

# Intermediate International Trade

Jose Miguel Mora Casasola

Marcos Adamson

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For any material corrections, please write to:

[cumasola.economics@hotmail.com](mailto:cumasola.economics@hotmail.com)



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## 1 Introduction

The formalization of trade theory has very old origins. For example, Aristotle (ca. 350 B.C./2009, *Nicomachean Ethics*, V.5, 1133a) employed the concept of proportional modeling developed by the mathematician Euclid (ca. 300 B.C./1956, *Elements*, Book V), and formalized an exchange equation that already included assumptions commonly used by economists. If  $A$  is a builder,  $B$  a shoemaker,  $C$  a house, and  $D$  a pair of shoes, the relationship is established as  $A : B = xD : C$ . Two aspects are fundamental: determining  $x$  (the number of pairs of shoes equivalent to one house) and interpreting the ratio builder/shoemaker. The theory of international trade has examined this problem from different perspectives. Even the “new” theoretical approaches that have emerged in recent decades frequently, though not explicitly, rely on Schumpeterian concepts, in which entrepreneurs, “new markets,” innovation, and market power play a central role, or draw on concepts from Newtonian physics, which itself was influenced by Aristotelian propositions.

It is therefore no coincidence that “Nothing exists in the world, except the blind forces of nature, that is not Greek in its origin” (Maine, cited in Livingstone, 1921). International trade theory is no exception. These are the conceptual foundations that later evolved into the propositions of the labor theory of value, which enabled the theories of absolute and comparative advantage. These theories can be extended to a larger number of goods and countries and explain trade patterns and the international organization of labor primarily through factor endowments, relative size, and technological differences.

The extension to two factors through the Heckscher–Ohlin (H–O) model, and its generalization in the Heckscher–Ohlin–Vanek (H–O–V) model, was enriched by a virtuous and intense cycle between empirical research and conceptual advances. This has been the evolution of trade theory—like many other fields of science—through empirical verification and the search for explanations of trade between relatively similar countries or of flows of goods in industries where close substitutes compete. As in other areas, increasing efforts with a stronger microeconomic foundation have emerged, seeking to explain how firms enter “new” markets and how global companies organize production processes across different locations and countries. These explanatory efforts are conventionally presented in textbooks and even in specialized journals as if isolated from entrepreneurial concepts, although in reality they are closely linked.

The relative availability of international trade data (values, volumes, identification of buyers and sellers, locations, among others) has also enabled the development of empirical explanations. These explanations do not necessarily follow models of welfare theory and are often ad hoc. Services pose an even greater challenge for the empirical verification of explanatory approaches. Similarly, Porter’s concepts, product life-cycle theory, and the incorporation of more dynamic aspects—despite the absence of equations derived from microeconomic optimization models—have contributed detail and improved characterization of observed trade structures. Much of this description remains fundamentally linked to material transformation (production functions, technological relationships such as increasing returns, productivity, and

technological change).

Trade relations have also acquired a strategic dimension, with the imposition of tariffs and trade barriers that modify the global equilibrium. This demands preparation to interpret and act upon regulatory and economic changes in this context. The concepts of “new markets” and the fundamental role of innovation, entrepreneurship, and market power—widely discussed since Schumpeter and influenced by Newtonian physics—are applied today in the analysis of international trade flows.

This document is the result of teaching international trade theory at the School of Economics of the University of Costa Rica. It addresses different topics, aiming to provide reference material with solid formal grounding, as well as exercises at an intermediate level of depth.

## 2 Microeconomic Overview

This chapter is a briefly review of: (i) [Consumer Theory](#), (ii) [Firm Theory](#) and (iii) [General Equilibrium in pure exchange](#).

### 2.1 Consumer Theory

Consumer theory analyzes how an individual chooses a consumption bundle to maximize utility (or satisfaction) given income and market prices. Dually, for a given utility level and given prices, the individual can choose the bundle that attains that utility at the minimum possible expenditure.

The individual's utility-maximization problem can be stated as follows:

$$\max_{x_1, \dots, x_n} U(x_1, \dots, x_n) \quad (2.1.1)$$

$$\text{s.t. } \sum_{i=1}^n p_i x_i \leq m, \quad (2.1.2)$$
$$x_i \geq 0 \quad \forall i = 1, \dots, n$$

Under non-satiation and an interior solution, the associated Lagrangian is

$$\mathcal{L}(x_1, \dots, x_n, \lambda) = U(x_1, \dots, x_n) + \lambda \left( m - \sum_{i=1}^n p_i x_i \right) \quad (2.1.3)$$

The first-order conditions are

$$\frac{\partial \mathcal{L}}{\partial x_i} = \frac{\partial U}{\partial x_i} - \lambda p_i = 0 \quad \forall i = 1, \dots, n, \quad (2.1.4)$$

$$\frac{\partial \mathcal{L}}{\partial \lambda} = m - \sum_{i=1}^n p_i x_i = 0 \quad (2.1.5)$$

Combining (2.1.4) for any two goods  $i$  and  $j$  yields the optimality (Marginal Rate of Substitution = price ratio) condition:

$$\frac{\partial U / \partial x_i}{\partial U / \partial x_j} = \frac{p_i}{p_j} \quad (2.1.6)$$

Substituting the optimal condition into the equation (2.1.2) (budget constraint) gives the *Marshallian (ordinary) demand* for each good  $i$ :

$$x_i = x_i(m, p_1, \dots, p_n) \quad (2.1.7)$$

Equation (2.1.7) states that the optimal quantity of good  $i$  depends on income and all prices. Plugging these demands into the utility function defines the *indirect utility function*:

$$v(m, p_1, \dots, p_n) = U(x_1^M(m, \mathbf{p}), \dots, x_n^M(m, \mathbf{p})) \quad (2.1.8)$$

The indirect utility  $v(m, \mathbf{p})$  gives the maximum attainable utility at income  $m$  and price vector  $\mathbf{p}$  and it is useful for comparing scenarios in which income and prices change simultaneously. By the envelope theorem, the Lagrange multiplier satisfies

$$\lambda^* = \frac{\partial v(m, \mathbf{p})}{\partial m}$$

so  $\lambda^*$  is the marginal utility of income.

Consider the following utility function

$$U(x_1, \dots, x_n) = \prod_{i=1}^n x_i^{\alpha_i}, \quad \alpha_i > 0 \quad (2.1.9)$$

From (2.1.6),

$$\frac{x_i}{x_j} = \frac{\alpha_i p_j}{\alpha_j p_i} \quad (2.1.10)$$

Substituting into (2.1.2) yields the Marshallian demand

$$x_i(m, \mathbf{p}) = \frac{\alpha_i m}{p_i \sum_{k=1}^n \alpha_k} \quad (2.1.11)$$

Plugging (2.1.11) into (2.1.9) gives the indirect utility:

$$v(m, p_1, \dots, p_n) = \left( \frac{m}{\sum_{k=1}^n \alpha_k} \right)^{\sum_{k=1}^n \alpha_k} \prod_{i=1}^n \left( \frac{\alpha_i}{p_i} \right)^{\alpha_i} \quad (2.1.12)$$

For a target utility level  $\bar{u}$ , the dual problem is

$$\min_{x_1, \dots, x_n} \sum_{i=1}^n p_i x_i \quad (2.1.13)$$

$$\text{s.t. } U(x_1, \dots, x_n) \geq \bar{u}, \quad (2.1.14)$$

$$x_i \geq 0 \quad \forall i = 1, \dots, n$$

With an interior solution, the Lagrangian is

$$\mathcal{L}(x_1, \dots, x_n, \lambda) = \sum_{i=1}^n p_i x_i + \lambda(\bar{u} - U(x_1, \dots, x_n)) \quad (2.1.15)$$

The first-order conditions are

$$\frac{\partial \mathcal{L}}{\partial x_i} = p_i - \lambda \frac{\partial U}{\partial x_i} = 0 \quad \forall i = 1, \dots, n \quad (2.1.16)$$

$$\frac{\partial \mathcal{L}}{\partial \lambda} = \bar{u} - U(x_1, \dots, x_n) = 0 \quad (2.1.17)$$

Combining the two-good first-order conditions in (2.1.16) once again produces the optimality

condition found in (2.1.6). Substituting this condition into (2.1.14) yields the *Hicksian (compensated) demand*.

$$h_i = h_i(\bar{u}, p_1, \dots, p_n) \quad (2.1.18)$$

Substituting the Hicksian demand into (2.1.13) defines the resulting *expenditure function*:

$$e(\bar{u}, p_1, \dots, p_n) = \sum_{i=1}^n p_i h_i(\bar{u}, \mathbf{p}) \quad (2.1.19)$$

The Hicksian demand tells how much of each good is needed to achieve utility  $\bar{u}$  at minimum cost, while the expenditure function gives that minimum cost. By the envelope theorem, the multiplier  $\lambda$  measures how much the minimum expenditure must increase to raise utility by one unit.

In the previous example, substituting (2.1.10) into the utility function yields to the Hicksian demand:

$$h_i(\bar{u}, \mathbf{p}) = \frac{\alpha_i \bar{u}^{\frac{1}{\sum_{i=1}^n \alpha_i}}}{p_i} \prod_{j=1}^n \left( \frac{p_j}{\alpha_j} \right)^{\frac{\alpha_j}{\sum_{i=1}^n \alpha_i}}$$

Inserting this result into the expenditure function gives:

$$e(\bar{u}, \mathbf{p}) = \left[ \bar{u}^{\frac{1}{\sum_{i=1}^n \alpha_i}} \prod_{j=1}^n \left( \frac{p_j}{\alpha_j} \right)^{\frac{\alpha_j}{\sum_{i=1}^n \alpha_i}} \right] \sum_{i=1}^n \alpha_i$$

### 2.1.1 Duality Properties

Let  $v(m, \mathbf{p})$  denote the indirect utility function,  $e(\bar{u}, \mathbf{p})$  the expenditure function,  $x_i(m, \mathbf{p})$  the Marshallian (ordinary) demand, and  $h_i(\bar{u}, \mathbf{p})$  the Hicksian (compensated) demand. Prices are  $\mathbf{p} = (p_1, \dots, p_n)$ , income is  $m$ , and  $\bar{u}$  is a target utility level.

#### Roy's identity

$$x_i(m, \mathbf{p}) = - \frac{\frac{\partial v(m, \mathbf{p})}{\partial p_i}}{\frac{\partial v(m, \mathbf{p})}{\partial m}} \quad \forall i = 1, \dots, n \quad (2.1.20)$$

#### Shephard's lemma

$$h_i(\bar{u}, \mathbf{p}) = \frac{\partial e(\bar{u}, \mathbf{p})}{\partial p_i} \quad \forall i = 1, \dots, n \quad (2.1.21)$$

#### Indirect utility and expenditure functions are inverses (duality)

$$e(v(m, \mathbf{p}), \mathbf{p}) = m, \quad (2.1.22)$$

$$v(e(\bar{u}, \mathbf{p}), \mathbf{p}) = \bar{u} \quad (2.1.23)$$

### Marshallian and Hicksian demands relationship

$$h_i(\bar{u}, \mathbf{p}) = x_i(e(\bar{u}, \mathbf{p}), \mathbf{p}), \quad (2.1.24)$$

$$x_i(m, \mathbf{p}) = h_i(v(m, \mathbf{p}), \mathbf{p}) \quad (2.1.25)$$

Given the Cobb–Douglas indirect utility function in equation (2.1.12), Roy’s identity delivers the Marshallian demand:

$$x_i(m, \mathbf{p}) = \frac{\alpha_i m}{p_i \sum_{k=1}^n \alpha_k} \quad (2.1.26)$$

Equation (2.1.23) asserts that the indirect utility evaluated at the minimum expenditure equals the target utility. Substituting the form (2.1.12) and solving for  $e(u, \mathbf{p})$  yields the minimum expenditure function

$$e(u, \mathbf{p}) = \left[ u \prod_{i=1}^n \left( \frac{p_i}{\alpha_i} \right)^{\alpha_i} \right]^{\frac{1}{\sum_{k=1}^n \alpha_k}} \sum_{k=1}^n \alpha_k \quad (2.1.27)$$

Applying Shephard’s lemma to the minimum expenditure function gives the Hicksian demand:

$$h_i(u, \mathbf{p}) = \frac{\alpha_i}{p_i} \left[ u \prod_{j=1}^n \left( \frac{p_j}{\alpha_j} \right)^{\alpha_j} \right]^{\frac{1}{\sum_{k=1}^n \alpha_k}} \quad (2.1.28)$$

Solving the Marshallian demand for good  $i$  for  $p_i$  and substituting it into the indirect utility function restores the original utility function.

## 2.2 Firm Theory

In the theory of the firm, input choice is viewed either as profit maximization or, equivalently, as minimizing the cost of producing a given output level; the analysis first adopts the cost-minimization perspective.

$$\begin{aligned} & \min_{z_1, z_2, \dots, z_n} \quad \sum_{i=1}^n w_i z_i \\ & \text{s.t.} \quad q(z_1, z_2, \dots, z_n) \geq \bar{q} \\ & \quad z_i \geq 0 \quad \forall i = 1, \dots, n \end{aligned}$$

Assuming an interior solution, the Lagrangian for the cost-minimization problem is:

$$\mathcal{L}(z_1, \dots, z_n, \lambda) = \sum_{i=1}^n w_i z_i + \lambda(\bar{q} - q(z_1, \dots, z_n))$$

By the envelope theorem, the Lagrange multiplier  $\lambda$  equals the marginal cost—the increase in

minimum total cost required to produce one additional unit of output.

$$\begin{aligned}\frac{\partial \mathcal{L}}{\partial z_i} &= w_i - \lambda \frac{\partial q(z_1, \dots, z_n)}{\partial z_i} = 0 \quad \forall i = 1, \dots, n, \\ \frac{\partial \mathcal{L}}{\partial \lambda} &= \bar{q} - q(z_1, \dots, z_n) = 0\end{aligned}$$

Combining the first-order conditions for any two inputs,  $i$  and  $j$ , implies that the marginal rate of technical substitution between them equals the ratio of their input prices.

$$\frac{\frac{\partial q(z_1, \dots, z_n)}{\partial z_i}}{\frac{\partial q(z_1, \dots, z_n)}{\partial z_j}} = \frac{w_i}{w_j} \quad \forall i, j = 1, \dots, n \quad (2.2.1)$$

Substituting the optimality condition (2.2.1) back into the production constraint yields the *conditional input demand functions*, denoted by

$$z_i = z(\bar{q}, w_1, \dots, w_n) \quad (2.2.2)$$

where  $\bar{q}$  is the fixed output target and  $\mathbf{w} = (w_1, \dots, w_n)$  is the vector of input prices. Each function  $z_i(\bar{q}, \mathbf{w})$  gives the amount of input that minimizes costs  $i$  required to produce units of output  $\bar{q}$  at the prevailing prices, thus completing the solution to the firm's cost-minimization problem.

