The World Income Distribution: The Effects of Unbundling of Production

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Introduction

- "Unbundling" of production in last two decades (Baldwin, 2006, 2012).
- Emergence of Global Supply Chains (e.g., iPhone).

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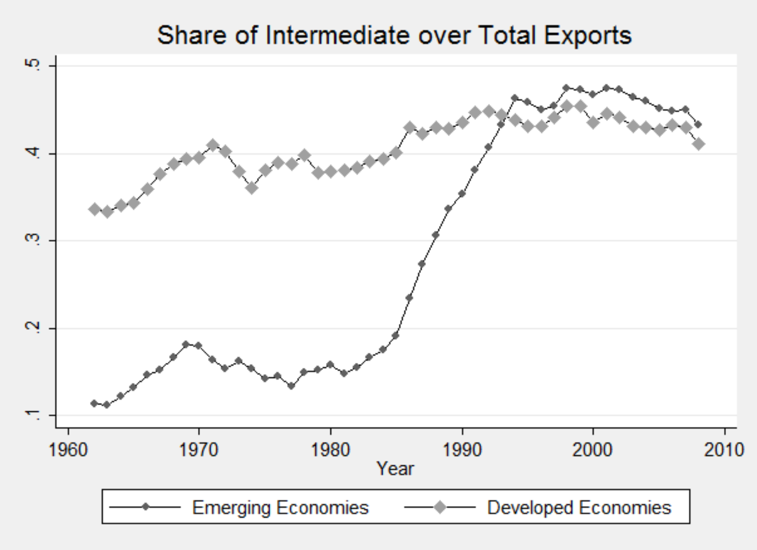
- Goal: Study effects of increased fragmentation and offshoring on world income distribution.

Motivation

- Share of world trade rich countries (EU, NAFTA) $\sim$ 60% from 1950 - to 1990s, sharply declined to 45% in 2012.
- Developing Asia, increased from $<$15% in 1990s to 35%.
- Unbundling of the production process is one of the main reasons behind the large increase in the volume of trade in developing countries (Baldwin 2012).

Evolution Trade in Intermediates



This Paper

- Develops a model that encompasses two trade regimes
  1. trade in final goods,
  2. trade in both final goods and intermediates (unbundling).
- Main Results:
  1. Symmetry breaking emerges with unbundling.
  2. World inequality increases, poor countries may loose in absolute terms.

Related Literature

- Unbundling of production: Baldwin (2006, 2012), Baldwin and Venables (2013), Baldwin and Robert-Nicoud (2014), Rodríguez Clare (2010),. . .
- Dynamic Trade models: Acemoglu and Ventura (1997), Bajona and Kehoe (2010), Atkeson and Kehoe (2000),. . .
- Symmetry Breaking: Matsuyama (2013, 1996), Ioanides (1999), . . .

Road Map

1. Introduction
2. Set-up of the Model
3. Equilibrium *without* Unbundling
4. Equilibrium *with* Unbundling
5. Conclusions

Model Outline

- World economy consisting of J of countries, $j = 1, \ldots, J$.
- Countries differ *only* in productivity θ_j.
- There is a continuum of varieties indexed by $v \in [0, N]$.
- Each variety requires a bundle of intermediates to be produced.
- There is one final good used for consumption and investment.
- No trade in final products or assets.

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- Study two different stationary equilibria:
  1. Trade only in varieties
  2. Unbundling: trade in variety and intermediates

Country j

- Representative consumer with utility

$$\int_0^\infty e^{-\rho t} \ln c_j(t) dt, \tag{1}$$

where $c_j(t)$ is consumption in country j at time t.
- Each country j starts with a capital stock $k_j(0) > 0$.
- Each country has a fixed stock of labor, normalized to one

$$L_j = 1. \tag{2}$$

- The budget constraint is

$$p_j(t) \left[\dot{k}_j(t) + c_j(t) \right] = p_j Y_j(t) = r_j(t) k_j(t) + w_j(t). \tag{3}$$

