | 14.3 |
| Share patents by top 50 assignees | 40.6 | 36.6 | 21 | 19.1 |
| Share patents by top 1 percent | 22.4 | 21.9 | 51.5 | 59 |
| Share patents by top 3 percent | 32.1 | 30.1 | 59.8 | 66.4 |
| Share patents by top 5 percent | 36 | 34.4 | 63.9 | 69.9 |
| Share patents by top 10 percent | 43 | 41.5 | 70 | 75 |
| Share patents by top 30 percent | 59.6 | 58.8 | 81.3 | 84.2 |
| Share patents by top 50 percent | 71.1 | 70.6 | 86.6 | 88.7 |

**Notes:** This table reports various measures of the concentration of patents issued by assignees. The Herfindahl-Hirschman Index is the sum of squares of the share percentage of patents issued by each assignee (ranges between 0 and 10,000). The sample consists of USPTO patents in the CPC "harvesting and mowing" subclass that mention one of the 16 crops (see text for details). Other patents include all other USPTO patents. All measures are calculated separately for each group of patents (sample/other patents) and years (1948-1964/1965-1985).

**Table A4:** Effects of Bracero Exclusion on Invention: Alternative Standard Errors

| | Analytical clustered SEs | | Bootstrap clustered SEs | |
|---|---|---|---|---|
| | (1) Patents | (2) Citations | (3) Patents | (4) Citations |
| Foreign share × post | 3.258*** | 2.271*** | 3.258** | 2.271** |
| | (1.257) | (0.825) | (1.487) | (0.975) |
| N (crops × years) | 608 | 608 | 608 | 608 |

*Notes:* This table shows standard errors clustered at the crop level (16 clusters) for the estimates of the baseline specifications reported in Table 2. The first two columns show the analytical clustered standard errors. The last two columns show bootstrap clustered standard errors based on 1,000 repetitions. In each repetition, 16 clusters are drawn (with replacement) from the sample of 16 clusters.

**Table A5:** 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) |
| 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 |
| N (crops × years) | 608 | 608 | 608 | 608 | 608 | 608 | 608 | 608 | 608 | 608 |

*Notes:* This table checks the sensitivity of the results to the definition of the treatment. The first two columns repeat the baseline specification, where the continuous treatment is the share of foreign workers in the total seasonal employment and the "post" year is 1965, the first year after the abrogation of the *bracero* program. The following two columns use a binary treatment: crop is in the treatment group if the foreign percentage is above the median. In columns (5) and (6), the treatment is defined according to the foreign share at the date of peak foreign employment of each crop. Columns (7) and (8) use the baseline (continuous) measure of the crop' exposure to the Bracero exclusion, but change the "post" year to be 1962, when the US administration started to restrict the program. The last two columns use the 1964 to 1965 change in the share of foreign workers to define the treatment. All specifications include crop and year fixed effects. Robust standard errors are shown in parentheses.

**Table A6:** 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) |
| 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 |
| N (crops × years) | 608 | 608 | 608 | 608 | 608 | 608 | 608 | 608 | 608 | 608 |

*Notes:* This table checks the sensitivity of the results to how the text-search algorithm allocates patents to crops. The first two columns repeat the baseline algorithm, where the patent is allocated to the first crop mentioned in the text of the patent. The next two columns allocate the patent to the crop with the maximum mentions in the text. Columns (5) and (6) assign one patent to each one of the crops mentioned in the text. Columns (7) and (8) assign equal weights to each one of the crops mentioned such that the sum of the weights is one. Finally, the last two columns assign weights proportional to the number of times each crop is mentioned. All specifications include crop and year fixed effects. Robust standard errors are shown in parentheses.

**Table A7:** 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) |
| 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 |
| N (crops × years) | 608 | 608 | 988 | 988 | 988 | 988 | 1,368 | 1,368 |

*Notes:* This table checks the sensitivity of the results to the crops comprising the sample. The first two columns repeat the baseline results, where the sample includes the sixteen crops for which there exist data on the foreign percentage of the total US seasonal labor. Crops are included in the data if they employed 4,000 or more person-months of foreign labor in 1964. In the next two columns, the sample is extended to include the ten greatest field crops (in terms of acreage, according to the 1964 agricultural census), and the foreign exposure of those crops is assumed to be equal to the foreign percentage of the group "Hay and Grain". The sample in columns (5) and (6) includes the baseline sixteen crops and additional ten crops for which data on the percentage of foreign workers in 1962 in California is available. The last two columns include all thirty-six crops together. All specifications include crop and year fixed effects. Robust standard errors are shown in parentheses.

**Table A8:** 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*** |
| | (0.543) | (0.532) | (0.525) | (0.523) | (0.519) | (0.516) | (0.513) | (0.511) | (0.508) | (0.502) | (0.502) |
| 1953 | 3.001*** | 2.975*** | 2.939*** | 2.983*** | 2.926*** | 2.929*** | 2.866*** | 2.801*** | 2.750*** | 2.737*** | 2.752*** |
| | (0.531) | (0.520) | (0.513) | (0.512) | (0.508) | (0.504) | (0.502) | (0.499) | (0.497) | (0.491) | (0.492) |

*Notes:* This table checks the sensitivity of the results to the period of the analysis. Every cell in the table reports the Poisson quasi-maximum likelihood estimator of $\beta$ in the equation $ln\left[\mathbb{E}(Innovation_{it}|X_{it})\right] = \beta \cdot ForeignShare_i \cdot post_t + \gamma_i + \delta_t$ where the analysis sample begins at one of the years 1943-1953 and end in one of the years 1980-1990. $Innovation_{it}$ is the number of US patents in crop $i$ and year $t$, and the other variables are as explained above. Robust standard errors are shown in parentheses.

**Table A9:** Effects of Bracero Exclusion on Agricultural Invention, Robustness to the Econometric Model

| | Poisson | | Negative binomial | | Zero-inflated Poisson | | OLS | |
|---|---|---|---|---|---|---|---|---|
| | (1) Patents | (2) Citations | (3) Patents | (4) Citations | (5) Patents | (6) Citations | (7) Log(patents) | (8) Log(citations) |
| Foreign share × post | 3.258*** | 2.271*** | 2.230*** | 1.978*** | 2.938*** | 1.808*** | 1.453*** | 1.985*** |
| | (0.474) | (0.497) | (0.449) | (0.596) | (0.463) | (0.424) | (0.365) | (0.550) |
| Mean patents/citations before 1965 | 4.06 | 23.90 | 4.06 | 23.90 | 4.06 | 23.90 | 6.20 | 36.52 |
| Year FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Crop FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| N (crops × years) | 608 | 608 | 608 | 608 | 608 | 608 | 446 | 446 |

*Notes:* This table checks the sensitivity of the results to the econometric model in use. The dependent variable is the number of patents in odd columns and the number of citations in even columns. The first two columns repeat the baseline results of the Poisson quasi-maximum likelihood model. Columns (3) and (4) report the results of the negative binomial model. The next two columns show the estimates of a zero-inflated Poisson model where the equation that determines the observed count is zero is logit with the same covariates as the main estimation equation. The last two columns are the results of an OLS model, where the dependent variable is the natural log of patents or citations, and crop-year pairs with zero patents/citations are not included in the regression. All specifications include crop and year fixed effects. Robust standard errors are shown in parentheses.