Substituting (2.2.2) into the cost objective yields the *minimum cost function*

$$C(\bar{q}, \mathbf{w}) = \sum_{i=1}^n w_i z_i(\bar{q}, \mathbf{w}), \quad (2.2.3)$$

which gives the least expenditure required to produce the target output  $\bar{q}$  at input prices  $\mathbf{w}$ . Define the *scale elasticity* as

$$\varepsilon_S = \sum_{i=1}^n \frac{\partial q(z_1, \dots, z_n)}{\partial z_i} \frac{z_i}{q}$$

Classification follows immediately:

$$\varepsilon_S \begin{cases} > 1 & \text{Increasing Returns to Scale (IRS),} \\ = 1 & \text{Constant Returns to Scale (CRS),} \\ < 1 & \text{Decreasing Returns to Scale (DRS).} \end{cases}$$

Additionally, the *cost elasticity* with respect to output is

$$\varepsilon_C(q) = \frac{\partial C(\bar{q}, \mathbf{w})}{\partial q} \frac{q}{C(\bar{q}, \mathbf{w})} = \frac{MC(q)}{AC(q)},$$

Hence

$$\varepsilon_C(q) \begin{cases} < 1 & \text{Economies of scale } (AC \downarrow), \\ = 1 & \text{Constant returns to scale,} \\ > 1 & \text{Diseconomies of scale } (AC \uparrow). \end{cases}$$

To illustrate these concepts, consider the following production function:

$$q(z_1, \dots, z_n) = \left( \sum_{i=1}^n a_i z_i^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}, \quad \sigma > 1 \quad (2.2.4)$$

The marginal product of input  $z_i$  is defined as

$$\frac{\partial q(z_1, \dots, z_n)}{\partial z_i} = \alpha_i z_i^{\frac{-1}{\sigma}} q \left( \sum_{i=1}^n a_i z_i^{\frac{\sigma-1}{\sigma}} \right)^{-1}$$

The (2.2.1) would yield to:

$$\left( \frac{z_k}{z_i} \right)^{\frac{1}{\sigma}} = \left( \frac{\alpha_k w_i}{\alpha_i w_k} \right)$$

Note that evaluating the *elasticity of substitution* between inputs  $i$  and  $j$  under the optimality condition yields

$$\sigma_{ij} = \frac{\partial(z_j/z_i)}{\partial(w_i/w_j)} \frac{(w_i/w_j)}{(z_j/z_i)} = \sigma$$

Because the elasticity of substitution,  $\sigma$ , remains constant for every input combination, the production function is called the *Constant Elasticity of Substitution (CES)* function.

Defining the Dixit–Stiglitz CES price index as

$$W(\mathbf{w}) = \left( \sum_{i=1}^n \alpha_i^\sigma p_i^{1-\sigma} \right)^{\frac{1}{1-\sigma}} \quad (2.2.5)$$

The *conditional input demand* associated to this production function can be written as

$$z_i(\bar{q}, \mathbf{w}) = \left( \frac{\alpha_i}{w_i} \right)^\sigma W^\sigma \bar{q}$$

Minimum cost function is

$$C(\bar{q}, \mathbf{w}) = q \sum_{i=1}^n w_i \left( \frac{\alpha_i}{w_i} \right)^\sigma W^\sigma$$

Note that  $\varepsilon_S = 1$  and  $\varepsilon_C(q) = 1$ .

The supply curve for the firm if the good market is competitive is as follows

$$P = \sum_{i=1}^n w_i \left( \frac{\alpha_i}{w_i} \right)^\sigma W^\sigma$$

Now if we were to maximize the firms profit

$$\max_{z_1, \dots, z_n} \pi = p q(z_1, \dots, z_n) - \sum_{i=1}^n w_i z_i$$

Assuming an interior solution; the *First Order Conditions (FOC)*

$$p \frac{\partial q(z_1, \dots, z_n)}{\partial z_i} = w_i, \quad \forall i = 1, \dots, n$$

Solving the system yields the *unconditional* (profit-maximizing) input demands

$$z_i^* = z_i(p, \mathbf{w}), \quad i = 1, \dots, n,$$

If the technology exhibits *decreasing returns to scale* (i.e. diseconomies of scale), marginal cost is increasing so supply curve is upward-sloping in the output price. Substituting the *unconditional* factor demands into the production function therefore yields the firm's supply function:

$$q = q(z_1(p, \mathbf{w}), \dots, z_i(p, \mathbf{w}))$$

### 2.3 General Equilibrium in pure exchange

Suppose an economy with  $I$  consumers and  $n$  goods. Consumer  $j$  is endowed with  $\omega_j = (\omega_{1j}, \dots, \omega_{nj}) \in \mathbb{R}_+^n$ . Through trade, every consumer tries to become *more satisfied* (i.e. reach a higher utility level) than at the initial endowment.

Considering a *Decentralized equilibrium*, consumer  $j$  solves

$$\max_{x_{1j}, \dots, x_{nj}} u_j(x_{1j}, \dots, x_{nj}) \tag{2.3.1}$$

$$\text{s.t. } \sum_{i=1}^n p_i x_{ij} = \sum_{i=1}^n p_i \omega_{ij} \tag{2.3.2}$$

The first-order (interior) optimality condition reads

$$\frac{\partial u_j / \partial x_{ij}}{\partial u_j / \partial x_{kj}} = \frac{p_i}{p_k}, \quad \forall i \neq k.$$

The optimality condition, once substituted into equation (2.3.2) (the budget constraint) generates individual  $j$ 's demand for each good. Repeating this procedure for every individual yields the complete system of demand functions—one for each of the  $n$  goods for each of the  $I$  individuals, i.e.  $n \times I$  demand functions. Note that this is the same as getting the Marshallian demand for each good and replacing income  $m$  with the value of individual  $j$ 's endowment,  $\sum_{i=1}^n p_i \omega_{ij}$ .

In equilibrium, by market clearing for every good  $i$  total demand equals total supply:

$$\sum_{j=1}^I x_{ij} = \sum_{j=1}^I \omega_{ij}, \quad i = 1, \dots, n.$$

The resulting system of  $n$  equations determines the equilibrium price vector  $(p_1^*, \dots, p_n^*)$  (defined up to a positive scalar normalization).

The equilibrium allocation is a *Pareto equilibrium*: no individual's utility can be increased without lowering someone else's. Varying individual endowments while maintaining the aggregate endowment fixed traces out the *Pareto set*. This set can be characterized by imposing, for each individual  $j$ , the optimality condition that equates the marginal substitution rate with the equilibrium price ratio, that is,

$$\frac{\partial u_j / \partial x_{ij}}{\partial u_j / \partial x_{kj}} = \frac{p_i^*}{p_k^*}$$

Note that some allocations make one or both individuals better off relative to their initial endowments while still allowing an increase in one person's utility without reducing the other's. This collection of allocations is called the *lens of trade*. Within this lens lies that segment of the *Pareto set* where no further utility gains are possible for anyone without harming someone else. The final allocation must therefore lie inside the lens of trade and on the Pareto set.

Take the following example with 2 individual and 2 goods; each individual's utility function is given by:

$$u_j(x_{1j}, x_{2j}) = \sqrt{x_{1j}x_{2j}} \quad j = 1, 2$$

The resulting demand functions are:

$$x_{1j} = \frac{1}{2} \cdot \frac{p_1 \omega_{1j} + p_2 \omega_{2j}}{p_1} \quad \wedge \quad x_{2j} = \frac{1}{2} \cdot \frac{p_1 \omega_{1j} + p_2 \omega_{2j}}{p_2} \quad j = 1, 2$$

Market clearing in equilibrium requires that

$$\begin{cases} \frac{1}{2} \cdot \frac{p_1 \omega_{11} + p_2 \omega_{21}}{p_1} + \frac{1}{2} \cdot \frac{p_1 \omega_{12} + p_2 \omega_{22}}{p_1} = \omega_{11} + \omega_{12} \\ \frac{1}{2} \cdot \frac{p_1 \omega_{11} + p_2 \omega_{21}}{p_2} + \frac{1}{2} \cdot \frac{p_1 \omega_{12} + p_2 \omega_{22}}{p_2} = \omega_{21} + \omega_{22} \end{cases}$$

Solving the first equation for the relative price yields:

$$\frac{p_2^*}{p_1^*} = \frac{(\omega_{11} + \omega_{12})}{(\omega_{21} + \omega_{22})} \quad (2.3.3)$$

The equilibrium *relative price* is unique, whereas the absolute price vector is determined only up to a positive scalar. For instance, in (2.3.3) one may set

$$p_2 = \lambda(\omega_{11} + \omega_{12}), \quad p_1 = \lambda(\omega_{21} + \omega_{22}),$$

for any  $\lambda > 0$ , leaving the ratio  $p_1/p_2$  unchanged.

Equation (2.3.3) states that the equilibrium *relative price* equals the ratio of total endowments. In words, the price of good 1 relative to good 2 equals the economy-wide endowment of good 2 relative to that of good 1, and vice-versa.

This illustrates *Walras's Law*: if a price vector clears total demand and supply in one market, it necessarily clears the remaining market. Concretely, choose any  $\lambda > 0$  and set

$$p_2 = \lambda(\omega_{11} + \omega_{12}), \quad p_1 = \lambda(\omega_{21} + \omega_{22}).$$

These prices equate aggregate demand and supply in the first market; by Walras's Law, they also clear the second market. More generally, if a price vector  $(p_1^*, \dots, p_n^*)$  clears  $n - 1$  markets, it clears all  $n$  markets.

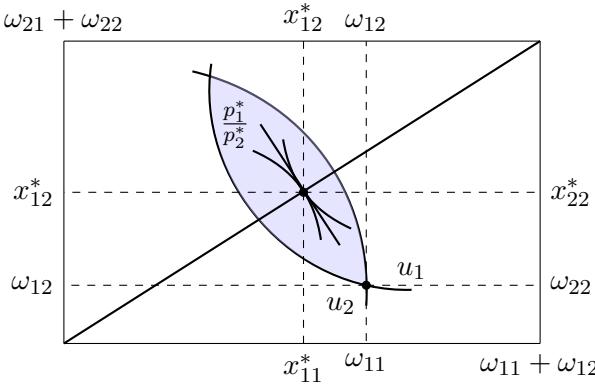
The Pareto-equilibrium allocation is as follows

$$x_{1j}^* = \frac{\omega_{1j}}{2} + \frac{\omega_{2j}}{2} \frac{\omega_{21} + \omega_{22}}{\omega_{11} + \omega_{12}}, \quad x_{2j}^* = \frac{\omega_{1j}}{2} \frac{\omega_{21} + \omega_{22}}{\omega_{11} + \omega_{12}} + \frac{\omega_{2j}}{2}, \quad j = 1, 2.$$

The Pareto-equilibrium allocation shown above depends on the *individual* endowments. If these endowments are redistributed—keeping the *aggregate* endowment constant—the Pareto allocation changes, yet the equilibrium relative price remains the one in (2.3.3). Hence a redistribution can raise one person's utility while lowering the other's.

The constancy of the relative price here is a special case: both agents share identical, symmetric preferences. In general, each Pareto equilibrium that arises from a given initial allocation is supported by its own relative-price vector, as stated by the Second Welfare Theorem. In this symmetric setting, however, every Pareto allocation is backed by the same price ratio in (2.3.3). Figure 1 illustrates the Edgeworth box for this example.

Figure 1: Edgeworth box for  $u_j(x_{1j}, x_{2j}) = \sqrt{x_{1j}x_{2j}}$



**Social–planner problem and the First Welfare Theorem** Finally, note that a benevolent social planner who reallocates each good so that the aggregate assignment equals the aggregate endowment would implement exactly the same Pareto–efficient allocation that arises in the

decentralized competitive equilibrium derived in (2.3.3). Formally, the planner solves

$$\begin{aligned} \max_{x_{ij} \forall i,j} & \sum_{j=1}^I \lambda_j u_j(x_{1j}, \dots, x_{nj}) \\ \text{s. t. } & \sum_{j=1}^I x_{ij} = \sum_{j=1}^I \omega_{ij}, \quad \forall i = 1, \dots, n, \end{aligned} \tag{2.3.4}$$

where the Pareto weights  $\lambda_j$  in (2.3.4) are proportional to the marginal utility of the value of household  $j$ 's original endowment. Because competitive markets already equate marginal rates of substitution across agents while respecting the resource constraints, the solution to (2.3.4) coincides with the decentralized equilibrium allocation—an illustration of the First Welfare Theorem.

## 2.4 Exercises

1. Consider a consumer whose preferences are represented by

$$U(x_1, x_2, \dots, x_n) = x_k \prod_{i \neq k}^{n}(x_i - \theta_i), \quad x_i > \theta_i \quad \forall i \neq k$$

1. Derive the Marshallian demand functions.
2. Obtain the indirect utility function.
3. Derive the Hicksian (compensated) demand functions.
4. Determine the expenditure function.
2. Let the expenditure function be

$$e(\bar{u}, \mathbf{p}) = \bar{u}p_1 - \frac{p_1^2}{4} \sum_{i=2}^n \frac{1}{p_i}, \quad \bar{u} > \frac{p_1}{2} \sum_{i=2}^n \frac{1}{p_i}$$

1. Derive the Marshallian demand functions.
2. Obtain the indirect utility function.
3. Derive the Hicksian (compensated) demand functions.
4. Recover the underlying utility function.
3. Consider a firm with the production function

$$q(L, K) = [\max \{\min\{2L, K\}, \min\{L, 2K\}\}]^\rho, \quad 0 < \rho < 1$$

1. Derive the conditional factor demand functions.
2. Determine the cost function.
3. Derive the firm's supply function.
4. Obtain the unconditional factor demands<sup>1</sup>.
4. Consider a firm with the production function

$$q(L, K) = [\min\{\max\{2L, K\}, \max\{L, 2K\}\}]^\rho, \quad 0 < \rho < 1$$

1. Derive the conditional factor demand functions.
2. Determine the cost function.
3. Derive the firm's supply function.
4. Obtain the unconditional factor demands.

---

<sup>1</sup>Consider  $z_i(p, \mathbf{w}) = z_i(q(p, z_i(p, \mathbf{w})), \mathbf{w})$

5. Consider a pure-exchange economy with two consumers. Consumer A's utility is

$$u^A(x_{1A}, x_{2A}) = 2x_{1A} + x_{2A}$$

while consumer B's utility is

$$u^B(x_{1B}, x_{2B}) = \min\{x_{1B}, x_{2B}\}$$

Their endowments are  $w^A = (0, \bar{w})$  and  $w^B = (\bar{w}, 0)$

1. State the initial endowment point.
  2. Determine the lens of trade.
  3. Characterize the Pareto set.
  4. Compute the equilibrium relative price.
  5. Identify the set of equilibrium allocations.
6. A small town has  $n$  residents. Resident  $i$  is endowed with  $\bar{w}$  units of good  $i$  and none of the other goods. Every resident's preferences are

$$u_i(x_1, \dots, x_n) = \sum_{j=1}^n \ln x_j$$

1. Derive the equilibrium relative prices.
2. Characterize the Pareto set.
3. Identify the equilibrium allocation set.
4. Show that equilibrium prices are independent of the endowments and explain the intuition.
5. Verify that the centralized allocation matches the competitive equilibrium.

### 3 The Export Condition and Ricardian Model

#### 3.1 The Export Condition

Suppose there is Home ( $H$ ) and ( $F$ ) and  $n$  goods. Each good  $i$  requires  $a_i$  units of labor per unit of output, and  $a_i^*$  units abroad. The wage rate in Home is  $w$ , and in Foreign it is  $w^*$ . If  $e$  denotes the nominal exchange rate (units of Foreign currency per unit of Home currency), the unit cost of producing good  $i$  is

$$c_i^H = e \cdot w \cdot a_i, \quad c_i^F = w^* \cdot a_i^*$$

Here,  $c_i^H$  is measured in Foreign currency by multiplying by  $e$ , while  $c_i^F$  is expressed in Foreign currency. This adjustment ensures cost to be measured in the same currency.

The fundamental export condition is that Home exports good  $i$  if it can supply the good at lower cost than Foreign:

$$c_i^H < c_i^F.$$

Substituting from above:

$$e \cdot w \cdot a_i < w^* \cdot a_i^* \tag{3.1.1}$$

Equation (3.1.1) can be written to state that Home exports good  $i$  if

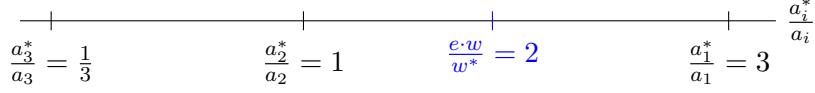
$$\frac{e \cdot w}{w^*} < \frac{a_i^*}{a_i} \tag{3.1.2}$$

Equation (3.1.2) can be interpreted as follows: Home exports good  $i$  whenever the relative wage—that is, the wage in Home expressed in terms of the Foreign wage—is lower than the relative cost of producing the good abroad, expressed in terms of Home's cost. The right-hand side of the inequality thus represents the relative unit labor requirements, capturing the notion of comparative efficiency.

To illustrate, consider three goods  $x_1$ ,  $x_2$ , and  $x_3$ . The unit labor requirements in Home are  $(1, 2, 3)$ , while in Foreign they are  $(3, 2, 1)$ . Suppose the Home wage (in Foreign currency) is 2, and the Foreign wage (in Foreign currency) is 1. According to the export condition, Home will have a cost advantage in goods  $x_1$ , thereby producing and exporting them, while it will import  $x_2$  and  $x_3$  from Foreign.

Figure 2 illustrates this scenario. The goods are ordered from lowest to highest according to Home's relative unit requirements. Relative wage adjusted by exchange rate is in blue. All goods positioned to the right of relative wage are produced and exported by Home (and imported by Foreign), while those to the left are produced and exported by Foreign (and imported by Home).

Figure 2: Export condition in example given



### 3.1.1 Transport Costs

Consider the presence of transport costs, denoted by  $\tau$ , which are assumed to be identical across countries and goods. The cost  $\tau$  is measured in units of the good itself. Such costs are commonly referred to as *iceberg costs*, since  $\tau$  represents the additional quantity of the good that must be shipped for one unit to arrive in the destination country.

The export condition for Home to supply good  $i$  under iceberg transport costs is given by

$$(1 + \tau)e \cdot w \cdot a_i < w^* \cdot a_i^*, \quad (3.1.3)$$

which can be rewritten as

$$\frac{e \cdot w}{w^*} < \frac{a_i^*}{(1 + \tau) \cdot a_i}, \quad (3.1.4)$$

where equation (3.1.4) expresses the condition in terms of relative wages.

Suppose that in the absence of transport costs, Home exports good  $i$  and Foreign exports good  $j$ . Once transport costs are introduced, the two goods may become nontraded if

$$(1 + \tau)e \cdot w \cdot a_i > w^* \cdot a_i^*, \quad (3.1.5)$$

$$e \cdot w \cdot a_j < w^* \cdot a_j^*(1 + \tau). \quad (3.1.6)$$

Although Home is assumed to have a comparative advantage in good  $i$ , a sufficiently high transport cost may lead condition (3.1.5) to hold, implying that Home no longer exports good  $i$  because the effective cost of exporting exceeds the cost of production in Foreign. Analogously, the same reasoning applies to Foreign with respect to good  $j$  in condition (3.1.6).

Equations (3.1.5) and (3.1.6) can be equivalently expressed as

$$\frac{(1 + \tau)e \cdot w}{w^*} > \frac{a_i^*}{a_i}, \quad (3.1.7)$$

$$\frac{e \cdot w}{(1 + \tau)w^*} < \frac{a_j^*}{a_j}. \quad (3.1.8)$$

Considering multiple goods, these inequalities define the range of nontraded goods. The relative requirements that satisfy equations (3.1.7) and (3.1.8) with equality determine the boundaries of the nontraded sector. Any good  $k$  whose relative requirement lies within these bounds will not be traded internationally.

### 3.2 The Ricardian Model of International Trade

Consider a world economy with two countries: Home (denoted by  $H$ ) and Foreign (denoted by  $F$ ). The economy produces two goods, indexed by  $q_1^i$  and  $q_2^i$ , where  $i \in \{H, F\}$ . Labor is the only factor of production, and each country is endowed with a fixed labor supply  $L^i > 0$ . Technology is characterized by constant unit labor requirements: producing one unit of good  $q_1$  in country  $i$  requires  $a_1^i$  units of labor, while producing one unit of good  $q_2$  requires  $a_2^i$  units of labor. We assume  $a_1^i, a_2^i > 0$  and constant returns to scale.

#### 3.2.1 Production

The production function for good  $i \in \{1, 2\}$  in country  $j \in \{H, F\}$  is given by:

$$q_i^j = \frac{L_i^j}{a_i^j} \quad (3.2.1)$$

where  $L_i^j$  denotes the amount of labor allocated to sector  $i$  in country  $j$ .

This functional form reflects a fixed-coefficient technology: each unit of output  $q_i^j$  requires exactly  $a_i^j$  units of labor. Equivalently,  $1/a_i^j$  is the marginal product of labor in sector  $i$  of country  $j$ .

Labor is perfectly mobile across sectors within a country but immobile across countries. The labor resource constraint is therefore:

$$L_1^j + L_2^j = L^j, \quad j \in \{H, F\}, \quad (3.2.2)$$

which reflects the fact that total labor demand must equal the exogenously supplied labor.

#### 3.2.2 Production Possibility Frontier

To characterize the set of feasible output combinations, substitute  $L_i^j = a_i^j q_i^j$  into the labor constraint:

$$a_1^j q_1^j + a_2^j q_2^j = L^j, \quad j \in \{H, F\}. \quad (3.2.3)$$

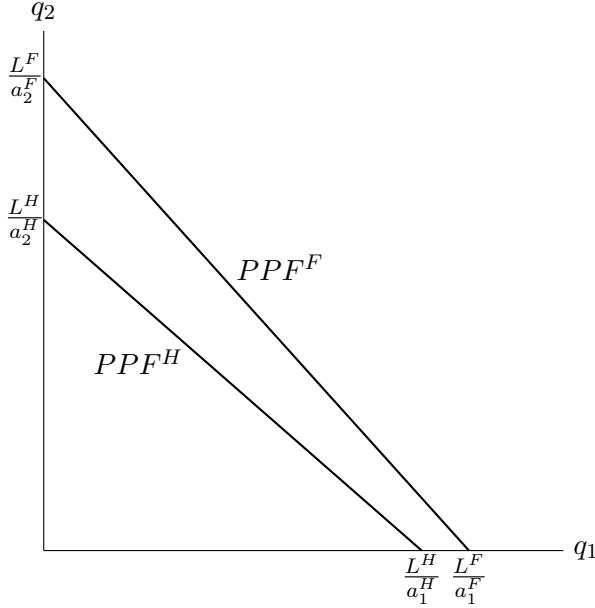
Equation (3.2.3) is a linear relationship between  $q_1^j$  and  $q_2^j$  with slope  $-\frac{a_1^j}{a_2^j}$ , which we refer to as the **relative requirements**. The intercepts are  $\frac{L^j}{a_1^j}$  on the  $q_1^j$  axis and  $\frac{L^j}{a_2^j}$  on the  $q_2^j$  axis. These represent the maximum quantity of each good that country  $j$  could produce if it devoted all its labor to that sector. Equation (3.2.3) thus defines the Production Possibility Frontier (PPF).

The linearity of the PPF follows directly from the assumption of constant unit labor requirements. Its slope,  $-\frac{a_1^j}{a_2^j}$ , measures the opportunity cost of producing one unit of  $q_1^j$  in terms of forgone units of  $q_2^j$ . Since this opportunity cost is constant, the model does not feature diminishing returns to specialization. As a result, **full specialization naturally emerges**

under trade.

Figure 3 illustrates the PPF in a case where Home has a comparative advantage in good  $q_1$ . The intercepts depend on each country's labor supply and labor requirements. Assuming  $L^H = L^F$ , the figure suggests that Foreign enjoys an absolute advantage in both goods, even though Home maintains a comparative advantage in good  $q_1$ .

Figure 3: Production Possibility Frontier



### 3.2.3 Autarky

In autarky, competitive equilibrium requires that the relative price of the two goods equals their opportunity cost in production. Let  $p_1^j$  and  $p_2^j$  denote the prices of goods  $q_1^j$  and  $q_2^j$  in country  $j$ , respectively. Under perfect competition and zero profits, the unit cost of producing good  $i$  must equal its price:

$$p_1^j = w^j a_1^j, \quad (3.2.4)$$

$$p_2^j = w^j a_2^j \quad (3.2.5)$$

where  $w^j$  is the wage in country  $j$ . Dividing equation (3.2.4) by equation (3.2.5) yields:

$$\frac{p_1^j}{p_2^j} = \frac{a_1^j}{a_2^j}. \quad (3.2.6)$$

Thus, in autarky, the relative price equals the constant marginal rate of transformation implied by the PPF.

### 3.2.4 Opening to Trade

When the economy opens to trade, the relevant relative price is the *world* relative price,  $\frac{p_1^W}{p_2^W}$ . Suppose that Home has a comparative advantage<sup>2</sup> in good  $q_1$ , meaning:

$$\frac{a_1^H}{a_2^H} < \frac{a_1^F}{a_2^F}, \quad (3.2.7)$$

where  $a_i^F$  are the unit labor requirements in Foreign.

Comparative advantage is therefore determined entirely by the ratio of unit labor requirements across goods and countries. If Home has a comparative advantage in  $q_1$ , then by construction, Foreign must have a comparative advantage in  $q_2$ .

It is also possible for one country to have an *absolute advantage*<sup>3</sup> in both goods. Absolute advantage is defined by direct productivity levels, while comparative advantage arises from relative productivity differences and ultimately governs trade patterns.

Figure 4 illustrates the relative offer curve of the model once the economy opens to trade. The derivation, assuming that Home has a comparative advantage in good  $q_1$ , proceeds as follows:

- If the world relative price  $\frac{p_1^W}{p_2^W}$  is lower than both Home's autarky price ratio  $\frac{a_1^H}{a_2^H}$  and Foreign's autarky price ratio  $\frac{a_1^F}{a_2^F}$ , then both Home and Foreign fully specialize in the production of  $q_2$ . In this case:

$$q_2^W = \frac{L^H}{a_2^H} + \frac{L^F}{a_2^F}, \quad q_1^W = 0$$

Thus,  $\frac{q_1^W}{q_2^W} = 0$ , since both countries specialize in  $q_2$  (whose relative price exceeds its relative cost in both economies). This corresponds to the segment A–B in Figure 4.

- If the world relative price  $\frac{p_1^W}{p_2^W}$  lies between Home's autarky price ratio  $\frac{a_1^H}{a_2^H}$  and Foreign's autarky price ratio  $\frac{a_1^F}{a_2^F}$ , then Home fully specializes in  $q_1$  and Foreign in  $q_2$ . In this case:

$$q_1^W = \frac{L^H}{a_1^H}, \quad q_2^W = \frac{L^F}{a_2^F}$$

Therefore,

$$\frac{q_1^W}{q_2^W} = \frac{L^H/a_1^H}{L^F/a_2^F}$$

This scenario is the most economically relevant: each country specializes in the good for which it has comparative advantage. It corresponds to the segment C–D in Figure 4.

<sup>2</sup>A country has a comparative advantage in good  $i$  if its relative cost of producing  $i$  is lower than that of the other country. In other words, Home sacrifices less of good  $j$  to produce one unit of  $i$  compared to Foreign.

<sup>3</sup>A country has an absolute advantage in good  $i$  if, with the same resources, it can produce more of  $i$  than the other country. Formally, country  $j$  has absolute advantage in good  $i$  if  $a_i^j < a_i^{-j}$ , where  $-j$  denotes the other country.

- If the world relative price  $\frac{p_1^W}{p_2^W}$  is higher than both Home's and Foreign's autarky price ratios, then both countries fully specialize in  $q_1$ . In this case:

$$q_1^W = \frac{L^H}{a_1^H} + \frac{L^F}{a_1^F}, \quad q_2^W = 0$$

Hence,  $\frac{q_1^W}{q_2^W} = \infty$ , as both countries allocate all resources to  $q_1$ . This corresponds to the segment D–∞ on the horizontal axis in Figure 4.

- If the world relative price equals Home's autarky price ratio,  $\frac{p_1^W}{p_2^W} = \frac{a_1^H}{a_2^H}$ , then Home is indifferent between producing  $q_1$ ,  $q_2$ , or any combination of both. If it participates in trade, it may choose any production in its PPF, while Foreign specializes in  $q_2$ . In this case:

$$\frac{q_1^W}{q_2^W} \in \left[ 0, \frac{L^H/a_1^H}{L^F/a_2^F} \right]$$

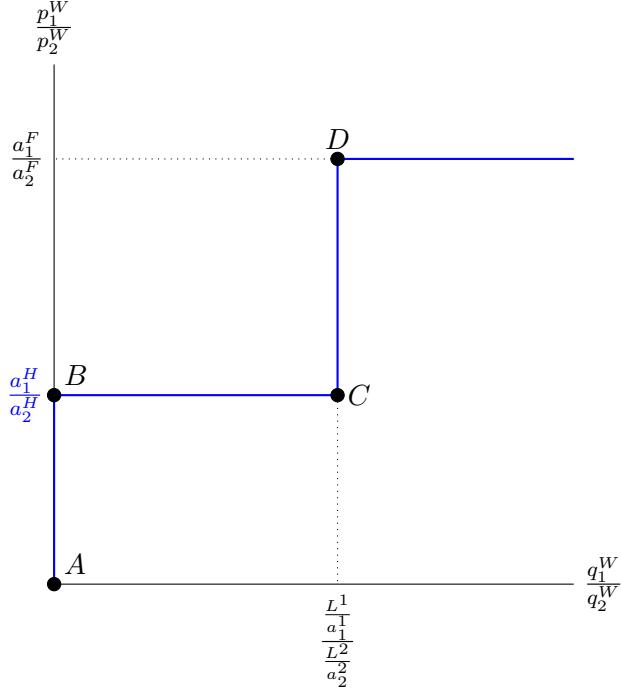
This corresponds to the segment B–C in Figure 4.

- If the world relative price equals Foreign's autarky price ratio,  $\frac{p_1^W}{p_2^W} = \frac{a_1^F}{a_2^F}$ , then Foreign is indifferent between producing  $q_1$ ,  $q_2$ , or any combination of both. If it participates in trade, it may choose any production in its PPF, while Home specializes in  $q_1$ . In this case:

$$\frac{q_1^W}{q_2^W} \in \left[ \frac{L^H/a_1^H}{L^F/a_2^F}, \infty \right]$$

This corresponds to the segment D–∞ in Figure 4.

Figure 4: Relative Market in the Ricardian model



As discussed earlier, the equilibrium arises when each country specializes in a different good. Figure 5 illustrates this equilibrium outcome.

Assume that both countries share a homothetic utility function. For example, let preferences be represented by

$$U_j(q_1, q_2) = q_1 q_2, \quad j \in H, F$$

The corresponding optimality condition is:

$$\frac{q_2}{q_1} = \frac{p_1}{p_2} \quad (3.2.8)$$

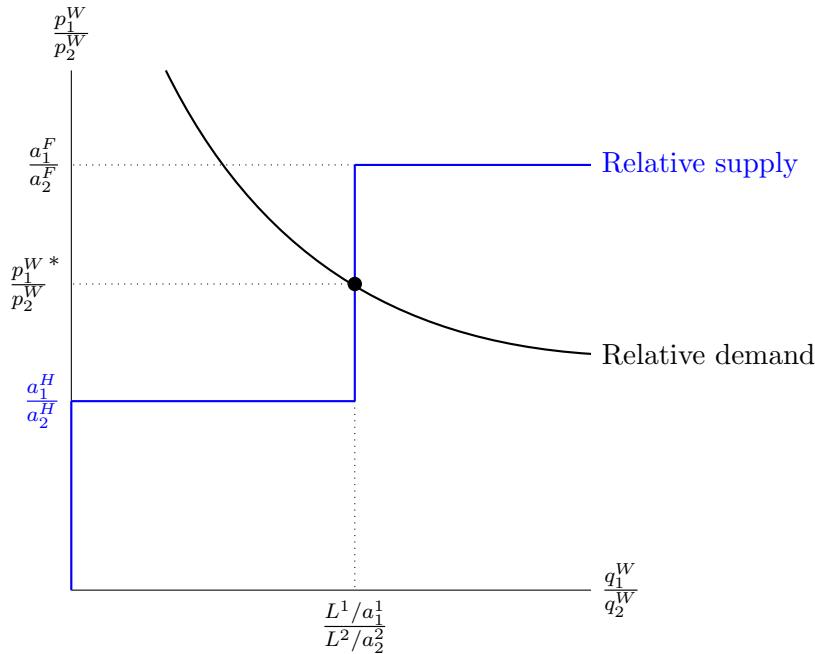
Equation (3.2.8) can be expressed as

$$\frac{p_1}{p_2} = \frac{1}{q_1/q_2} \quad (3.2.9)$$

Equation (3.2.9) represents the relative demand. This curve has a negative slope and is convex in relative quantities. To determine the equilibrium world relative price, the ratio  $\frac{q_1^W}{q_2^W}$  can be substituted for the case in which each country specializes in the good for which it holds a comparative advantage. The resulting expression yields the equilibrium world relative price:

$$\frac{p_1^W}{p_2^W} = \frac{L^2/a_2^2}{L^1/a_1^1} \quad (3.2.10)$$

Figure 5: Relative Market in the Ricardian model



For the relative demand curve to intersect the vertical segment of the relative supply curve at the relative quantity  $\frac{L^H/a_1^H}{L^F/a_2^F}$  in Figure 5, the equilibrium world relative price must satisfy

$$\left(\frac{p_1^W}{p_2^W}\right)^* \in \left[\frac{a_1^H}{a_2^H}, \frac{a_1^F}{a_2^F}\right]$$

### 3.3 Exercises

1. Consider the Export Condition studied here ([Section 3.1](#)) where there are three goods and three countries. Table 1. reports the unit labor requirements for each good in each country.

Requirements	A	B	C
$a_1$	2	3	4
$a_2$	4	3	1
$a_3$	1	2	4

1. Suppose it is known that country A produces and exports good  $x_3$ , country B produces and exports good  $x_1$ , and country C produces and exports good  $x_2$ . What must be true about the relative wages, expressed in the currency of country C?
2. Based on the export condition ([Section 3.1](#)), consider an economy with  $n$  goods, where wages are identical across countries, expressed in a common currency. The labor requirements are specified as

$$(a_1, a_2, \dots, a_n) = (1, 2, \dots, n), \quad (a_1^*, a_2^*, \dots, a_n^*) = (n, n-1, \dots, 1).$$

1. Determine which goods are produced and exported by Home, and which goods are produced and exported by Foreign.
2. Assume a transport cost of  $\frac{1}{4}$  and  $n = 10$ . Identify the set of goods produced and exported by Home and those produced and exported by Foreign. Additionally, determine whether any goods become nontraded.
3. Consider a transport cost equal to  $\tau$  and  $n$  goods. Characterize the goods produced and exported by Home and Foreign. Furthermore, assess the existence of nontraded goods as a function of  $\tau$ . Demonstrate that the range of nontraded goods expands as the transport cost increases.
3. Consider the Ricardian model ([Section 3.2](#)) where country A requires 2 units of labor to produce one unit of  $q_1$  and 1 unit of labor to produce one unit of  $q_2$ . Country B requires 4 units of labor to produce one unit of  $q_1$  and 3 units of labor to produce one unit of  $q_2$ . The labor endowment in each country is not specified.
  1. Identify which country has absolute advantage and which has comparative advantage.
  2. Derive the Production Possibility Frontier (PPF) for each country.
  3. Obtain the world relative supply.
  4. Assuming preferences are represented by  $U(q_1, q_2) = q_1^2 q_2$  in both countries, determine equilibrium production, relative prices, and wages under autarky.

5. Using the same utility function, determine equilibrium production, relative prices, and wages under international trade.
  6. Propose a method to evaluate whether each country is better off under trade compared to autarky.
4. Consider the Ricardian model ([Section 3.2](#)) where Home has a comparative advantage in  $q_2$ . Suppose the economy is open to trade and equilibrium occurs at a point where each country fully specializes in the good for which it has comparative advantage. Answer the following questions and explain the underlying intuition:
1. Why can Home still benefit from trade even if it has an absolute advantage in both goods?
  2. What happens if the population in Home increases? Is Home better off? Is Foreign better off?
  3. What happens if the population in Foreign decreases? Is Home better off? Is Foreign better off?
  4. What happens if technology improves in Home at the same proportional rate for both goods? Is Home better off? Is Foreign worse off?
  5. What happens if technology improves in Foreign for good  $q_1$  only? Is Home better off? Is Foreign worse off?

## 4 Comparative Advantage, Trade, and Payments in a Ricardian Model with a Continuum of Goods (Dornbusch et al., 1977)

Dornbusch et al. (1977) extend the basic Ricardian framework to a continuum of goods. Consider two countries, Home ( $H$ ) and Foreign ( $F$ ), and a single factor of production, labor, with endowments  $L^H$  and  $L^F$ , respectively. Labor is assumed to be perfectly mobile across sectors within each country but immobile across countries. Markets operate under perfect competition and exhibit constant returns to scale. Wages are denoted by  $w^H$  in Home and  $w^F$  in Foreign. The exchange rate, defined as the price of one unit of Foreign's currency in terms of Home's currency, is represented by  $e^H$ .

### 4.1 Supply

Relative efficiency between the two countries for any good  $z$  is defined as

$$A(z) = \frac{a^F(z)}{a^H(z)}, \quad A'(z) < 0 \tag{4.1.1}$$

where  $a^H(z)$  denotes the unit labor requirement (units of labor necessary to produce one unit of good  $z$ ) in Home, and  $a^F(z)$  represents the corresponding requirement in Foreign.

Goods are represented by a continuum indexed by  $z \in [0, 1]$ , ordered such that Home's comparative advantage decreases with  $z$ . This implies that goods located near  $z = 0$  are those in which the relative productive efficiency of Home with respect to Foreign is most evident, whereas goods located near  $z = 1$  are those in which the relative productive efficiency of Foreign is most pronounced. This ordering justifies the assumption  $A'(z) < 0$  in equation (4.1.1).

Under free trade, each good  $z$  is produced in the country with the lower unit cost. The export condition requires that Home produces  $z$  if

$$a^H(z) e^H w^H \leq a^F(z) w^F \Leftrightarrow \frac{e^H w^H}{w^F} \leq \frac{a^F(z)}{a^H(z)}$$

The cutoff good  $\tilde{z}$  is defined at the point where the unit costs are exactly equal across countries. This condition determines the supply schedule for the model:

$$\frac{e^H w^H}{w^F} = \frac{a^F(z)}{a^H(z)} \tag{4.1.2}$$

All goods with  $z < \tilde{z}$  are produced by Home (the range in which it holds comparative advantage), while all goods with  $z > \tilde{z}$  are produced by Foreign.

Given constant returns to scale and perfect competition, the price of good  $z$  equals its marginal

cost. Hence, the relative price of two goods produced in Home is

$$\frac{p^H(z)}{p^H(z')} = \frac{w^H \cdot a^H(z)}{w^H \cdot a^H(z')} = \frac{a^H(z)}{a^H(z')}$$

which corresponds to the relative labor requirements between the two goods.

By contrast, the relative price of a Home-produced good  $z$  in terms of a Foreign-produced good  $z''$  is given by

$$\frac{p^H(z)}{p^F(z'')} = \frac{e^H w^H \cdot a^H(z)}{w^F \cdot a^F(z'')}$$

## 4.2 Demand

Preferences are assumed to be identical and homothetic across countries. Let  $b^H(z)$  denote the *expenditure-share density function* for good  $z$  in Home, which must satisfy

$$\int_0^1 b^H(z) dz = 1, \quad b^H(z) = \frac{p^H(z) x^H(z)}{y^H} > 0 \quad (4.2.1)$$

where  $p^H(z)$  is the price of good  $z$  in Home,  $x^H(z)$  is the quantity consumed in Home, and  $y^H$  denotes Home's income. Hence,  $b^H(z)$  represents the fraction of home's income spent on good  $z$ . Because preferences are identical across countries, it follows that  $b^H(z) = b^F(z)$ .

Define

$$B(\tilde{z}) = \int_0^{\tilde{z}} b^H(z) dz \quad (4.2.2)$$

where  $B(\tilde{z})$  is the share of global spending on Home-produced goods.

World income is given by

$$Y^W = e^H w^H L^H + w^F L^F \quad (4.2.3)$$

In equilibrium, the value of Home's exports must equal the value of its production:

$$B(\tilde{z}) Y^W = e^H w^H L^H \quad (4.2.4)$$

Substituting (4.2.2) and (4.2.3) into (4.2.4) and solving for relative factor prices yields the demand side of the model:

$$\frac{e^H w^H}{w^F} = \left( \frac{\int_0^{\tilde{z}} b^H(z) dz}{1 - \int_0^{\tilde{z}} b^H(z) dz} \right) \frac{L^F}{L^H} \quad (4.2.5)$$

Note that  $1 - \int_0^{\tilde{z}} b^H(z) dz$  represents the share of global expenditure on Foreign-produced goods.

Equation (4.2.5) can be interpreted as follows: if the range of domestically produced goods were to expand at constant relative wages, demand for domestic labor (and goods) would rise while demand for Foreign labor would decline. To restore equilibrium, an increase in the

domestic relative wage is required. Consequently, equation (4.2.5) is upward-sloping in relative wages.

Another way to understand why equation (4.2.5) is upward-sloping is that, as when  $z$  increases, the share of income allocated to home goods rises, while the share allocated to foreign goods declines. Consequently,  $\left( \frac{\int_0^z b^H(z) dz}{1 - \int_0^z b^H(z) dz} \right)$  increases.

An alternative formulation of the trade balance condition is

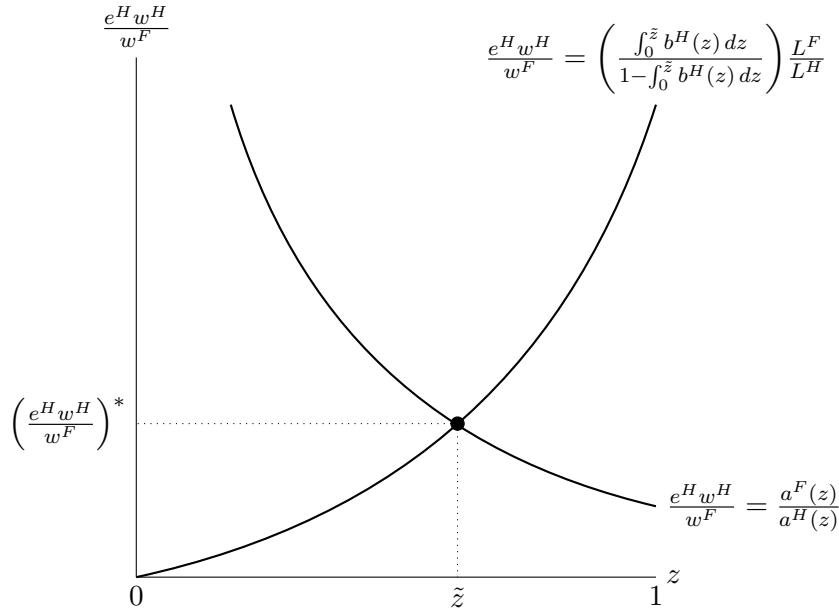
$$e^H w^H L^H \left( 1 - \int_0^{\tilde{z}} b^H(z) dz \right) = w^F L^F \int_0^{\tilde{z}} b^H(z) dz \quad (4.2.6)$$

Equation (4.2.6) states that equilibrium in trade requires imports (the left-hand side) to equal exports (the right-hand side). The schedule implied by (4.2.6) is upward-sloping because an expansion in the range of goods produced at Home, at constant relative wages, reduces imports and increases exports. The resulting imbalance must be corrected through an increase in Home's relative wage.

### 4.3 Equilibrium

Equilibrium is attained at the relative wage that equalizes the right-hand sides of equations (4.1.2) and (4.2.5). This condition determines  $\tilde{z}$ , the equilibrium cutoff that delineates the range of goods produced and exported by Home from those produced and exported by Foreign. Figure 6 illustrates the equilibrium in this framework.

Figure 6: Equilibrium in the model



Note that, given a home wage  $w^H$ , all goods produced and exported by Home (i.e.,  $z \in [0, \tilde{z}]$ ) have a price equal to the Home autarky price for that  $z$ , expressed in foreign currency.

Meanwhile, all goods produced and exported by Foreign are priced at the foreign autarky price. Formally, this can be written as

$$p(z) = \begin{cases} e^H w^H a^H(z), & z \in [0, \tilde{z}], \\ w^F a^F(z), & z \in [\tilde{z}, 1]. \end{cases} \quad (4.3.1)$$

If welfare in Home is measured by its real wage, observe that for those goods exported by Home, the real wage in equilibrium remains the same as under autarky. However, for goods imported by Home, the real wage is higher, since the foreign price of these goods is lower than the autarky price, given the export condition. This implies that Home is better off when trade is opened. The same intuition applies symmetrically to the foreign country.

To illustrate these mechanisms more clearly, consider a discrete setting with  $n$  goods, where the two countries are characterized by the following production functions:

$$x_i^H = \frac{1}{i} L_i^H, \quad x_i^F = \frac{1}{(n-i+1)} L_i^F$$

The utility function is specified as

$$U^j(x_1, \dots, x_n) = \prod_{i=1}^n x_i^i, \quad j = H, F$$

The supply schedule is given by

$$\frac{e^H w^H}{w^F} = \frac{(n-i+1)}{i} \quad (4.3.2)$$

The fraction of national income spent on good  $i$  is

$$b_i = \frac{2i}{n(n+1)}$$

Accordingly, the fraction of world income devoted to goods produced by Home is

$$\sum_{i=1}^{i^*} \frac{2i}{n(n+1)} = \frac{i^*(i^*+1)}{n(n+1)}$$

where  $i^*$  denotes the cutoff good separating production between Home and Foreign. This condition implies the following demand schedule:

$$\frac{e^H w^H}{w^F} = \left( \frac{\frac{i^*(i^*+1)}{n(n+1)}}{1 - \frac{i^*(i^*+1)}{n(n+1)}} \right) \frac{L^F}{L^H} \quad (4.3.3)$$

The cutoff  $i^*$  is determined by combining (4.3.2) and (4.3.3) and solving for  $i^*$ :

$$\frac{(n - i^* + 1)}{i^*} = \left( \frac{\frac{i^*(i^*+1)}{n(n+1)}}{1 - \frac{i^*(i^*+1)}{n(n+1)}} \right) \frac{L^F}{L^H} \quad (4.3.4)$$

Expression (4.3.4) implies that  $i^*$  increases with either  $n$  or  $L^H$ , whereas  $i^*$  decreases with an increase in  $L^F$ .

Note expression (4.3.4) is increasing in  $i^*$  if  $n$  or  $L^H$  increases and  $i^*$  decreases if  $L^F$  increases.

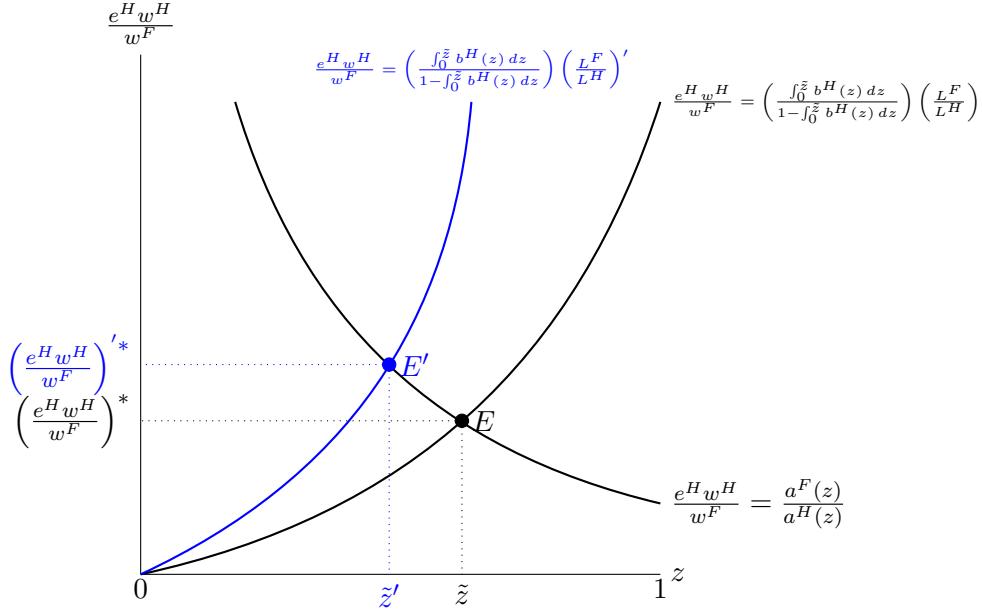
#### 4.4 The Price-Specie Flow Mechanism

This mechanism was first articulated by Hume (1752) in which gold or silver served as the means of international settlement. Suppose that Home initially runs a trade surplus. The excess demand for Home goods implies that foreign buyers must pay in specie, leading to an inflow of gold or silver into Home. As specie enters the economy, the domestic money supply expands, generating an increase in the price level of Home goods. This raises Home's wage measured in specie, thereby eroding the set of goods for which Home has a comparative cost advantage. Goods that were previously competitive for Home shift toward the Foreign production margin. Consequently, Home's exports contract and imports expand until there is a balance in trade.

#### 4.5 Comparative statics in the model

Equilibrium in Figure 6 is determined by preferences, technology in both Home and Foreign, and the labor endowments of each country. Suppose there is an increase in the relative labor endowment  $\frac{L^F}{L^H}$ . This shift raises the right-hand side of equation (4.2.5), thereby shifting the demand schedule upward.

At the initial equilibrium, this adjustment generates an imbalance in equation (4.2.5) (or equivalently in equation (4.2.6)), as the value of Home's exports exceeds the value of its imports. According to the Price-Specie Flow Mechanism, this imbalance induces an increase in wages at Home. The resulting rise in relative wages reduces Home's competitiveness, causing the cutoff  $\bar{z}$  to decline until a new equilibrium is reached at point  $E'$ , as illustrated in Figure 7.

Figure 7: Effect of an increase in relative labor endowment  $\frac{L^F}{L^H}$ 


Suppose that  $w^H$  remains constant while  $w^F$  decreases, thereby raising Home's relative wage in the new equilibrium shown in Figure 7. The welfare analysis can then be summarized as follows:

1. For  $z \in [0, \tilde{z}']$ , the price of  $z$  remains unchanged after the increase in the foreign relative labor endowment. This is because neither  $w^H$  nor  $a^H(z)$  is affected.
2. For  $z \in (\tilde{z}, 1]$ , the price of  $z$  is lower after the increase in foreign labor endowment because  $w^F$  falls while  $a^F(z)$  remains unchanged.
3. For  $z \in (\tilde{z}, \tilde{z}')$ , the price of  $z$  becomes

$$p'(z) = w'^F a^F(z),$$

which is strictly lower than its equilibrium price before the change in the foreign relative labor endowment, that is,

$$p(z) = e^H w^H a^H(z),$$

due to the export condition.

From this analysis, and measuring welfare by the relative wage, it follows that Home is better off after the increase in the foreign relative labor endowment, while Foreign is worse off. Home benefits because the price of  $z$  is lower for  $z > \tilde{z}'$  while its wage remains constant. In contrast, the foreign relative wage does not change for  $z \in [\tilde{z}, 1]$ , but it decreases for  $z < \tilde{z}$ .

## 4.6 Exercises

1. Examine the behavior of the exchange rate in recent years for Costa Rica, measured in colones per U.S. dollar.

Table 1: Average exchange rate: colones per U.S. dollar

Year	Bid	Ask
2022	₡644	₡651
2023	₡541	₡547
2024	₡512	₡518
2025 <sup>4</sup>	₡502	₡508
<b>Average 2022 to 2025</b>		<b>571</b>
<b>577</b>		

1. Based on the model developed in this section, analyze the implications of this evolution for Costa Rica. Illustrate your explanation with a graph.
2. Using the model studied in this section, analyze the effects of the following changes (support your answer with graphs):
  1. An increase in the population (and therefore the labor force) in Home.
  2. A decrease in the population (and therefore the labor force) in Foreign.
  3. An improvement in technology in Home.
  4. An improvement in technology in Foreign.
  5. A stronger preference for goods produced in Foreign.
3. Consider a continuum of goods indexed by  $z \in [0, 1]$ , with the following production functions for Home and Foreign:

$$x^H(z) = \frac{L^H(z)}{(\alpha\sqrt{z} - b\sqrt[3]{z^2})}, \quad x^F(z) = \frac{L^F(z)}{\sqrt{z}}$$

Preferences in both countries are represented by the utility function

$$U = \int_0^1 \ln(x) dx$$

Initially, the labor endowment is the same in both countries.

1. Derive the supply curve implied by the model.
2. Derive the demand curve implied by the model.

3. Determine the cutoff (borderline) between goods produced by Home and those produced by Foreign. Also, compute relative wages in equilibrium.
4. Compute the production of each good.
5. Suppose Foreign's labor endowment increases by 5%. Analyze how this change affects the equilibrium and provide the economic intuition behind the result.

## 5 General Equilibrium in production

Two equilibrium concepts are distinguished: (i) [Equilibrium with only production](#), and (ii) [Equilibrium with consumption and production](#). Together, these concepts provide the theoretical foundation for the *Heckscher–Ohlin–Vanek* model.

### 5.1 Equilibrium with only production

Consider an economy that produces two goods,  $q_1$  and  $q_2$ , using two factors of production—labour ( $L$ ) and capital ( $K$ ). The aggregate endowments of these factors are  $\bar{L}$  and  $\bar{K}$ , respectively. Each sector is described by a production function exhibiting constant returns to scale (i.e. a function homogeneous of degree 1).

Assume that the two sectors differ in factor intensities: good  $q_i$  is *capital-intensive* relative to good  $q_j$ , meaning

$$\frac{K_i^*(q_i, w, r)}{L_i^*(q_i, w, r)} > \frac{K_j^*(q_j, w, r)}{L_j^*(q_j, w, r)}$$

This ordering is invariant for all admissible factor-price pairs  $(w, r)$ ; that is, there is *no factor-intensity reversal*.

Solving the problem:

$$\begin{aligned} \min_{L_i, K_i} \quad & wL_i + rK_i \\ \text{s.t.} \quad & q_i = q_i(L_i, K_i), \quad \forall i = 1, 2 \end{aligned}$$

The optimization delivers the conditional factor demands  $L_i^*(q_i, w, r)$  and  $K_i^*(q_i, w, r)$ . Substituting these expressions into the total cost function generates the minimum total cost (same as unit cost as per constant returns to scale) for the good  $i$ , denoted  $C_i(q_i, w, r)$ . Differentiating  $C_i$  with respect to the output yields the marginal cost and because the production function exhibits constant returns to scale, profits are zero, and under perfect competition the good's price equals its (constant) marginal cost

$$p_i = \frac{\partial C_i(q_i, w, r)}{\partial q_i} = c_i(w, r)$$

Let  $a_{Li}$  and  $a_{Ki}$  denote the labour and capital required to produce one unit of good  $i$  ( $q_i = 1$ ):

$$a_{Li} \equiv L_i^*(1, w, r), \quad a_{Ki} \equiv K_i^*(1, w, r)$$

Consequently, the zero-profit conditions can be expressed as

$$\begin{cases} p_1 = w a_{L1} + r a_{K1}, \\ p_2 = w a_{L2} + r a_{K2} \end{cases} \tag{5.1.1}$$

where prices equal unit costs for each sector.

Factor–market clearing (full utilization of labor and capital) requires

$$\begin{cases} \bar{L} = L_i^*(q_i, w, r) + L_j^*(q_j, w, r), \\ \bar{K} = K_i^*(q_i, w, r) + K_j^*(q_j, w, r) \end{cases} \quad (5.1.2)$$

which is equivalent to

$$\begin{cases} \bar{L} = a_{Li}q_i + a_{Lj}q_j, \\ \bar{K} = a_{Ki}q_i + a_{Kj}q_j \end{cases}$$

Solving this linear system yields the equilibrium outputs  $(q_i^*, q_j^*)$ .

Sector  $i$  is *labor-intensive* relative to sector  $j$  if

$$\frac{a_{Li}}{a_{Ki}} > \frac{a_{Lj}}{a_{Kj}} \iff \frac{L_i^*}{K_i^*} > \frac{L_j^*}{K_j^*}$$

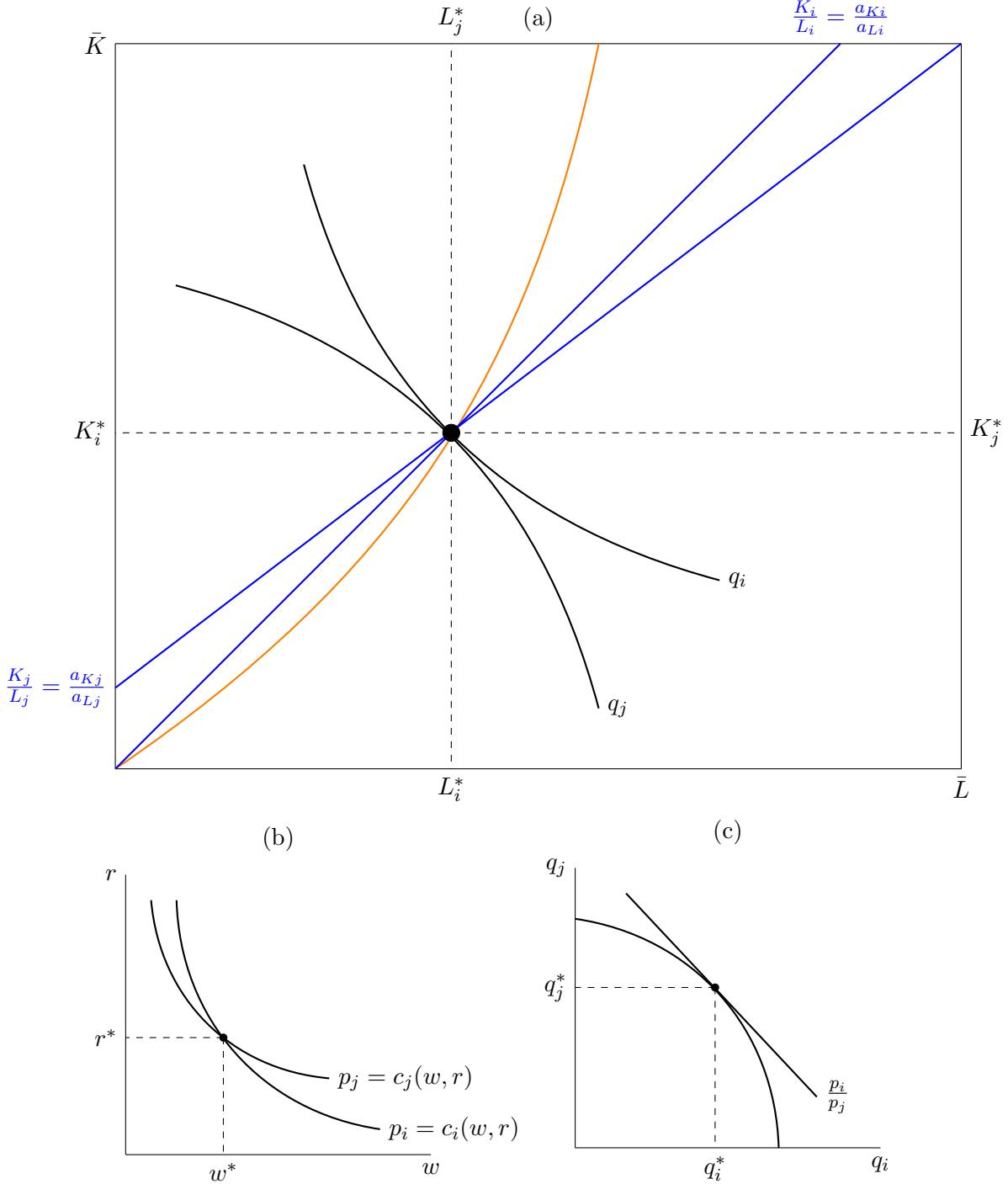
This ranking is invariant to all admissible factor-price pairs  $(w, r)$ , reflecting the assumption of *no factor-intensity reversal*.

The equilibrium allocation of labor and capital in each sector must satisfy the optimal factor ratio:

$$\frac{L_i}{K_i} = \frac{a_{Li}}{a_{Ki}}, \quad i = 1, 2 \quad (5.1.3)$$

Figure 8 summarizes the equilibrium. Panel (a) presents the Production Edgeworth box: the equilibrium allocation is the point where the two marginal rates of technical substitution coincide, lying on the production Pareto set (orange curve). The blue rays correspond to equation (5.1.3). Panel (b) plots equations (5.1.1); the intersection of the two lines determines the equilibrium factor–price. Panel (c) depicts the production–possibility frontier, whose slope—the marginal rate of transformation—equals the relative price of the goods.

Figure 8: Equilibrium in production



**Stolper-Samuelson Theorem:** Suppose good  $i$  is labour-intensive and its relative price rises ( $d p_i > d p_j$ ). Then the real wage of labor,  $w$ , increases, whereas the real return to capital,  $r$ , decreases. Moreover, the proportional change in  $w$  exceeds that in  $p_1$ , while the change in  $r$  is smaller.

As established above, under competitive markets the price of each good equals its unit cost:

$$\begin{cases} p_1 = c_1(w, r), \\ p_2 = c_2(w, r) \end{cases} \quad (5.1.4)$$

Taking total differentials of system (5.1.4) and applying Shepard's lemma yields

$$\begin{cases} dp_1 = a_{L1} dw + a_{K1} dr, \\ dp_2 = a_{L2} dw + a_{K2} dr, \end{cases} \quad (5.1.5)$$

Assume that  $dp_2 = 0$ , so that the price of good 2 remains constant, while  $p_1$  increases. The system (5.1.5) then implies

$$dr = \frac{a_{L2} dp_1}{a_{K1}a_{L2} - a_{L1}a_{K2}} \quad (5.1.6)$$

The sign of (5.1.6) depends on factor intensities. If  $q_1$  is labor-intensive, the denominator is negative and thus  $dr < 0$ ; if good 1 is capital-intensive, then  $dr > 0$ .

