# Quantitative International Economics

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Weeks 7 and 8 - Economic Development - Part 1
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# Outline

- Economic Development - An introduction
- We will cover a series of tools and applications to think about economic development
  - Non-homothetic preferences
  - Structural change
  - Heterogeneous workers and land

# Facts about Economic Development

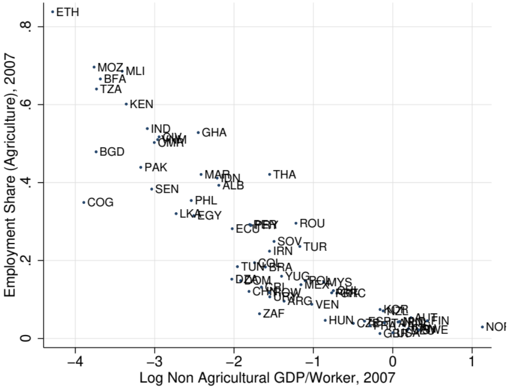
# Facts about Economic Development

1. Structural change
2. Agricultural Productivity
3. Agricultural Modernization
4. Trade Patterns

# Fact 1: Structural Change

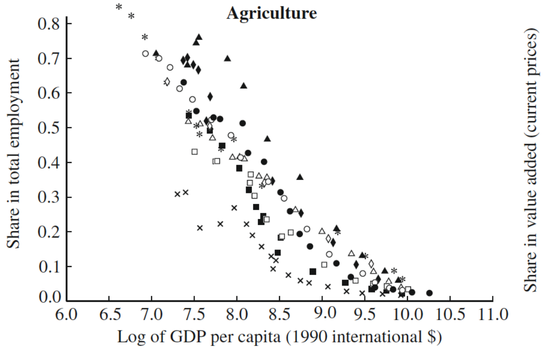
- As countries develop, economic activity reallocates between sectors
- This observation goes back at least to Simon Kuznets (Nobel Prize in 1971)
- Modern versions
  - Kongsamut, Rebelo, Xie (1997): Non-homothetic preferences
  - Ngai and Pissarides (2007): Relative productivity differences

# Fact 1: Structural Change



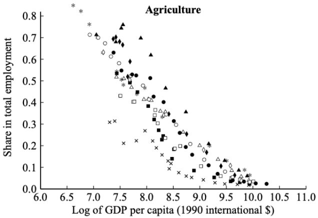

- Farrokhi and Pellegrina (2023) ⇒ Share of labor in agriculture falls with economic development

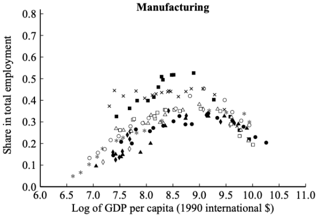
# Fact 1: Structural Change

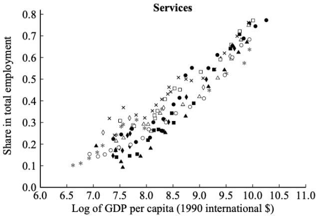



- Herrendorf et al. (2013) $\Rightarrow$ Share of labor in agriculture falls within countries over time

# Fact 1: Structural Change




- Herrendorf et al. (2013) ⇒ Negative U-shape for manufacturing

# Fact 1: Structural Change

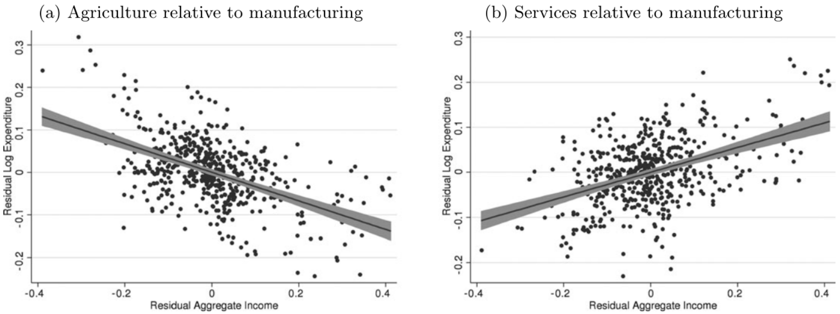



FIGURE 1.—Partial correlations of sectoral expenditure and aggregate consumption. Notes: Data for OECD countries, 1970–2005. Each point corresponds to a country-year observation after partialling-out sectoral prices and country fixed effects. The red line depicts the OLS fit, the shaded regions, the 95% confidence interval.