Final Good Production – Armington assumption

- The production of the final good is CRS Cobb-Douglas

$$Y_j(t) = \exp\left(\frac{1}{N}\int_0^N \ln x_j(v,t)dv\right), \tag{4}$$

  where N is the total number of varieties.
- Varieties are differentiated by origin.
- Each country produces μ_j varieties,

$$\sum_{i=1}^{J} \mu_i = N. \tag{5}$$

Production of Varieties and Intermediates

- Production of a variety requires intermediates $a(z)$,

$$x(v,t) = \exp\left[\int_0^1 \ln a_j(z,v,t)dz\right]. \tag{6}$$

- Intermediates use labor l and capital k in different proportions

$$a_j(z,t) = \theta_j \left(\frac{k_j(z,t)}{z}\right)^z \left(\frac{l_j(z,t)}{1-z}\right)^{1-z}, \quad z \in [0,1]. \tag{7}$$

Innovation

- To produce varieties it is necessary to hire labor to innovate,

$$\mu_j = \kappa(\theta_j) L_{j,R}^{\lambda}, \qquad 0 < \lambda \leq 1 \tag{8}$$

  with $\kappa(\cdot)$ continuously increasing.
- As in Jones (1995), perceived production function,

$$\mu_j = \nu_j L_{j,R} \tag{9}$$

  with

$$\nu_j = \kappa(\theta_j) L_{j,R}^{\lambda-1}. \tag{10}$$

Market Structure

- Free entry in innovation.
- Once an innovation occurs, a patent is given to inventor.
- Inventor sells patent to variety producer $\rightarrow$ becomes monopolist of that variety.
- Competitive fringe can copy any variety at a marginal cost $(1+\sigma)$ higher than the marginal cost, $\sigma > 0$, $\implies$

$$p_j^x(v,t) = (1+\sigma)MC_j(v,t) \tag{11}$$

- Final good production is competitive.

World Equilibrium without Unbundling

World Equilibrium without Unbundling

- Countries can only trade in varieties.

World Equilibrium without Unbundling

Definition

An equilibrium without unbundling is defined by a sequence of prices $\{w_j(t), r_j(t), p_j(t)\}_{t=0,\ j=1,\dots,J}^{\infty}$ and allocations $\{l_j(z,t), k_j(z,t), c_j\}_{t=0,\ z\in[0,1],\ j=1,\dots,J}^{\infty}$ such that for each country:

- the representative agent maximizes utility (1) subject to (3),
- final good producers maximize given (4), variety producers maximize profits subject to (6) and (11), intermediate producers maximize profits given (7), the innovation producers maximize profits given the perceived production function (9),
- labor market and capital market clears, the total amount of innovation in one country is consistent with (8), aggregate innovation in the world is given by (5), and **trade in varieties** is balanced among each country pair.

Equilibrium Characterization

Go to Trade Balance

- From the consumer maximization problem,

$$\frac{\dot{c}_j(t)}{c_j(t)} = \frac{r_j(t)}{p_j(t)} - \rho, \tag{12}$$

$$\lim_{t\to\infty} e^{-\rho t} c_j(t)^{-1} \left(\frac{r_j(t)}{p_j(t)} k_j(t) \right) = 0. \tag{13}$$

Demand For Varieties

- Demand of country j of variety v produced in f

$$\max_{x_j(v)} \quad p_j Y_j - \int_0^N p^x(v) x_j(v) dv \tag{14}$$

which implies

$$\frac{1}{N} p_j Y_j = p_f^x(v) x_j(v) \tag{15}$$

- The world demand of variety v produced in f is

$$x(v) = \sum_{i=1}^{J} x_i(v) = \frac{1}{N} \frac{\sum_{i=1}^{J} p_i Y_i}{p_f^x(v)} \tag{16}$$

Production of Varieties

- The price charged for variety v is

$$p_j^x(v) = (1+\sigma)MC_j(v) = (1+\sigma)\exp\left(\int_0^1 \ln p_j(z)dz\right) \quad (17)$$

- Profits of the producer of a variety are total revenues less variable costs and the price of purchasing the idea p_j^R,

$$\pi_j(v) = \frac{\sigma}{1+\sigma}\beta(v)\sum_{i=1}^{J} p_i Y_i - p_j^R. \quad (18)$$

Demand of Intermediates

- The demand of intermediates to produce variety v is

$$a_j(z,v)p_j(z) = x_j(v)\exp\left(\int_0^1 \ln p_j(z)dz\right) \qquad (19)$$

- Aggregate demand of intermediate $a_j(z)$ in country j is

$$a_j(z) = \mu_j a_j(z,v) \qquad (20)$$

where μ_j is the mass of varieties produced in j.

