

14.581 International Trade  
— Lecture 3: The Ricardian Model (Theory) —

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# Today's Plan

- 1 Taxonomy of neoclassical trade models.
- 2 Standard Ricardian model: Dornbush, Fischer and Samuelson (AER 1977).
  - 1 Free trade equilibrium.
  - 2 Comparative statics.
- 3 Multi-country extensions.
- 4 The origins of cross-country technological differences.

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# Taxonomy of Neoclassical Trade Models

- As we saw last week, in a neoclassical trade model, comparative advantage, i.e. differences in relative autarky prices, is the rationale for trade.
- Differences in autarky prices can have two origins:
  - ① Demand (periphery of the field).
  - ② Supply (core of the field).
    - ① **Ricardian theory:** Technological differences.
    - ② **Factor proportion theory:** Factor endowment differences.

# Taxonomy of Neoclassical Trade Models

- In order to shed light on the role of technological and factor endowment differences:
  - Ricardian theory: assumes only one factor of production.
  - Factor proportions (Heckscher-Ohlin/Ricardo-Viner) theory: rules out technological differences.
- Neither set of assumptions is realistic, but both may be useful depending on the question one tries to answer:
  - If you want to understand the impact of the rise of China on real wages in the US, Ricardian theory is a natural place to start.
  - If you want to study its effects on the skill premium, more factors will (obviously) be needed.
- Note that:
  - Technological and factor endowment differences are exogenously given.
  - No relationship between technology and factor endowments (Skill-biased technological change?)

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# Standard Ricardian Model

Dornbush, Fischer and Samuelson (AER 1977)

- Consider a world economy with **two countries**: Home and Foreign.
  - Asterisk denotes variables related to the Foreign country.
- Ricardian models differ from other neoclassical trade models in that there only is **one factor** of production.
  - Equivalently, you can think that there are many (nontradable) factors, but that they can all be aggregated into a single composite.
  - And if a factor is perfectly mobile then its return will be equalized across countries (and hence not generate comparative advantage) anyway.
- We denote by:
  - $L$  and  $L^*$  the endowments of labor (in efficiency units) in the two countries.
  - $w$  and  $w^*$  the wages (in efficiency units) in the two countries.

# Standard Ricardian Model

## Supply-side assumptions

- There is a **continuum** of goods indexed by  $z \in [0, 1]$ .
- Since there are CRTS, we can define the (constant) unit labor requirements in both countries:  $a(z)$  and  $a^*(z)$ .
- $a(z)$  and  $a^*(z)$  capture all we need to know about technology in the two countries.
- Wlog, we order goods such that  $A(z) \equiv \frac{a^*(z)}{a(z)}$  is decreasing.
  - Hence Home has a comparative advantage in the low- $z$  goods.
  - For expositional simplicity, we'll assume strict monotonicity.

# Standard Ricardian Model

Free trade equilibrium (I): Efficient international specialization

- Previous supply-side assumptions are all we need to make qualitative predictions about pattern of trade.
- Let  $p(z)$  denote the price of good  $z$  in both countries, under free trade.
- Profit-maximization requires:

$$p(z) - wa(z) \leq 0, \text{ w equality if } z \text{ is produced at Home} \quad (1)$$

$$p(z) - w^*a^*(z) \leq 0, \text{ w equality if } z \text{ is produced Abroad} \quad (2)$$

- **Proposition:** *There exists  $\tilde{z} \in [0, 1]$  such that Home produces all goods  $z < \tilde{z}$  and Foreign produces all goods  $\tilde{z} > z$*

# Standard Ricardian Model

Free trade equilibrium (I): Efficient international specialization

- **Proof:** By contradiction. Suppose that there exists  $z' < z$  such that  $z$  produced at Home and  $z'$  is produced abroad. (1) and (2) imply

$$\begin{aligned}p(z) - wa(z) &= 0 \\p(z') - wa(z') &\leq 0 \\p(z') - w^* a^*(z') &= 0 \\p(z) - w^* a^*(z) &\leq 0\end{aligned}$$

This implies

$$wa(z) w^* a^*(z') = p(z) p(z') \leq wa(z') w^* a^*(z),$$

which can be rearranged as

$$a^*(z') / a(z') \leq a^*(z) / a(z)$$

This contradicts  $A$  strictly decreasing.