**Table A10:** Effects of Bracero Exclusion on Invention: Controlling for Linear Pretrends

| | Baseline | | Linear pretrends | |
|---|---|---|---|---|
| | (1) Patents | (2) Citations | (3) Patents | (4) Citations |
| Foreign share × post | 3.258*** | 2.271*** | 4.856*** | 4.547*** |
| | (0.474) | (0.497) | (0.944) | (1.052) |
| Mean patents/citations before 1965 | 4.06 | 23.90 | 4.06 | 23.90 |
| Year FE | Yes | Yes | Yes | Yes |
| Crop FE | Yes | Yes | Yes | Yes |
| Crop-specific linear pre-trends | No | No | Yes | Yes |
| N (crops × years) | 608 | 608 | 608 | 608 |

*Notes:* Poisson quasi-maximum likelihood estimators of the Difference-in-differences model with continuous treatment. The regressions reported in columns 3-4 include crop-specific linear pre-trends: $ln\left[\mathbb{E}(Innovation_{it}|X_{it})\right] = \beta \cdot ForeignShare_i \cdot post_t + \eta_i \cdot t \cdot (1 - post_t) + \gamma_i + \delta_t$. Robust standard errors are shown in parentheses.

**Table A11:** Correlation Matrix

| | Foreign share | Value/ labor | Acreage/ labor | Value/ acreage | Value | Labor | Acreage |
|---|---|---|---|---|---|---|---|
| Foreign share | 1.000 | | | | | | |
| Value/ labor | -0.102 | 1.000 | | | | | |
| | (0.729) | | | | | | |
| Acreage/ labor | -0.304 | 0.459 | 1.000 | | | | |
| | (0.291) | (0.115) | | | | | |
| Value/ acreage | 0.303 | 0.087 | -0.628 | 1.000 | | | |
| | (0.314) | (0.777) | (0.022) | | | | |
| Value | -0.450 | 0.378 | 0.573 | -0.149 | 1.000 | | |
| | (0.106) | (0.182) | (0.041) | (0.626) | | | |
| Labor | -0.415 | 0.193 | 0.526 | -0.176 | 0.976 | 1.000 | |
| | (0.110) | (0.509) | (0.053) | (0.566) | (0.000) | | |
| Acreage | -0.344 | 0.199 | 0.688 | -0.286 | 0.908 | 0.934 | 1.000 |
| | (0.228) | (0.516) | (0.007) | (0.343) | (0.000) | (0.000) | |

*Notes:* Pairwise correlation between the variables. Observations are crops ($N = 16$). %Foreign is the share of foreign seasonal workers in the total seasonal labor in 1964. Seasonal labor in 1964 in person-months units. Average acreage in 1948-1964 in acres. Average value of production in 1948-1964 in 1980 dollars. P-values in parentheses.

**Table A12:** First Stage: Regressions of the Exposure to the Bracero Program on Instruments

| | Foreign percentage × post | | |
|---|---|---|---|
| | (1) | (2) | (3) |
| Log Av. distance from Mexico × post | -0.099*** | | -0.016 |
| | (0.012) | | (0.023) |
| Av. Mexican population percentage × post | | 1.375*** | 1.246*** |
| | | (0.141) | (0.281) |
| Year FE | Yes | Yes | Yes |
| Crop FE | Yes | Yes | Yes |
| F-statistic on instrument(s) | 66.67 | 119.74 | 60.03 |
| N (crops × years) | 608 | 608 | 608 |

*Notes:* This table reports the coefficients on the instruments from OLS regressions of the treatment variable $ForeignShare_i \cdot post_t$ on the instrument $z_i \cdot post_t$, where $z_i$ is either the log average distance from Mexico, or the average percentage of the Mexican population in 1940 of the counties growing the crops (or both). The average distance from Mexico of a crop $i$ is measured by $d_i = \sum_c d_c w_{ic}$ where $d_c$ is the minimal distance between the Mexican border and the centroid of county $c$, and $w_{ic}$ is the percent of acreage of crop $i$ in county $c$ out of the total acreage of crop $i$. The average Mexican population of a crop is calculated in a similar way using data from the 1940 US population census. All specifications include crop and year fixed effects. Robust standard errors are shown in parentheses. Last row reports the Cragg-Donald Wald F-statistic.

**Table A13:** Similarity Matrix

| Crop | Apples | Aspara | Beans | Celery | Citrus | Cotton | Cucumb | Grapes | Lettuc | Melons | Potato | Strawb | Sugarb | Sugarc | Tobacc | Tomato |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Apples | 0 | 1 | 2 | 0 | 58 | 3 | 1 | 11 | 1 | 1 | 7 | 3 | 2 | 0 | 2 | 8 |
| Asparagus | 8 | 0 | 0 | 17 | 0 | 0 | 0 | 8 | 25 | 0 | 8 | 0 | 8 | 0 | 0 | 25 |
| Beans | 3 | 0 | 0 | 3 | 3 | 25 | 7 | 14 | 3 | 2 | 7 | 3 | 3 | 2 | 7 | 17 |
| Celery | 0 | 10 | 10 | 0 | 0 | 0 | 10 | 0 | 25 | 0 | 10 | 0 | 0 | 0 | 10 | 25 |
| Citrus | 63 | 0 | 2 | 0 | 0 | 5 | 4 | 9 | 1 | 1 | 7 | 2 | 1 | 0 | 0 | 6 |
| Cotton | 7 | 0 | 25 | 0 | 8 | 0 | 3 | 3 | 2 | 5 | 10 | 8 | 7 | 2 | 12 | 7 |
| Cucumbers | 1 | 0 | 6 | 3 | 6 | 3 | 0 | 6 | 6 | 7 | 15 | 8 | 1 | 0 | 7 | 31 |
| Grapes | 24 | 2 | 15 | 0 | 19 | 4 | 7 | 0 | 4 | 2 | 7 | 4 | 0 | 0 | 2 | 11 |
| Lettuce | 3 | 9 | 6 | 14 | 3 | 3 | 11 | 6 | 0 | 6 | 9 | 6 | 0 | 0 | 0 | 26 |
| Melons | 4 | 0 | 4 | 0 | 4 | 12 | 19 | 4 | 8 | 0 | 4 | 0 | 0 | 0 | 4 | 38 |
| Potatoes | 7 | 1 | 3 | 2 | 6 | 5 | 9 | 3 | 2 | 1 | 0 | 7 | 24 | 1 | 5 | 26 |
| Strawberries | 10 | 0 | 5 | 0 | 5 | 13 | 15 | 5 | 5 | 0 | 20 | 0 | 3 | 0 | 5 | 15 |
| Sugarbeets | 4 | 2 | 4 | 0 | 2 | 9 | 2 | 0 | 0 | 0 | 64 | 2 | 0 | 4 | 2 | 2 |
| Sugarcane | 0 | 0 | 14 | 0 | 0 | 14 | 0 | 0 | 0 | 0 | 14 | 0 | 29 | 0 | 29 | 0 |
| Tobacco | 5 | 0 | 10 | 5 | 0 | 17 | 12 | 2 | 0 | 2 | 15 | 5 | 2 | 5 | 0 | 20 |
| Tomatoes | 7 | 2 | 8 | 4 | 5 | 3 | 17 | 5 | 7 | 8 | 24 | 5 | 1 | 0 | 6 | 0 |

*Notes:* The similarity between two crops is measured by the number of patents in the sample that mention both crops. The weights are normalized such that each row sums to one hundred.

