J. Tybout

Economics 507a: International Trade
Lecture 7
September 19, 2007

Last time: EK (2002)

assumptions

- $Z_i(j) =$ amount of good *j* that a bundle of inputs can produce in country *i* (exogenous). Physical output of *j* can be written as: $R(j) = Z_i(j) \cdot L_j^{\alpha} B_j^{1-\alpha}$, where $B_j = \left[\int_0^1 q_j(k)^{\sigma-1/\sigma} dk \right]^{\sigma/\sigma-1}$ and $q_j(k)$ is the volume of good *k* used as an intermediate in the production of good *j*.

- $P[Z_i(j) \le z] = e^{-T_i z^{-\theta}}$ Frechet, or "Type II extreme value" distribution, both T_i and θ are exogenous to the model.

- c_i = cost of a unit bundle of inputs, made up of labor and materials. The cost of a unit of materials solves $\min_{q(\cdot)} \int_0^1 P_i(j) q(j) dj$ subject to $1 = \left[\int_0^1 q(j)^{\sigma-1/\sigma} dj \right]^{\sigma/\sigma-1}$, so it amounts to p_i.

- All consumers and users of intermediate inputs value goods according to the same CES function: $U = \left[\int_0^1 Q(j)^{\sigma-1/\sigma} dj \right]^{\sigma/\sigma-1}$

Implications

(2) The distribution of *observed* prices for any good *j* in country *n* is
$G_n(p) = 1 - \exp\left(-\Phi_n p^{\theta}\right)$, where $\Phi_n \equiv \sum_{i=1}^{N} \phi_i d_{ni}^{-\theta} = \sum_{i=1}^{N} T_i \left(c_i d_{ni}\right)^{-\theta}$.

(3) The probability that country *n* buys good *j* from country *i* is $\pi_{ni} = \frac{d_{ni}^{-\theta} \phi_i}{\Phi_n}$:

(4) The price of any good *j* that country *n* buys also has the distribution $G_n(p)$, and is *not* dependent upon source.

(5) The exact price index for consumers and intermediate goods users is $p_n = \gamma \Phi_n^{-1/\theta}$

Closing the model

The model can be closed by expressing prices as functions of wages and pinning down wages with a homogeneous product sector that produces traded goods. First, assume Cobb-Douglas production functions in labor and intermediates, so the unit cost function is: $c_i = w_i^{\beta} p_i^{1-\beta}$ in all sectors and countries. Substituting this into $\Phi_n \equiv \sum_{i=1}^{N} \phi_i d_{ni}^{-\theta} = \sum_{i=1}^{N} T_i \left(c_i d_{ni}\right)^{-\theta}$, and the result into $p_n = \gamma \Phi_n^{-1/\theta}$ yields *N* equations in *N* prices and *N* wages. The former can be found in terms of the latter. Then pin down wages by letting the homogeneous good be a costlessly traded numeraire, so that each country's wage reflects its productivity in terms of that good: $\frac{w_i^{\beta} p_i^{1-\beta}}{Z_{0i}} = 1$. This gives *N* more equations in *N* wages. (The share of labor in manufacturing adjusts in each country so that trade flows balance.)

Empirical implications

We're now ready to say something empirical about how technology differences and transport costs shape trade in manufactured products and thereby influence welfare. From this point onward we'll be talking about trade shares at the level of manufacturing industry, aggregating over the individual goods.

Since the prices that country *n* pays do not depend upon the source of its goods (only Φ_n and θ), the share of a particular country, *i*, in *n*'s expenditures is the same as its share in the number of goods:

$$\frac{X_{ni}}{X_n} = \pi_{ni} = \frac{T_i (c_i d_{ni})^{-\theta}}{\Phi_n} = \frac{T_i (c_i d_{ni})^{-\theta}}{\sum_{k=1,N} T_k (c_k d_{nk})^{-\theta}}$$

where X_{ni} is country *n*'s spending on country *i*'s goods and X_n is *n*'s total spending.