# Standard Ricardian Model

## Free trade equilibrium (I): Efficient international specialization

- Proposition simply states that Home should produce and specialize in the goods in which it has a CA.
- Note that:
  - Proposition does not rely on continuum of goods.
  - But continuum of goods and continuity of  $A$  is important to derive:

$$A(\tilde{z}) = \frac{w}{w^*} \equiv \omega \quad (3)$$

- Equation (3) is the first of DFS's two equilibrium conditions:
  - Conditional on wages, goods should be produced in the country where it is cheaper to do so.
- To complete characterization of free trade equilibrium, we need look at the demand side to pin down the relative wage  $\omega$ .

# Standard Ricardian Model

## Demand-side assumptions

- Consumers have **identical Cobb-Douglas** prefs around the world.
- We denote by  $b(z) \in (0, 1)$  the share of expenditure on good  $z$ :

$$b(z) = \frac{p(z) c(z)}{wL} = \frac{p(z) c^*(z)}{w^*L^*}$$

where  $c(z)$  and  $c^*(z)$  are consumptions at Home and Abroad.

- By definition, shares of expenditure satisfy:  $\int_0^1 b(z) dz = 1$ .

# Standard Ricardian Model

Free trade equilibrium (II): trade balance

- Let us denote by  $\theta(\tilde{z}) \equiv \int_0^{\tilde{z}} b(z)$  the fraction of income spent (*in both countries*) on goods produced at Home.
- Trade balance requires

$$\theta(\tilde{z}) w^* L^* = [1 - \theta(\tilde{z})] wL$$

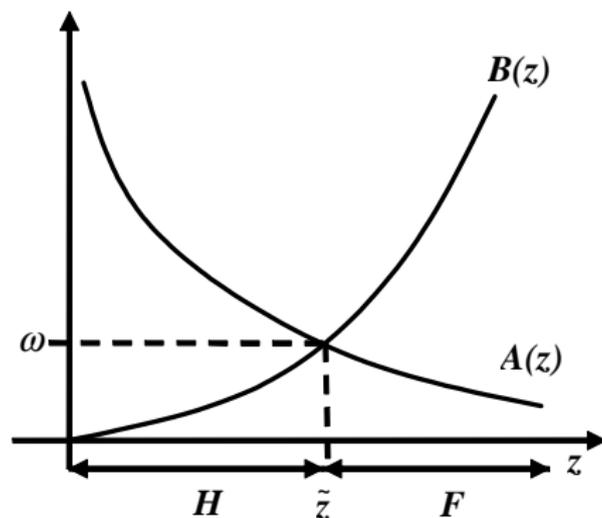
- where LHS  $\equiv$  Home exports; RHS  $\equiv$  Home imports.
- Previous equation can be rearranged as

$$\omega = \frac{\theta(\tilde{z})}{1 - \theta(\tilde{z})} \left( \frac{L^*}{L} \right) \equiv B(\tilde{z}). \quad (4)$$

- Note that  $B' > 0$ : an increase in  $\tilde{z}$  leads to a trade surplus at Home, which must be compensated by an increase in Home's relative wage  $\omega$

# Standard Ricardian Model

Putting things together



- Efficient international specialization, ie Equation (3), and trade balance, ie Equation (4), jointly determine  $(\tilde{z}, \omega)$ .
- Note: this figure is essentially a set of relative labor demand and labor supply curves.

# Standard Ricardian Model

A quick note on the gains from trade

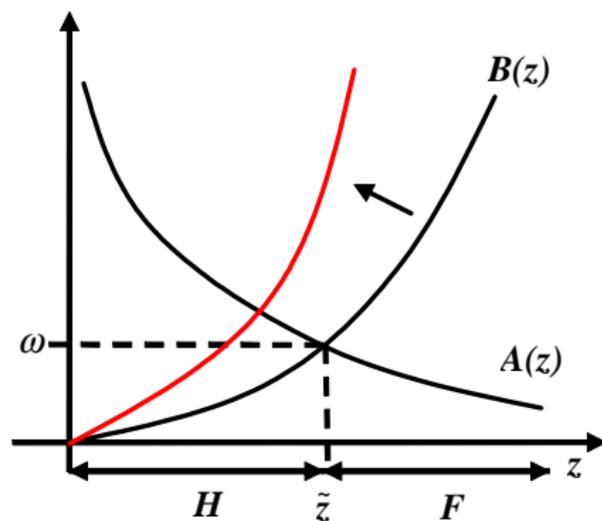
- Since Ricardian model is a neoclassical model, general results derived in Lecture 1 hold.
- However, one can directly show the existence of gains from trade in this environment.
- **Argument:**
  - Take  $w$  as the numeraire under autarky and free trade.
  - So indirect utility of Home representative household only depends on  $p(\cdot)$ .
  - For goods  $z$  produced at Home under free trade: no change compared to autarky.
  - For goods  $z$  produced in Foreign under free trade:  
 $p(z) = w^* a^*(z) < a(z)$ .
  - Since all prices are constant or go down, indirect utility must go up.