**Table A14:** Plant-Agricultural Subclasses in the CPC Classification System: Definition of the Subclass, Number of Crop-Specific Patents and Labor Requirements

| Subclass | Definition | Patents | | | Labor share | |
|---|---|---|---|---|---|---|
| | | 1948-64 | 1965-85 | Total | mean | sd |
| B | Soil Working In Agriculture Or Forestry; Parts, Details, Or Accessories Of Agricultural Machines Or Implements, In General | 204 | 195 | 399 | 0.15 | 0.14 |
| C | Planting; Sowing; Fertilising | 192 | 288 | 480 | 0.04 | 0.07 |
| D | Harvesting; Mowing | 981 | 936 | 1,917 | 0.50 | 0.25 |
| F | Processing Of Harvested Produce; Hay Or Straw Presses; Devices For Storing Agricultural Or Horticultural Produce | 50 | 77 | 127 | 0.03 | 0.06 |
| G | Horticulture; Cultivation Of Vegetables, Flowers, Rice, Fruit, Vines, Hops Or Seaweed; Forestry; Watering | 198 | 581 | 779 | 0.26 | 0.15 |
| N | 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 | 3 | 38 | 41 | 0.02 | 0.01 |

*Notes:* The table shows the definition and summary statistics for the six subclasses of the A01 class (Agriculture) in the Cooperative Patent Classification (CPC), which are related to plants. Columns (3)-(5) show the number of US patents belonging to each subclass that mention one of the crops in the extended sample (Baseline + California) in 1948-1964,1965-1985, and 1948-1985, respectively. The sixth column reports the share of hours of labor related to each subclass required to produce an acre of a crop, averaged over eighteen crops for which there exist information on both the seasonal foreign labor share and labor requirements in California in 1960. The last column reports the standard deviation of those averages.

**Table A15:** Task Classification

| Task | Class | Task | Class | Task | Class |
|---|---|---|---|---|---|
| baling | D | harvest | D | planting cover crops | C |
| banking out | D | harvest labor | D | plowing | B |
| bird control | G | harvesting | D | post-harvest cleanup | B |
| blight cutting | G | hauling | D | post-harvest mite control | N |
| brush disposal | B | hauling out | D | pre-irrigation | G |
| brush removal | B | hauling seed | D | preparing ground for harvest | B |
| brush shredding | B | hauling to market | D | propping | G |
| checking | G | hauling to mill | D | pruning | G |
| chiseling | B | hoeing | B | racking | D |
| chopping fern | B | housing | D | raking | D |
| combining | D | hulling | F | removing | C |
| cover crop | G | hulling boxes | F | renovation | B |
| cultivating | G | insecticide application | N | ridging | B |
| cultivation | G | inspection | D | rodent control | N |
| cultural labor | G | irrigating | G | rolling | B |
| cutting | D | irrigation | G | rolling beds | B |
| cutting (seed) | C | irrigation preparation | G | scratching | G |
| defoliate air application | N | knocking | D | seeding | C |
| digging | D | land planing | B | shaking | D |
| digging around trees | G | land preparation | B | shping beds | B |
| disease control | N | leveling | B | sledding operation | D |
| disease prevention | N | linstalling flumes | G | splitting ridges | B |
| disking | B | list | B | spraying | N |
| distributing | D | listing beds | B | subsoiling | B |
| ditching | B | loading | D | subsoilingiling | B |
| draining | G | lrrigating | G | supervision | D |
| dusting | N | maintaining checks | G | survey for leveling | B |
| dusting or spraying | N | manure application | C | surveying | G |
| fertilizing | C | mechanical harvesting | D | thinning | B |
| field hauling | D | mowing | D | threshing | F |
| floating | G | mulching beds | G | tillage | B |
| flooding | G | packing | D | turning vines | G |
| frost protection | G | pest | N | tying | G |
| furrowing | B | pest control | N | weed control | N |
| furrowing out | B | picking | D | weeding | B |
| girdling | G | planting | C | | |
| harrowing | B | planting cover crop | C | | |

*Notes:* The table lists all task descriptions that appear in the labor requirement data (State of California 1963), and the technological subclass (of the CPC Agriculture class A01) I assigned the task to (see Table A14 for the definition the subclasses). If a task description combines multiple tasks (e.g. "cultivating and fertilizing"), I classify it according to (and report in this table only) the first task.

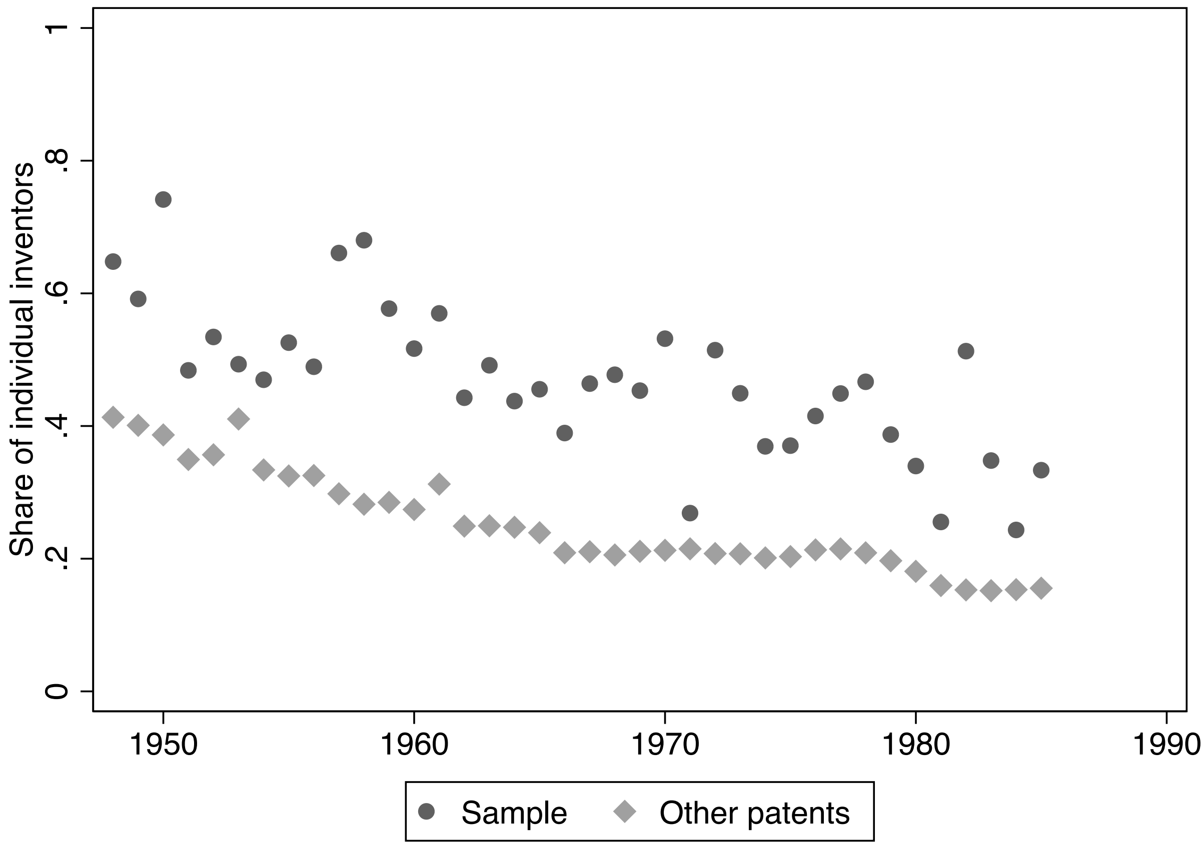


**Figure A1:** Share of Patents by Individual Inventors by Year

*Notes:* This figure shows the share of patents by individual inventors for the years 1948-1985. Patents are classified as invented by individual inventors if one of the inventors is also the patent's assignee. The sample consists of USPTO patents in the CPC "harvesting and mowing" subclass that mention one of the 16 crops (see text for details). Other patents include all other USPTO patents.