Aside: Relation to gravity equations

The EK model provides a new explanation for why gravity equations work. A simple gravity equation expresses the bilateral trade between two countries as a function of their size (GDP) and the distance between them. Defining the exporting country's total sales as $Q_i = \sum_{m=1}^{N} X_{mi} = T_i c_i^{-\theta} \sum_{m=1}^{N} \frac{d_{mi}^{-\theta} X_m}{\Phi_m}$, one can solve for $T_i c_i^{-\theta} = Q_i \Big/ \sum_{m=1}^{N} \frac{d_{mi}^{-\theta} X_m}{\Phi_m}$. From (6), $p_n = \gamma \Phi_n^{-1/\theta}$ implies $\Phi_n = p_n^{-\theta} \gamma^{1/\theta}$, so we can re-state the share equation above this box to obtain:

$$X_{ni} = \frac{X_n \left(\frac{d_{ni}}{p_n} \right)^{-\theta}}{\sum_{k=1,N} X_m \left(\frac{d_{mi}}{p_m} \right)^{-\theta}} Q_i$$

That is, imports of *n* from *i* depend upon the size of *n*, the size of *i* and the distance between the two countries. The latter is adjusted for cost differences.

note: This is not the only way to motivate gravity equations. We'll see that monopolistic competition models can be used to do the same.

Intra-country technology dispersion

By exploiting the structure of the EK model, we can back out information on country-specific efficiency and distance barriers from bilateral trade flows.

First, note that θ can be estimated using data on bilateral trade flows along with information on prices and distance.

- Price data come from international comparisons of prices for the same bundle of 50 manufactured goods. The average ratio across commodities measures relative commodity prices and can be approximated as: $\log\left(\frac{p_i}{p_n}\right) = \frac{1}{J} \sum_{j=1,J} \log\left(\frac{p_i(j)}{p_n(j)}\right)$. (Note that this expression gives equal weight to each good, unlike the conceptually correct *p*'s.)

- Distance really means physical plus other barriers to trade (language, terrain, commercial policy, etc.) Since $p_n(j) \leq p_i(j) d_{ni}$ with equality when the good is purchased from *i*, distance can be imputed as the highest value of $p_n(j)/p_i(j)$ across commodities. (More precisely, EK use the second highest value to reduce sensitivity to outliers.) This distance measure corresponds pretty well to geographic distance (Table 2).

Substituting $c_i = w_i^{\beta} p_i^{1-\beta}$ into the expenditure share equation above and using $p_n = \gamma\Phi_n^{-1/\theta}$ yields:

$$\frac{X_{ni}}{X_n} = \pi_{ni} = \frac{T_i (w_i^{\beta} p_i^{1-\beta} d_{ni})^{-\theta}}{\Phi_n} = T_i \left(\frac{w_i^{\beta} p_i^{1-\beta} \gamma d_{ni}}{p_n} \right)^{-\theta} \tag{11}$$

Forming the ratio $\frac{X_{ni}/X_n}{X_{ii}/X_i} = \frac{\Phi_i}{\Phi_n} d_{ni}^{-\theta} = \left(\frac{p_i\, d_{ni}}{p_n} \right)^{-\theta}$, where the last equality follows from

$\Phi_n = p_n^{-\theta} \gamma^{1/\theta}$. The bigger is θ, recall, the less dispersion in productivity draws and thus the more similar countries are. This is why market shares become more responsive to factor price differences as θ goes up.

Figure 2 present the scatter plot for $\log\left(X_{ni}/X_n \right) - \log\left(X_{ii}/X_i \right), \log\left(\frac{p_i\, d_{ni}}{p_n} \right)$. Since theory says the line should pass through the origin, a simple ratio of means provides a consistent estimator that is robust to (country-specific) measurement error. The implied parameter value is $\hat{\theta} = 8.28$. OLS implies a flatter slope—is this measurement error bias?

<u>The roles of distance and inter-country technology dispersion</u>

Next, EK use this $\hat{\theta}$ to estimate other model parameters and impute the role technology differences and distance differences in driving trade flows.

First use (11) to form the ratio of the expenditure share for good from *i* versus (home) goods from *n*:

$$\frac{X_{ni}}{X_{nn}} = \frac{T_i}{T_n} \left(\frac{w_i^{\beta} p_i^{1-\beta} d_{ni}}{w_n^{\beta} p_n^{1-\beta}} \right)^{-\theta} = \frac{T_i}{T_n} d_{ni}^{-\theta} \left(\frac{w_i}{w_n} \right)^{-\theta\beta} \left(\frac{p_i}{p_n} \right)^{-\theta(1-\beta)} \tag{12}$$