- Comin et al. (2021) $\Rightarrow$ Expenditure shares in agriculture fall with development

# Fact 2: Agricultural Productivity

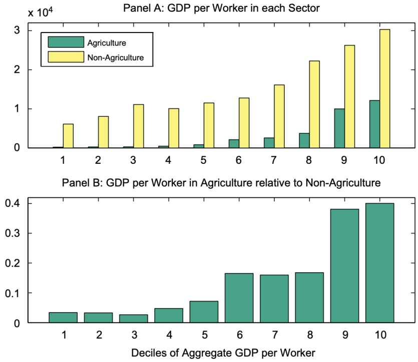
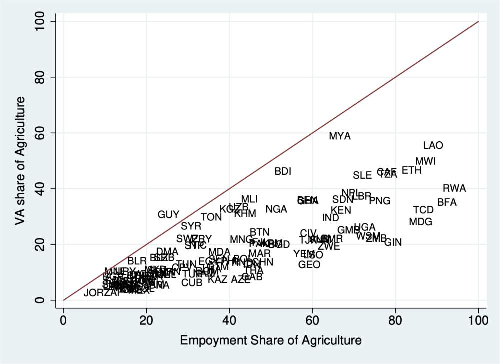



Fig. 2. Sectoral labor productivity across countries—1985. Countries are ranked according to aggregate GDP per worker from PWT5.6 where decile 10 groups the richest countries. Each decile contains eight countries (10% of countries in our sample) except decile 5, which contains 13 countries.

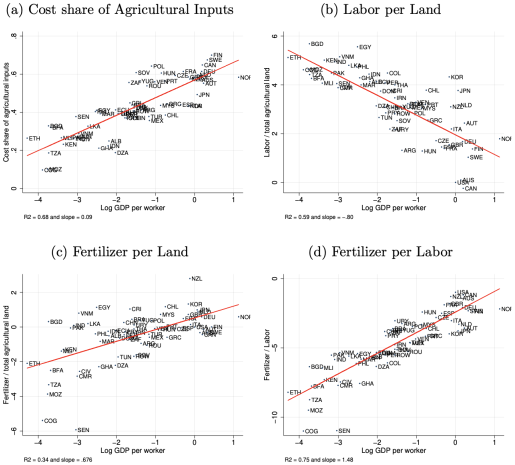
- Restuccia et al. (2008) $\Rightarrow$Large part of the cross-country differences in aggregate TFP comes from differences in agricultural TFP

# Fact 2: Agricultural Productivity




- Gollin et al. (2014) $\Rightarrow$ Within countries, value added per worker tends to be lower in agriculture relative to urban activities, <u>especially in developing countries</u>. Selection? Migration costs?

# Fact 3: Agricultural Modernization




- Farrokhi and Pellegrina (2023) ⇒ Agricultural inputs rise significantly with economic development

# Fact 3: Agricultural Modernization

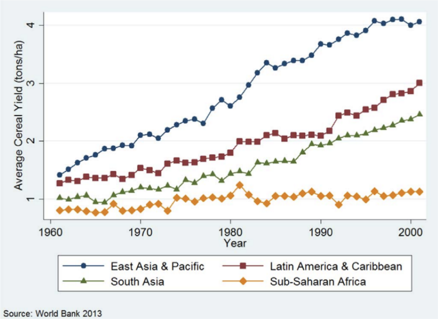



**Fig. 1.** Cereal yields across developing regions, 1961–2001.

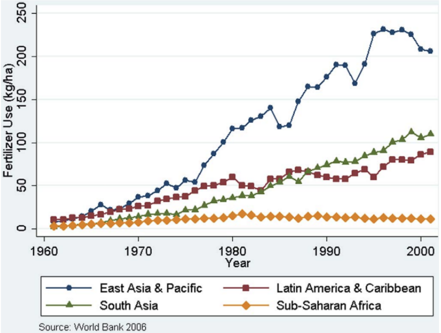
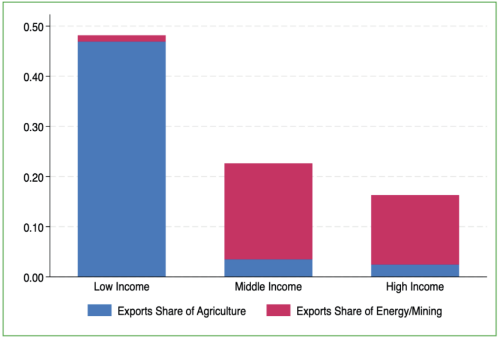



**Fig. 2.** Fertilizer use in developing regions, 1961–2001.

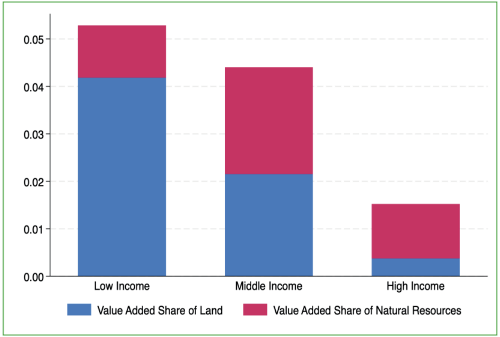
- McArthur and McCord (2017) $\Rightarrow$ Over time, massive rise in the use of chemical fertilizers

# Fact 4: Trade Patterns

(a) Exports




(b) Value Added




- VoxDev on Foreign Direct Investments $\Rightarrow$ Agriculture and natural resources are particularly important for poor countries' exports