Production of intermediates and demand for labor and capital

- The problem of producer of intermediates is

$$\max_{l_j(z),k_j(z)} p_j(z)\theta_j \left(l_j(z)\right)^{1-z} k_j(z)^z - w_j l_j(z) - r_j k_j(z), \quad (21)$$

which implies that

$$\begin{aligned} (1-z)p_j(z)a_j(z) &= w_j l_j(z) && (22) \\ z p_j(z)a_j(z) &= r_j k_j(z) && (23) \end{aligned}$$

- The unit price of intermediate z is

$$p_j(z) = \theta_j^{-1} w_j^{1-z} r_j^z. \quad (24)$$

Production of Ideas

- Profit maximization

$$\max_{L_{j,R}} \quad p_j^R \nu_j L_{j,R} - w_j L_{j,R} \tag{25}$$

- This implies that

$$w_j = p_j^R \nu_j \tag{26}$$

in equilibrium this will require that

$$w_j = p_j^R \nu_j = p_j^R N \kappa(\theta_j) L_{j,R}^{\lambda-1} = p_j^R \frac{\mu_j}{L_{j,R}}. \tag{27}$$

Trade Balance

- Value of exports has to be equal to the value of imports,

$$\frac{\mu_j}{N}\left(\sum_{i=1}^{J} p_i Y_i - p_j Y_j\right) = \frac{\sum_{i=1}^{J}\mu_i - \mu_j}{N} p_j Y_j \tag{28}$$

$$\frac{\mu_j}{\sum_{i=1}^{J}\mu_i} = \frac{p_j Y_j}{\sum_{i=1}^{J} p_i Y_i} \tag{29}$$

Steady State Solution

- In Steady State, $\dot{k} = \dot{c} = 0$.
- By the Euler equation,

$$r_j = \rho. \tag{30}$$

- Note that $p_j = p_i$ for all $i, j \in \{1, \ldots, J\}$.
- Normalize,

$$p_j = 1. \tag{31}$$

Characterization

- Innovation

$$\mu_j = \kappa(\theta_j)\left(\frac{2\sigma}{1+2\sigma}\right)^{\lambda}. \tag{32}$$

- Share of World Income

$$\frac{Y_j}{\sum_{i=1}^{J} Y_i} = \frac{\kappa(\theta_j)}{\sum_{i=1}^{J}\kappa(\theta_i)}. \tag{33}$$

- Capital and Labor

$$w_j,\ k_j \ \propto\ \kappa(\theta_j)\sum_{i=1}^{J} Y_i. \tag{34}$$

- Labor allocation $L_j^R = 2\sigma L_j^{Int}$.

The Unbundling Equilibrium

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- Trade both in intermediates and varieties.

The Unbundling Equilibrium

Definition

An equilibrium unbundling is defined by a sequence of prices $\{w_j(t), r_j(t), p_j(t)\}_{t=0,\ j=1,\dots,J}^{\infty}$ and allocations $\{l_j(z,t), k_j(z,t), c_j\}_{t=0,\ z\in[0,1],\ j=1,\dots,J}^{\infty}$ such that for each country:

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Key Differences

- The marginal cost of producing a variety in country j is

$$MC_j(v) = \exp\left(\int_0^1 \ln\left(\min_{i\in\{1,\ldots,J\}}\{p_i(z)\}\right) dz\right) \tag{35}$$

