Fragmentation and The Product Cycle

Edwin L.-C. LAI Hong Kong University of Science and Technology
Han (Steffan) QI Baptist University of Hong Kong

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Motivation

- International fragmentation of production, which refers to the phenomenon that different tasks of the process of producing a good are carried out in different countries, has become widespread in recent decades.
- Some countries may specialize in the production and exporting of intermediate goods while other countries may specialize in assembly of final goods using imported as well as home-produced intermediate goods. They often become assembly centers for other countries.
- As a result, the domestic value-added embodied in the gross exports of the assembly center can be substantially lower than the value of their gross exports.

Introduction

The two main goals of the paper are to answer the following questions:

- In the product cycle setting, what factors determine the degree of fragmentation of the global economy?
- In the product cycle setting, what is the long-term repercussions of fragmentation on the income gap between the 'North' (the more advanced countries) and 'South' (less developed countries)?

Preview of Results

- In this paper, we develop a model of fragmentation in the context of product cycles, with Ricardian comparative advantage driving trade of intermediate goods.
- Fragmentation is defined as the separation of the location of production of intermediate goods and that of the assembly of the final good.
- The North carries out innovation, production of intermediate goods and final goods assembly at the earlier stage of the life cycle of the products, while the South carries out intermediate goods production and final goods assembly at the later stage of the life cycle.
- Fragmentation is caused by standardization of technology in producing the final goods accompanied by offshoring of final goods from the North to the South.

Preview of Results (cont'd)

- An increase in the rate of standardization of technology of the production of final goods lowers the North-South wage gap, making Northern intermediate goods more competitive in the South, raising the extent of global fragmentation.
- An increase in the North's capability to develop new final goods lowers the degree of global fragmentation, as it raises North-South wage gap and makes Northern intermediate goods less competitive in the South.
- As the North becomes better in producing intermediate goods relative to the South, it leads not only in a rise in North-South wage gap but also an increase in the extent of global fragmentation.
- An exogenous increase in fragmentation, possibly due to changes in technology of production, would increase the North-South wage gap, making North better off at the expense of South.

Literature Review

- Vernon (1966)
- Krugman (1979)
- Grossman and Helpman (1991)
- Eaton and Kortum (2002)
- Lai (1998)
- Johnson and Noguera (2012)
- Koopman, Wang and Wei (2014)

A Product Cycle Model with Offshoring

- There are two countries (North and South) in the world, where there is free trade.
- Innovation is the development of new products, In equilibrium, only Northern firms will innovate.
- We only focus on the analysis of the balanced growth path, i.e. the long run equilibrium.
- Along the balanced growth path, growth rate is constant over time.

A Product Cycle Model with Offshoring (cont'd)

- There is only one factor input, labor.
- Production of an intermediate good requires only labor, while assembly of a final good requires a set of intermediate goods specific to the final product, as well as labor.
- At any instant, a number of differentiated final goods (denoted by n) have been developed by North. Each innovation takes the form of the introduction of a new differentiated final product by a firm.

A Product Cycle Model with Offshoring (cont'd)

- At the early stage of a final product's life, only North can produce the intermediate goods as well as assemble the final good.
- Some time after the development of the final good, the technology of producing the final good become standardized, meaning that the South acquires the capability of producing the set of intermediate goods specific to the final good as well as assembly of the final good.
- Offshoring is defined as the setting up of a multinational corporation (MNC) by a Northern firm in the South for assembling the final good and possibly producing some intermediate goods specific to the final good.
- Offshoring of final good is possible only after standardization of technology of producing that final good. In equilibrium, after standardization of the technology of producing a final good, the Northern innovator will offshore the final good to South (i.e. setting up an MNC there to assemble the final good), since wage is lower there.

A Product Cycle Model with Offshoring (cont'd)

- In equilibrium, the final good will be assembled only in South once the technology of producing the final good is standardized. After offshoring, the labor productivity of assembly of the final good in South is assumed to be the same as that in North.
- After offshoring of the final good from North to South, some intermediate goods continue to be produced in North and some are produced in South.
- After offshoring of the final goods, some intermediate goods are exported from North to South for production of the final goods, some of which are exported back to the North.
- Thus, there is fragmentation and back-and-forth trade.

