# Factor Endowments and Trade

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# Introduction

- Inequality is considered a consequence of globalization by a majority of people
- Ricardian model says nothing about the redistributive effects of trade (only one production factor)
- The Ricardian model predicts full specialization, which rarely occurs in reality
- HO: **factor endowments** as the (**only**) source of comparative advantage
- Key elements:
  1. Countries differ in terms of factor abundance [i.e relative factor supply]
  2. Goods differ in terms of factor intensity [i.e relative factor demand]

**New questions**:

- How do endowments affect trade specialization?
- How are factors prices affected by free trade (and therefore, how are distributed the gains from trade?)

# Outline

I - HO models

– Ricardo-Viner Model
– Two-by-Two Heckscher-Ohlin Model
– Heckscher-Ohlin Theorem
– Heckscher-Ohlin-Vanek Model

II - Empirical evidence

# Ricardo-Viner model

## Basic environment

- Consider an economy with
  - Two goods, $g = 1, 2$
  - Three factors with endowments $l, k_1, k_2$
- Output of good g is given by

$$y_g = f^g(l_g, k_g)$$

  where:
  - $l_g$ is the endogenous amount of labor in sector $g$
  - $f^g$ is homogeneous of degree 1 in $(l_g, k_g)$
- **Comments:**
  - $l$ is a “mobile” factor in the sense that it can be employed in all sectors
  - $k_1$ and $k_2$ are “immobile” factors in the sense that they can only be employed in one of the sectors
  - The model is isomorphic to DRS model: $y_g = f^g(l_g)$ with $f_l^g > 0, f_{ll}^g < 0$
  - Payments to specific factors under CRS$\equiv$profits under DRS

# Ricardo-Viner model

## Equilibrium (I): Small open economy

- We denote by
  - $p_1, p_2$ the prices of goods 1 and 2
  - $w, r_1$ and $r_2$ the prices of $l, k_1$ and $k_2$ respectively
- For now, $(p_1, p_2)$ is exogenously given: "**small open economy**"
  - So no need to look at good market clearing
- Profit maximization

$$p_g f_l^g(l_g, k_g) = w \tag{1}$$

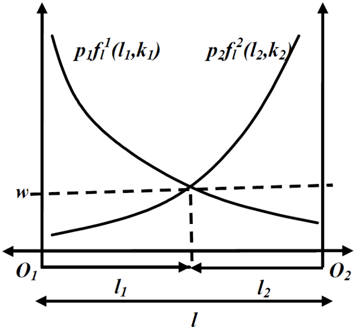
$$p_g f_k^g(l_g, k_g) = r_g \tag{2}$$

- Labor market clearing

$$l = l_1 + l_2 \tag{3}$$

# Ricardo-Viner model

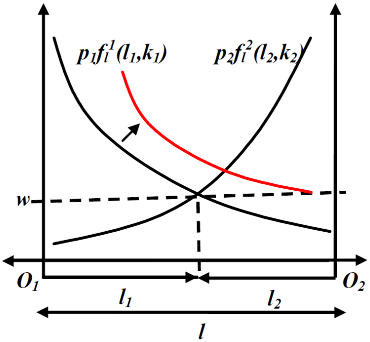
## Graphical analysis




- Equations (1) and (3) jointly determine labor allocation and wage
- How do we recover payments to the specific factor from this graph?

# Ricardo-Viner model

## Comparative statics




- Consider a terms of trade shock such that $p_1$ increases
  - $w \nearrow$, $l_1 \nearrow$ and $l_2 \searrow$
  - Condition (2) $\Longrightarrow$ $r_1/p_1 \nearrow$ whereas $r_2$ (and $r_2/p_1$) $\searrow$

# Ricardo-Viner model

## Comparative statics

- One can use the same type of arguments to analyze consequences of
  - Productivity shocks
  - Changes in factor endowments
- In all cases, results are intuitive
  - Dutch disease (boom in export sectors bids up wages, which leads to a contraction in the other sectors)
- Easy to extend the analysis to more than 2 sectors
  - Plot labor demand in one sector vs. rest of the economy

# Ricardo-Viner model

## Equilibrium (II): Two-country world

- Predictions on the pattern of trade in a two-country world depend on whether differences in factor endowments come from
  - Differences in the relative supply of specific factors
  - Differences in the relative supply of mobile factors
- Accordingly, any change in factor prices is possible as we move from autarky to free trade

# Two-by-two Heckscher-Ohlin model (HO)

- Also called HO or HOS model:
  - H for Eli Heckscher, O for Bertil Ohlin: for the insights
  - S for Paul Samuelson: for the maths
  - $2 \times 2 \times 2$ model
- Generalization to many goods, many factors: HOV
  - V for Jaroslav Vanek, covered after HOS in this chapter

# HO model

## Assumptions

- $2 \times 2 \times 2$ model: 2 countries, 2 goods, 2 factors (labor and capital)
- Production functions: $y_g = f_g(l_g, k_g)$, $g = 1, 2$
- Increasing, concave, homogeneous of degree 1 in the inputs (*constant returns to scale*)
- Factors fully mobile across sectors, immobile across countries
- Resource constraints:
  $L_1 + L_2 \leq L$, $K_1 + K_2 \leq K$
- Perfect competition
- Small country (exogenous world price)

# HO model

## Unit-costs functions

- Minimum cost to produce one unit of output

$$c_g(w, r) = \min_{L_g, K_g \geq 0} \{wl_g + rk_g | f_g(l_g, k_g) \geq 1)\} \tag{4}$$

- CRS implies that $c_g(w, r) = AC = MC$
- Write the cost function (i.e. the solution to the minimization problem) as: $c_g(w, r) = wa_{gl} + ra_{gk}$ where $a_{gL}$ is the optimal choice of input $l_h$ (same for $k$)
- We can show that $\frac{\partial c_g}{\partial w} = a_{gl}$ and $\frac{\partial c_g}{\partial r} = a_{gk}$ (application of the envelope theorem)
- Derivatives of the unit-costs with respect to factor prices are simply the unit factor requirements

# HO model

## Equilibrium conditions

- **Zero-profit conditions**

$$p_1 = c_1(w, r) \tag{5}$$

$$p_2 = c_2(w, r) \tag{6}$$

- **Full-employment**

$$a_{l1}y_1 + a_{l2}y_2 = L_1 + L_2 = L \tag{7}$$

$$a_{k1}y_1 + a_{k2}y_2 = K_1 + K_2 = K \tag{8}$$

- 4 equations, 4 unknowns $(w, r, y_1, y_2)$ and 4 parameters $(p_1, p_2, L, K)$
- But non-linear system: need to study its properties

# HO model

## Three main questions

1. What is the solution for factor prices?
2. If prices change, how do factor prices change?
3. If endowments change, how does output change?