# Fact 4: Trade Patterns

Table 1: Import Share of Agricultural Inputs

| | Imports as share of a country's expenditure | | | | Exports as share of global exports | |
|---|---|---|---|---|---|---|
| | Avg | p10 | p50 | p90 | Top 10 | Not top 10 |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| All | 0.65 | 0.31 | 0.70 | 0.91 | 0.77 | 0.23 |
| Fertilizer | 0.69 | 0.36 | 0.74 | 0.97 | 0.82 | 0.18 |
| Machinery | 0.67 | 0.28 | 0.73 | 0.93 | 0.78 | 0.22 |
| Pesticide | 0.69 | 0.30 | 0.72 | 0.99 | 0.85 | 0.15 |

- Farrokhi and Pellegrina (2023) $\Rightarrow$ Trade is essential for the use of agricultural inputs

# Mechanisms

# Mechanisms

- What does generate structural change?
  - Relative productivities?
  - Income effects?
- Preference structures with income effects
  1. Stone-Geary (Tomber, 2015)
  2. PIGL (Peters, 2022; Fraga et al. 2025)
  3. Non-homothetic CES (Sposi et al., 2022, Correa et al., 2025)

# Mechanisms

- Plan

1. First understand how relative productivities can generate structural change, without any income effects
2. Study each type of preference, their costs and benefits in terms of modelling
3. Present a trade model with non-homothetic CES
4. Discuss how to generate structural change in a SOE (Bustos et al. 2016)

# Relative Prices

# Relative Prices

- "Baumol Disease"
  - Wages in sectors experiencing no increase in productivity rising due to increases in productivity elsewhere
  - Manufacturing productivity growth leading to expansion in services
    - Health, education, culture, etc.
  - Employment growth in the stagnant sector
- Ngai and Pissarides (2007)
  - Low elasticity of substitution across sectors (below 1) leads to shifts in employment shares to sectors with low TFP growth

# Relative Prices: Basic Structure

- Preferences

$$U = \left( \sum_k C_k^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}$$

  - two sectors $k \in \{A, M\}$

- Technology

$$Q_k = A_k N_k$$

- Endowment

$$\sum_k N_k = N$$

# Relative Prices: GE

- Perfect competition

$$p_k = w/A_k$$

- Labor market clearing

$$wN = \sum_k X_k$$

- Income

$$E = wN$$

- Consumption

$$X_k = \frac{p_k^{1-\sigma}}{\sum_k p_k^{1-\sigma}} wN$$

# Relative Prices: Structural Change

- From the consumption equation

$$
\begin{aligned}
\frac{X_A}{X_M} &= \left(\frac{p_A}{p_M}\right)^{1-\sigma} \\
\frac{wN_A}{wN_M} &= \left(\frac{w/A_A}{w/A_M}\right)^{1-\sigma} \\
\frac{N_A}{N_M} &= \left(\frac{A_M}{A_A}\right)^{1-\sigma}
\end{aligned}
$$

- If $\sigma < 1$, agriculture and manufacturing are complements, an increase in $A_A$ leads to
  - Fall in the share of workers in agriculture $N_A$
  - Fall in the share of expenditure in agriculture $X_A$
- Does it mean that $C_A$ falls as well?

# Relative Prices: Structural Change

- From previous equations we get

$$N_A = \frac{A_M^{1-\sigma}}{A_A^{1-\sigma} + A_M^{1-\sigma}} N$$

- We have $C_A = Q_A = A_A N_A$, which gives

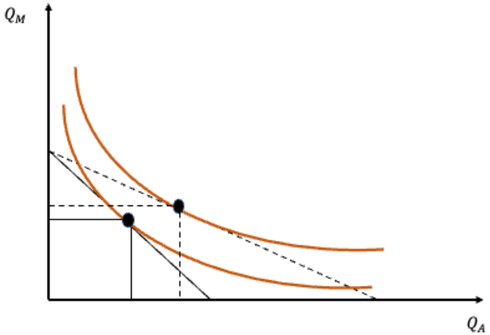
$$C_A = A_A \left( \frac{A_M^{1-\sigma}}{A_A^{1-\sigma} + A_M^{1-\sigma}} \right) N$$

$$\log C_A = \log A_A + \log A_M^{1-\sigma} - \log \left( A_A^{1-\sigma} + A_M^{1-\sigma} \right) + \log N$$

$$\frac{\partial \log C_A}{\partial \log A_A} = 1 - \frac{A_A^{1-\sigma}}{A_A^{1-\sigma} + A_M^{1-\sigma}} (1 - \sigma)$$

- For any $\sigma > 0$, the derivative above is positive. Intuition:
  - A 1 percent increase in TFP reduces the labor by less than 1 percent.
  - Reduction in *expenditure share* occurs with increase in $C_A$. How? Prices fall more than quantities rise.

# Relative Prices: A Graphical Representation




- Consider an expansion in agricultural productivity. That should increase consumption of $Q_A$.
- If goods are complements, consumers also want to consume more of $Q_M$. TFP, however, did not increase for $M$. How can we increase $Q_M$?