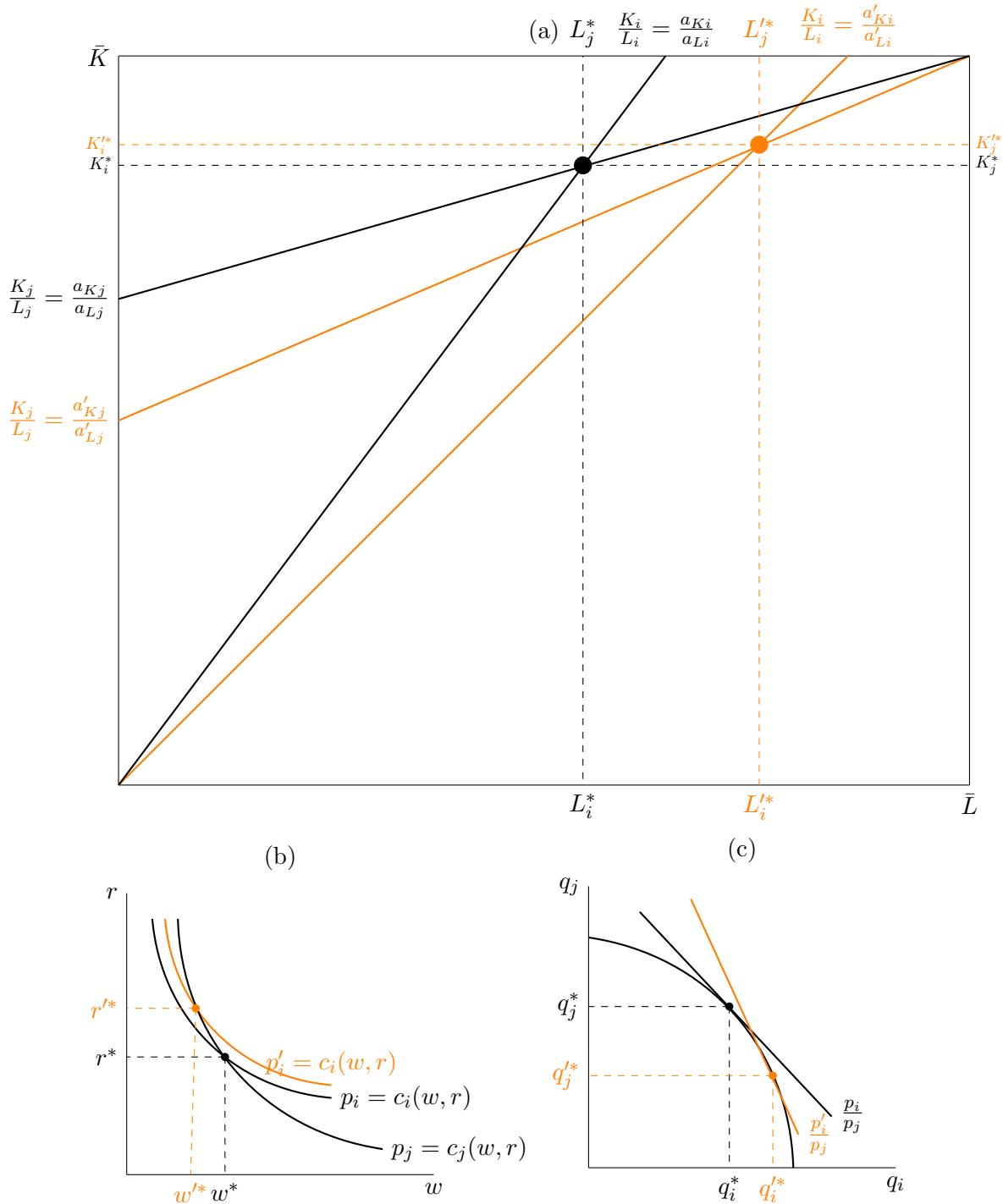
Similarly, the change in the wage rate is given by

$$dw = \frac{a_{K2} dp_1}{a_{K1}a_{L2} - a_{L1}a_{K2}} \quad (5.1.7)$$

Equation (5.1.7) is positive when  $q_1$  is labor-intensive and negative when it is capital-intensive. Equations (5.1.6) and (5.1.7) formalize the Stolper–Samuelson theorem: an increase in the relative price of the labor-intensive good raises the real wage and lowers the return to capital, whereas an increase in the relative price of the capital-intensive good raises the return to capital and lowers the real wage.

Figure 9 illustrates the Stolper–Samuelson theorem in the case where sector  $i$  is *capital-intensive* and its output price  $p_i$  increases.

Figure 9: Stolper–Samuelson Theorem



**Rybczynski Theorem:** With goods prices fixed, an increase in the labor endowment expands the output of the labor-intensive good more than proportionally and reduces the output of the other good; analogously, a rise in the capital endowment enlarges the capital-intensive sector and contracts the labour-intensive one.

When factor endowments change, the market-clearing conditions in equation (5.1.2) become

$$\begin{cases} a_{Li} dq_i + a_{Lj} dq_j = d\bar{L}, \\ a_{Ki} dq_i + a_{Kj} dq_j = d\bar{K} \end{cases}$$

Suppose an increase in  $\bar{L}$ , therefore

$$(a_{Kj}a_{Li} - a_{Lj}a_{Ki}) dq_i = a_{Kj}d\bar{L}$$

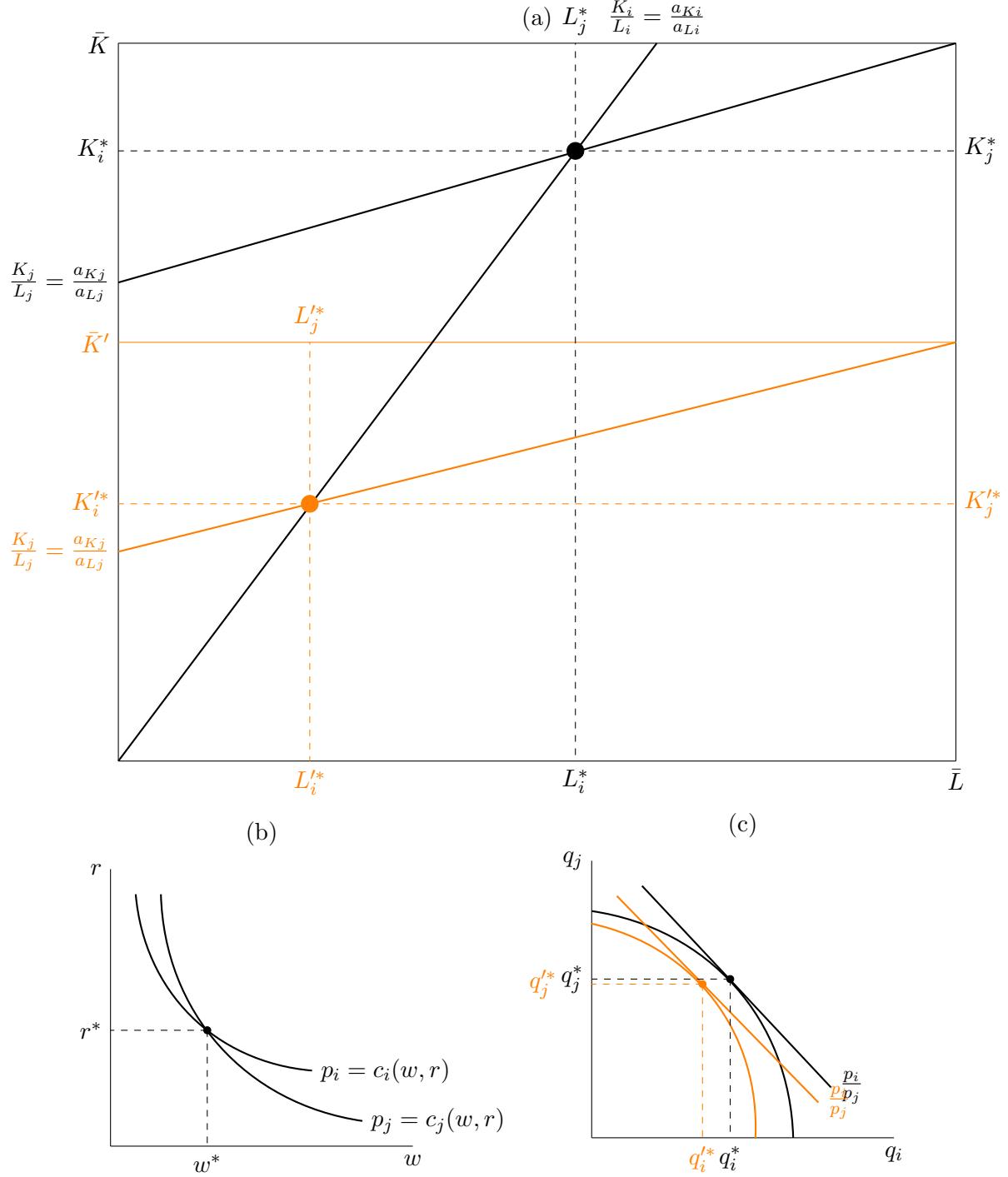
If good  $i$  is labour-intensive, then  $\frac{a_{Li}}{a_{Ki}} > \frac{a_{Lj}}{a_{Kj}}$ , implying  $a_{Kj}a_{Li} - a_{Lj}a_{Ki} > 0$ ; hence  $dq_i > 0$ . Substituting back gives

$$dq_j = \frac{d\bar{L} - a_{Li}dq_i}{a_{Lj}} < 0$$

Thus, an increase in labour endowment expands the labour-intensive sector and contracts the capital-intensive one.

Figure 10 illustrates the Rybczynski theorem when sector  $i$  is *capital-intensive* and the aggregate capital endowment  $\bar{K}$  falls, while goods prices and factor prices remain unchanged. In panel (c) the production–possibility frontier shifts inward; the maximum feasible output of good  $i$  ( $q_i$ -intercept) contracts by a larger amount than that of good  $j$ , reflecting the disproportionate impact on the capital-intensive sector.

Figure 10: Rybczynski Theorem



To illustrate, consider an economy endowed with  $\bar{L}$  units of labor and  $\bar{K}$  units of capital. The two sectors exhibit production functions given by

$$q_1 = L^\alpha K^{1-\alpha}, \quad q_2 = L^{1-\alpha} K^\alpha, \quad \frac{1}{2} < \alpha < 1.$$

Conditional factor demands are:

$$\begin{cases} L_1^*(q_1, w, r) = q_1 \left( \frac{\alpha}{1-\alpha} \cdot \frac{r}{w} \right)^{1-\alpha} \\ K_1^*(q_1, w, r) = q_1 \left( \frac{1-\alpha}{\alpha} \cdot \frac{w}{r} \right)^\alpha \\ L_2^*(q_2, w, r) = q_2 \left( \frac{1-\alpha}{\alpha} \cdot \frac{r}{w} \right)^\alpha \\ K_2^*(q_2, w, r) = q_2 \left( \frac{\alpha}{1-\alpha} \cdot \frac{w}{r} \right)^{1-\alpha} \end{cases}$$

Equivalently:

$$\begin{cases} a_{L1}(w, r) = \left( \frac{\alpha}{1-\alpha} \cdot \frac{r}{w} \right)^{1-\alpha} \\ a_{K1}(w, r) = \left( \frac{1-\alpha}{\alpha} \cdot \frac{w}{r} \right)^\alpha \\ a_{L2}(w, r) = \left( \frac{1-\alpha}{\alpha} \cdot \frac{r}{w} \right)^\alpha \\ a_{K2}(w, r) = \left( \frac{\alpha}{1-\alpha} \cdot \frac{w}{r} \right)^{1-\alpha} \end{cases}$$

The marginal costs for each sector are as follows:

$$\begin{cases} p_1 = c_1(w, r) = w \cdot \left( \frac{\alpha}{1-\alpha} \cdot \frac{r}{w} \right)^{1-\alpha} + r \cdot \left( \frac{1-\alpha}{\alpha} \cdot \frac{w}{r} \right)^\alpha \\ p_2 = c_2(w, r) = w \cdot \left( \frac{1-\alpha}{\alpha} \cdot \frac{r}{w} \right)^\alpha + r \cdot \left( \frac{\alpha}{1-\alpha} \cdot \frac{w}{r} \right)^{1-\alpha} \end{cases}$$

Solving the above system for the factor–price ratio yields:

$$\frac{w}{r} = \left( \frac{p_1}{p_2} \right)^{\frac{1}{2\alpha-1}}$$

Because  $\alpha > \frac{1}{2}$ , sector 1 is labour-intensive:

$$\frac{a_{L1}}{a_{K1}} = \frac{\alpha}{1-\alpha} > \frac{a_{L2}}{a_{K2}} = \frac{1-\alpha}{\alpha}$$

Factor–market clearing implies:

$$\begin{cases} \bar{L} = q_1 \left( \frac{\alpha}{1-\alpha} \cdot \frac{r}{w} \right)^{1-\alpha} + q_2 \left( \frac{1-\alpha}{\alpha} \cdot \frac{r}{w} \right)^\alpha \\ \bar{K} = q_1 \left( \frac{1-\alpha}{\alpha} \cdot \frac{w}{r} \right)^\alpha + q_2 \left( \frac{\alpha}{1-\alpha} \cdot \frac{w}{r} \right)^{1-\alpha} \end{cases}$$

Solving the system yields

$$q_1 = \frac{\bar{L} \left( \frac{\alpha}{1-\alpha} \frac{w}{r} \right)^{1-\alpha} - \bar{K} \left( \frac{1-\alpha}{\alpha} \frac{r}{w} \right)^\alpha}{\left( \frac{\alpha}{1-\alpha} \right)^{2(1-\alpha)} - \left( \frac{1-\alpha}{\alpha} \right)^{2\alpha}},$$

$$q_2 = \frac{\bar{K} \left( \frac{\alpha}{1-\alpha} \frac{r}{w} \right)^{1-\alpha} - \bar{L} \left( \frac{1-\alpha}{\alpha} \frac{w}{r} \right)^\alpha}{\left( \frac{\alpha}{1-\alpha} \right)^{2(1-\alpha)} - \left( \frac{1-\alpha}{\alpha} \right)^{2\alpha}}.$$

The contract curve is obtained by equating the marginal rates of technical substitution (MRTS) in both sectors:

$$\begin{aligned} \frac{\partial q_1 / \partial L_1}{\partial q_1 / \partial K_1} &= \frac{\partial q_2 / \partial L_2}{\partial q_2 / \partial K_2} \implies \frac{K_1}{L_1} = \frac{K_2}{L_2} \\ &\implies \frac{K_1}{L_1} = \frac{\bar{K} - K_1}{\bar{L} - L_1} \implies K_1 = \frac{\bar{K}}{\bar{L}} L_1. \end{aligned}$$

## 5.2 Equilibrium with consumption and production

Consider a closed economy with two firms. Firm 1 produces output  $q_1$  and Firm 2 produces output  $q_2$ . Both firms employ labor  $L$  and capital  $K$ , and each technology exhibits constant returns to scale. The aggregate factor endowment is  $(\bar{L}, \bar{K})$ . Social welfare is represented by the utility function  $u(x_1, x_2)$ , defined over the two consumption goods  $x_1$  and  $x_2$ .

In a competitive, decentralized equilibrium, each agent maximizes their own objective function. The representative consumer solves

$$\max_{x_1, x_2} u(x_1, x_2) \quad \text{s.t.} \quad w\bar{L} + r\bar{K} + \pi_1(p_1, w, r) + \pi_2(p_2, w, r) = p_1 x_1 + p_2 x_2,$$

where  $w$  and  $r$  are the prices of labor and capital, respectively, and  $\pi_j(p_j, w, r)$  denotes the profit of firm  $j \in \{1, 2\}$ . Since both production technologies display *constant returns to scale* and markets are perfectly competitive, equilibrium profits satisfy  $\pi_1 = \pi_2 = 0$ . The representative consumer's budget constraint therefore simplifies to

$$p_1 x_1 + p_2 x_2 = w\bar{L} + r\bar{K}, \tag{5.2.1}$$

where the right-hand side represents the total income from the factor endowment  $(\bar{L}, \bar{K})$ .