Answering these questions generates three of the main results of traditional trade theories

# HO model

## Factor Price Equalization (FPE)

What is the solution for factor prices?

- First classical result from the HO literature, and the answer is affirmative
- To establish this result formally, we'll need the following definition:
- **Definition**: Factor Intensity Reversal (FIR) does not occur if:

  i) $a_{l1}(w,r)/a_{k1}(w,r) > a_{l2}(w,r)/a_{k2}(w,r)$ for all $(w,r)$, or
  ii) $a_{l1}(w,r)/a_{k1}(w,r) < a_{l2}(w,r)/a_{k2}(w,r)$ for all $(w,r)$

# HO model

## Factor Price Insensitivity (FPI)

- **FPI Lemma**: If both goods are produced in equilibrium and FIR does not occur, then factor prices $\omega \equiv (w, r)$ are uniquely determined by good prices $p \equiv (p_1, p_2)$
- **Proof**: If both goods are produced in equilibrium, then $p = A'(\omega)\omega$. By Gale and Nikaido (1965), this equation admits a unique solution if $a_{fg}(w) > 0$ for all $f, g$ and det $[A(w)] \neq 0$ for all $\omega$, which is guaranteed by no FIR
- **Comments**
  - Good prices rather than factor endowments determine factor prices
  - In a closed economy, good prices and factor endowments are related, but not for a small open economy
  - All economic intuition can be gained by simply looking at Leontief case
  - Proof already suggests that "dimensionality" will be an issue for FIR

# HO model

## Factor Price Equalization (FPE) Theorem

- The previous lemma directly implies the *FPE Theorem* (Samuelson 1949)
- **FPE Theorem:** If two countries produce both goods under free trade with the same technology and FIR does not occur, then they must have the same factor prices
- **Comments**
  - Important result: trade acts as a perfect substitute for factor mobility
  - Countries with different factor endowments can sustain the same factor prices through different allocation of factors across sectors
  - Assumptions for FPE are stronger than for FPI: we need free trade and same technology in the two countries

# HO model

## Stolper-Samuelson (1941) Theorem:

- **Stolper-Samuelson Theorem** *An increase in the relative price of a good will increase the real return to the factor used intensively in that good, and reduce the real return to the other factor*
- **Proof**:
  - W.l.o.g, suppse that (i) $a_{l1}(w,r)/a_{k1}(w,r) > a_{l2}(w,r)/a_{k2}(w,r)$ and (ii) $\widehat{p}_2 > \widehat{p}_1$.
  - Differentiating the zero profit condition (Equations (5) and (6)), we get

$$\widehat{p}_g = \theta_{\mathrm{lg}}\widehat{w} + (1-\theta_{lg})\widehat{r}, \tag{9}$$

where $\widehat{x} \equiv d\ln x = dx/x$ and $\theta_{\mathrm{lg}} \equiv wa_{\mathrm{lg}}(\omega)/c_g(\omega)$. Equation (9) + (ii) imply

$$\widehat{w} > \widehat{p}_2 > \widehat{p}_1 > \widehat{r} \text{ or } \widehat{r} > \widehat{p}_2 > \widehat{p}_1 > \widehat{w}$$

By (i), $\theta_{l1} > \theta_{l2}$. So (ii)+(8) further implies $\widehat{r} > \widehat{w}$. Combing the previous inequalities, we get

$$\widehat{r} > \widehat{p}_2 > \widehat{p}_1 > \widehat{w}$$

# HO model

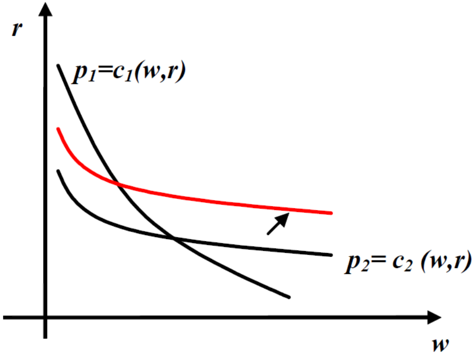
## Stolper-Samuelson (1941) Theorem

**Comments**

- Previous "hat" algebra is often referred to as "Jones (1965) algebra"
- The chain of inequalities $\hat{r} > \hat{p}_2 > \hat{p}_1 > \hat{w}$ is referred to as a "magnification effect"
- SS predict both winners and losers from change in relative prices
- Like FPI and FPE, SS entirely comes from zero-profit condition
- Like FPI and FPE, sharpness of the result hinges on dimensionality
- In the empirical literature, people often talk about "Stolper-Samuelson effects" whenever looking at changes in relative factor prices (though changes in relative good prices are rarely observed)

# HO model

## Stolper-Samuelson (1941) Theorem: graphical analysis




- Like for FPI and FPE, all economic intuition could be gained by looking at the simpler Leontief case:
  - In the general case, iso-cost curves are not straight lines, but under no FIR, same logic applies

# HO model

## Rybczynski (1965) Theorem

- Previous results have focused on the implication of zero profit condition, Equations (5) and (6), for *factor prices*

- We now turn our attention to the implication of factor market clearing, Equations (7) and (8), for *factor allocation*

- **Rybczynski Theorem**: *An increase in factor endowment will increase* the output of the industry using it intensively, and decrease the output of the other industry

# HO model

## Rybczynski (1965) Theorem

**Proof:**

- W.l.o.g, suppse that (i) $a_{l1}(w,r)/a_{k1}(w,r) > a_{l2}(w,r)/a_{k2}(w,r)$ and (ii) $\widehat{k} > \widehat{l}$
- Differentiating factor market clearing conditions, Equation (7) and (8), we get

$$\begin{aligned} \widehat{l} &= \lambda_{l1}\widehat{y}_1 + (1-\lambda_{l1})\widehat{y}_2 \\ \widehat{k} &= \lambda_{k1}\widehat{y}_1 + (1-\lambda_{k1})\widehat{y}_2 \end{aligned} \tag{10}$$

where $\lambda_{l1} \equiv a_{l1}(\omega)y_1/l$ and $\lambda_{k1} \equiv a_{k1}(\omega)y_1/k$ Equation (10) + (ii) imply

$$\widehat{y}_1 > \widehat{k} > \widehat{l} > \widehat{y}_2 \text{ or } \widehat{y}_2 > \widehat{k} > \widehat{l} > \widehat{y}_1$$