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# What Are the Consequences of (Relative) Country Growth?

One of many classical comparative statics exercises using DFS (1977)



- Suppose that  $L^*/L$  goes up (eg rise of China):
  - $\omega$  goes up and  $\tilde{z}$  goes down.
  - At initial wages, an increase in  $L^*/L$  creates a trade deficit in Foreign, which must be compensated by an increase in  $\omega$ .

# What are the Consequences of (Relative) Country Growth?

- Increase in  $L^*/L$  raises indirect utility, i.e. real wage, of representative household at Home and lowers it in Foreign:
  - Take  $w$  as the numeraire before and after the change in  $L^*/L$ .
  - For goods  $z$  whose production remains at Home: no change in  $p(z)$ .
  - For goods  $z$  whose production remains in Foreign:  
 $w \nearrow \Rightarrow w^* \searrow \Rightarrow p(z) = w^* a^*(z) \searrow$ .
  - For goods  $z$  whose production moves in Foreign:  
 $w^* a^*(z) \leq a(z) \Rightarrow p(z) \searrow$ .
  - So Home gains. Similar logic implies welfare loss in Foreign.
- **Comments:**
  - In spite of CRS at the industry-level, everything is as if we had DRS at the country-level.
  - As Foreign's size increases, it specializes in sectors in which it is relatively less productive (compared to Home), which worsens its terms-of trade, and so, lowers real GDP per capita.
  - The flatter the  $A$  schedule, the smaller this effect.
  - Acemoglu and Ventura (QJE, 2002) exploit this to get convergence in a global AK growth model (see Lecture 17).

# What are the Consequences of Technological Change?

- There are many ways to model technological change:
  - ① Global uniform technological change: for all  $z$ ,  $\hat{a}(z) = \hat{a}^*(z) = x > 0$ .
  - ② Foreign uniform technological change: for all  $z$ ,  $\hat{a}(z) = 0$ , but  $\hat{a}^*(z) = x > 0$ .
  - ③ International transfer of the most efficient technology: for all  $z$ ,  $a(z) = a^*(z)$  (Offshoring?)
- Using the same logic as in the previous comparative static exercise, one can easily check that:
  - ① Global uniform technological change increases welfare everywhere.
  - ② Foreign uniform technological change increases welfare everywhere (For Foreign, this depends on Cobb-Douglas assumption).
  - ③ If Home has the most efficient technology,  $a(z) < a^*(z)$  initially, then it will lose from international transfer (no gains from trade).

# Other Comparative Static Exercises

## Transfer problem

- Suppose that there is  $T > 0$  such that:
  - Home's income is equal to  $wL + T$ ,
  - Foreign's income is equal to  $w^*L^* - T$ .
- If preferences are identical in both countries, transfers do not affect the trade balance condition:

$$[1 - \theta(\tilde{z})] (wL + T) - \theta(\tilde{z}) (w^*L^* - T) = T$$

$\Leftrightarrow$

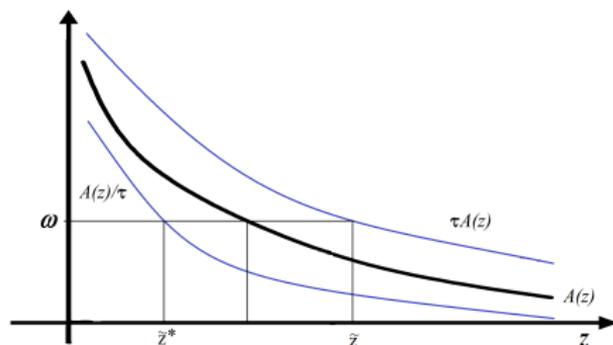
$$\theta(\tilde{z}) w^*L^* = [1 - \theta(\tilde{z})] wL.$$

- So there are no terms-of-trade effect.
- If Home consumption is biased towards Home goods,  $\theta(z) > \theta^*(z)$  for all  $z$ , then transfer further improves Home's terms-of trade.
- See Dekle, Eaton, and Kortum (2007) for a recent application.

# Adding Trade Costs

- As we will see in Week 8, there is an abundance of evidence that international trade is impeded by significant trade costs.
  - It is therefore attractive if a model permits the easy inclusion of trade costs—to potentially bring it closer to the data.
  - TCs can be hard to add to some trade models, and easy(ier) to add to others.
- TCs turn out to be easy to add to DFS 1977 (and many other models we'll see), if we assume a particular 'iceberg' (Samuelson, 1954) form for TCs:
  - This just means that if trade costs are  $\tau > 1$ , then whenever one unit of a good is shipped internationally only  $1/\tau$  units arrive. ( $\tau = 1$  is free trade).
- This means that:
  - Home will produce goods  $z$  that satisfy:  $wa(z) \leq \tau w^* a^*(z)$ .
  - And Abroad will produce goods  $z$  that satisfy:  $w^* a^*(z) \leq \tau wa(z)$ .

# What Are the Consequences of Trade Costs?



- We now have a range of (endogenously determined) non-traded goods.
  - Defined by two cutoffs: H exports  $z \in [0, \tilde{z}^*]$ , F exports  $z \in [\tilde{z}, 1]$ ; both H and F also make the range of non-traded goods,  $z \in (\tilde{z}^*, \tilde{z})$ .
  - See DFS 1977 for equations that generalize the new trade balance equations in the presence of TCs to determine  $\omega$ .

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# Multi-country extensions

- DFS 1977 provides extremely elegant version of the Ricardian model:
  - Characterization of free trade equilibrium boils down to finding  $(\tilde{z}, \omega)$  using efficient international specialization and trade balance.
- Problem is that this approach does not easily extend to economies with more than two countries.
  - In the two-country case, each country specializes in the goods in which it has a CA compared to the other country.
  - Who is the other country if there are more than 2?
- **Multi-country extensions of the Ricardian model:**
  - 1 Jones (1961)
  - 2 Costinot (2009)
  - 3 Wilson (1980)
  - 4 Eaton and Kortum (2002)
  - 5 Costinot, Donaldson and Komunjer (2010)

# Multi-country extensions

Jones (1961)

- Assume  $N$  countries,  $G$  goods.
- **Trick:** restrict attention to situations where each country only produces one good (“Assignment”).
- Characterize the properties of optimal assignment.
- **Main result:**  
*Optimal assignment of countries to goods, within any ‘class of assignments’ (see paper for details), will minimize the product of their unit labor requirements.*

# Multi-country extensions

Costinot (2009)

- Assume  $N$  countries,  $G$  goods.
- **Trick:** put enough structure on the variation of unit-labor requirements across countries and industries to bring back two-country intuition.
- Suppose that:
  - countries  $i = 1, \dots, N$  have characteristics  $\gamma^i \in \Gamma$ .
  - goods  $g = 1, \dots, G$  have characteristics  $\sigma^g \in \Sigma$ .
- $a(\sigma, \gamma) \equiv$  unit labor requirement in  $\sigma$ -sector and  $\gamma$ -country.

# Multi-country extensions

Costinot (2009)

- **Definition**  $a(\sigma, \gamma)$  is strictly log-submodular if for any  $\sigma > \sigma'$  and  $\gamma > \gamma'$ ,  $a(\sigma, \gamma) a(\sigma', \gamma') < a(\sigma, \gamma') a(\sigma', \gamma)$ .
- If  $a$  is strictly positive, this can be rearranged as

$$a(\sigma, \gamma) / a(\sigma', \gamma) < a(\sigma, \gamma') / a(\sigma', \gamma') .$$

- In other words, high- $\gamma$  countries have a comparative advantage in high- $\sigma$  sectors.
- Examples:
  - In Krugman (1986),  $a(\sigma^s, \gamma^c) \equiv \exp(-\sigma^s \gamma^c)$ , where  $\sigma^s$  is an index of good  $s$ 's "technological intensity" and  $\gamma^c$  is a measure of country  $c$ 's closeness to the world "technological frontier".
  - In Nunn (QJE, 2007),  $a(\sigma^s, \gamma^c) = \sigma^s \gamma^c$ , where  $\sigma^s$  is good  $s$ 's "contract intensity" and  $\gamma^c$  is country  $c$ 's quality of contracting institutions.

# Multi-country extensions

Costinot (2009)

- **Proposition** *If  $a(\sigma, \gamma)$  is log-submodular, then high- $\gamma$  countries specialize in high- $\sigma$  sectors.*
- **Proof:** By contradiction. Suppose that there exists  $\gamma > \gamma'$  and  $\sigma > \sigma'$  such that country  $\gamma$  produces good  $\sigma'$  and country  $\gamma'$  produces good  $\sigma$ . Then profit maximization implies

$$\begin{aligned}p(\sigma') - w(\gamma) a(\sigma', \gamma) &= 0 \\p(\sigma) - w(\gamma) a(\sigma, \gamma) &\leq 0 \\p(\sigma) - w(\gamma') a(\sigma, \gamma') &= 0 \\p(\sigma') - w(\gamma') a(\sigma', \gamma') &\leq 0\end{aligned}$$

This implies

$$a(\sigma, \gamma') a(\sigma', \gamma) \leq a(\sigma, \gamma) a(\sigma', \gamma')$$

which contradicts  $a$  log-submodular.

# Multi-country extensions

Wilson (1980)

- Same as in DFS 1977, but with multiple countries and more general preferences.
- **Trick:** Although predicting the exact pattern of trade is difficult in general, one doesn't actually need to know this to make comparative static predictions.
- At the aggregate level, Ricardian model is similar to an exchange-economy in which countries trade their own labor for the labor of other countries.
  - Since labor supply is fixed, changes in wages can be derived from changes in (aggregate) labor demand.
  - Once changes in wages are known, changes in all prices, and hence, changes in welfare can be derived.

# Multi-country extensions

Eaton and Kortum (2002) — we will see more details next lecture

- **Trick:** For each country  $i$  and each good  $z$ , they assume that productivity,  $1/a(z)$ , is drawn from a Fréchet distribution:

$$F(1/a) = \exp\left(-T_i a^\theta\right)$$

- EK show that only this distribution will deliver certain closed forms.
  - Why? Fréchet is an extreme value distribution and perfect competition selects extreme values (lowest prices).
  - EK also describe some realistic features of this distribution.
- Like Wilson (and unlike Jones), no attempt at predicting which goods countries trade:
  - Instead focus on bilateral trade flows and their implications for wages.
- Unlike Wilson, trade flows only depend on a few parameters ( $T_i, \theta$ ).
  - This allows for calibration and counterfactual analysis.
  - This methodological approach has had a large impact on the field.

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# The Origins of Technological Differences Across Countries

- **Obvious limitation of the Ricardian model:**

Where do productivity differences across countries come from?

- For some goods (eg agricultural goods):

Clearly some production characteristics are immobile (eg weather conditions; Portuguese vs. English wine)

- But for other goods (eg manufacturing goods):

Why don't the most productive firms reproduce their production process everywhere?

- **"Institutions and Trade"** literature offers answer to this question

# Institutions as a Source of Ricardian CA

- **Basic Idea:**

- ① Even if firms have access to same technological know-how around the world, institutional differences across countries may affect how firms will organize their production process, and, in turn, their productivity.
- ② If institutional differences affect productivity relatively more in some sectors, than institutions become source of comparative advantage.

- **General Theme in the “Institutions and Trade” Literature:**

Countries with “better institutions” tend to be relatively more productive, and so to specialize, in sectors that are more “institutionally dependent” .

# Examples of Institutional Trade Theories

## ① **Contract Enforcement:**

Acemoglu, Antras, Helpman (2007), Antras (2005), Costinot\* (2009), Levchenko (2007), Nunn (2007), Vogel (2007).

## ② **Financial Institutions:**

Beck (2000), Kletzer, Bardhan (1987), Matsuyama\* (2005), Manova (2007).

## ③ **Labor Market Institutions:**

Davidson, Martin, Matusz (1999), Cunat and Melitz\* (2007), Helpman, Itskhoki (2006).