# Explaining Structural Change: Agriculture vs. Mfg

- Based on relative prices, we must have had a larger increase in *agricultural* productivity, relative to manufacturing, to explain the movement of labor out of agriculture

- Manufacturing growth could only shrink the employment in the manufacturing sector, leading to an expansion in employment in agriculture

- Next, we will introduce income effects, which allows for sectoral shifts without relying on changes in relative productivities between

# Income Effects

# Non-Homothetic 1: Stone-Geary

- Preferences

$$U = \left(C_A - \bar{C}_A\right)^{\mu_A} \left(C_M\right)^{\mu_M}$$

- The share of expenditure on agricultural goods

$$\begin{aligned}\xi_A &= \frac{P_A \bar{C}_A}{E} + \mu_A \left(1 - \frac{P_A \bar{C}_A}{E}\right) \\ &= \mu_A + \left(1 - \mu_A\right) \frac{P_A \bar{C}_A}{E}\end{aligned}$$

- The elasticity of $\xi_A$ w.r.t. income is

$$\frac{\partial \ln \xi_A}{\partial \ln E} = \frac{\left(1 - \mu_A\right) \frac{P_A \bar{C}_A}{E}}{\mu_A + \left(1 - \mu_A\right) \frac{P_A \bar{C}_A}{E}}$$

- What happens to the income elasticity when $E >> P_A \bar{C}_A$?

# Non-Homothetic 2: PIGL

- An individual $\omega$'s indirect utility is given by

$$V(\omega) = \frac{1}{\varepsilon}\left(\frac{E(\omega)}{P_A^{\mu_A} P_M^{\mu_M}}\right)^{\varepsilon} - \nu \ln\left(\frac{P_A}{P_M}\right)$$

- By roy's identity, the share of expenditure on agricultural goods is

$$\xi_A(\omega) = \mu_A + \nu\left(\frac{E(\omega)}{P_A^{\mu_A} P_M^{\mu_M}}\right)^{-\varepsilon}$$

- The elasticity of $\xi_A$ w.r.t. income $E(\omega)$ is

$$\frac{\partial \ln \xi_A(\omega)}{\partial \ln E(\omega)} = -\nu\epsilon\left(\frac{E(\omega)}{P_A^{\mu_A} P_M^{\mu_M}}\right)^{-\varepsilon-1}$$

- What happens when $E(\omega) >> P_A^{\mu_A} P_M^{\mu_M}$?

- PIGL has convenient aggregation properties, particularly if combined with Fréchet distribution (see Eckert and Peters, 2022). The aggregate expenditure (the one that integrates over $\omega$) has a closed-form solution.

# Non-Homothetic 3: Non-homothetic CES

- Utility is defined implicitly

$$C = \left[ \sum_k (a_k)^{\frac{1}{\sigma}} \left(U^{\varepsilon_k}\right)^{\frac{1}{\sigma}} C_k^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}$$

- The share of expenditure on goods $k$

$$\xi_k = \frac{a_k U^{\varepsilon_k} P_k^{1-\sigma}}{P^{1-\sigma}}$$

where

$$P = \left( \sum_k a_k U^{\epsilon_k} P_k^{1-\sigma} \right)^{\frac{1}{1-\sigma}}$$

and

$$U = \frac{E}{P}$$

# Non-Homothetic 3: Non-homothetic CES

- Let's check what is the income elasticity now. First, it is possible to show that

$$\begin{aligned}\frac{\partial \ln P}{\partial \ln E} &= \frac{1}{1-\sigma}\left(1-\frac{\ln P}{\ln E}\right)\\ &= \frac{1}{1+(1-\sigma)}\end{aligned}$$

- The elasticity of $\xi_A$ w.r.t. income $E(\omega)$ is

$$\begin{aligned}\frac{\partial \ln \xi_k}{\partial \ln E} &= \varepsilon_k\left(\frac{\partial \ln E}{\partial \ln E}-\frac{\partial \ln P}{\partial \ln E}\right)-(1-\sigma)\frac{\partial \ln P}{\partial \ln E}\\ &= (\varepsilon_k-1)\times\frac{(1-\sigma)}{1+(1-\sigma)}\end{aligned}$$

- What happens when $E >> P$?

- Accounts for behavior of expenditure at high levels of income, but no closed-form expression for aggregate demand

# Comin et al. (2021)

- Comin et al. (2021) estimate non-homothetic CES
  - Household level data
  - Cross-country data
- Using estimated parameters, they decompose the role of income and price effects
  - Income effects are the main driver of structural change, account for 73 percent

# Comin et al. (2021)

TABLE III

CROSS-COUNTRY ESTIMATES, $\epsilon_m = 1$[a]

| | World | | OECD | | Non-OECD | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| $\sigma$ | 0.57 | 0.50 | 0.25 | 0.35 | 0.63 | 0.48 |
| | [0.32, 0.69] | [0.26, 0.71] | [0.20, 0.66] | [0.03, 0.55] | [0.06, 0.74] | [0.34, 0.75] |
| $\epsilon_a - 1$ | −0.98 | −0.89 | −0.99 | −0.99 | −0.91 | −0.80 |
| | [−1.13, −0.41] | [−1.14, −0.46] | [−1.00, −0.38] | [−1.00, −0.66] | [−1.15, −0.58] | [−1.14, −0.40] |
| $\epsilon_s - 1$ | 0.17 | 0.21 | 0.27 | 0.25 | 0.18 | 0.37 |
| | [0.07, 0.60] | [0.03, 0.67] | [0.03, 0.55] | [0.09, 1.95] | [0.11, 2.08] | [0.03, 0.67] |
| Country × Sector FE | Y | Y | Y | Y | Y | Y |
| Trade Controls | N | Y | N | Y | N | Y |
| Observations | 1626 | 1626 | 492 | 492 | 1134 | 1134 |