By (i), $\lambda_{l1} > \lambda_{k1}$. So (ii)+(10) further implies $\widehat{y}_2 > \widehat{y}_1$. Combing the previous inequalities, we get

$$\widehat{y}_2 > \widehat{k} > \widehat{l} > \widehat{y}_1$$

# HO model

## Rybczynski (1965) Theorem

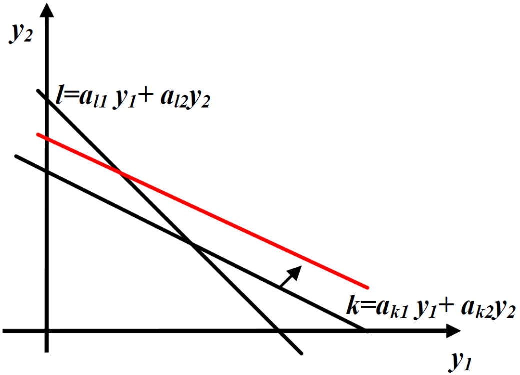
**Comments**

- Like for FPI and FPE Theorems
  - $(p_1, p_2)$ is exogenously given $\implies$ factor prices and factor requirements are not affected by changes in factor endowments
  - Empirically, Rybczynski Theorem suggests that impact of immigration may be very different in closed vs. open economy
- Like for SS Theorem, we have a “magnification effect”
- Like for FPI, FPE, and SS Theorems, sharpness of the result hinges on “dimensionality”

# HO model

## Rybczynski (1965) Theorem: graphical analysis

- Since good prices are fixed, it is as if we were in Leontief case



# HO model

## Heckscher-Ohlin Theorem

- We now turn to a world economy with two countries, North and South
- We maintain the two-by-two HO assumptions:
  - Two goods, $g = 1, 2$, and two factors, $k, l$
  - Identical technology around the world, $y_g = f^g(l_g, k_g)$
  - Identical homothetic preferences around the world, $d_g^c = \alpha_g(p)I^c$
  - Different factor endowments, summarized by the endowment vectors $(v^s, v^n)$
- **Question:** What is the pattern of trade in this environment?

# Heckscher-Ohlin Theorem

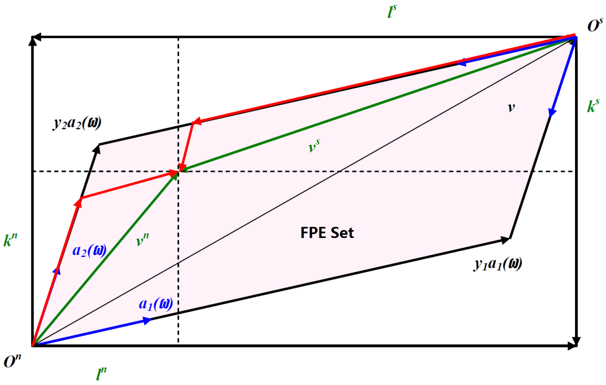
## Integrated equilibrium

- If we divide the world into two countries, H and F, with $v^H + v^F = v^w$. What devisions of world endowments $v^w$ lead to a trade equilibrium in which prices, factor rewards, aggregate output and employment levels are the same as in a equilibrium of a single country?
- This type of trading equilibrium is called an "*integrated equilibrium*"

# Heckscher-Ohlin Theorem

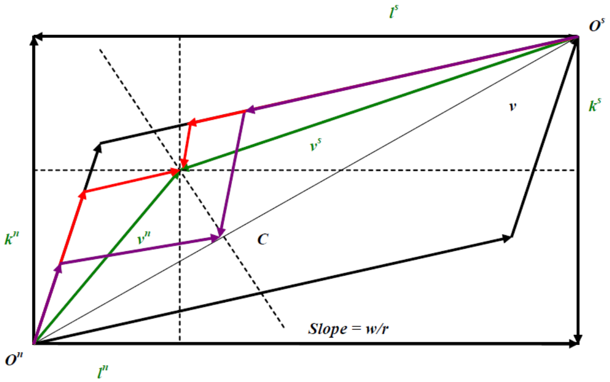
## The FPE set

- The set of vectors $(v^H, v^F)$ that leads to an integrated equilibrium can be described by the factor equalization set, or FPE set



# Heckscher-Ohlin Theorem

- Suppose that $(v^s, v^n)$ is in the FPE set (i.e. factor price equalization holds)
- **HO Theorem**: *In the free trade equilibrium, each country will export the good that uses its abundant factor intensively*




- Outside the FPE set, additional technological and demand considerations matter

# High-Dimensional predictions

## Heckscher-Ohlin-Vanek model (HOV)

- Many countries, $c = 1, ..., i$
- Many industries (goods), $g = 1, ..., n$
- Many factors, $f = 1, ..., m$
- Identical technologies and preferences across countries, factor price equalization
- Technology A $m \times n$ technology matrix which contain all unitary inputs

  Ex: $2 \times 2$ model: $A = \begin{pmatrix} a_{l1} & a_{l2} \\ a_{k1} & a_{k2} \end{pmatrix}$

$\rightarrow$ $y^c$ vector $(n \times 1)$ of output of each good in country $c$

$\rightarrow$ $d^c$ vector $(n \times 1)$ of demand of each good in country $c$

$\rightarrow$ **Vector of net export flows:** $t^c = y^c - d^c$

$\rightarrow$ **Net factor content of trade** ($m \times 1$ vector)**:** $f^c = At^c$

# High-Dimensional predictions

## Heckscher-Ohlin-Vanek model

- Homothetic tastes + free trade $\rightarrow$ consumption vectors in all countries should be proportional to each others: $d^c = s^c d^w$
  where $s^c$ is country $c$'s share of world consumption and $d^w$ is the vector of world consumption (equal to world production)
- Hence $t^c = y^c - s^c d^w = y^c - s^c y^w \rightarrow At^c = Ay^c - s^c Ay^w$

$\Longrightarrow$ **HOV Theorem**: $\boxed{f^c = v^c - s^c v^w}$

- If a country $c$'s endowment of factor $k$ exceeds $c$'s share of world output, we say that country $c$ is abundant in this factor and the factor content of trade in this factor should be positive ($c$ must be a net exporter of the services of this factor)
- Country c is **abundant in factor** f if $\frac{v_f^c}{v_f^w} > s^c$

# Empirical evidence

# The factor content of trade

## Recap: the Heckscher-Ohlin-Vanek Theorem

- Vector of net export flows: $t^c = y^c - d^c$
- Net factor content of trade: $F^c = A^c t^c$, which implies

$$A^c(w^c)t^c = v^c - A^c(w^c)\alpha^c(p^c)Y^c$$

- Where $\alpha^c(p^c)$ is the expenditure share on each good
- If we have free trade ($p^c = p$), identical technology ($A^c = A$), identical tastes ($\alpha^c = \alpha$), and factor endowments inside the FPE set so FPE holds ($w^c = w$), then HOV equation simplifies to:

$$F^c \equiv A(w)t^c = v^c - s^c v^w$$

# Test of HO model: comments

**To perform a complete test need data on**

- trade ($\mathbf{t}^i$)
- technology (**A**)
- endowment ($\mathbf{v}^i$)