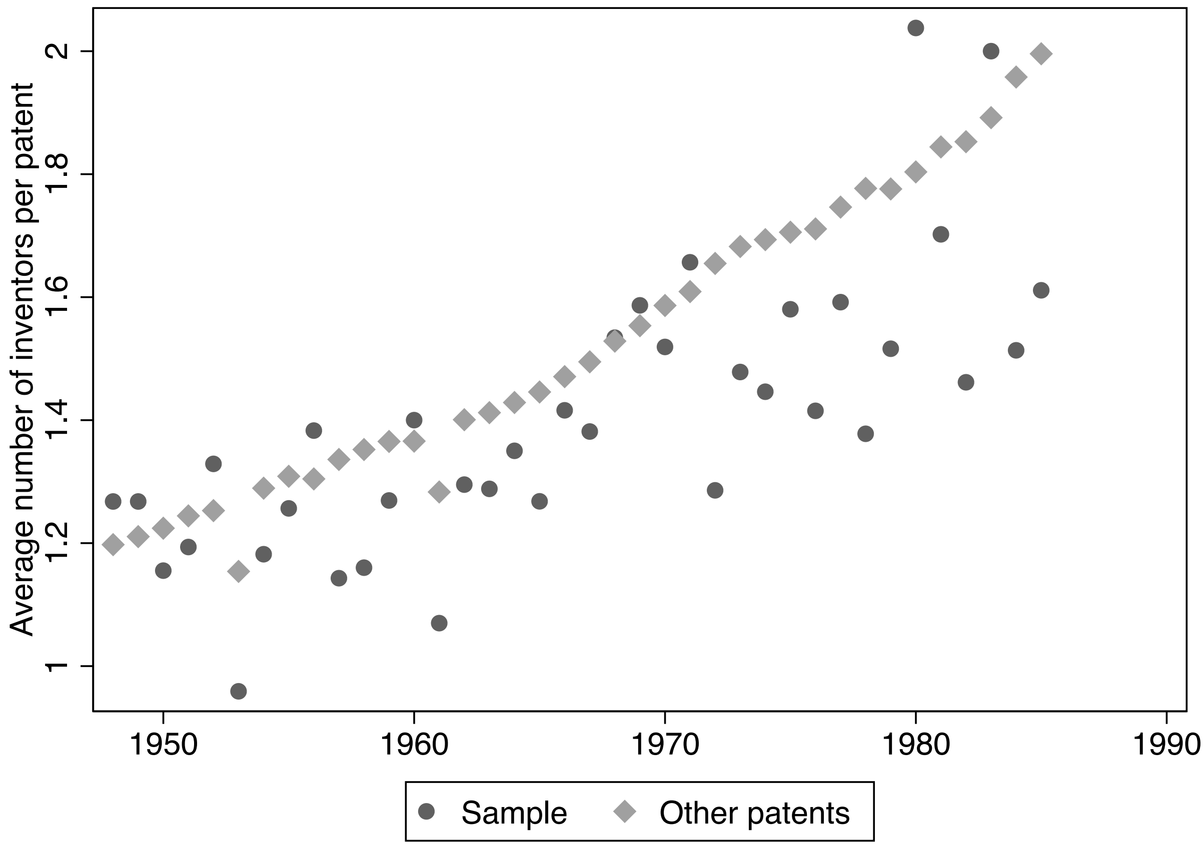


**Figure A2:** Average Number of Inventors per Patent by Year

*Notes:* This figure shows the average number of inventors per patent for the years 1948-1985. The sample consists of USPTO patents in the CPC "harvesting and mowing" subclass that mention one of the 16 crops (see text for details). Other patents include all other USPTO patents.

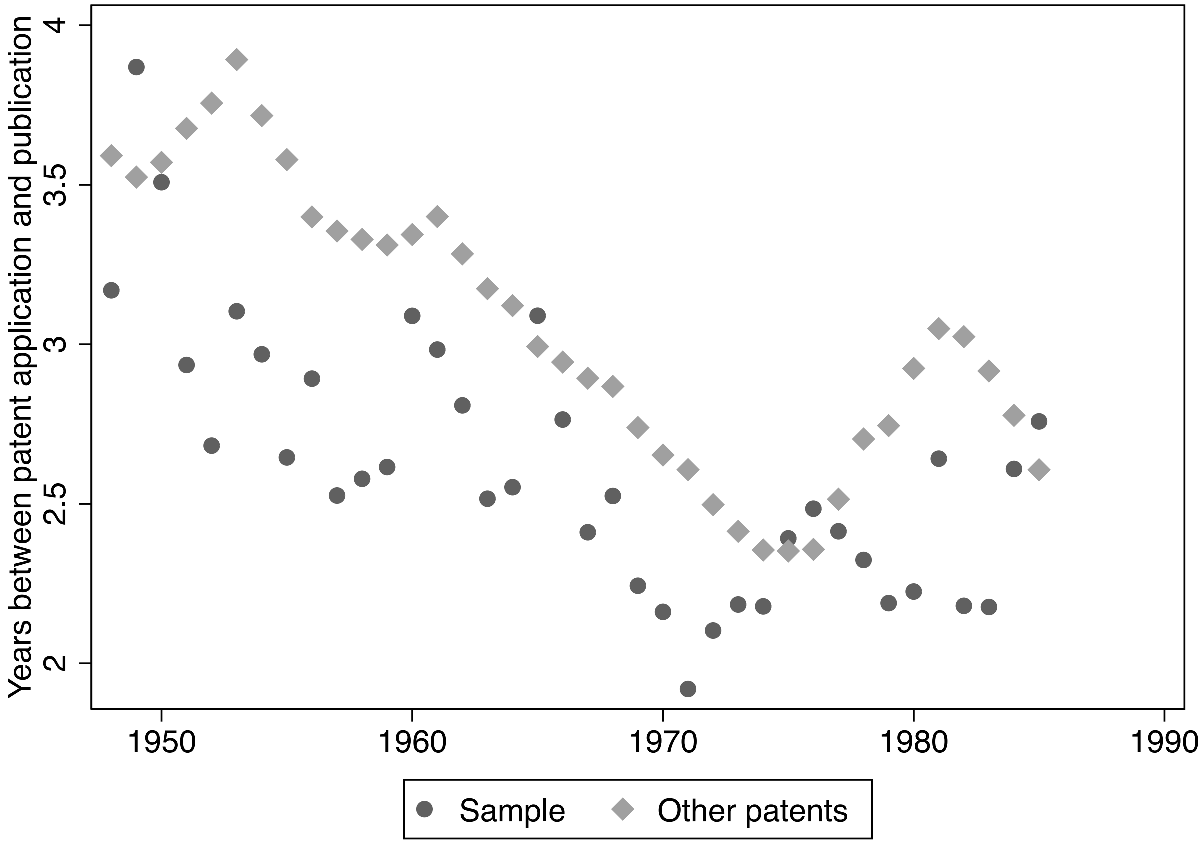


**Figure A3:** Years Between Patent Application and Publication by Year

*Notes:* This figure shows the average number of years between patent application and publication for the years 1948-1985. The sample consists of USPTO patents in the CPC "harvesting and mowing" subclass that mention one of the 16 crops (see text for details). Other patents include all other USPTO patents.

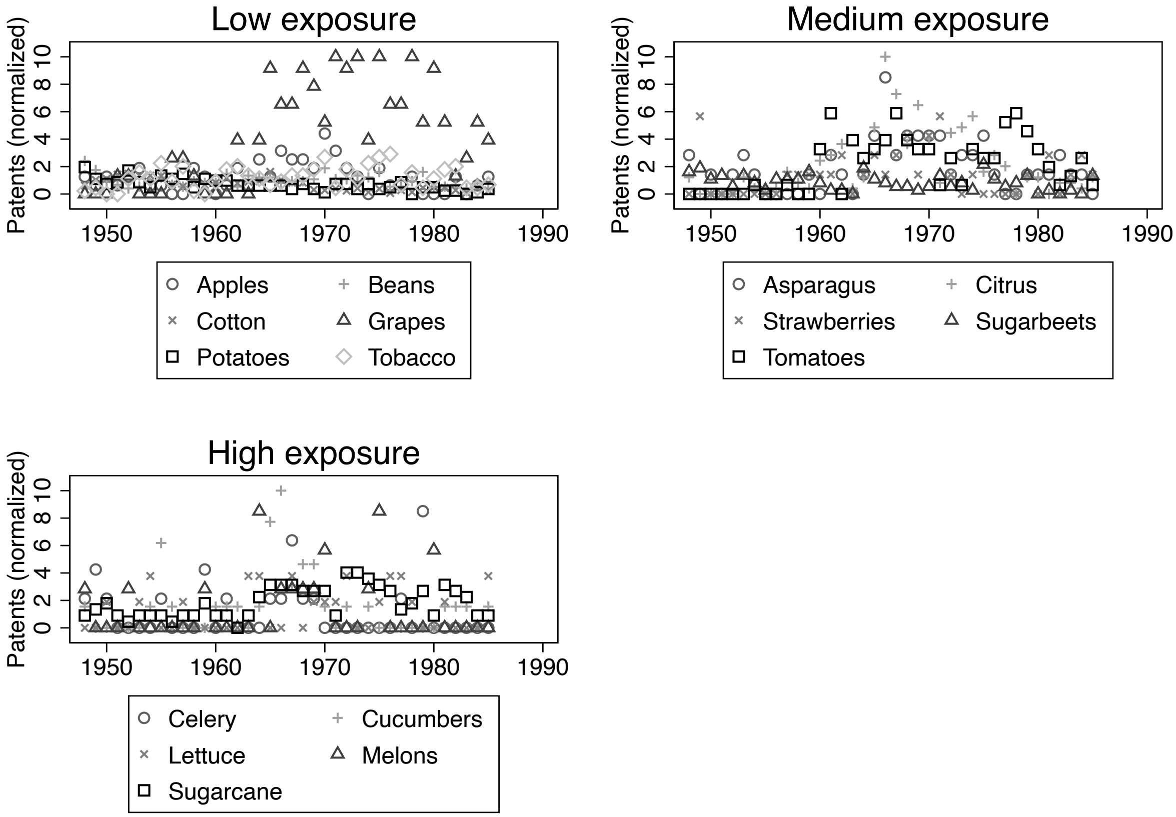


**Figure A4:** Invention over Time by Crop

*Notes:* Low exposure: six crops with at most 3.8 percent of foreign workers. Medium exposure: five crops with between 3.8-26.2 percent foreigners. High exposure: five crops with at least 26.2 percent foreigners. The normalized patents measure is the number of patents divided by the crop's pre-period (1948-1964) average number of patents per year. Observations with (normalized) patent values higher than ten are replaced with ten.

# B Models

This appendix constructs a theoretical framework to capture the opposing effects of labor supply on technological change. I explicitly introduce two types of technologies. The first is labor-augmenting machines that increase the production for every level of labor (Acemoglu 1998). The second type is labor-saving technologies in the spirit of Zeira (1998).[32] I show that an increase in the labor supply encourages the creation of new labor-augmenting technologies but discourages the creation of new labor-saving technologies. Summing up the effects on the two different types of technology, the overall effect of labor supply on technological progress is theoretically unclear.

## B.1 Labor-Augmenting Improvements

Following Acemoglu (1998, 2002), the production function of a representative competitive firm is:

$$Y = AL^{\beta} \tag{B1}$$

where:

$$A = \int_0^1 q_A(a) x_A(a)^{\alpha} da \quad , \quad q_A(a) \in \{0,1\} \quad , \quad \alpha, \beta > 0 \quad , \quad \alpha + \beta < 1 \tag{B2}$$

The output produced from labor input $L$, assumed to be supplied inelastically, and labor-augmenting machines $\{x_A(a)\}$. The technology level is determined by the set of technologies available, $\{q_A(a)\}$.

Technology products are supplied by technology monopolists. Each monopolist sets a rental price $p_A(a)$ for the technology it supplies to the market. Following Alesina et al. (2018), I assume that the invention cost of technology $a$ increases with $a$:

$$K_A(a) = g_A(a) \quad , \quad g'_A(a) > 0 \tag{B3}$$

For simplicity, I also assume that the cost function is continuous and satisfies the Inada conditions $g_A(0) \to 0$ and $g_A(1) \to \infty$. After the invention of the machine, the inventor has full rights on that technology. The marginal cost of producing one machine unit is $\psi_A$.

[32] In a recent paper, Acemoglu and Restrepo (2018) model the invention of new tasks, besides labor-saving inventions. Note, however, that new task inventions in their model are similar to labor-augmenting inventions, as they effectively increase the productivity of manual labor. More precisely, the invention of a new task is equivalent to a positive labor-augmenting shock and a negative labor-saving shock, as the share of automated tasks decreases. One can think about the invention of new tasks as an example of labor-augmenting technology improvements.

***Definition of equilibrium:*** Given labor supply, $L$, marginal cost of machines production $\psi_A$, entry cost function $g_A(a)$, and the Cobb-Douglas parameters $\alpha$ and $\beta$, an equilibrium is defined by the wage rate $w$, machine prices $\{p_A(a)\}$, machine quantities $\{x_A(a)\}$, and the set of technologies available $\{q_A(a)\}$, such that:

1. Given the prices and the set of technologies available, $\{x_A(a)\}$ and $L$ maximize the producer's profits.

2. For each task $a \in [0,1]$ such that $q_A(a) = 1$, the machine price $p_A(a)$ maximizes the monopolist's gross profits.

3. Free entry condition: for each task $a \in [0,1]$, the monopolist chooses $q_A(a) = 1$ if and only if her net profits are positive.

The competitive producer chooses the quantity of machines of each type $\{x_A(a)\}$, and the quantity of the labor input $L$ in order to maximize profits:

$$\max_{\{x_A(a)\},L} \left( \int_0^1 q_A(a) x_A(a)^{\alpha} da \right) L^{\beta} - wL - \int_0^1 q_A(a) p_A(a) x_A(a) da \tag{B4}$$

where the wage rate $w$, the prices of the machines $\{p_A(a)\}$, and the set of machines available $\{q_A(a)\}$, are given. The price of the final good is normalized to 1.