The Demand for goods

- There is a representative agent in each country who chooses instantaneous expenditure $E_i(\tau)$ to maximize welfare at time t:

$$W_i = \int_t^{\infty} e^{-\rho(\tau - t)} \left[\frac{U_i(\tau)^{1-\sigma} - 1}{1-\sigma} \right] d\tau \tag{1}$$

subject to the intertemporal budget constraint.[1]

$$\int_t^{\infty} e^{-r(\tau - t)} E_i(\tau) d\tau = \int_t^{\infty} e^{-r(\tau - t)} I_i(\tau) d\tau + A_i(t) \qquad \text{for all } t \tag{2}$$

where $0 < \sigma$ and $1/\sigma =$ intertemporal elasticity of substitution; ρ is the time rate of preference; r is the nominal interest rate ; $U_i(\tau)$ is instantaneous utility at time τ ; $E_i(\tau)$ is instantaneous expenditure at τ ; $I_i(\tau)$ is instantaneous income at τ ; $A_i(t)$ is the current value of assets at t.

[1] The 'flow equation' implied from the 'stock equation' shown here is $I_i(t) - E_i(t) + rA_i(t) = \dot{A}_i(t)$.

The Demand for goods (cont'd)

- Instantaneous utility is given by

$$U_i(t) = \left\{ \int_0^{n(t)} \left[x_i(z) \right]^{\alpha} dz \right\}^{\frac{1}{\alpha}} \quad \text{where } 0 < \alpha < 1. \tag{3}$$

- The welfare maximization problem can be reduced to a two-stage budgeting problem: the agent solves a dynamic optimization problem of allocating $E_i(t)$ over time, then solves a static optimization problem of choosing the various $x_i(z)$ subject to a budget constraint of $E_i(t)$ at time t to maximize instantaneous utility.

The Demand for goods (cont'd)

- Because of symmetry in unit costs, the prices of all final goods assembled in the same country are equal. Denote the wage of country i by w_i, the price of a final good assembled in North (in South by MNC) by p_N (p_m).
- Normalize by setting $p_N = 1$, which implies that

$$\frac{\dot{w}_i}{w_i} = \frac{\dot{E}_i}{E_i} = \frac{\dot{p}_N}{p_N} = 0 \quad \text{for } i = N, S.$$

- Solution of the dynamic optimization problem:

$$\begin{aligned} r &= \rho + (\sigma - 1)\left(\frac{1-\alpha}{\alpha}\right)\frac{\dot{n}}{n} \qquad (4) \\ &= \rho + \psi g, \quad \text{where} \quad \psi \equiv (\sigma - 1)\left(\frac{1-\alpha}{\alpha}\right) \text{ and } g \equiv \frac{\dot{n}}{n}. \end{aligned}$$

- Assume that $\rho + \psi g > g$ (discount dominates growth) so as to make sure that welfare is finite.

The Demand for goods (cont'd)

- The static optimization problem of the two-stage budgeting problem is given by

$$\max_{x_i(z)} \quad U_i(t)$$

s. t.

$$\int_0^n x_i(z)p_i(z)dz = E_i(t), \tag{5}$$

- The solution is

$$x_i(z) = \frac{p_i(z)^{-\epsilon}}{\int_0^n p_i(u)^{1-\epsilon}du}E_i \qquad \text{where } \epsilon = \frac{1}{1-\alpha} \tag{6}$$

The Balanced Growth Path

- $n = n_m + n_N$
- On the balanced growth path, $\frac{\dot{n}_N}{n_N} = \frac{\dot{n}_m}{n_m} = \frac{\dot{n}}{n} = g$. Moreover, g and $\frac{n_m}{n}$ are constant over time.

Final and intermediate good production

- Country i's ($i = N, S$) labor productivity φ in producing each intermediate good is a random variable that follows a Fréchet distribution:

$$F_i(\varphi) = e^{-T_i \varphi^{-\theta}}$$

- The production function of final good z is given by

$$y(z) = [M(z)]^{\mu} [I(z)]^{1-\mu}$$

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$$M(z) = \left\{ \int_0^1 [q_z(j)]^{\frac{\widetilde{\sigma}}{1-\widetilde{\sigma}}} dj \right\}^{\frac{1-\widetilde{\sigma}}{\widetilde{\sigma}}}$$

Final and intermediate good production (cont'd)

- Before offshoring, unit cost of the aggregate intermediate good is

$$c^M(z) = c_N^M = \gamma w_N T_N^{-\frac{1}{\theta}}$$

- After offshoring, the unit cost of aggregate intermediate good is

$$c^M(z) = c_m^M = \gamma \left(T_N w_N^{-\theta} + T_S w_S^{-\theta} \right)^{-\frac{1}{\theta}}$$

- Before offshoring, unit cost of final good is

$$c(z) = c_N(z) = c_N = K \left(\gamma w_N T_N^{-\frac{1}{\theta}} \right)^{\mu} w_N^{1-\mu} \tag{7}$$

- After offshoring, unit cost is

$$c(z) = c_m(z) = c_m = K \left[\gamma \left(T_N w_N^{-\theta} + T_S w_S^{-\theta} \right)^{-\frac{1}{\theta}} \right]^{\mu} w_S^{1-\mu}. \tag{8}$$

Rate of innovation and rate of offshoring

- Assume that rate of innovation $g \equiv \frac{\dot{n}}{n}$ is exogenous, being determined by the limited supply of research resource (number of scientists) in North.
- Rate of standardization $\frac{\dot{n}_m}{n_N}$ (which is also equal to the rate of offshoring in equilibrium), denoted by ω, is also assumed to be exogenous and constant over time.
- These assumptions are also made by Krugman (1979).

Instantaneous Profits of Northern Firms and MNCs

- Price of a North-produced final good:

$$p_N = \frac{c_N}{\alpha}. \tag{9}$$

- Price of a MNC-produced final good:

$$p_m = \frac{c_m}{\alpha} \tag{10}$$

- Therefore,

$$\frac{\pi_m}{\pi_N} = \left(\frac{c_m}{c_N}\right)^{1-\epsilon} \tag{11}$$

Solution of the Model

- $$\pi_m = \frac{w_S L_S}{n_m (1 - \mu\beta_N)} \left(\frac{1-\alpha}{\alpha} \right) \tag{12}$$

  where β_N is the share of intermediate goods produced by North for those final goods that have been offshored.

- $$\pi_N = \left[L_N - \frac{w_S L_S \mu\beta_N}{(1 - \mu\beta_N) w_N} \right] \frac{w_N}{n_N} \left(\frac{1-\alpha}{\alpha} \right) \tag{13}$$

- In steady state,

$$\frac{n_m}{n_N} = \frac{\omega}{g}$$

Solution of the Model (cont'd)

$$\left[\left(\beta_N\right)^{\frac{\mu}{\theta}}\left(\frac{w_S}{w_N}\right)^{1-\mu}\right]^{\epsilon-1}=\left[L_N-\frac{w_S}{w_N}L_S\left(\frac{\mu\beta_N}{1-\mu\beta_N}\right)\right]\frac{w_N}{w_S}\left(\frac{\omega}{g}\right)\frac{1-\mu\beta_N}{L_S} \tag{14}$$

where

$$\beta_N=\frac{T_N\left(w_N\right)^{-\theta}}{T_N\left(w_N\right)^{-\theta}+T_S w_S^{-\theta}}=\frac{\frac{T_N}{T_S}\left(\frac{w_N}{w_S}\right)^{-\theta}}{\frac{T_N}{T_S}\left(\frac{w_N}{w_S}\right)^{-\theta}+1}.$$

- This equation implicitly expresses w_N/w_S as a function of the exogenous variables.

- μ, $T_N / T_S \uparrow$ or w_N / w_S, α, $\theta \downarrow \Longrightarrow LHS_{14} \uparrow$
- L_N, w_N / w_S, ω, $\theta \uparrow$ or L_S, g, μ, $T_N / T_S \downarrow \Longrightarrow RHS_{14} \uparrow$
- $DVAR_S$ = domestic value-added ratio of South = fraction of gross exports attributed to domestic value-added
- $DVAR_S$ lower $\Longrightarrow$ more global fragmentation
- $DVAR_S = 1 - \mu\beta_N$
- $1 - DVAR_S = \mu\beta_N$ is called the degree of global fragmentation.