Not available until quite recently, so a lot of tests were "incomplete"

# Test of HO model: comments

## Bowen, Leamer and Sveikauskas (1987)

**"Sign test"**

$$\text{sign}(\mathbf{f}_k^i) = \text{sign}(\mathbf{v}_k^i - \mathbf{s}^i \mathbf{v}_k^w)$$

**"Rank test"**

$$\mathbf{f}_k^i > \mathbf{f}_l^i \Rightarrow \mathbf{v}_k^i - \mathbf{s}^i \mathbf{v}_k^w > \mathbf{v}_l^i - \mathbf{s}^i \mathbf{v}_l^w$$

# Test of HO model: comments

In reality, production uses intermediates

- This means (for example) that the capital content of shoe production includes not only the direct use of capital in making shoes, but also the indirect use of capital in making all upstream inputs to shoes (like rubber)
- Let A(w) be the input-output matrix for commodity production, and let $B(w)$ be the matrix of direct factor inputs
- Then, if we assume that only final goods are traded (it takes some algebra, due to Leontief, to show that) the only change we have to make to the HOV Theorem is to use $\bar{B}(w) \equiv B(w)(I - A(w))^{-1}$ in place of $A(w)$ above

# Test on HOV equations: comments

How do we test $\bar{B}(w)t^c = v^c - s^c v^w$?

- This is really a set of vector equations (one element per factor k)
- So there is one of these predictions per country c and factor k
- There are of course many things one can do with these predictions, so many different tests have been performed

# Leontief (1953) and Leamer (1980)

# Leontief's paradox

- The first work based on the NFCT was in Leontief (1953)
- Circa 1953, Leontief had just computed (for the first time), the input-output table (which delivers $A_{US}(w_{US})$ and $B_{US}(w_{US})$) for the 1947 US economy.

# Leontief's paradox

Leontief then argued as follows

- Leontief's table only had $k$ and $l$ inputs (and 2 factors was the bare minimum needed to test the HOV equations)
- He used $\bar{B}^{US}(w^{US})$ to compute the $k/l$ ratio of US exports: $F^{US}_{k/l,t} \equiv \bar{B}(w)_{k/l} t^{US} =$ 13,700 per worker
- He didn't have $\bar{B}^{c}(w^{c})$ for all (or any!) countries that export to the US (to compute the factor content of US imports), so he applied the standard HO assumption that all countries have the same technology and face the same prices and that FPE and FPI hold. Hence, $\bar{B}^{US}(w^{US}) = \bar{B}^{c}(w^{c}), \forall c$
- He then used $\bar{B}^{US}(w^{US})$ to compute the $k/l$ ratio of US imports: $F^{US}_{k/l,m} \equiv \bar{B}(w)_{k/l} m^{US} =$ 18,200 per worker

The fact that $F^{US}_{k/l,m} > F^{US}_{k/l,t}$ was a bit surprise, as everyone assumed the US was relatively K-endowed relative to the world as a whole

# Leamer (JPE, 1980)

Leamer (1980) pointed out that Leontief's application of HO theory, while intuitive, was wrong if either trade is unbalanced, or there are more than 2 factors in the world

- Either of these conditions can lead to a setting where the US exports both k and l services—which is impossible in a balanced trade, 2-factor world. It turns out that this is exactly what the US was doing in 1947

In particular, Leamer (1980) showed that the intuitive content of HO theory really says that

- $\frac{K^{US}}{L^{US}} > \frac{K^{US}-F_k^{US}}{L^{US}-F_l^{US}}$, where $F_i^{US} \equiv \bar{B}(w)_i t^{US}$ is the factor content of US net exports in factor i
- This just takes a ratio of HOV equations, for two factors (k and l). HOV equations just say that, for any factor, the factor content of production has to be greater than the factor content of consumption
- But HOV does not necessarily say that the factor content of exports should exceed the factor content of imports, as Leontief (1953) had tested

# Bowen, Leamer and Sveikauskas (1987)

# Bowen, Leamer and Sveikauskas (1987)

**“Sign test”**

$$\text{sign}(F_f^c) = \text{sign}(v_f^c - s^c v_f^w)$$

**“Rank test”**

$$F_k^c > F_l^c \Rightarrow v_k^c - s^c v_k^w > v_l^c - s^c v_l^w$$

# Bowen, Leamer and Sveikauskas (1987)

Data for 27 countries, 12 factors

Sign test: ok in about 61% of the cases

Rank test... 49% of the cases

$\rightarrow$ Very disappointing... purely random pattern of trade would give you 50% of good matches...

Why such a failure?

# Bowen, Leamer and Sveikauskas (1987)

TABLE 2—SIGN AND RANK TESTS, FACTOR BY FACTOR

| Factor | Sign Test[a] | Rank Tests[b] | |
|---|---|---|---|
| Capital | .52 | 0.140 | .45 |
| Labor | .67 | 0.185 | .46 |
| Prof/Tech | .78 | 0.123 | .33 |
| Managerial | .22 | −0.254 | .34 |
| Clerical | .59 | 0.134 | .48 |
| Sales | .67 | 0.225 | .47 |
| Service | .67 | 0.282[c] | .44 |
| Agricultural | .63 | 0.202 | .47 |
| Production | .70 | 0.345[c] | .48 |
| Arable | .70 | 0.561[c] | .73 |
| Pasture | .52 | 0.197 | .61 |
| Forest | .70 | 0.356[c] | .65 |

[a] Proportion of 27 countries for which the sign of net trade in factor matched the sign of the corresponding factor abundance.