From the producer's first order conditions, the demand for machines is:

$$x_A(a) = \left( \frac{p_A(a)}{\alpha} \right)^{-\frac{1}{1-\alpha}} L^{\frac{\beta}{1-\alpha}} \tag{B5}$$

and the demand for labor is:

$$L = w^{-\frac{1}{1-\beta}} (\beta A)^{\frac{1}{1-\beta}} \tag{B6}$$

The inventor is confronted by a two-stage problem: (1) whether to enter the market and pay the fixed cost required to develop the new technology; and (2) to choose the optimal monopolistic price. Starting with the second problem, given that the new technology is available, the inventor maximizes gross profits (not including the entry cost):

$$\max_{p_A(a)} \Pi_A(a) = (p_A(a) - \psi_A)\, x_A(a) \tag{B7}$$

where the demand function is given in (B5). The optimal monopolistic price is:

$$p_A(a) = \frac{\psi_A}{\alpha} \tag{B8}$$

and the corresponding gross profits are:

$$\Pi_A = \psi_A \left(\frac{1-\alpha}{\alpha}\right)\left(\frac{\psi_A}{\alpha^2}\right)^{\frac{-1}{1-\alpha}} L^{\frac{\beta}{1-\alpha}} \tag{B9}$$

which are independent of $a$: $\Pi_A(a) = \Pi_A$.

Returning to the inventor's first stage problem: the optimal gross profits are equal across all machine types, but the fixed cost is an increasing function of $a$.

the assumptions above about the entry cost function $g_A(a)$ guarantee the existence of a unique internal threshold $\bar{a} \in (0,1)$, such that the inventor has zero net profits:

$$g_A(\bar{a}) = \Pi_A(L) \tag{B10}$$

To see it, note that because $\beta \in (0,1)$, the gross profits $\Pi_A$ are positive for each combination of the parameters $\psi_A$, $\beta$, and $L$. Second, because $g_A(0) \to 0$, there exist $\epsilon > 0$ small enough such that $g_A(\epsilon) < \Pi_A$. Similarly, because $g_A(1) \to \infty$, there exist $\epsilon < \delta < 1$ close enough to 1 such that $g_A(\delta) > \Pi_A$. Finally, the monotonicity and continuity of $g_A(a)$ guarantee the existences of a unique $\bar{a} \in (0,1)$ such that $g_A(\bar{a}) = \Pi_A$.

Next, notice that an increase in the labor supply, $L$, increases the profits of each technology monopolist, and therefore the technology level, $\bar{a}$:

$$\frac{\partial \bar{a}}{\partial L} > 0 \tag{B11}$$

This is a pure Acemoglu (1998)'s market size effect: a larger market for the technology, namely more workers who use it, leads to more innovation.

Next, I examine what happens to the other equilibrium outcomes of the model, namely the number of machines ($x_A$), the TFP ($A$), the output($Y$), and the wage rate ($w$), when the labor supply is increasing. From equation B9, we have $\Pi_A = C_1 L^{\frac{\beta}{1-\alpha}}$ where $C_1$ is a constant term that depends only on the parameters $\psi_A$ and $\beta$. Because, $g_A(a)$ is monotonically increasing in $a$, we obtain: $\frac{\partial \bar{a}}{\partial L} > 0$.

From equation B5, the amount of machines is

$$x_A(a) = \left(\frac{\psi_A}{\alpha^2}\right)^{-\frac{1}{1-\alpha}} L^{\frac{\beta}{1-\alpha}} \equiv C_2 L^{\frac{\beta}{1-\alpha}} \tag{B12}$$

which increases with $L$. Substituting into equation B2, the TFP is

$$A = C_2 \bar{a} L^{\frac{\alpha\beta}{1-\alpha}} \tag{B13}$$

which is also an increasing function of $L$. So is the output $Y = A \cdot L^{\beta}$. The wage rate is now:

$$w = C_3 \bar{a} L^{-\frac{1-\alpha-\beta}{1-\alpha}}. \tag{B14}$$

Note that with an exogenous technology level $\bar{a}(L) = \bar{a}$, the wage rate is a decreasing function of $L$. This results from the decreasing return to scale production function, together with the constant price of machines. However, when the technology level $\bar{a}$ is endogenous, it increases when $L$ increases. This effect dampens the wage response to a change in the labor supply and might even change the sign of the effect.

## B.2 Labor-Saving Improvements

What happens when technology, rather than augmenting the production of each unit of labor, replaces human labor? In this section, I present a simple model with labor-saving technology progress in the spirit of Zeira (1998). The producer's technology is now:

$$Y = A \int_0^1 \left(e(l) + q_L(l) x_L(l)\right)^{\beta} dl \tag{B15}$$

where $\beta \in (0,1)$ and $q_L(l) \in \{0,1\}$.[33] Each task, $l$, can be done by manual labor $e(l)$. If a machine of this type exists, i.e., $q_L(l) = 1$, the task can also be done by labor-replacing machine $x_L(l)$. Manual labor, $L$, is again assumed to be supplied inelastically. The cost of inventing technology $l$ is:

$$K_L(l) = g_L(l) \quad , \quad g_L'(l) > 0, \tag{B16}$$

where $g_L(l)$ is continuous and satisfies the Inada conditions $g_L(0) \to 0$ and $g_L(1) \to \infty$. The

[33] Qualitative similar results obtained when $A = \int_0^1 q_A(a) x_A(a)^{\alpha} da, \alpha + \beta < 1$, and $q_A(a) \in \{0,1\}$ is given exogenously. For simplicity, I show the results of a model with a fixed $A$.

marginal cost of producing one machine unit is $\psi_L$.

***Definition of equilibrium:*** Given the labor supply, $L$, marginal cost of machines production $\psi_L$, entry cost function $g_L(l)$, and the Cobb-Douglas parameter $\beta$, an equilibrium is defined by the wage rate $w$, machine prices $\{p_L(l)\}$, manual labor demand $\{e(l)\}$, machine quantities $\{x_L(l)\}$, and the set of technologies available $\{q_L(l)\}$, such that:

1. Given the prices and the set of technologies available, $\{x_L(l)\}$ and $\{e(l)\}$ maximize the producer's profits.
2. For each task $l \in [0,1]$ such that $q_L(l) = 1$, the machine price $p_L(l)$ maximizes the monopolist's gross profits.
3. Free entry condition: for each task $l \in [0,1]$, the monopolist chooses $q_L(l) = 1$ if and only if her net profits are positive.
4. The labor market clears: $\int_0^1 e(l)dl = L$

The producer chooses the quantity of machines of each type $\{x_L(l)\}$, and the quantity labor for each task $\{e(l)\}$ to maximize profits:

$$\max_{\{x_L(l)\},\{e(l)\}} A\left[\int_0^1 q_L(l)x_L(l)^\beta dl + \int_0^1 e(l)^\beta dl\right] - \int_0^1 p_L(l)x_L(l)dl - w\int_0^1 e(l)dl \tag{B17}$$

where the uniform wage rate $w$, the prices of the machines $\{p_L(l)\}$, and the set of machines available $\{q_L(l)\}$, are given. Because of the perfect substitution between manual labor and machines, if a machine of type $l$ is available, the producer will use only the cheaper factor. Moreover, if no one buys the machine in equilibrium, the machine will not be invented as it is costly to invent it. For simplicity, I assume that if the producer is indifferent between hiring manual labor or machines, she will choose to employ only machines. Taking together, there is a threshold $\bar{l}$ such that tasks $l \leq \bar{l}$ are produced by machines, and tasks $l > \bar{l}$ are produced by labor. From the first-order conditions, the demand for machines is:

$$x_L(l) = p_L(l)^{-\frac{1}{1-\beta}}(\beta A)^{\frac{1}{1-\beta}}, \tag{B18}$$

and the demand for labor is:

$$e(l) = w^{-\frac{1}{1-\beta}}(\beta A)^{\frac{1}{1-\beta}}. \tag{B19}$$

Given that a machine $l$ exists, the monopolist inventor sets the price to maximize gross profits:

$$\Pi_L(l) = (p_L(l) - \psi_L)\, p_L(l)^{-\frac{1}{1-\beta}} (\beta A)^{\frac{1}{1-\beta}}. \tag{B20}$$