Factors determining degree of fragmentation of global economy

	w_N/w_S	β_N	π_m/π_N	$DVAR_S$	Degree of fragmentation
				$(1-\mu\beta_N)$	$(1-DVAR_S)$
$L_S \uparrow$	$\uparrow$	$\downarrow$	$\uparrow$	$\uparrow$	$\downarrow$
$L_N \uparrow$	$\downarrow$	$\uparrow$	$\downarrow$	$\downarrow$	$\uparrow$
$\frac{T_N}{T_S} \uparrow$	$\uparrow$	$\uparrow$	?	$\downarrow$	$\uparrow$
$\alpha \uparrow$	$\downarrow$	$\uparrow$	$\downarrow$	$\downarrow$	$\uparrow$
$\omega \uparrow$	$\downarrow$	$\uparrow$	$\downarrow$	$\downarrow$	$\uparrow$
$g \uparrow$	$\uparrow$	$\downarrow$	$\uparrow$	$\uparrow$	$\downarrow$
$\mu \uparrow$	$\uparrow$	$\downarrow$	$\uparrow$	$\uparrow$	$\downarrow$
$\theta \uparrow^{\dagger}$	$\uparrow$	$\downarrow$	$\uparrow$	$\uparrow$	$\downarrow$

† True if $\frac{T_S}{T_N} + \left(\frac{w_S}{w_N}\right)^{\theta} > 1$.

Highlights of some comparative steady-states analyses

- $T_N / T_S \uparrow$ or $w_N / w_S \downarrow \Longrightarrow \beta_N \uparrow$
- Thus, w_N / w_S is a crucial factor in determining β_N, which indicates the degree of fragmentation. Intuitively, Any exogenous factor except T_N / T_S that raises w_N / w_S would lower the competitiveness of North-produced intermediate goods, inducing MNC's to use a lower fraction of North-produced intermediate goods, thus lowering β_N, and hence the degree of fragmentation. For example,
  1. An increase in the rate of standardization of technology in producing final goods lowers the North-South wage gap, making Northern intermediate goods more competitive, thus raising the degree of global fragmentation.
  2. An increase in the North's capability to develop new final goods raises North-South wage gap and makes Northern intermediate goods less competitive, thus lowering the degree of global fragmentation.

Highlights of some comparative steady-states analyses (cont'd)

- As T_N / T_S increases, the North becomes better in producing intermediate goods relative to the South, which raises North-South wage gap but also an increase in the extent of global fragmentation.

Effects of fragmentation on world distribution of income

- Some thought experiments:
  1. Assume that South is able to produce and export intermediate goods to North according to Ricardian comparative advantage even before offshoring
     - more fragmentation than the baseline model
     - leads to an increase in w_N/w_S
  2. Assume that North produces all intermediate goods even after offshoring
     - there is **full fragmentation**
     - leads to an increase in w_N/w_S
  3. Assume that South produces all intermediate goods after offshoring
     - there is **no fragmentation**
     - leads to a decrease in w_N/w_S
- Conclusion: An exogenous increase in the degree of fragmentation would increase the North-South wage gap, making North better off at the expense of South.

Conclusion

- We have built a tractable model of fragmentation in the context of product cycles.
- We identify a few factors that determine the degree of fragmentation in the global economy, and the accompanying North-South wage gap.
  1. An increase in the rate of standardization of technology in producing final goods lowers the North-South wage gap, making Northern intermediate goods more competitive, thus raising the degree of global fragmentation.
  2. An increase in the North's capability to develop new final goods raises North-South wage gap and makes Northern intermediate goods less competitive, thus lowering the degree of global fragmentation.
  3. As the North becomes better in producing intermediate goods relative to the South, it raises North-South wage gap but also an increase in the extent of global fragmentation.
- An exogenous increase in the degree of fragmentation would increase the North-South wage gap, making North better off at the expense of South.

Q & A

Thank you!