[b] The first column is the Kendall rank correlation among 27 countries; the second column is the proportion of correct rankings out of 351 possible pairwise

# Bowen, Leamer and Sveikauskas (1987)

TABLE 3—SIGN AND RANK TESTS, COUNTRY BY COUNTRY

| Country | Sign Tests[a] | Rank Tests[b] | |
|---|---|---|---|
| Argentina | .33 | 0.164 | .58 |
| Australia | .33 | −0.127 | .44 |
| Austria | .67 | 0.091 | .56 |
| Belgium-Luxembourg | .50 | 0.273 | .64 |
| Brazil | .17 | 0.673[c] | .86 |
| Canada | .75 | 0.236 | .64 |
| Denmark | .42 | −0.418 | .29 |
| Finland | .67 | 0.164 | .60 |
| France | .25 | 0.418 | .71 |
| Germany | .67 | 0.527[c] | .76 |
| Greece | .92 | 0.564[c] | .80 |
| Hong Kong | 1.00 | 0.745[c] | .89 |
| Ireland | .92 | 0.491[c] | .76 |
| Italy | .58 | 0.345 | .69 |
| Japan | .67 | 0.382 | .71 |
| Korea | .75 | 0.345 | .69 |
| Mexico | .92 | 0.673[c] | .86 |
| Netherlands | .58 | −0.236 | .38 |
| Norway | .25 | −0.236 | .38 |
| Philippines | .50 | 0.527[c] | .78 |
| Portugal | .67 | 0.091 | .56 |
| Spain | .67 | 0.200 | .62 |
| Sweden | .42 | 0.200 | .62 |
| Switzerland | .67 | 0.382 | .69 |
| United Kingdom | .92 | 0.527[c] | .78 |
| United States | .58 | 0.309 | .67 |
| Yugoslavia | .83 | −0.055 | .49 |

[a] Proportion of 12 factors for which the sign of net trade in factor matched the sign of the corresponding excess supply of factor.

[b] The first column is the Kendall rank correlation among 11 factors (total labor excluded); the second column is the proportion of correct rankings out of 55 possible pairwise comparisons.

[c] Statistically significant at the 5 percent level.

# Trefler (1993)

# Trefler (1993)

- Starting point: HOV assumptions are violated
  - No FPE (at all!)
  - Different technologies across countries
- Leontieff himself suggested that his “paradox” could be explained by productivity differences
- Not strictly speaking a test of HOV, but shows that Leontief may be right: productivity differences can explain the failure of the empirical tests of HOV

# Trefler (1993)

- All factors can differ in their productivity (the US is chosen as a benchmark; productivity 1 for all factors)
- **Effective endowment** of factor $f$ in country $c$ is therefore

  $\widetilde{v}_f^c = \pi_f^c v_f^c$ where $\pi_f^c$ is the productivity of factor f
- No more FPE equalization but "conditional FPE"
- Let $\widetilde{F}^c \equiv \widetilde{A}t^c$, $\widetilde{A}$ is the effective factor adjusted technology matrix

$$\widetilde{F}_f^c = \pi_f^c v_f^c - s^c \sum_{j=1}^{C} \pi_f^j v_f^j, \quad f = 1, ..F; c = 1, ..., C \tag{11}$$

$$\frac{w_f^c}{\pi_f^c} = \frac{w_f^{c'}}{\pi_f^{c'}}, \quad f = 1, ..F; c, c' = 1, ..., C \tag{12}$$

# Trefler (1993)

Data for year 1983, for 33 countries, 10 factors

Uses equation (11) to compute the $\pi_f^c$, i.e. technology / productivity parameters

In doing so, cannot assess the fit of the model with the trade / endowment data but

- If the $\pi_f^c$ are negative, bad fit
- Can test for FPE
  - i.e. Trefler takes equation (11) as given and test equation (12); any problems?

# Trefler (1993)

- Conditional Factor Prices equalization approximately hold
  - For labor $\ln w_l^c = -0.18 + 0.678 \ln \pi_l^c \qquad R^2 = 0.9$

    ($R^2 = 0.6$ for capital)
  - Smaller correlation for capital: measurement problems
- Is it consistent with Leontief's idea?

# Trefler (1993)

Factor Prices and the $\pi_{fc}$ for Capital and Aggregate Labor

| Aggregate Labor | | | Capital | | | |
|---|---|---|---|---|---|---|
| Country | $\pi_{Lc}/\pi_{L,\mathrm{US}}$ (1) | $w_{Lc}/w_{L,\mathrm{US}}$ (2) | Country | $\pi_{Kc}/\pi_{K,\mathrm{US}}$ (3) | $w_{Kc}/w_{K,\mathrm{US}}$ (4) | $\alpha\pi_{Kc}/\pi_{K,\mathrm{US}}$ (5) |
| Bangladesh | .02 | .05 | Sri Lanka | .13 | .22 | .22 |
| Sri Lanka | .04 | .07 | Indonesia | .26 | .39 | .43 |
| Pakistan | .04 | .11 | Portugal | .31 | .86 | .52 |
| Indonesia | .05 | .19 | Yugoslavia | .31 | .88 | .52 |
| Thailand | .05 | .14 | Panama | .34 | .75 | .56 |
| Portugal | .20 | .29 | Singapore | .34 | .97 | .57 |
| Colombia | .22 | .29 | Thailand | .41 | .67 | .68 |
| Yugoslavia | .22 | .22 | Uruguay | .42 | .51 | .70 |
| Uruguay | .22 | | Trinidad | .43 | .86 | .73 |
| Panama | .25 | .26 | Greece | .45 | .97 | .77 |
| Greece | .35 | .37 | Ireland | .49 | 1.00 | .83 |
| Hong Kong | .42 | .26 | Colombia | .50 | .62 | .84 |
| Ireland | .46 | .56 | Pakistan | .50 | .69 | .84 |
| Spain | .47 | .56 | Israel | .52 | .90 | .88 |
| Trinidad | .51 | | Italy | .53 | .95 | .89 |

# Trefler (1993)

| | | |
|---|---|---|
| Singapore | .54 | .34 |
| New Zealand | .64 | .84 |
| Austria | .64 | .91 |
| United Kingdom | .66 | .70 |
| Japan | .66 | .71 |
| Italy | .66 | .80 |
| Israel | .67 | .61 |
| Finland | .77 | .48 |
| Denmark | .78 | .76 |
| Belgium | .81 | .74 |
| Sweden | .82 | .68 |
| France | .84 | .57 |
| Canada | .84 | 1.08 |
| Norway | .85 | .65 |
| West Germany | .86 | .72 |
| Netherlands | .88 | .86 |
| United States | 1.00 | 1.00 |
| Switzerland | 1.04 | .94 |
| Mean | .53 | .54 |
| Correlation | .90 | |
| Rank correlation | .86 | |

| | | | |
|---|---|---|---|
| Spain | .53 | .91 | .90 |
| Hong Kong | .53 | 1.18 | .90 |
| Austria | .56 | 1.06 | .94 |
| Switzerland | .62 | 1.19 | 1.05 |
| France | .63 | 1.07 | 1.06 |
| Norway | .64 | 1.28 | 1.07 |
| New Zealand | .64 | 1.17 | 1.07 |
| Finland | .66 | 1.10 | 1.12 |
| Belgium | .66 | 1.11 | 1.12 |
| Japan | .67 | 1.27 | 1.12 |
| West Germany | .68 | 1.10 | 1.15 |
| Denmark | .72 | 1.13 | 1.22 |
| Canada | .75 | .98 | 1.27 |
| Netherlands | .77 | 1.15 | 1.29 |
| United Kingdom | .84 | 1.22 | 1.41 |
| Bangladesh | .94 | .78 | 1.58 |
| Sweden | .97 | 1.63 | 1.64 |
| United States | 1.00 | 1.00 | 1.68 |
| Mean | .57 | .96 | .96 |
| Correlation | .68 | | |
| Rank correlation | .71 | | |

NOTE.—Col. 5 is col. 3 multiplied by $\alpha = .96/.57$. This ensures that col. 5 has the same mean as col. 4.