Key Differences II

- Denote by Z_j the set of tasks produced by country j,

$$\underbrace{\frac{\mu_j}{N}\left(\sum_{i=1}^{J} p_i Y_i - p_j Y_j\right)}_{Varieties\ \ Exp} + \underbrace{Z_j \frac{(N-\mu_j)}{N(1+\sigma)} \sum_{i=1}^{J} p_i Y_i}_{Intermediates\ \ Exp} =$$

$$\underbrace{\frac{N-\mu_j}{N} p_j Y_j}_{Varieties\ \ Imp} + \underbrace{\frac{\mu_j}{N(1+\sigma)} \sum_{i=1}^{J} p_i Y_i (1-Z_j)}_{Intermediates\ \ Imp}.$$

Key Differences II

- Denote by Z_j the set of tasks produced by country j,

$$\frac{Y_j}{\sum_i Y_i} = \frac{\sigma}{1+\sigma}\frac{\mu_j}{\sum_i \mu_i} + \frac{1}{1+\sigma}Z_j \tag{36}$$

Key Differences II

- Denote by Z_j the set of tasks produced by country j,

$$\underbrace{\frac{Y_j}{\sum_i Y_i}}_{Income\ \ Share} = \underbrace{\frac{\sigma}{1+\sigma}\frac{\mu_j}{\sum_i \mu_i}}_{Varieties} + \underbrace{\frac{1}{1+\sigma}Z_j.}_{Intermediates} \tag{36}$$

Steady State Solution

- Euler equation $r_j = \rho$
- Cost of intermediate z produced in j

$$c_j(z) = \theta_j^{-1} w_j^{1-z} \rho^z. \tag{37}$$

- Suppose two countries produce the same intermediate $\tilde{z}$

$$c_j(\tilde{z}) = c_i(\tilde{z}) \quad \rightarrow \quad \theta_j^{-1} w_j^{1-\tilde{z}} = \theta_i^{-1} w_i^{1-\tilde{z}} \tag{38}$$

$$\Longrightarrow \quad \frac{w_j}{w_i} = \left(\frac{\theta_j}{\theta_i}\right)^{\frac{1}{1-\tilde{z}}} \tag{39}$$

- Suppose that $\theta_j > \theta_i$. As $\frac{1}{1-z}$ is an increasing function of z, country i will not produce any intermediate with $z > \tilde{z}$.
- Productive countries have comparative advantage in capital intensive intermediates.

Sorting in Intermediate Production

Result

Suppose that there exists a strict ranking of productivities across countries, $\theta_1 < \theta_2 < \ldots < \theta_J$. Then, in the steady state, each country j specializes in a non-overlapping subset of tasks, such that country 1 produces $[0, z_1]$, country 2, $(z_1, z_2]$,. . . , country J, $(z_{J-1}, 1]$.

- Decreasing returns in innovation ensures all countries innovate.
- Equation (39) implies that J specializes in the most capital intensive tasks.

Equilibrium Characterization

- Assume $\lambda = 1/2$.
- Equilibrium given by second-order equation in differences

$$\left(\frac{\theta_j}{\theta_{j+1}}\right)^{\frac{1}{1-z_j}} = \frac{\Delta_j + \sqrt{\Delta_j^2 + 4\kappa(\theta_j)^2\sigma^2 N^{-2}}}{\Delta_{j+1} + \sqrt{\Delta_{j+1}^2 + 4\kappa(\theta_{j+1})^2\sigma^2 N^{-2}}} \tag{40}$$

  with

$$\Delta_j = \int_{z_{j-1}}^{z_j} (1-z)dz,$$

  and boundary conditions $z_0 = 0$ and $z_J = 1$.
- Unique solution to recursion equation.

Symmetry-Breaking

- Consider a world composed of $J = 2$ countries, $\theta_2 = \theta_1 + \varepsilon$ for $\varepsilon \geq 0$.
- In the equilibrium without unbundling both countries have one half of the world income.
- Equilibrium with unbundling, make $\varepsilon \to 0$, the solution of equation (40) is $z_1 = \frac{1}{2}(2 - \sqrt{2}) \simeq .29$.
- Can show that,

$$\frac{Y_2 - Y_1}{\sum_i Y_i} = \frac{1 - 2z_1}{1 + \sigma} > 0. \tag{41}$$

Symmetry-Breaking Generalization

- For an arbitrary number of countries,

$$z_j = 1 - \sqrt{1 - \frac{j}{J}} \tag{42}$$

which is an increasing, convex function of j.

Proposition

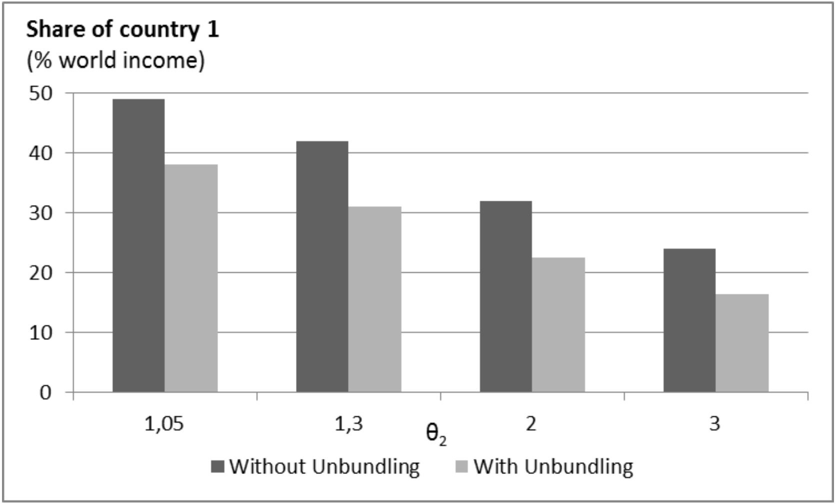
There exists a strict ranking in income of ex-ante identical countries in the unbundling equilibrium

- Complementarity between capital accumulation and the pattern of specialization.
- Symmetric Equilibrium is not stable.

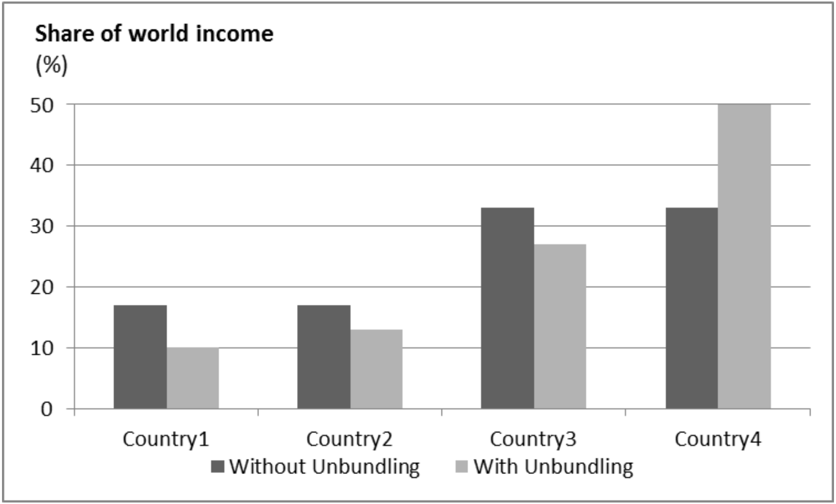
Heterogeneous Countries

- Consider the two country case with $\theta_2 > \theta_1$.
- More inequality than with symmetry-breaking.
- More inequality than without unbundling.
  - Can show it locally, simulate for other ranges.
- Country 1 can loose in absolute terms (more likely when θ_1 is close to θ_2).

Numerical Example: $\sigma = 1$, $\theta_1 = 1$ and $\kappa(\theta_j) = \theta_j$



Four countries, $\theta_1 = \theta_2 = 1$ and $\theta_3 = \theta_4 = 2$



Conclusions

- Present a model of unbundling of production.
- Sorting in the production of intermediates generates different incentives to accumulate capital.
- Increases inequality among similar countries in the equilibrium with unbundling.
- With heterogeneous countries, increase of top-bottom inequality, compression in the middle?
- Next Steps:
  1. Approximate solution by differential equation to obtain sharper characterization.
  2. Computerization: changes in capital requirements of intermediates $\rightarrow$ comparative statics in composition of bundle.