The (interior) first-order condition equates the marginal rate of substitution to the relative price ratio:

$$\frac{\partial u(x_1, x_2)/\partial x_1}{\partial u(x_1, x_2)/\partial x_2} = \frac{p_1}{p_2}$$

Combining the optimality condition with the budget constraint (5.2.1) yields the demand functions

$$x_i = x_i(w, r, \bar{L}, \bar{K}, p_1, p_2), \quad i \in \{1, 2\}$$

For firm  $j$ , the cost-minimization problem is

$$\min_{K_j, L_j} C_j(q_j, w, r) = rK_j + wL_j \quad \text{s.t.} \quad q_j = q_j(K_j, L_j)$$

where  $q_j(K_j, L_j)$  is the production function for sector  $j$ . The first-order condition equates the *marginal rate of technical substitution* to the ratio of input prices:

$$\frac{\partial q_j(K_j, L_j)/\partial L_j}{\partial q_j(K_j, L_j)/\partial K_j} = \frac{w}{r}$$

Solving the programme yields the conditional (input demand) functions

$$K_j = K_j(q_j, w, r), \quad L_j = L_j(q_j, w, r)$$

Under perfect competition and constant returns to scale, price equals marginal cost

$$p_j = c_j(q_j, w, r)$$

Considering all output is consumed, and households hold no initial endowments of the goods, equilibrium in the goods markets requires

$$x_i = q_i, \quad i = 1, 2$$

Equilibrium in the factor markets equates total factor demand with the aggregate endowment:

$$\bar{L} = L_1 + L_2, \quad \bar{K} = K_1 + K_2$$

A *competitive equilibrium* is a collection of prices

$$(p_1^*, p_2^*, w^*, r^*)$$

and allocations

$$(q_1^*, q_2^*, x_1^*, x_2^*, K_1^*, K_2^*, L_1^*, L_2^*)$$

that jointly satisfy

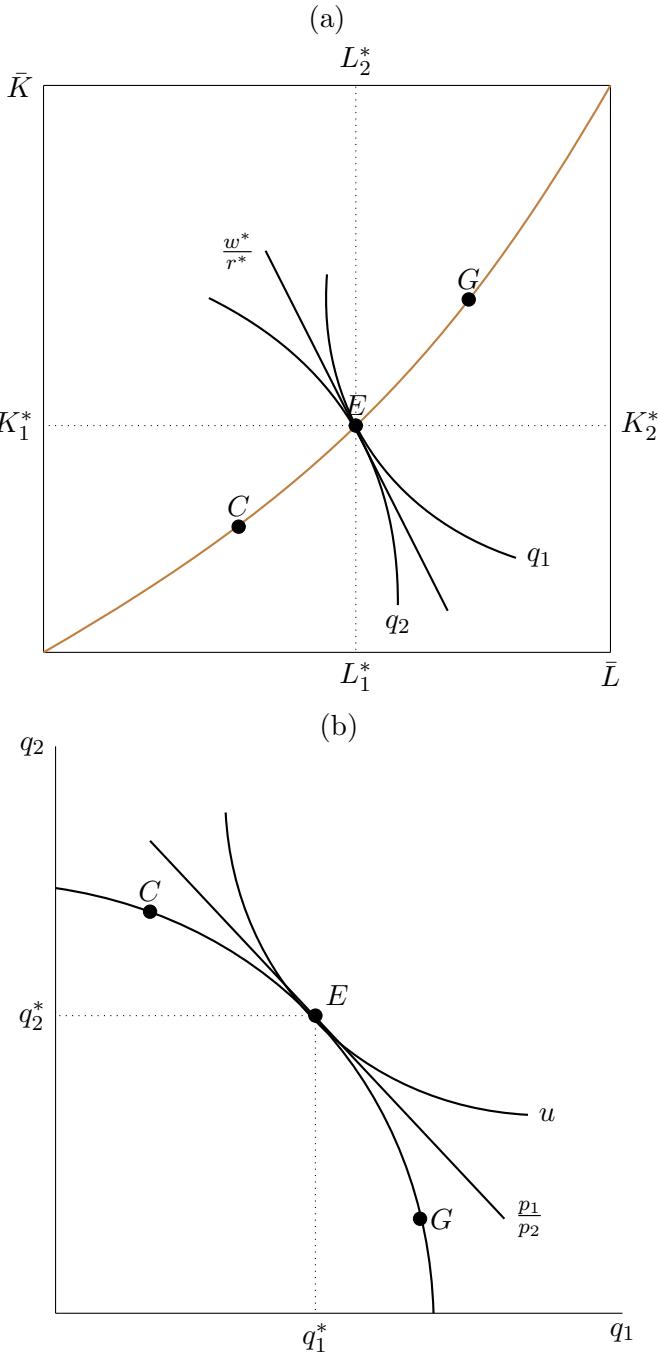
$$\left\{ \begin{array}{ll} x_i^* = q_i^*, & i = 1, 2, \quad (\text{goods clearing}) \\ x_i^* = x_i(w^*, r^*, \bar{L}, \bar{K}, p_1^*, p_2^*), & i = 1, 2, (\text{household demand}) \\ L_j^* = L_j(q_j^*, w^*, r^*), & j = 1, 2, \quad (\text{labour demand}) \\ K_j^* = K_j(q_j^*, w^*, r^*), & j = 1, 2, \quad (\text{capital demand}) \\ p_j^* = c_j(w^*, r^*), & j = 1, 2, \quad (\text{zero-profit}) \\ \bar{L} = L_1^* + L_2^*, & \quad (\text{labour market}) \\ \bar{K} = K_1^* + K_2^*. & \quad (\text{capital market}) \end{array} \right.$$

Equations (5.2.2) constitute a system of twelve equations in the twelve unknowns

$$(p_1^*, p_2^*, w^*, r^*, q_1^*, q_2^*, x_1^*, x_2^*, K_1^*, K_2^*, L_1^*, L_2^*) \quad (5.2.3)$$

whose solution yields the competitive-equilibrium prices and allocation.

Figure 11 summarizes the general-equilibrium. Panel (a) displays the production Edgeworth box, with the contract curve—the locus of Pareto-efficient factor allocations—highlighted. Panel (b) maps those efficient allocations into output space, tracing the *Production-Possibility Frontier* (PPF). Equilibrium is found at the point where the PPF is tangent to the indifference curve, so that the marginal rate of transformation equals the marginal rate of substitution.

Figure 11: General Equilibrium in  $2 \times 2 \times 1$ 

Let the representative household have Cobb–Douglas preferences

$$u(x_1, x_2) = x_1 x_2$$

and suppose each firm  $j \in \{1, 2\}$  produces with the Cobb–Douglas technology

$$q_j(K_j, L_j) = K_j^{1/2} L_j^{1/2}$$

Optimal consumption satisfies

$$x_1 = \frac{w\bar{L} + r\bar{K}}{2p_1}, \quad x_2 = \frac{w\bar{L} + r\bar{K}}{2p_2}$$

Cost minimization yields the conditional factor–demand functions

$$K_j = q_j \sqrt{\frac{w}{r}}, \quad L_j = q_j \sqrt{\frac{r}{w}}$$

and the (zero–profit) pricing condition

$$p_j = 2\sqrt{wr}$$

Adding up across firms,

$$\bar{K} = (q_1 + q_2) \sqrt{\frac{w}{r}}, \quad \bar{L} = (q_1 + q_2) \sqrt{\frac{r}{w}}$$

Taking the ratio of the two equations gives the equilibrium

$$\frac{w}{r} = \frac{\bar{K}}{\bar{L}} \implies w^* = r^* \frac{\bar{K}}{\bar{L}}$$

Since all output is consumed, goods-market clearing implies  $x_i = q_i$  for  $i = 1, 2$ . Substituting  $p_1 = p_2 = 2\sqrt{wr}$  into the household demand functions then yields to

$$q_1 = q_2 = \frac{1}{2} \sqrt{\bar{K}\bar{L}}$$

Factor demands at the optimum.

$$K_1 = K_2 = \frac{\bar{K}}{2}, \quad L_1 = L_2 = \frac{\bar{L}}{2}$$

Choosing  $r^* = 1$  (any positive normalization works), the equilibrium is

$$\begin{aligned} & (p_1^*, p_2^*, w^*, r^*, q_1^*, q_2^*, x_1^*, x_2^*, K_1^*, K_2^*, L_1^*, L_2^*) \\ &= \left( 2\sqrt{\frac{\bar{K}}{\bar{L}}}, 2\sqrt{\frac{\bar{K}}{\bar{L}}}, \frac{\bar{K}}{\bar{L}}, 1, \frac{1}{2}\sqrt{\bar{K}\bar{L}}, \frac{1}{2}\sqrt{\bar{K}\bar{L}}, \frac{1}{2}\sqrt{\bar{K}\bar{L}}, \frac{\bar{K}}{2}, \frac{\bar{K}}{2}, \frac{\bar{L}}{2}, \frac{\bar{L}}{2} \right) \end{aligned}$$

### 5.3 Exercises

1. Consider the general-equilibrium production model in [Section 5.1](#). Sector  $i$  is capital-intensive.
  1. The economy opens to international trade and the relative price of good  $i$  rises above its autarky level. Using a graphical approach, describe
    1. the impact on equilibrium factor prices,
    2. the resulting changes in the output of each good and distribution of factor between sectors, and
    3. the economic intuition behind these effects.
  2. Keeping the economy open, suppose a natural disaster cuts the aggregate capital stock in half. Reassess your answers: how are factor prices and output levels now affected?
2. Consider the production economy of [Section 5.1](#). Output is produced according to

$$q_1 = L_1 + 2K_1, \quad q_2 = 2L_2 + K_2, \quad \frac{1}{2} < \frac{w}{r} < 2$$

1. Express the factor–price ratio  $\frac{w}{r}$  as a function of the goods–price ratio  $\frac{p_1}{p_2}$ . Determine the output levels  $q_1^*$  and  $q_2^*$ , and illustrate the results.
2. Explain why  $\frac{1}{2} < \frac{w}{r} < 2$  must hold. Derive the corresponding admissible range for  $\frac{p_1}{p_2}$ .
3. A storm halves the aggregate capital stock. Re-evaluate part 1 using the graphical approach and relate your findings to the relevant theorem.
4. Suppose the economy remains open and  $p_1$  doubles. Re-do part 1 graphically and link the outcome to the theorem discussed.
5. Now both prices double. How does the equilibrium adjust, and what is the intuition?
6. If  $\frac{w}{r} = 1$  and the endowments are  $(\bar{L}, \bar{K}) = (1, 1)$ , what is the optimal allocation?
3. In the general-equilibrium model with consumption and production ([Section 5.2](#)), the representative consumer has Cobb–Douglas preferences.
  1. Assume the consumer’s preferences shift, making good 2 relatively more preferred than before. How does this shift affect the relative price  $\frac{p_2}{p_1}$ , the output mix  $(q_1, q_2)$ , and the allocation of labor and capital across sectors? Illustrate the adjustments a graphical approach.
  2. Total factor productivity rises in sector 2. Analyze the impact on  $\frac{p_2}{p_1}$ ,  $(q_1, q_2)$ , and factor allocation, and depict the outcome graphically.
  3. Repeat part 2 assuming Leontief preferences. How do the results change? Explain the roles of income and substitution effects.

4. Consider an economy described as in [Equilibrium with consumption and production](#). The representative consumer has Cobb–Douglas preferences.
1. Suppose the preferences of the individual changes and now good 2 is more preferred than what it was. How do this change the relative prices of the goods and the optimal produced in each sector? How do capital and labor distribution between sector change? Use graphical approach
  2. Suppose an increase in technology for sector  $q_2$ . How do this change the relative prices of the goods and the optimal produced in each sector? How do capital and labor distribution between sector change? Use graphical approach ([5.2.3](#))? Use graphical approach
  3. Suppose an increase in technology for sector  $q_2$  but with preferences by Leontief utility function, how do your previous answers change? What does income and substitution effect have to be related with this?
5. In the general-equilibrium model with consumption and production ([Section 5.2](#)), the representative consumer has preferences given by

$$u(x_1, x_2) = \min\{x_1, x_2\}$$

Firms produce according to

$$q_1 = (L_1^{1/2} + 4K_1^{1/2})^2, \quad q_2 = (4L_2^2 + K_2^2)^{1/2}$$

1. Find the competitive-equilibrium vector ([5.2.3](#)) and illustrate it with the chapter's graphical approach.
6. In the general-equilibrium model with consumption and production ([Section 5.2](#)), the representative consumer has preferences given by

$$u(x_1, x_2) = x_1 x_2$$

Additionally, the consumer is endowed with  $\phi_1$  for good 1 and  $\phi_2$  for good 2. Firms produce according to

$$q_1 = \min\left\{\frac{L_1}{2}, K_1\right\}, \quad q_2 = \min\left\{L_2, \frac{K_2}{2}\right\}$$

1. Find the competitive-equilibrium vector ([5.2.3](#)) and illustrate it with the chapter's graphical approach.

## 6 The Armington Model

### 6.1 Introduction

The Armington model, introduced by Armington (1969), provides a framework to analyze international trade when goods are differentiated by their country of origin. Unlike the Ricardian, which assume goods are homogeneous across producers, the Armington model postulates that even within the same sector, goods from different countries are imperfect substitutes. This assumption introduces product differentiation and plays a central role in modern empirical trade analysis.

### 6.2 The model

Consider a world economy consisting of  $n$  countries, where each country produces a differentiated variety of a common type of good. The total population of country  $j$  is denoted by  $L_j$ , and each individual is endowed with one unit of the domestically variety and none of the other varieties. Let  $w_j$  denote the endowment value of variety  $j$  for a representative consumer  $j$ .<sup>5</sup> The aggregate value of country  $j$ 's endowment across all individuals defines the value of country  $j$ 's gross domestic product (GDP).

$$X_j = L_j w_j \quad (6.2.1)$$

Consumers exhibit preferences over the full set of available varieties. Let  $x_{kj}$  denote the quantity of the variety associated with country  $k$  that is consumed by a representative individual in country  $j$ . The preferences of the representative consumer are assumed to be described by a Constant Elasticity of Substitution (CES) utility function of the form

$$U_j = \left( \sum_{k=1}^n \alpha_{kj}^{\frac{1}{\sigma}} x_{kj}^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \quad (6.2.2)$$

where  $\sigma > 1$  denotes the elasticity of substitution across varieties, and  $\alpha_{kj}$  represents the taste parameter associated with variety  $k$  in country  $j$ .

The budget constraint of a representative consumer  $j$  is expressed as

$$w_j = \sum_{k=1}^n p_{kj} x_{kj} \quad (6.2.3)$$

where  $p_{kj}$  denotes the price of variety  $k$  in country  $j$ . The right-hand side of equation (6.2.3) corresponds to the total expenditure of the representative consumer in country  $j$  on all available varieties.