# Trefler (1993)

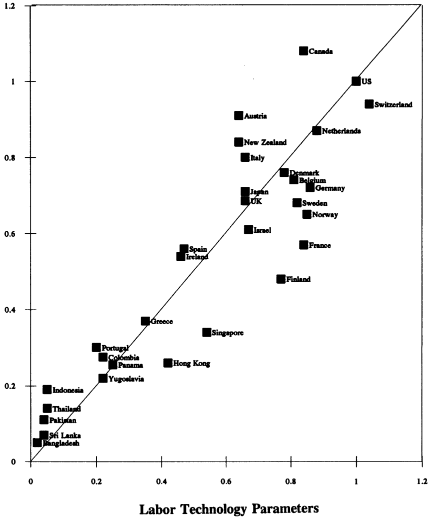



FIG. 1.—Wages and labor technology parameters

# Trefler (1993)

THE LEONTIEF PARADOX AND HIS EXPLANATION

| Factor | $\frac{[\mathbf{A}^* \mathbf{X}_{US}]_f}{[\mathbf{A}^* \mathbf{M}_{US}]_f}$ (1) | $\frac{F_{f,US} - \hat{F}_{f,US}}{\hat{F}_{f,US}}$ (2) | $\frac{V_{f,US}/V_{fw}}{s_c}$ (3) | $\frac{V^*_{f,US}/V^*_{fw}}{s_c}$ (4) |
|---|---|---|---|---|
| Capital | .84 | −.95 | .71 | .97 |
| Labor | .78 | −.98 | .54 | .96 |
| Land | 2.12 | −.40 | 1.28 | 1.19 |

NOTE.—Col. 1 reports the factor content of exports relative to the factor content of imports. Col. 2 reports deviations from the HOV theorem: $F_{f,US} = [\mathbf{A}^* \mathbf{T}_{US}]_f$ is the factor content of U.S. trade and $\hat{F}_{f,US} = V_{f,US} - s_{US}V_{fw}$ is the endowment-based prediction of $F_{f,US}$. In the HOV theorem, a factor is defined to be abundant if its factor abundance ratio $(V_{f,US}/V_{fw})/s_{US}$ exceeds unity. In the productivity-equivalent version of the HOV theorem (eq. [4]), a factor is defined to be abundant if $(V^*_{f,US}/V^*_{fw})/s_{US}$ exceeds unity.

# Trefler (1995)

# Trefler (1995)

Two advances in understanding of NFCT

- Identifies 2 key facts about the NFCT data, which isolate 2 aspects of the data in which the HOV equations appear to fail. (Previous work hadn't said much more than, 'the HOV equations fail badly in the data.')

- Explores how a number of parsimonious (as opposed to the approach in Trefler (1993) which was successful, but deliberately anything but parsimonious!) extensions to basic HO theory can improve the fit of the HOV equations

# Fact 1: “The Case of the Missing Trade”

Consider a plot of HOV deviations (defined as $\epsilon_f^c \equiv F_f^c - (v_f^c - s^c v_f^w)$) against predicted NFCT (ie $v_f^c - s^c v_f^w$) as in Figure 1 next slide

- The vertical line is where $v_f^c - s^c v_f^w = 0$
- The diagonal line is the ‘zero [factor content of] trade’ line: $F_f^c = 0$, or $\epsilon_f^c = -(v_f^c - s^c v_f^w)$

This plot helps us to visualize the failure of the HOV equations

- If the ‘sign test’ always passed, all observations would lie in the top-right or bottom-left quadrants. (They don’t.)
- If the HOV equations were correct,$\epsilon_f^c = 0$, so all observations would lie on a horizontal line. (They definitely don’t.)
- Most fundamentally, the clustering of observations along the ‘zero [factor content of] trade’ line means that factor services trade is far lower than the HOV equations predict. Trefler (1995) calls this “the case of the missing trade.”

# Fact 1: “The Case of the Missing Trade”

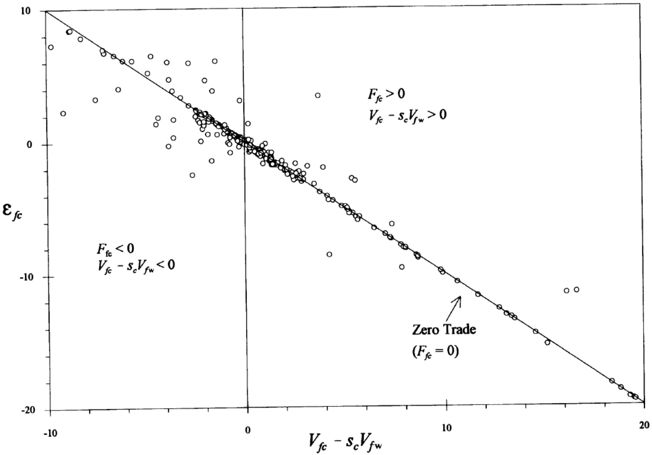



FIGURE 1. PLOT OF $\varepsilon_{fc} = F_{fc} - (V_{fc} - s_c V_{fw})$ AGAINST $V_{fc} - s_c V_{fw}$

# Fact 2: “The Endowments Paradox”

Trefler (1995) then looks at HOV deviations by country, see Figure 2 next slide

- Here he plots the number of times (out of 9, the total number of factors f) that $\epsilon_f^c < 0$
- Because $F_f^c$ is so small (Fact 1), this is mirrored almost one-for-one in $v_f^c - s^c v_f^w > 0$ (i.e. country c is abundant in factor f)

The plot helps us to visualize another failing of the HOV equations

- Poor countries appear to be abundant in all factors
- This can’t be true with balanced trade, and it is not true (in Trefler’s sample) that poor countries run higher trade imbalances.
- So this must mean that there is some omitted factor that tends to be scarce in poor countries
- A natural explanation (a la Leontieff) is that some factors are not being measured in ‘effective (ie productivity-equivalent) units’