[a]Bootstrapped 95% confidence intervals clustering at the country level shown in square brackets (computed through bootstrapping 50 samples with replacement). The estimations in columns (3) and (4) are performed by imposing the constraint that $\epsilon_a \geq 0$ (by estimating an exponential transformation of the variable).[41]

# A Trade Model with Non-Homothetic CES

# Model

- Many countries $i$ and $n$
- Many sectors $k$
- Endowment of labor in each country $N_i$
- Iceberg trade cost $\tau_{in}$

# Preferences

- Upper-tier

$$C_i = \left[ \sum_k (a_{i,k})^{\frac{1}{\sigma}} \left(U_i^{\varepsilon_k}\right)^{\frac{1}{\sigma}} C_{i,k}^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}$$

  - $\varepsilon_k$ controls income elasticity
  - $\sigma$ controls elasticity of substitution between sectors

- Lower-tier

$$C_{i,k} = \left[ \sum_n (a_{ni,k})^{\frac{1}{\eta}} (c_{ni,k})^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}$$

  - $\eta$ controls the elasticity of substitution between origin

# Technology and prices

- CRS

$$q_{i,k} = \frac{N_{i,k}}{T_{i,k}}$$

- Perfect competition ensures

$$p_{i,k} = \frac{w_i}{T_{i,k}}$$

- The price of a good from $i$ arriving in $n$ is

$$p_{in,k} = p_{i,k}\tau_{in,k}$$

# Trade and Consumption Shares

- Share of expenditure in sector $k$

$$\beta_{i,k} = \frac{a_{i,k} U_i^{\varepsilon_k} P_{i,k}^{1-\sigma}}{P_i^{1-\sigma}}$$

where

$$P_i^{1-\sigma} = \sum_k a_{i,k} U_i^{\varepsilon_k} P_{i,k}^{1-\sigma}$$

and

$$U_i = \frac{E_i}{P_i}$$

- Share of expenditure of country $n$ on goods from $i$

$$\beta_{in,k} = \frac{a_{in,k} p_{in,k}^{1-\eta}}{P_{i,k}^{1-\eta}}$$

where

$$P_{i,k}^{1-\eta} = \sum_n a_{ni,k} p_{ni,k}^{1-\eta}$$

# General Equilibrium

- Total payments to factors

$$E_n = w_n N_n \tag{1}$$

- Labor market clears

$$w_n N_n = \sum_k \sum_i X_{ni,k} \tag{2}$$

- Trade flows are given by

$$X_{in,k} = \beta_{in,k} \beta_{n,k} E_n \tag{3}$$

- Trade shares, consumption shares, prices and utilities are given by

$$\beta_{i,k} = \frac{a_{i,k} U_i^{\varepsilon_k} P_{i,k}^{1-\sigma}}{P_i^{1-\sigma}} \quad \text{and} \quad \beta_{in,k} = \frac{a_{in,k} \left(\tau_{in,k} w_i / T_{i,k}\right)^{1-\eta}}{P_{i,k}^{1-\eta}} \tag{4}$$

$$P_i^{1-\sigma} = \sum_k a_{i,k} U_i^{\varepsilon_k} P_{i,k}^{1-\sigma} \quad \text{and} \quad P_{i,k}^{1-\eta} = \sum_n a_{ni,k} \left(\tau_{in,k} w_i / T_{i,k}\right)^{1-\eta} \tag{5}$$

$$U_i = \frac{E_i}{P_i} \tag{6}$$

**Definition**: Given technology $\{T_n\}_n$, trade costs $\{d_{ni}\}_{ni}$, preferences $\left\{\sigma, \eta, \varepsilon_k, a_{in,k}, a_{i,k}\right\}$ and population $\{N_n\}_n$, an equilibrium is a vector of wages $\{w_n\}_n$ that satisfies equations (1)-(6).

# An Algorithm

- Step 1: Guess a vector of wages $w_n^g$ (pick a normalization) and utilities $U_i^g$
- Step 2: Construct $E_n$
- Step 3: Construct $\beta_{ni,k}$, $\beta_{i,k}$ and $X_{in,k}$
- Step 4: Obtain the demand for workers $N_n^{dem} = \sum_k \sum_i X_{ni,k}/w_n^g$
- Step 5: Construct $U_i$
- Step 6: Check labor market clearing
  - If $\max_n\{|N_n^{dem} - N_n|\} < \epsilon$ and $\max_n\{|U_n^g - U_n|\} < \epsilon$ , then stop algorithm
  - Otherwise, update $w_n^g$ and $U_i^g$ and go back to step 2
    - Increase $w_n^g$ if $N_n^{dem} - N_n > 0$ and decrease $w_n^g$ if $N_n^{dem} - N_n < 0$
    - Increase $U_n^g$ if $U_n - U_n^g > 0$ and decrease $U_n^g$ if $U_n - U_n^g < 0$