Next get prices out of the picture because they're endogenous and also hard to measure. Solve for relative prices by evaluating the share equation for home sales in both country *i* and country *j*:

$$\frac{X_{nn}}{X_n} = T_n \left(\frac{w_n^{\beta} p_n^{1-\beta} \gamma}{p_n} \right)^{-\theta} = p_n^{\theta\beta} T_n w_n^{-\theta\beta}, \qquad \frac{X_{ii}/X_i}{X_{nn}/X_n} = \frac{T_i}{T_n} \frac{p_i^{\theta\beta} w_i^{-\theta\beta}}{p_n^{\theta\beta} w_n^{-\theta\beta}}$$

$$\frac{p_i}{p_n} = \left(\frac{w_i}{w_n}\right)\left(\frac{X_{ii}/X_i}{X_{nn}/X_n}\right)^{1/\theta\beta}\left(\frac{T_i}{T_n}\right)^{-1/\theta\beta} \tag{13}$$

Using this expression to eliminate prices from the share equation, we obtain

$$\frac{X_{ni}}{X_{nn}} = \left(\frac{T_i}{T_n}\right)^{1/\beta} d_{ni}^{-\theta}\left(\frac{w_i}{w_n}\right)^{-\theta}\left(\frac{X_{ii}/X_i}{X_{nn}/X_n}\right)^{-(1-\beta)/\beta} \tag{14}$$

Finally, we can bring shares over to the left-hand side by defining $\ln X'_{ni} = \ln X_{ni} + \left[\frac{1-\beta}{\beta}\right]\ln\left(\frac{X_i}{X_{ii}}\right)$, so that $\ln\left(\frac{X'_{ni}}{X'_{nn}}\right) = -\theta \ln d_{ni} + S_i - S_n$ where $S_i \equiv \frac{1}{\beta}\ln T_i - \theta \ln w_i$ is a measure of the competitiveness of country *i*. By fixing β at the average labor share in manufacturing income (0.21) and parameterizing d_{ni} as a function of distance (*d*), effect of sharing a border (*b*), effect of sharing a language (ℓ), effect of belonging to the same trading area (*e*) and an "overall destination effect" (*m*), the model to be estimated emerges:

$$\ln\left(\frac{X'_{ni}}{X'_{nn}}\right) = S_i - S_n - \theta m_n - \theta d_k - \theta b - \theta\ell - \theta e_h + \theta\delta^2_{ni} + \theta\delta^1_{ni} \tag{15}$$

where δ^2_{ni} is the error component that affects two-way trade (barriers common to both countries—a mountain between them), while δ^1_{ni} affects one-way trade (e.g., tariffs in one of the countries). This error specification leads to GLS estimation. The data are bilateral trade flows for 19 countries (342 observations).

Note: The overall destination effect m_n is identified by the observations for country *n*'s imports, while S_n is identified by observations on country *n*'s exports.

Results are presented in Table 3.

Japan is the most competitive country, followed by the U.S. At the other extreme, Belgium and Greece are the least competitive.

Increased distance substantially reduces trade, while shared language increases. The other variables are not very important. Dividing by θ gives the correct percentage effects, as we will see shortly.

Table 5 disaggregates the country competitiveness effect into technical efficiency and factor price components. The research stock matters, as does the wage rate. Human capital doesn't seem very important. (Missing: physical capital—including it would mean admitting that it belonged in the model somehow.)

Table 7 calculates the effects of the various types of distance on efficiency.

Finally, by solving the model subject to autarky restrictions, it is possible to determine the implied gains from trade (table 9). Similarly, setting all d_{ni} =1, it is possible to calculate the implied gains that would result if all distance barriers were eliminated (table 10). The former is fairly modest, especially for large countries. This is consistent with other CGE studies. On the other hand, the potential gains from wholesale elimination of trade frictions are quite large!

3. Trade with monopolistic competition

Thus far we have assumed perfect competition among multiple producers of each product. This kept things simple, but it swept some potentially important effects of trade under the rug:

- Pricing discipline effects: competition from abroad might reduce monopoly power.
- Product menu effects: with imperfect competition, the menu of product varieties available may be endogenous with respect to trade policy.
- Market share effects: trade can change the joint distribution of firm sizes and firm productivity levels.
- Innovation effects: trade policy can change the returns to innovative effort.

We'll begin our discussion with a famous model that captures the second effect, but not the others.