Taking the first order condition with respect to the price, the optimal price is $p_A(a) = p_A = \frac{\psi_A}{1-\beta}$. However, where $w < \frac{\psi_A}{1-\beta}$, because machines and labor are perfect substitutes, if the monopolistic charged this price, the producers would choose to produce with labor and to pay a lower price. Therefore, the monopolistic price is:

$$p_L(l) = min(\frac{\psi_L}{\beta}, w). \tag{B21}$$

Additionally, if $w < \psi_L$, the producers would lose from the production of every machine (even without the entry cost), and therefore will choose not to produce (even if the technology already exists).

We can distinguish between three cases: 1) $w \geq \frac{\psi_L}{\beta}$, 2) $\psi_L \leq w \leq \frac{\psi_L}{\beta}$, and 3) $w \leq \psi_L$.

**Case 1:** $w \geq \frac{\psi_L}{\beta}$. In this range, the price of the machines does not depend on $l$ or $L$. The gross profits $\Pi_L^* = \left(\frac{\psi_L}{\beta} - \psi_L\right)\left(\frac{\psi_L}{\beta}\right)^{-\frac{1}{1-\beta}} (\beta A)^{\frac{1}{1-\beta}}$ are fixed and positive. Because of the continuity and monotonicity of $g_L(l)$ and the Inada conditions, a unique equilibrium technology level exists that satisfies $\bar{l} \in (0,1)$. This technology level is independent of $L$: $\frac{\partial \bar{l}}{\partial L} = 0$.

**Case 2:** $\psi_L \leq w \leq \frac{\psi_L}{\beta}$. In this case $p_L = w$. The technological level $\bar{l}$ is determined such that the marginal inventor has zero net profits:

$$g_L(\bar{l}) = \Pi_L = (w - \psi_L) \cdot (\beta A)^{\frac{1}{1-\beta}} w^{-\frac{1}{1-\beta}}. \tag{B22}$$

An increase in the wage rate increases the maximal price the inventors can charge for the machines, and because this price is bellow the optimal unrestricted price, $w < \frac{\psi_L}{\beta}$, this increases the profits of all inventors, hence the technology level. Now, because $g_L(l)$ is continuous, monotonically increasing in $l$, and satisfies the Inada conditions, for each level of $\Pi_L \geq 0$ a unique $\bar{l} \in [0,1)$ exists such that $g_L(\bar{l}) = \Pi_L$ and $\frac{\partial \bar{l}}{\partial \Pi_L} > 0$. Hence, we can write $w = h(\bar{l})$ such that $h'(\bar{l}) > 0$. Using the simplifying assumption that if a producer is indifferent between manual labor and machines she will use machines only, together with the uniform wage rate and the decreasing return to scale in each task ($\beta < 1$), we obtain $e(l) = \frac{L}{1-\bar{l}}$. Substituting into equation B19, we obtain:

$$L = \left(\frac{h(\bar{l})}{\beta A}\right)^{-\frac{1}{1-\beta}} (1 - \bar{l}) \tag{B23}$$

Differentiating $L$ with respect to $\bar{l}$, we get:

$$\frac{\partial L}{\partial \bar{l}} = -\left(\frac{h(\bar{l})}{\beta A}\right)^{-\frac{1}{1-\beta}} - \frac{h'(\bar{l})}{\beta A(1-\beta)}\left(\frac{h(\bar{l})}{\beta A}\right)^{\frac{\beta-2}{1-\beta}}. \tag{B24}$$

Because $h(\bar{l}) > 0$ and $h'(\bar{l}) > 0$, both terms are negative, so we have $\frac{\partial L}{\partial \bar{l}} < 0$ and hence $\frac{\partial \bar{l}}{\partial L} < 0$. Finally, $\frac{\partial w}{\partial L} = \frac{\partial h(\bar{l})}{\partial L} = \frac{\partial h(\bar{l})}{\partial \bar{l}}\frac{\partial \bar{l}}{\partial L} < 0$

**Case 3:** $w < \psi_L$. In this case, the gross profits of the inventor are negative for every positive amount of production. Hence, there is no reason to pay the fixed cost of the invention, and no machine is invented ($\bar{l} = 0$). Changes in the labor supply in this range do not affect the technology level $\frac{\partial \bar{l}}{\partial L} = 0$.

In what follows, I show that we can divide the parameters space into three disjoint groups that correspond to the three cases. First, note that in all three cases $\frac{\partial w}{\partial L} < 0$. I have already demonstrated this for case 2. For cases 1 and 3, it can be seen from the producer's F.O.C:

$$w = \beta A\left(\frac{L}{1-\bar{l}}\right)^{\beta-1}, \tag{B25}$$

and the fact that $\frac{\partial \bar{l}}{\partial L} = 0$.

***Claim:*** For each set of parameters $L$, $\psi_L$, $\beta$, and entry cost function $g_L(l)$, there exist a unique equilibrium $(w, p_L, x_L, e.\bar{l})$. Moreover, let $\bar{L} = \left(\frac{\psi_L}{\beta A}\right)^{-\frac{1}{1-\beta}}$ and $\underline{L} = \left(\frac{\psi_L}{\beta^2 A}\right)^{-\frac{1}{1-\beta}}\left(1 - g_L^{-1}(\Pi_L^*)\right)$, then:

1. $w \geq \frac{\psi_L}{\beta} \iff L \leq \underline{L}$.
2. $\psi_L \leq w \leq \frac{\psi_L}{\beta} \iff \underline{L} \geq L \geq \bar{L}$.
3. $w \leq \psi_L \iff L \geq \bar{L}$.

***Proof:*** Assume $w \geq \frac{\psi_L}{\beta}$ and let $L = \underline{L}$. Because we are at the range of case 1, $\Pi_L = \Pi_L^*$ and therefore $\bar{l} = g_L^{-1}(\Pi_L^*)$. From equation B25 we obtain $w = \frac{\psi_L}{\beta}$, so we can verify that indeed $w \geq \frac{\psi_L}{\beta}$. Now, assume that $L < \underline{L}$. Because $w$ is strictly decreasing in $L$, we have $w > w(\underline{L}) = \frac{\psi_L}{\beta}$. On the other hand, for $L < \underline{L}$ we have $w < \frac{\psi_L}{\beta}$. Therefore, a solution of the type $w \geq \frac{\psi_L}{\beta}$ exists only if $L \leq \underline{L}$, and exists and is unique if $L \leq \underline{L}$.

Now, consider a solution of the type $w \leq \psi_L$. In this case $\bar{l} = 0$ and $w = \beta A L^{\beta-1}$. For $L = \bar{L}$, we have $w = \psi_L$. Because $w$ is strictly decreasing in $L$, a solution of this type exists if only if $L \geq \bar{L}$ and is unique if $L \geq \bar{L}$.

