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

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Today's Plan

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

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:
  - Demand (periphery of the field).
  - Supply (core of the field).
    - **Ricardian theory:** Technological differences.
    - **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* $\widetilde{z} \in [0,1]$ *such that Home produces all goods* $z < \widetilde{z}$ *and Foreign produces all goods* $\widetilde{z} > z$

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:

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

- 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 ω.

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 $\theta\left(\widetilde{z}\right) \equiv \int_0^{\widetilde{z}} b\left(z\right)$ the fraction of income spent (*in both countries*) on goods produced at Home.
- Trade balance requires

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

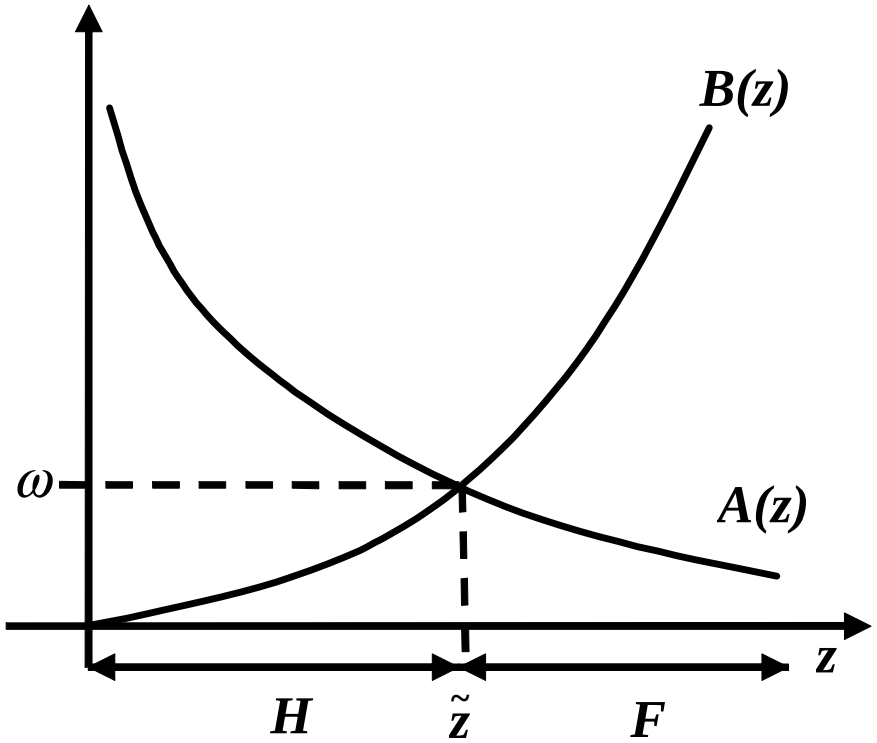
  - where LHS$\equiv$ Home exports; RHS$\equiv$ Home imports.
- Previous equation can be rearranged as

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

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

Standard Ricardian Model

Putting things together



- Efficient international specialization, ie Equation (3), and trade balance, ie Equation (4), jointly determine $(\widetilde{z}, \omega)$.
- 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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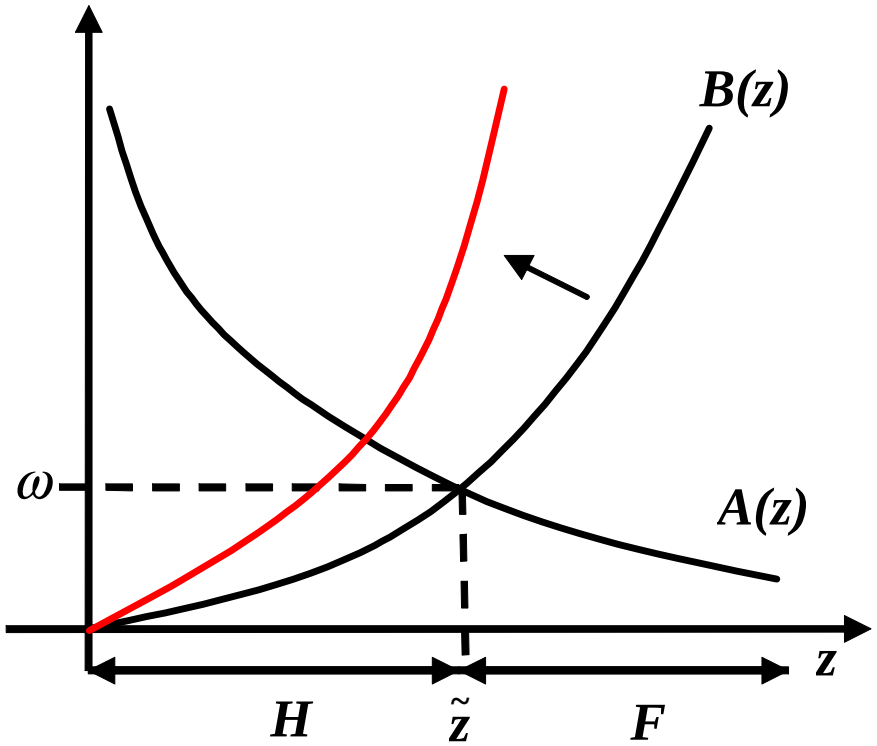
What Are the Consequences of (Relative) Country Growth?