# An Example: Sposi et al. (2024)

- Industrialization and development
  - Countries today, at the same level of GDP per capita, allocate a smaller share of total value-added to manufacturing than did their counterparts decades ago
  - Industry polarization $\Rightarrow$ There is a widened cross-country dispersion in the manufacturing share of value-added

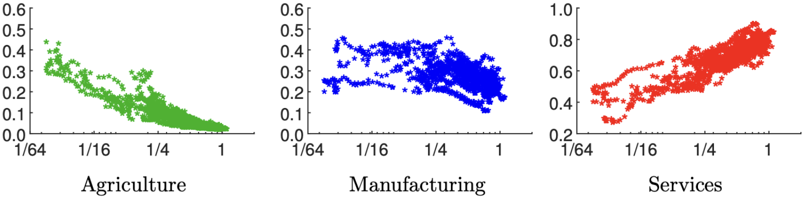
- They calibrate a dynamic trade model that incorporates
  - Relative price effects
  - Income and scale effects
  - Comparative advantage
  - Investment

# Sposi et al. (2024)

- Dynamic model with many countries and many sectors in discrete time
- Households make consumption and investment decisions
  - Consumption good in period $t$
    - Upper tier: Non-homothetic CES over agriculture, services and manufacturing
    - Lower tier: Eaton and Kortum
  - Investment good in period $t$
    - A non-homothetic CES aggregator
- Production employs labor, capital, and intermediate inputs
  - Intermediate inputs: A non-homothetic CES aggregator, which brings scale economies to production

# Sposi et al. (2024)

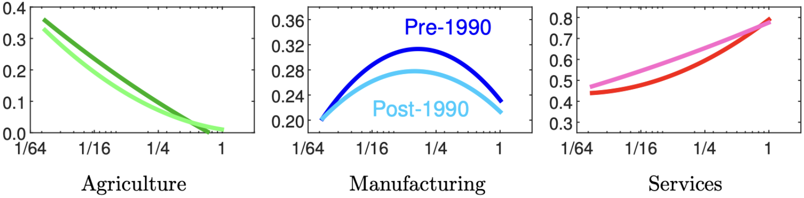
Figure 1: Sectoral Value Added Shares: 1971–2011




Notes: The x-axes are real income per capita at PPP prices, relative to United States in 2011, and the y-axes are HP trends of sectoral value added shares. The data is a balanced panel covering 28 countries from 1971–2011.

# Sposi et al. (2024)

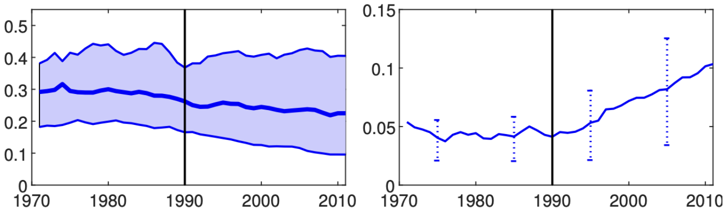
Figure 2: Deindustrialization: Predicted Sectoral Value Added Shares Pre-90 vs. Post-90




Notes: Each line plots the predicted value added share for a sector (y-axis), estimated from a balanced panel of 28 countries over 1971–2011 using equation (1) under the average country fixed effect and over the observed ranges of income per capita (x-axis). Dark lines - pre 1990; Light lines - post 1990. ROW is excluded from the calculations.

# Sposi et al. (2024)

Figure 3: Industry Polarization




Cross-Country Distribution        Log-variance

Notes: In the left panel, the middle line plots the median value of the manufacturing value added shares across 28 countries over time (x-axis), while the upper and lower bands correspond to the $100^{th}$ and $1^{st}$ percentiles, respectively. In the right panel, the solid line reports the variance of the log-manufacturing VA share across countries over time (x-axis), with 95% confidence intervals (based on 1000 bootstrap samples) reported every 10 years beginning with 1975. ROW is excluded from the calculations.

# Sposi et al. (2024)

Table 1: Elasticity Estimates

| | Final demand | | Intermediate demand | | |
|---|---|---|---|---|---|
| | Cons | Inv | Agr | Mfg | Srv |
| **Price elasticities** | | | | | |
| $\sigma$ | 0.232 | 0.292 | 0.211 | 0.009 | 0.265 |
| | (0.046) | (0.150) | (0.109) | (0.003) | (0.054) |
| **Scale elasticities** | | | | | |
| $\varepsilon^a$ | 0.102 | 0.300 | 1.248 | 0.373 | 0.647 |
| | (0.005) | (0.153) | (0.194) | (0.035) | (0.100) |
| $\varepsilon^s$ | 1.333 | 1.080 | 1.036 | 0.879 | 1.332 |
| | (0.093) | (0.107) | (0.066) | (0.043) | (0.063) |
| $R^2$ | 0.05 | 0.31 | 0.11 | 0.21 | 0.06 |
| $\mathrm{F}_{(H_0:\, \varepsilon^j=1)}$ | 14.6 | 919.6 | 93.0 | 448.4 | 121.8 |

Notes: Each column reports the elasticity estimates for one of the five demand systems. For each system, we estimate three parameters to from 2240 observations using constrained NLS regressions. The manufacturing scale effect within each demand system is normalized so that $\varepsilon^m = 1$. Standard errors (in parentheses) are bootstrapped using 1000 sample iterations, clustered at the country level. The F statistic tests the general specification against a restricted one with no scale effects (i.e., scale elasticities $\varepsilon^a = \varepsilon^s = 1$). The critical value for the F statistic at the 0.01 significance level is 4.6. This test statistic only approximately follows an F distribution when using NLS.

# Sposi et al. (2024)

- Key Results
  - Sector-biased productivity growth explains almost 60 percent of deindustrialization, but does not explain industry polarization
    - Remaining 40 percent explained by non-linear interaction between sector-biased productivity growth and sectoral trade imbalances
    - Large productivity growth of manufacturing relative to services explain results
    - Global manufacturing expenditure as a share of global GDP has fallen in recent decades
  - Countries with a comparative disadvantage rely more on manufacturing imports, the opposite happens with countries with a comparative advantage
    - Trade generates, in the model, stronger polarization than in the data. Sector-biased productivity growth mitigates part of the effect.

# Structural Change in a SOE

# Structural Change in a SOE

- So far, we have been assuming CRS technologies
- We will now consider the role of technology adoption
- We will hold output prices fixed. All action will come from the supply side.
- Theory inspired by Bustos et al. (2016)
  - Reduced-form impact of soybeans and corn on structural change

# A SOE with 2 sectors

- A small open economy with $L$ residents
- There are 2 sectors
  - Manufacturing uses labor
$$Q_M = A_M L_M$$
  - Agriculture uses labor and land
$$Q_A = A_N \left[ \gamma \left( A_L L_A \right)^{\frac{\sigma - 1}{\sigma}} + (1 - \gamma) \left( A_T T_A \right)^{\frac{\sigma - 1}{\sigma}} \right]^{\frac{\sigma}{\sigma - 1}}$$
    - $A_N$ is a Hicks-neutral technical change
    - $A_L$ is a labor-augmenting technical change
    - $A_T$ is a land-augmenting technical change
  - For simplicity, $P_M = P_A = 1$
- Marginal product of labor must equalize between sectors

# Marginal Product of Labor

- Marginal product of labor

$$MPL_A = A_N A_L \gamma \left[ \gamma + (1-\gamma) \left( \frac{A_T T_A}{A_L L_A} \right)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{1}{\sigma-1}}$$

  - What happens when productivity increases?
  - $A_N$ increases $\Rightarrow MPL_A$ increases
  - $A_T$ increases $\Rightarrow MPL_A$ increases
  - $A_L$ increases $\Rightarrow$ ambiguous effects
    - Each workers can deliver more *efficient units of labor*
    - Each worker has *fewer efficient units of land* to complement its labor

# Marginal Product of Labor

- One can show that

$$\frac{\partial \log MPL_A}{\partial \log A_L} = 1 - \frac{1}{\sigma} \frac{(1-\gamma)(A_T T_A)^{\frac{\sigma-1}{\sigma}}}{\gamma (A_A L_A)^{\frac{\sigma-1}{\sigma}} + (1-\gamma)(A_T T_A)^{\frac{\sigma-1}{\sigma}}}$$

- Here, $\dfrac{\partial \log MPL_A}{\partial \log A_L} < 0$ if

$$\sigma < \frac{(1-\gamma)(A_T T_A)^{\frac{\sigma-1}{\sigma}}}{\gamma (A_A L_A)^{\frac{\sigma-1}{\sigma}} + (1-\gamma)(A_T T_A)^{\frac{\sigma-1}{\sigma}}}$$

- We need $\sigma < 1$ at least, i.e., labor and land must be complements
- When $\sigma < \dfrac{(1-\gamma)(A_T T_A)^{\frac{\sigma-1}{\sigma}}}{\gamma (A_A L_A)^{\frac{\sigma-1}{\sigma}} + (1-\gamma)(A_T T_A)^{\frac{\sigma-1}{\sigma}}}$, we say that they are strongly complement
  - Notice that $L_A$ and $T_A$ are endogenous

# More Intuition

- Marginal product of land can be written as

$$MPT_A = \frac{Q_A}{T_A} \frac{(1-\gamma)(A_T T_A)^{\frac{\sigma-1}{\sigma}}}{\gamma (A_L L_A)^{\frac{\sigma-1}{\sigma}} + (1-\gamma)(A_T T_A)^{\frac{\sigma-1}{\sigma}}}$$

  Notice that, when $\sigma \to 1$ (cobb-douglas), then $Q_A = L_A^{\gamma} T_A^{1-\gamma}$ gives $MPT_A = \frac{Q_A}{T_A}(1-\gamma)$

- The second term on the right hand side is therefore share of payments to land
  - When that share is higher, there is large employment of efficient units of land, relative to efficient units of labor
  - In that case, we need a weaker condition on $\sigma$

# Bustos et al. (2016)

- What is the impact of agricultural technologies on structural change?
- Data from Brazil between 2000 and 2010
  - Two shocks
    - A labor-saving shock $\Rightarrow$ soybeans
    - A land-augmenting shock $\Rightarrow$ double-cropping with corn
  - Data from FAO-GAEZ on agricultural suitability for traditional and modern technologies
    - Suitability is constructed based only on agroclimatic characteristics, no local market conditions are used in the construction of the data
    - Difference between modern and traditional are associated with technology adoption for each of these crops

# Bustos et al. (2016)

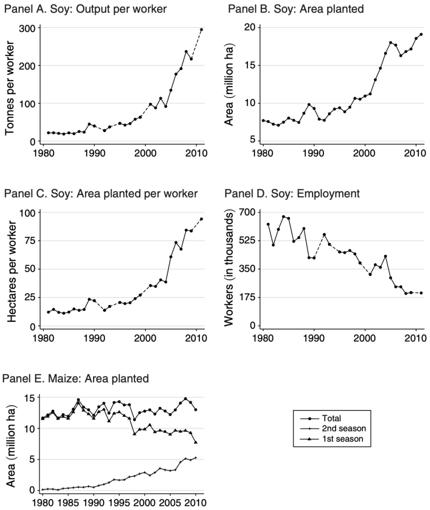



FIGURE 1. SOY AND MAIZE IN BRAZIL, 1980–2011

# Bustos et al. (2016)

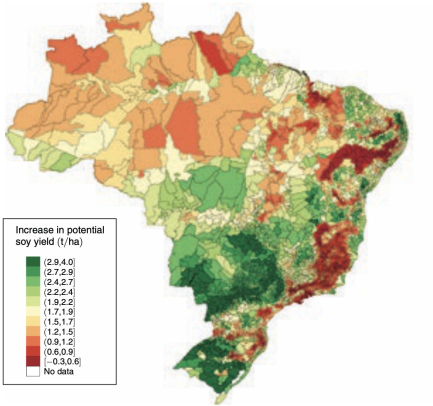



Figure 2. Technological Change in Soy: Municipalities

*Notes:* Authors' calculations from FAO-GAEZ data. Technical change in soy production for each municipality is computed by deducting the average potential yield under low inputs from the average potential yield under high inputs.

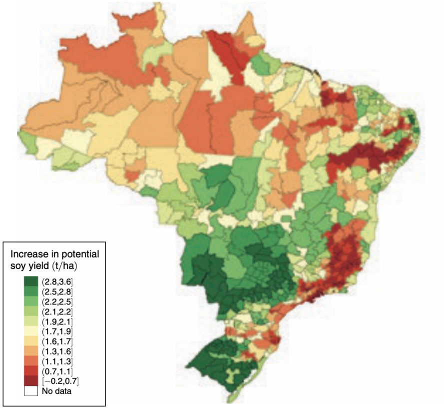



Figure 3. Technological Change in Soy: Microregions

*Notes:* Authors' calculations from FAO-GAEZ data. Technical change in soy production for each microregion is computed by deducting the average potential yield under low inputs from the average potential yield under high inputs.

# Bustos et al. (2016)

TABLE 9—THE EFFECT OF AGRICULTURAL TECHNOLOGICAL CHANGE ON MANUFACTURING (*Employment Share, Employment, and Wages*)

| | Δ Employment share | | Δ log employment | | Δ log wage | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| $\Delta A^{soy}$ | 0.023 | 0.021 | 0.218 | 0.186 | −0.032 | −0.024 |
| | (0.002) | (0.002) | (0.018) | (0.020) | (0.012) | (0.012) |
| $\Delta A^{maize}$ | −0.005 | −0.004 | −0.057 | −0.043 | 0.018 | 0.014 |
| | (0.001) | (0.001) | (0.009) | (0.009) | (0.005) | (0.005) |
| Share rural population | −0.006 | 0.011 | −0.186 | 0.051 | 0.197 | −0.014 |
| | (0.004) | (0.005) | (0.044) | (0.056) | (0.026) | (0.035) |
| log income per capita | | 0.002 | | 0.093 | | −0.107 |
| | | (0.003) | | (0.037) | | (0.026) |
| log pop. density | | 0.002 | | 0.020 | | −0.035 |
| | | (0.001) | | (0.008) | | (0.005) |
| Literacy rate | | 0.034 | | 0.197 | | 0.093 |
| | | (0.010) | | (0.117) | | (0.075) |
| Observations | 4,149 | 4,149 | 4,149 | 4,149 | 4,149 | 4,149 |
| $R^2$ | 0.063 | 0.073 | 0.056 | 0.068 | 0.022 | 0.045 |

*Notes:* Changes in dependent variables are calculated over the years 2000 and 2010. All municipality controls are from the population census of 1991. The unit of observation is the municipality. Robust standard errors reported in parentheses.

# Conclusion

# Conclusion

- We discussed key mechanisms that can generate structural change, how to incorporate them, and their empirical evidence
- In the empirical facts, we discussed two additional features
  - Agricultural productivity gap
  - Agricultural modernization
- Next class we will discuss models with heterogeneous factors of production, which can be used to incorporate these features into quantitative trade models