# Fact 2: “The Endowments Paradox”

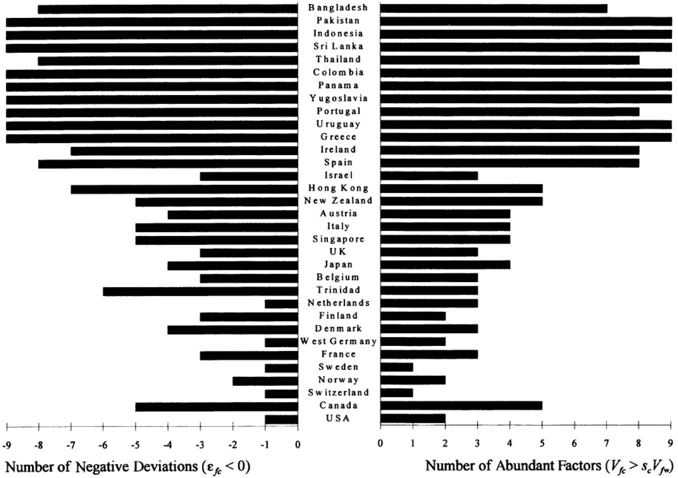



FIGURE 2. DEVIATIONS FROM HOV AND FACTOR ABUNDANCE

# Trefler (1995): Altering the Simple HO Model I

Trefler (1995) then (extending an approach initially pursued in BLS,1987) seeks alterations to the simple HO model that

- Are parsimonious (i.e. they use only a few parameters, unlike in Trefler (1993))
- Have estimated parameters that are economically sensible (analogous to considerations in Trefler (1993)).
- Can account for Facts 1 and 2
- Fit the data well (in a 'goodness-of-fit' sense): e.g. success on sign/rank tests
- Fit the data best (in a likelihood or model selection sense) among the class of alterations tried. (But the 'best' need not fit the data 'well')

# Trefler (1995): Altering the Simple HO Model II

The alterations that Trefler tries are

- T1: restrict $\pi_f^c$ in Trefler (1993) to $\pi_f^c = \delta^c$. ('Neutral technology differences')
- T2: restrict $\pi_f^c$ in Trefler (1993) to $\pi_f^c = \delta^c \phi_f$ for less developed countries ($y^c < \kappa$, where $\kappa$ is to be estimated too) and $\pi_f^c = \delta^c$ for developed countries
- C1: allow the $s^c$ terms to be adjusted to fit the data (this corrects for countries' non-homothetic tastes for investment goods, services and non-traded goods)
- C2: Armington Home Bias: Consumers appear to prefer home goods to foreign goods (tastes? trade costs?). Let $\alpha_c^*$ be the 'home bias' of country c
- TC2: $\delta_c = y_c / y_{US}$ and C2

# Trefler (1995)

By most tests, TC2 (neutral technological differences with Armington home bias) does best. Sign test is nearly perfectly accurate, mysteries improved considerably.

TABLE 1—HYPOTHESIS TESTING AND MODEL SELECTION

| Hypothesis | Description: Parameters ($k_i$) | Description: Equation | Likelihood: $\ln(L_i)$ | Likelihood: Schwarz criterion | Mysteries: Endowment paradox | Mysteries: Missing trade | Goodness-of-fit: Weighted sign | Goodness-of-fit: $\rho(F, \hat{F})$ |
|---|---|---|---|---|---|---|---|---|
| **Endowment differences** | | | | | | | | |
| $H_0$: unmodified HOV theorem | (0) | (1) | −1,007 | −1,007 | −0.89 | 0.032 | 0.71 | 0.28 |
| **Technology differences** | | | | | | | | |
| $T_1$: neutral | $\delta_c$ (32) | (4) | −540 | −632 | −0.17 | 0.486 | 0.78 | 0.59 |
| $T_2$: neutral and nonneutral | $\phi_f, \delta_c, \kappa$ (41) | (6) | −520 | −637 | −0.22 | 0.506 | 0.76 | 0.63 |
| **Consumption differences** | | | | | | | | |
| $C_1$: investment/services/ nontrade. | $\beta_c$ (32) | (7) | −915 | −1,006 | −0.63 | 0.052 | 0.73 | 0.35 |
| $C_2$: Armington | $\alpha_c^*$ (24) | (11) | −439 | −507 | −0.42 | 3.057 | 0.87 | 0.55 |
| **Technology and consumption** | | | | | | | | |
| $TC_1$: $\delta_c = y_c/y_{US}$ | (0) | (4) | −593 | −593 | −0.10 | 0.330 | 0.83 | 0.59 |
| $TC_2$: $\delta_c = y_c/y_{US}$ and Armington | $\alpha_c^*$ (24) | (12) | −404 | −473 | 0.18 | 2.226 | 0.93 | 0.67 |

*Notes:* Here $k_i$ is the number of estimated parameters under hypothesis $i$. For "likelihood," $\ln(L_i)$ is the maximized value of the log-likelihood function, and the Schwarz-model selection criterion is $\ln(L_i) - k_i \ln(297)/2$. Let $\hat{F}_{fc}$ be the predicted value of $F_{fc}$. The "endowment paradox" is the correlation between per capita GDP, $y_c$, and the number of times $\hat{F}_{fc}$ is positive for country $c$ (see Fig. 2). "Missing trade" is the variance of $F_{fc}$ divided by the variance of $\hat{F}_{fc}$ (see Fig. 1). "Weighted sign" is the weighted proportion of observations for which $F_{fc}$ and $\hat{F}_{fc}$ have the same sign. Finally, $\rho(F, \hat{F})$ is the correlation between $F_{fc}$ and $\hat{F}_{fc}$. See Section V for further discussion.

# (Some) recent models with comparative advantage

- **Nunn (2007), QJE and Levchenko (2007)**: good contract enforcement generate a comparative advantage in goods for which relationship-specific investment are more important
- **Beck (2003)**: financial development generates a comparative advantage in “financially dependent” industries
- **Cunat and Melitz (2007)**: countries with more flexible labor markets specialize in sectors with higher volatility

# Nunn (2007)

- **Idea**: institutional differences might affect productivity across industry
- **Intuition**: imperfect contract enforcement leads to under-investment of input suppliers who make relationship-specific inputs (fear of hold-up)
- This harms productivity and prices especially in industries that are particularly dependent on relationship-specific inputs and in countries with bad courts
- Model productivity as the product of both $a_i^k = z^k \times Q_i$

# Nunn (2007)

Nunn (2008) estimates:

$$\ln x_i^k = \alpha^k + \alpha_i + \beta_1 z^k \times Q_i + \beta_2 h^k H_i + \beta_3 k^k K_i + \varepsilon_i^k \tag{13}$$

where $x$ is total exports, $\alpha^k$ and $\alpha_i$ are industry and country fixed effects, $h^k$ and $H_i$ are industry-specific skill-intensity and country-level skill endowment (similar for capital)

$\rightarrow$ Romalis (2004, AER) derives a similar expression from a HO model

# Nunn (2007)

Is a country's ability to enforce contracts an important determinant of comparative advantage?