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



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

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: $\omega \nearrow \Rightarrow w^* \searrow \Rightarrow p(z) = w^* a^*(z) \searrow$.
  - 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:
  - Global uniform technological change: for all z, $\widehat{a}(z) = \widehat{a}^*(z) = x > 0$.
  - Foreign uniform technological change: for all z, $\widehat{a}(z) = 0$, but $\widehat{a}^*(z) = x > 0$.
  - 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:
  - Global uniform technological change increases welfare everywhere.
  - Foreign uniform technological change increases welfare everywhere (For Foreign, this depends on Cobb-Douglas assumption).
  - 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:

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

$$\Leftrightarrow$$

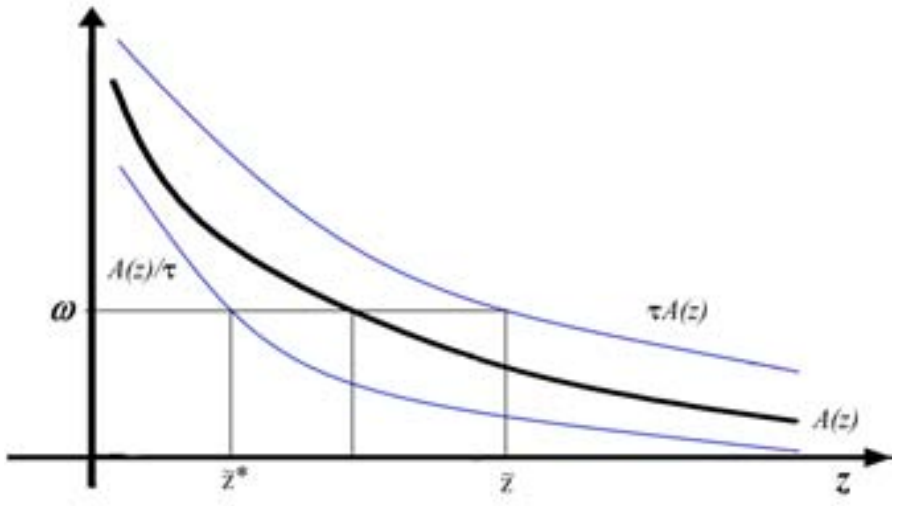
$$\theta\left(\widetilde{z}\right) w^*L^* = \left[1 - \theta\left(\widetilde{z}\right)\right] wL.$$

- So there are no terms-of-trade effect.
- If Home consumption is biased towards Home goods, $\theta\left(z\right) > \theta^*\left(z\right)$ 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 $z \in [0, \widetilde{z}^*]$, F exports $z \in [\widetilde{z}, 1]$; both H and F also make the range of non-traded goods, $z \in (\widetilde{z}^*, \widetilde{z})$.
  - See DFS 1977 for equations that generalize the new trade balance equations in the presence of TCs to determine ω.

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- **Multi-country extensions.**
- The origins of cross-country technological differences.

Multi-country extensions

- DFS 1977 provides extremely elegant version of the Ricardian model:
  - Characterization of free trade equilibrium boils down to finding $(\widetilde{z}, \omega)$ 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:**
  - Jones (1961)
  - Costinot (2009)
  - Wilson (1980)
  - Eaton and Kortum (2002)
  - 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 $i = 1, ..., N$ have characteristics $\gamma^i \in \Gamma$.
  - goods $g = 1, ..., G$ have characteristics $\sigma^g \in \Sigma$.
- $a(\sigma, \gamma) \equiv$ unit labor requirement in σ-sector and γ-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-γ countries have a comparative advantage in high-σ sectors.
- Examples:
  - In Krugman (1986), $a(\sigma^s, \gamma^c) \equiv \exp(-\sigma^s \gamma^c)$, where σ^s is an index of good s's "technological intensity" and γ^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 σ^s is good s's "contract intensity" and γ^c is country c's quality of contracting institutions.

Multi-country extensions

Costinot (2009)

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

- **Contract Enforcement:**
  Acemoglu, Antras, Helpman (2007), Antras (2005), Costinot* (2009), Levchenko (2007), Nunn (2007), Vogel (2007).
- **Financial Institutions:**
  Beck (2000), Kletzer, Bardhan (1987), Matsuyama* (2005), Manova (2007).
- **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:**
  - *Gains from specialization*
    $\Rightarrow$ vary with *complexity* of production process (sector-specific)
  - *Transaction costs*
    $\Rightarrow$ vary with *quality of contract enforcement* (country-specific)
- **Two steps:**
  - *Under autarky*, trade-off between these 2 forces pins down the extent of the division of labor across sectors in each country.
  - *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:

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

- 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 θ and θ^*:
  - 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 "$\gamma^i \equiv \theta$" 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** (γ) and **institutional dependence** (σ).
- Examples:
  - Matsuyama (2005): $\gamma \equiv$ "credit access"; $\sigma \equiv$ "pledgeability"
  - 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-γ countries relatively more productive in high-σ 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.

14.581 International Economics I

Spring 2011