Finally, consider the case of $\psi_L \leq w \leq \frac{\psi_L}{\beta}$. If $L = \bar{L}$, $w = \psi_L$ and $\bar{l} = 0$ solve the system of equations B22 and B25. Similarly, If $L = \underline{L}$, the unique solution is $w = \frac{\psi_L}{\beta}$ and $\bar{l} = g_L^{-1}(\Pi_L^*)$.

Again, because $w$ is strictly decreasing in $L$, a solution of this type exists if only if $\underline{L} \geq L \geq \bar{L}$ and is unique if $\underline{L} \geq L \geq \bar{L}$.

Notice that for each of the three ranges of $w$, a solution exists only if $L$ satisfies the corresponding parametric condition; therefore, there cannot be more than one equilibrium for a given set of parameters. □

Intuitively, when labor supply is very high, wages are low, so the marginal cost of producing each machine is higher than its potential price, bound above by the wage rate; therefore, no technology is invented. On the other hand, when the labor supply is very low, the optimal monopolistic price of the machines is lower than the wage rate. In this range, the gross profits of the inventors, hence the technological level, are constant and do not react to shifts in the labor supply.

When labor supply is not very high or very low, an exogenous increase in the labor supply decreases the wage rate and therefore decreases the technology level, $\bar{l}$:

$$\frac{\partial \bar{l}}{\partial L} < 0. \tag{B26}$$

This is Hicks (1932)'s substitution effect. When the labor supply is higher, wages are lower; therefore, the potential saving from each new machine is lower. In this case, fewer labor-saving technologies will be developed.

I have already shown that the technology level $\bar{l}$ does not depend on the labor supply when $L \leq \underline{L}$ and $L \geq \bar{L}$, and is decreasing in $L$ otherwise. I have also shown that $w$ is decreasing in $L$ in all regions. Next, I turn to explore what happens to the other elements of the model.

**Case 1:** In this region, the technology level and the monopolistic price of the machines are constant in $L$; therefore the quantity of machines $x_L(l)$ is also constant for each $l \leq \bar{l}$ (denote it by $x_L(l) = x^*$). The output in this case is $Y = A\left[\bar{l}x^{*\beta} + (1-\bar{l})\left(\frac{L}{1-\bar{l}}\right)^{\beta}\right]$ which increases in $L$.

**Case 2:** In this case we have $w = p_L(l)$ and $e(l) = x(l)$. As $w = \beta A e(l)^{\beta-1}$ and $\frac{\partial w}{\partial L} < 0$ , we know that $\frac{\partial e(l)}{\partial L} = \frac{\partial x(l)}{\partial L} > 0$. The output is $Y = Ae(l)^{\beta}$, increases in $L$.

**Case 3:** In this case we have $w = \beta A L^{\beta-1}$ and $e(l) = L$. There are no machines. The output is $Y = AL^{\beta}$, increases in $L$.

# C Data Appendix

## C.1 US Patents

I collected patent data from Google Patents for successful applications for patents between 1940-1990. The data include the full text of the patent (title, abstract, claims, and description) as well as patent identification numbers, number of citations, CPC classification, and application and publication (issue) years. I used the application, rather than publication year, to define the timing of the invention because the application date is closer to the date of the invention. Publication dates are typically delayed by several years. I proxy the application date for patents with missing application dates by subtracting the median lag between application and publication dates (2.6 years) from the publication date.

## C.2 Crop-level information

Total and foreign seasonal labor by crop for the years 1964-1965 was collected from (Bureau of Employment Security 1966, Table 5, p. 11). Total and foreign seasonal labor by crop at the date of peak foreign employment was collected from (Bureau of Employment Security 1966, Table 21, p. 48). Information for the total and Mexican seasonal labor in California for the additional ten crops was collected from (University of California 1963, Table 5, p. 17)

To construct the labor-intensity measures, I collected data on labor requirements per acre (in terms of hours and cost of labor) by task and crop in California in 1960 from the State of California's "Report and Recommendations of the Agricultural Labor Commission" (State of California 1963). This data includes information on person-hours and labor cost per acre for the various tasks required for the production process for California's 25 most valuable crops in 1960. I manually classified each task into one of the six agricultural CPC subclasses. See the definition of these subclasses in Table A14. I classify it according to the first task if a task description combines multiple tasks (e.g., "cultivating and fertilizing"). Table A15 reports the classification of all tasks.

Production, acreage, and value by crop for the years 1940-1990 were collected from various publications of the Department of Agriculture (see Table C1). Crops' values were adjusted to 1980 dollars using the CPI-U (Bureau of Labor Statistics 2018).

**Table C1:** Sources of data on acreage, production, and value by crop

| Crop | Acreage | Production | Value (current prices) |
|---|---|---|---|
| Sugarbeets | NASS (40-90) | NASS (40-90) | NASS (40-90) |
| Sugarcane | NASS (40-90) | NASS (40-90) | NASS (78-90) |
| Bean | NASS (40-90) | NASS (40-90) | NASS (40-90) |
| Cotton | NASS (40-90) | NASS (40-90) | NASS (40-90) |
| Tobacco | NASS (40-90) | NASS (40-90) | NASS (40-90) |
| Grapes | NASS (47-90) | NASS (44-90) | NASS (44-90) |
| Potatoes | NASS (40-90) | NASS (40-90) | NASS (40-90) |
| Tomatoes | RE (40-59), ERS (60-90) | RE (40-59), ERS (60-90) | RE (40-59), ERS (60-90) |
| Lettuce | RE (40-49), ERS (50-90) | RE (40-49), ERS (50-90) | RE (40-49), ERS (50-90) |
| Asparagus | RE (40-49), ERS (50-81,83-90 ) | RE (40-49), ERS (50-81,83-90 ) | RE (40-49), ERS (50-81,83-90 ) |
| Straebwrries | RE (40-59, 64-69), AS (60-63), ERS (70-90) | RE (40-59, 64-69), AS (60-63), ERS (70-90) | RE (40-59, 64-69), AS (60-63), ERS (70-90) |
| Celery | RE (40-59, 64-81), AS (60-63) | RE (40-59, 64-81), AS (60-63) | RE (40-59, 64-81), AS (60-63) |
| Cucumbers | RE (40-59, 64-70, 74-81) | RE (40-59, 64-70, 74-81) | RE (40-59, 64-70, 74-81) |
| Mellons | RE (40-81) | RE (40-81) | RE (40-81) |
| Citrus | No Data | CF (40-81) | CF (40-81) |
| Apples | No Data | No Data | No Data |

*Notes:* This table uses the following abbreviations for the Department of Agriculture's publications. NASS: National Agricultural Statistics Service. RE: Revised Estimates. ERS: Economic Research Service. AS: Annual Summary. CF: Citrus Fruits.

## C.3 County-level information

Share of Mexicans by county is calculated from the complete count 1940 US population census (Ruggles et al. 2018). Distance from Mexico is the minimal distance between the Mexico border and the centroid of the county. I calculated the centroid of the counties using the county boundaries in 1960, downloaded from NHGIS (Manson et al. 2017). US-Mexico border points were downloaded from U.S. Geological Survey (2007). To calculate the weight of each county in the production of each crop, I use information on the total acreage by crop and county from the 1964 census of agriculture (Haines et al. 2018). Farm values per acre were collected from the census of agriculture for the years 1950, 1954, 1959, 1964, 1969, 1974, 1978, and 1982 (Haines et al. 2018). Finally, the list of Bracero and non-Bracero states used in section 7 are from (Clemens et al. 2018, Figure 2, p. 1476).