The Helpman-Krugman model (19885)

<u>The utility function (Dixit/Stiglitz)</u>
Suppose industry *i* is characterized by differentiated products, indexed by $i\omega$, and represent the utility consumers derive from these products by: $U_i = \left[\int_{\omega} (D_{i\omega})^{\beta} d\omega \right]^{1/\beta}$

where $\beta = 1 - \frac{1}{\sigma}$ and $\sigma > 1$ is the elasticity of substitution among goods. If consumers spend E_i on products from this industry, they do best to allocate their expenditures according to $D_i = E_i \left[\frac{p_{i\omega}^{-\sigma}}{\int_{\omega'} p_{i\omega'}^{(1-\sigma)} d\omega'} \right]$, implying that the elasticity of demand for any given good is σ, holding expenditure constant. Notice that with this particular utility function, there are no elasticity effects from changing the set of goods. Thus there are no size effects of trade liberalization and firms always choose the same mark-up. (This would not have been true if we had used a discrete version of the utility function.)

The utility function does, however, depend upon the range of differentiated products that is consumed. People are happier with small amounts of many goods than with a large amount of one good—love of variety. Suppose ω ranges from 0 to n_i, and suppose that because of symmetry in production technologies, all of the prices are for the n_i goods are identical. Then, substituting demands back into the utility function and evaluating the definite integral yields: $U_i = (n_i)^{1/(\sigma-1)} \frac{E_i}{p_i}$. Since $\sigma > 1$, spreading a fixed expenditure over a large range of goods generates more utility than spreading a fixed expenditure over a small range.

To deal with differentiated and homogeneous goods industries in a single model, we nest the sub-utility function above in a general utility function $U = f(U_1, \cdots U_n)$. If this nesting function is Cobb-Douglas, consumers spend a constant share of their income on each type of good.

General equilibrium with monopolistic competition: a simple case

Consider an economy with a differentiated product sector $i = X$ (manufacturing) and a homogeneous product sector $i = Y$ (food). Let there be two primary factors of production, labor and capital. The differentiated product industry must not have constant returns to scale (why not?), so we use the total cost function $C(w, x)$ to characterize total costs for this sector rather than the unit cost function. All differentiated product producers are assumed to have the same cost function, so we have left off an ω subscript.

pricing

Demand for the differentiated goods is characterized by Dixit-Stiglitz preferences, as described earlier. Therefore producers of these goods use the pricing rule:

$\left[1 - \frac{1}{\sigma}\right] p = \frac{\partial C(w,x)}{\partial x}$, or $\frac{R}{\theta(x)} = \frac{p}{C}$ where $R = \left[1 - \frac{1}{\sigma}\right]^{-1}$. (I'm assuming homothetic technologies, so θ depends only on output levels.)

In the competitive industry, the demand elasticity is infinite and there are constant returns to scale, so $p_Y = c_Y$ obtains, as usual. Hereafter let the price of food be the numeraire, implying $1 = c_Y$.

the zero profit (free entry) condition
With free entry, profits must be zero among differentiated products (and, of course among homogenous products). Thus we require $p \cdot x = C(w,x)$, implying $R = \theta$, which pins down *x*. Then, the number of firms is simply $n = \frac{X}{x}$, where *X* is aggregate output of the differentiated product industry.

factor market clearing
Derivatives of cost functions yield factor demands, $a_{\ell Y}(w)$ and $A_{\ell X}(w,x)$, where capitals indicate factor usage *per firm* rather than per unit output. The factor market clearing conditions are:

$$\begin{aligned} a_{LY}(w)\overline{Y} + A_{LX}(w,x)n &= \overline{L} \\ a_{KY}(w)\overline{Y} + A_{KX}(w,x)n &= \overline{K} \end{aligned}, \quad \text{or} \quad \begin{aligned} a_{LY}(w)\overline{Y} + a_{LX}(w,x)\overline{X} &= \overline{L} \\ a_{KY}(w)\overline{Y} + a_{KX}(w,x)\overline{X} &= \overline{K} \end{aligned}$$

product market clearing
Letting $\alpha(p)$ be the share of total spending devoted to the homogeneous good, product market clearing occurs in autarky when: $\alpha(p) = \frac{\overline{Y}}{\overline{Y} + pnx} = \frac{\overline{Y}}{\overline{Y} + p\overline{X}}$

The integrated equilibrium
Given factor prices and factor endowments, the output mix is determined by the factor market clearing conditions. Output prices are also determined by the mark-up conditions above. When the output mix is the one demanded at the output price vector, the economy is in equilibrium. If not, the price of the rationed good rises, inducing substitution in production toward that good (and associated movements in factor prices) until equilibrium is attained. The only thing new here, relative to HOS, is that as *p* adjusts, so does the number of firms.

Trading equilibrium
The standard type of diagram establishes whether the trading equilibrium replicates the integrated equilibrium: