Quantitative International Economics

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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) $\Rightarrow$ 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) ⇒ 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

- VoxDev on Foreign Direct Investments ⇒ 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 agricultural productivity growth in open economies

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

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

- 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? <u>Prices fall more than quantities rise</u>.

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

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

- The elasticity of ξ_A w.r.t. income is

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

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

Non-Homothetic 2: PIGL

- An individual ω'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 ξ_A w.r.t. income $E(\omega)$ is

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

- 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 ω) 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 ξ_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

Income Effects: A Graphical Representation

- Relative prices are the same, but relative consumption falls for agriculture

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)
σ	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 τ_{in}

Preferences

- Upper-tier

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

  - ε_k controls income elasticity
  - σ controls elasticity of substitution between sectors

- Lower-tier

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

  - η 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

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

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

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

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

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

Definition: Given technology $\{T_n\}_n$, trade costs $\{\tau_{ni}\}_{ni}$, preferences $\{\sigma, \eta, \varepsilon_k, a_{in,k}, a_{i,k}\}$ 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

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 100th and 1st 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					
σ	0.232	0.292	0.211	0.009	0.265
	(0.046)	(0.150)	(0.109)	(0.003)	(0.054)
Scale elasticities					
ε^a	0.102	0.300	1.248	0.373	0.647
	(0.005)	(0.153)	(0.194)	(0.035)	(0.100)
ε^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.

Agricultural Productivity Growth in Open Economies

Agricultural Productivity Growth in Open Economies

- We discussed how ag-productivity growth leads to a reduction in agricultural employment
  - Relative productivities
  - Income effects
- Schultz (Nobel Prize 1979) $\Rightarrow$ "The Food Problem"
  - Too many people are employed in agriculture because of low productivity, but low productivity forces too many people to stay in agriculture, because of subsistence needs
  - How do you feed workers in urban sectors of the economy?
  - Agricultural productivity growth is needed to produce the food required for an urban sector to emerge
- In an open economy, however, increasing ag-productivity may amplify the CA in agriculture

Agricultural Productivity Growth in Open Economies

- There has been large concerns about the specialization of poor economies in primary sectors
  - "Dutch Disease"
  - Economies allocate all factors of production in extracting sectors (oil)
  - Similar concerns with specialization in agriculture

Agricultural Productivity Growth in Open Economies

- Matsuyama (1992)
  - Two sectors: agriculture and manufacturing
  - Manufacturing has larger productivity growth than agriculture
  - If a country specializes in agriculture, for example because of increase in agricultural productivity, it generates gains from trade in the short-run by specializing there. However, it can hurt its economy in the long-run, by having fewer workers moving to the high productivity-growth sector

Foster and Rosenzweig (2004)

- Foster and Rosenzweig (2004)
  - What was the impact of the green revolution in India on structural transformation?
  - Evidence on the relationship between agricultural growth and nonfarm growth was mixed
  - Within country, however, they find agricultural productivity growth to limit non-agricultural expansion

Foster and Rosenzweig (2004)

FIG. 1.—Average maximum HYV yield index (Laspeyres-weighted HYV crops), by year: 1971–99.

Foster and Rosenzweig (2004)

FIG. 2.—Absolute growth of HYV yields, 1971–99, by growth quintile

Foster and Rosenzweig (2004)

FIG. 12.—Proportion of nonfarm income in total income, by year and HYV yield growth quintile.

Foster and Rosenzweig (2004)

FIG. 16.—Proportion of villages with at least one factory, by year and HYV yield growth quintile

Foster and Rosenzweig (2004)

FIG. 17.—Number of factory workers per village in 1982 and 1999, by HYV yield growth quintile.

Factor-Biased Productivity Growth

- So far, agricultural productivity growth was Hicks-neutral
- We will now consider the role of factor-biased productivity growth
- 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, $\frac{\partial \log MPL_A}{\partial \log A_L} < 0$ 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 $\sigma < \frac{(1-\gamma)(A_T T_A)^{\frac{\sigma-1}{\sigma}}}{\gamma (A_A L_A)^{\frac{\sigma-1}{\sigma}} + (1-\gamma)(A_T T_A)^{\frac{\sigma-1}{\sigma}}}$, we 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 σ

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)
ΔA^{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)
ΔA^{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