(\* denote papers explicitly building on DFS 1977)

# A Simple Example

Costinot JIE (2009)

- **Starting point:**  
*Division of labor*  $\equiv$  key determinant of productivity differences.
- **Basic trade-off:**
  - ① *Gains from specialization*  
 $\Rightarrow$  vary with *complexity* of production process (sector-specific)
  - ② *Transaction costs*  
 $\Rightarrow$  vary with *quality of contract enforcement* (country-specific)
- **Two steps:**
  - ① *Under autarky*, trade-off between these 2 forces pins down the extent of the division of labor across sectors in each country.
  - ② *Under free trade*, these endogenous differences in the efficient organization of production determine the pattern of trade.

# A Simple Example

## Technological know-how

- 2 countries, one factor of production, and a continuum of goods.
- Workers are endowed with 1 unit of labor in both countries.
- **Technology (I): Complementarity.** In order to produce each good  $z$ , a continuum of tasks  $t \in [0, z]$  must be performed:

$$q(z) = \min_{t \in T_z} [q_t(z)]$$

- **Technology (II): Increasing returns.** Before performing a task, workers must learn how to perform it:

$$l_t(z) = q_t(z) + f_t$$

- For simplicity, suppose that fixed training costs are s.t.  $\int_0^z f_t dt = z$
- Sectors differ in terms of **complexity**  $z$ : the more complex a good is, the longer it takes to learn how to produce it

# A Simple Example

## Institutional constraints

- A crucial function of economic institutions: **contract enforcement**.
- Contracts assign tasks to workers.
- Better institutions—either formal or informal—increase the probability that workers perform their contractual obligations.
- Let  $e^{-\frac{1}{\theta}}$  and  $e^{-\frac{1}{\theta^*}}$  denote this probability at Home and Abroad.
- So if Home has **better institutions**:  $\theta > \theta^*$ :

# A Simple Example

## Endogenous organization

- In each country and sector  $z$ , firms choose “division of labor”  $N \equiv$  number of workers cooperating on each unit of good  $z$ .
- Conditional on the extent of the division of labor, (expected) unit labor requirements at Home can be expressed as:

$$a(z, N) = \frac{ze^{\frac{N}{\theta}}}{\left(1 - \frac{z}{N}\right)}$$

- In a competitive equilibrium,  $N$  will be chosen optimally:

$$a(z) = \min_N a(z, N)$$

- Similar expressions hold for  $a^*(z, N)$  and  $a^*(z)$  Abroad.

# A Simple Example

## The Origins of Comparative Advantage

- **Proposition** *If  $\theta > \theta^*$ , then  $A(z) \equiv a^*(z) / a(z)$  is decreasing in  $z$ .*
- From that point on, we can use DFS 1977 to determine the pattern of trade and do comparative statics.
- One benefit of micro-foundations is that they impose some structure on  $A$  as a function of  $\theta$  and  $\theta^*$ :
  - So we can ask what will be the welfare impact of institutional improvements at Home and Abroad?
- The same result easily generalizes to multiple countries by setting " $\gamma^j \equiv \theta$ " and " $\sigma^g \equiv z$ "
  - Key prediction is that  $a(\sigma, \gamma)$  is log-submodular

# Institutional Trade Theories

## Crude summary

- Institutional trade theories differ in terms of content given to notions of **institutional quality** ( $\gamma$ ) and **institutional dependence** ( $\sigma$ ).
- Examples:
  - ① Matsuyama (2005):  $\gamma \equiv$  “credit access”;  $\sigma \equiv$  “pledgeability”
  - ② Cunat and Melitz (2007):  $\gamma \equiv$  “rigidity labor market”;  $\sigma \equiv$  “volatility”
- However institutional trade theories share same fundamental objective: Providing micro-foundations for the log-submodularity of  $a(\sigma, \gamma)$ .
- **Key theoretical question:**  
Why are high- $\gamma$  countries relatively more productive in high- $\sigma$  sectors?

# Other Extensions of DFS 1977

See problem set for details!

- **Non-homothetic preferences:** Matsuyama (2000)
  - Goods are indexed according to priority.
  - Home has a comparative advantage in the goods with lowest priority.
- **External economies of scale:** Grossman and Rossi-Hansberg (2009)
  - Unit labor requirements depend on total output in a given country-industry.
  - Like institutional models,  $a$  is endogenous, but there is a two-way relationship between trade on productivity.