**How to measure this?**

$\rightarrow$ Construct for each good a variable that measures the proportion of its intermediate inputs that require relationship-specific investments

$\rightarrow$ Combine this with data on trade flows and judicial quality

**Why this measure?**

$\rightarrow$ When investments are relationship-specific, under-investment occurs if contracts cannot be enforced

$\hookrightarrow$ Countries with better contract enforcement $\rightarrow$ less under-investment $\rightarrow$ cost advantage (or comparative advantage)

**Conclusions:**

$\rightarrow$ Hypothesis is confirmed

$\hookrightarrow$ Contract enforcement explains more of the global pattern of trade than countries' endowments of capital and skilled labor combined

# Nunn (2007)

Figure: The least and most contract intensive industries

| Least contract intensive: lowest $z_i^{rs1}$ | | Most contract intensive: highest $z_i^{rs1}$ | |
|---|---|---|---|
| $z_i^{rs1}$ | Industry description | $z_i^{rs1}$ | Industry description |
| .024 | Poultry processing | .810 | Photographic & photocopying equip. manuf. |
| .024 | Flour milling | .819 | Air & gas compressor manuf. |
| .036 | Petroleum refineries | .822 | Analytical laboratory instr. manuf. |
| .036 | Wet corn milling | .824 | Other engine equipment manuf. |
| .053 | Aluminum sheet, plate & foil manuf. | .826 | Other electronic component manuf. |
| .058 | Primary aluminum production | .831 | Packaging machinery manuf. |
| .087 | Nitrogenous fertilizer manufacturing | .840 | Book publishers |
| .099 | Rice milling | .851 | Breweries |
| .111 | Prim. nonferrous metal, excl. copper & alum. | .854 | Musical instrument manufacturing |
| .132 | Tobacco stemming & redrying | .872 | Aircraft engine & engine parts manuf. |
| .144 | Other oilseed processing | .873 | Electricity & signal testing instr. manuf. |
| .171 | Oil gas extraction | .880 | Telephone apparatus manufacturing |
| .173 | Coffee & tea manufacturing | .888 | Search, detection, & navig. instr. manuf. |

# Nunn (2008): Institutions

TABLE IV
THE DETERMINANTS OF COMPARATIVE ADVANTAGE

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| Judicial quality interaction: $z_i Q_c$ | .289** | .318** | .326** | .235** | .296** |
| | (.013) | (.020) | (.023) | (.017) | (.024) |
| Skill interaction: $h_i H_c$ | | | .085** | | .063** |
| | | | (.017) | | (.017) |
| Capital interaction: $k_i K_c$ | | | .105** | | .074 |
| | | | (.031) | | (.041) |
| Log income × value added: $va_i \ln y_c$ | | | | −.117* | −.137* |
| | | | | (.047) | (.067) |
| Log income × intra-industry trade: $iit_i \ln y_c$ | | | | .576** | .546** |
| | | | | (.041) | (.056) |
| Log income × TFP growth: $\Delta tfp_i \ln y_c$ | | | | .024 | −.010 |
| | | | | (.033) | (.049) |
| Log credit/GDP × capital: $k_i CR_c$ | | | | .020 | .021 |
| | | | | (.012) | (.018) |
| Log income × input variety: $(1 - hi_i) \ln y_c$ | | | | .446** | .522** |
| | | | | (.075) | (.103) |
| Country fixed effects | Yes | Yes | Yes | Yes | Yes |
| Industry fixed effects | Yes | Yes | Yes | Yes | Yes |
| $R^2$ | .72 | .76 | .76 | .77 | .76 |
| Number of observations | 22,598 | 10,976 | 10,976 | 15,737 | 10,816 |

Dependent variable is $\ln x_{ic}$. The regressions are estimates of (1). The dependent variable is the natural log of exports in industry $i$ by country $c$ to all other countries. In all regressions the measure of contract intensity used is $z_i^{rs1}$. Standardized beta coefficients are reported, with robust standard errors in brackets. * and ** indicate significance at the 5 and 1 percent levels.

# Beck (2003): Financial development

**Table 2: Industry Exports and Trade Balances and Financial Development**

| Dependent variable | Export share | Export share | Export share | Export share |
|---|---|---|---|---|
| Interaction (external dependence x log[TOTAL CAPITALIZATION] ) | 1.274<br>*(0.001)* | | | |
| Interaction (external dependence x log[PRIVATE CREDIT] ) | | 1.259<br>*(0.001)* | | 1.256<br>*(0.005)* |
| Interaction (external dependence x log[MARKET CAPITALIZATION] ) | | | 0.766<br>*(0.001)* | 0.079<br>*(0.768)* |
| F-test joint significance | | | | 17.28<br>*(0.001)* |
| Number of observations | 1420 | 1945 | 1420 | 1420 |

# Cunat and Melitz (2011): Labor market flexibility

TABLE 5. Pooled regression—baseline.

| SIC aggregation<br>GDPPC cutoff | SIC-4<br>2000 | SIC-3<br>2000 | SIC-4<br>5000 | SIC-3<br>5000 |
|---|---|---|---|---|
| VOL_s * log FLEX_c | 0.300 | 0.298 | 0.356 | 0.382 |
| | (0.060)*** | (0.073)*** | (0.070)*** | (0.083)*** |
| log K_s * log FLEX_c | −0.239 | −0.300 | −0.173 | −0.223 |
| | (0.069)*** | (0.094)*** | (0.080)** | (0.114)* |
| logK_s * logK_c | 0.773 | 1.055 | 0.546 | 1.057 |
| | (0.092)*** | (0.119)*** | (0.169)*** | (0.232)*** |
| log S_s * log S_c | 0.802 | 0.961 | 0.822 | 0.973 |
| | (0.063)*** | (0.091)*** | (0.077)*** | (0.102)*** |
| Observations | 13203 | 6513 | 9739 | 4675 |
| R-squared | 0.7016 | 0.7481 | 0.6913 | 0.7472 |

Notes: Beta coefficients are reported. Country and sector dummies suppressed. Heteroskedasticity robust standard errors in parentheses. *significant at 10%; **significant at 5%; ***significant at 1%.

# Conclusion

- HO is a rich model, but hard to estimate when out of the $2 \times 2 \times 2$ case
- To obtain a decent fit with actual data, one needs to use the extension by Vanek and to allow (at least) for technological differences, i.e. to get back to the type of Ricardian cause for trade that Heckscher and Ohlin wanted to avoid.

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