Furthermore, assume the presence of iceberg trade costs  $\tau_{kj} \geq 1$ , such that  $\tau_{kj}$  units must be

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<sup>5</sup>Since the representative consumer in country  $j$  is endowed with one unit of variety  $j$ , it follows that  $w_j = p_{jj}$ , where  $p_{jj}$  denotes the price of variety  $j$  in country  $j$ .

shipped from country  $k$  to country  $j$  for one unit of variety  $k$  to be delivered in country  $j$ . Under this assumption, the consumer price of variety  $k$  in country  $j$  is given by

$$p_{kj} = w_k \tau_{kj} \quad (6.2.4)$$

The corresponding optimality condition when maximizing the utility function in equation (6.2.2) subject to the budget constraint in equation (6.2.3) is

$$\frac{\frac{1}{\sigma} x_{ij}^{\frac{1}{\sigma}}}{\frac{1}{\sigma} x_{kj}^{\frac{1}{\sigma}}} = \frac{p_{ij}}{p_{kj}} \quad (6.2.5)$$

The CES price index in country  $j$  is defined as

$$P_j = \left( \sum_{k=1}^n \alpha_{kj} p_{kj}^{1-\sigma} \right)^{\frac{1}{1-\sigma}} \quad (6.2.6)$$

The Marshallian demand of the representative consumer in country  $j$  for variety  $i$ , expressed in terms of the CES price index in equation (6.2.6), is given by

$$x_{ij} = \alpha_{ij} p_{ij}^{-\sigma} \frac{w_j}{P_j^{1-\sigma}} \quad (6.2.7)$$

Equation (6.2.7) can equivalently be written to express the Marshallian demand in terms of trade costs as

$$x_{ij} = \alpha_{ij} w_i^{-\sigma} \tau_{ij}^{-\sigma} \frac{w_j}{P_j^{1-\sigma}} \quad (6.2.8)$$

Denoting by  $p_{ij} x_{ij}$  the expenditure of the representative consumer in country  $j$  on variety  $i$ , equation (6.2.8) can be rewritten as

$$p_{ij} x_{ij} = \alpha_{ij} w_i^{1-\sigma} \tau_{ij}^{1-\sigma} \frac{w_j}{P_j^{1-\sigma}} \quad (6.2.9)$$

### 6.3 From the Representative Consumer to the Aggregate Economy

Let  $\tilde{x}_{ij}$  denote the total consumption of variety  $i$  by the population in country  $j$ . This equals the demand of the representative consumer in country  $j$  for variety  $i$ , multiplied by the population size  $L_j$ . The total expenditure on variety  $i$  by the population in country  $j$  is obtained by multiplying both sides of equation (6.2.9) by  $L_j$ .

$$p_{ij} \tilde{x}_{ij} = \alpha_{ij} w_i^{1-\sigma} \tau_{ij}^{-\sigma} \frac{L_j w_j}{P_j^{1-\sigma}} \quad (6.3.1)$$

Using equation (6.2.1), the total expenditure on variety  $i$  by the population in country  $j$  is

defined in terms of country  $j$ 's GDP as follows

$$p_{ij}\tilde{x}_{ij} = \alpha_{ij}w_i^{1-\sigma}\tau_{ij}^{-\sigma}\frac{X_j}{P_j^{1-\sigma}} \quad (6.3.2)$$

Additionally, country  $i$ 's GDP is defined via the income approach as the total revenue earned from selling its variety to all countries, that is

$$X_i = \sum_{j=1}^n L_j p_{ij} x_{ij} \quad (6.3.3)$$

The right-hand side of equation (6.3.3) represents the sum of the total expenditures by the populations of all countries on variety  $i$ .

Substituting equation (6.2.9) into equation (6.3.3) yields

$$X_i = \sum_{j=1}^n L_j w_i^{1-\sigma} \left( \frac{\tau_{ij}}{P_j} \right)^{1-\sigma} \alpha_{ij} w_j \quad (6.3.4)$$

Using equation (6.2.1) for country  $j$ , equation (6.3.4) can be rewritten as

$$X_i = \sum_{j=1}^n w_i^{1-\sigma} \left( \frac{\tau_{ij}}{P_j} \right)^{1-\sigma} \alpha_{ij} X_j \quad (6.3.5)$$

Equation (6.3.5) can be equivalently expressed by isolating the domestic price term  $w_i^{1-\sigma}$  as

$$w_i^{1-\sigma} = \frac{X_i}{\sum_{j=1}^n \left( \frac{\tau_{ij}}{P_j} \right)^{1-\sigma} \alpha_{ij} X_j} \quad (6.3.6)$$

Finally, substituting equation (6.3.6) into (6.3.2) leads to the gravity equation of the model:

$$p_{ij}\tilde{x}_{ij} = \frac{\alpha_{ij} \left( \frac{\tau_{ij}}{P_j} \right)^{1-\sigma} X_i X_j}{\sum_{j=1}^n \left( \frac{\tau_{ij}}{P_j} \right)^{1-\sigma} \alpha_{ij} X_j} \quad (6.3.7)$$

Equation (6.3.7) expresses bilateral expenditure  $\tilde{x}_{ij}$  as a function of the exporter's income  $X_i$ , the importer's income  $X_j$ , on the taste parameter  $\alpha_{ij}$ , trade costs  $\tau_{ij}$ , the elasticity of substitution  $\sigma$ , and the multilateral resistance terms captured in the denominator.

## 6.4 Exercises

1. Indicate whether each of the following propositions is true or false. Justify your answer.
  1. Countries  $z$ ,  $x$ , and  $y$  share identical preferences and trade costs. However, country  $x$  is larger than country  $y$ . Country  $z$  will always trade more with  $x$  than with  $y$ .
  2. If preferences for variety  $x$  increase in country  $z$  (*ceteris paribus*), trade between  $z$  and  $x$  will increase, while trade between  $z$  and  $y$  will decrease.
  3. If the price of good  $x$  in country  $z$  increases (*ceteris paribus*), trade between  $x$  and  $z$  will decrease, while trade between  $y$  and  $z$  will remain unchanged.
  4. If the trade cost of exporting good  $x$  to country  $z$  increases (*ceteris paribus*), trade between  $x$  and  $z$  will decrease, while trade between  $y$  and  $z$  will remain unchanged.
  5. If GDP increases in all countries except  $z$  and  $y$  (*ceteris paribus*), trade between  $z$  and  $y$  will remain constant.
2. Suppose a pandemic reduces the population by half in all countries  $h+1, \dots, n$ , within a set of countries indexed by  $k = 1, \dots, h, \dots, n$ . Analyze how this shock affects trade flows between countries. Consider all possible bilateral cases (four in total).
3. Suppose there is migration from country  $i$  to country  $j$ . Analyze the effects of this migration on the following:
  1. Country  $j$ 's imports of good  $i$ .
  2. Country  $j$ 's imports of good  $k$ .
  3. Country  $i$ 's imports of good  $k$ .

## 7 The Specific Factors Model

The Specific Factors Model constitutes a natural extension of the Ricardian framework by introducing multiple factors of production and relaxing the assumption of full mobility. It captures the idea that some factors are mobile across sectors, while others remain sector-specific. This asymmetry in factor mobility generates sectoral distributional effects from trade that are absent in the Ricardian model.

### 7.1 The Model

Consider a small economy that produces two goods, denoted  $q_1$  and  $q_2$ . The production of good  $q_1$  employs capital  $K$ , which is specific to sector  $q_1$ , together with labor  $L_1$ , whereas the production of good  $q_2$  uses land  $T$ , which is specific to sector  $q_2$ , together with labor  $L_2$ . Labor is perfectly mobile across sectors, and the total labor endowment is denoted by  $\bar{L}$ . Under the assumption of full employment, it follows that  $\bar{L} = L_1 + L_2$ . The economy is thus endowed with three factors of production: one mobile factor (labor) and two sector-specific factors (capital and land). Note that sector  $q_1$  employs the entire endowment of capital, while sector  $q_2$  employs the entire endowment of land, since  $q_1$  does not use land and  $q_2$  does not use capital in production.

The production functions are assumed to be strictly concave and to exhibit constant returns to scale with respect to labor and the specific factor within each sector:

$$q_1 = q_1(K, L_1), \quad q_2 = q_2(T, L_2) \quad (7.1.1)$$

Marginal products of labor are positive and diminishing, implying the existence of downward-sloping labor demand schedules in each sector.

Under perfect competition, factors are remunerated according to the value of their marginal products. Since labor is perfectly mobile across sectors, the wage rate  $w$  is equalized across sectors and satisfies

$$w = p_1 \cdot \frac{\partial q_1}{\partial L_1} = p_2 \cdot \frac{\partial q_2}{\partial L_2} \quad (7.1.2)$$

where  $p_1$  and  $p_2$  denote the world prices of goods  $q_1$  and  $q_2$ , respectively. The allocation of labor is determined at the point where the value of the marginal product of labor is equal across sectors.

Owners of the specific factors receive returns given by the residual product once labor is compensated. In sector  $q_1$ , the return to capital is

$$r_K = p_1 \cdot \frac{\partial q_1}{\partial K} \quad (7.1.3)$$

while in sector  $q_2$ , the return to land is

$$r_T = p_2 \cdot \frac{\partial q_2}{\partial T} \quad (7.1.4)$$

Under the assumption of constant returns to scale, it follows that

$$p_1 q_1 = w L_1 + r_k \bar{K} \quad (7.1.5)$$

$$p_2 q_2 = w L_2 + r_t \bar{T} \quad (7.1.6)$$

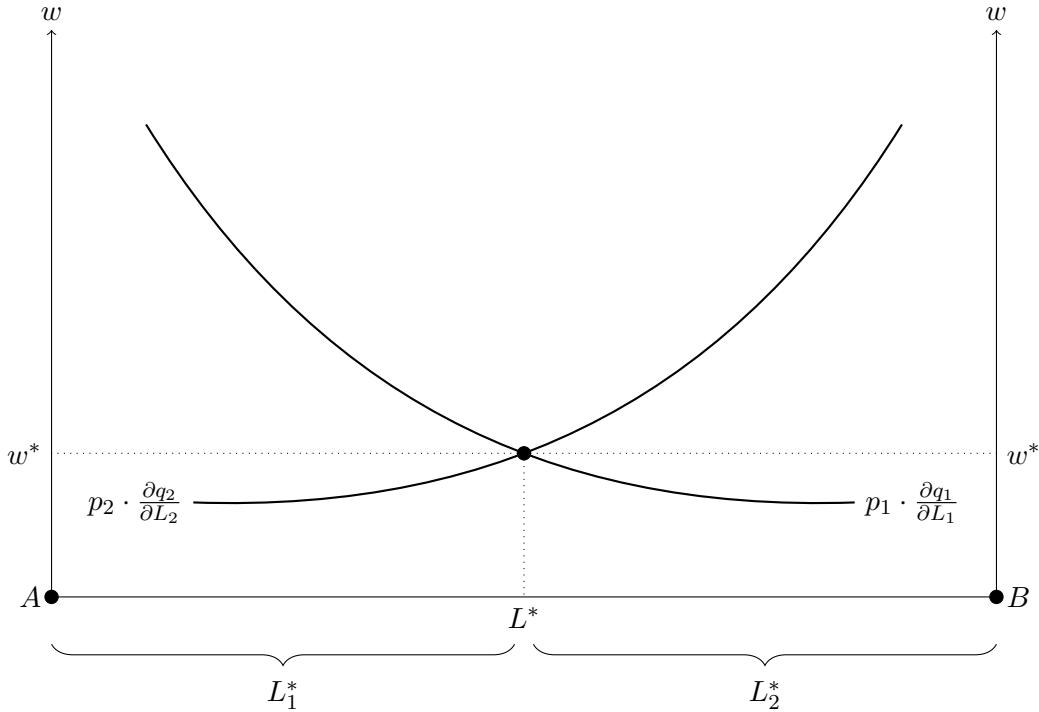
Equations (7.1.3) and (7.1.4) can equivalently be written as

$$r_K = \frac{p_1 \cdot q_1 - w L_1}{\bar{K}}, \quad (7.1.7)$$

$$r_T = \frac{p_2 \cdot q_2 - w L_2}{\bar{T}} \quad (7.1.8)$$

Figure 12 illustrates the equilibrium in the model. The wage is represented on the vertical axis and labor on the horizontal axis. The marginal product value curves of both sectors are depicted, with point A serving as the origin for sector  $q_1$  and point B as the origin for sector  $q_2$ . The intersection of the marginal product value curves determines the equilibrium wage and the allocation of labor between sectors.

Figure 12: The Specific Factors model equilibrium



These specific-factor returns are not equalized across sectors. Consequently, changes in goods

prices translate into changes in the distribution of income among capital owners, landowners, and workers.

## 7.2 Welfare in the Specific Factors Model

Welfare is measured in terms of the purchasing power of the return to each factor. For workers, the real wage in terms of good  $q_1$  and in terms of good  $q_2$  can be expressed as

$$\frac{w}{p_1} = \frac{\partial q_1}{\partial L_1}, \quad (7.2.1)$$

$$\frac{w}{p_2} = \frac{\partial q_2}{\partial L_2} \quad (7.2.2)$$

For capital owners, the real return to capital can be written as

$$\frac{r_K}{p_1} = \frac{\partial q_1}{\partial K}, \quad (7.2.3)$$

$$\frac{r_K}{p_2} \quad (7.2.4)$$

For landowners, the real return to land is

$$\frac{r_T}{p_1}, \quad (7.2.5)$$

$$\frac{r_T}{p_2} = \frac{\partial q_2}{\partial T} \quad (7.2.6)$$

## 7.3 Impact of Trade in Specific Factors Model

The introduction of trade alters the relative prices faced by the economy as the country integrates into world markets. Suppose that the world price of good  $q_1$  increases while the price of good  $q_2$  remains constant. This raises the value of the marginal product of labor in sector  $q_1$ , thereby attracting labor from sector  $q_2$  into sector  $q_1$ . As a result, wages increase due to the higher value of marginal products of labor in both sectors (the value of the marginal product in  $q_2$  rises as labor employed in that sector declines). This adjustment is illustrated in Figure 13.

The return to capital in sector  $q_1$  increases as the use of additional labor raises the productivity of capital, whereas the return to land in sector  $q_2$  declines due to the withdrawal of labor from that sector.

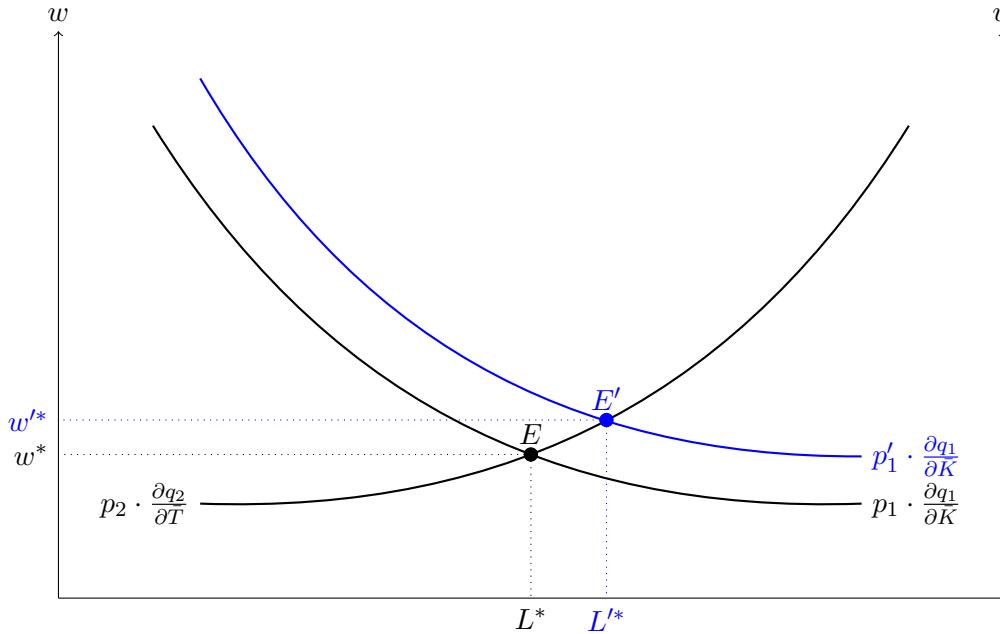
Workers, being mobile, experience an ambiguous effect: the real wage may either increase or decrease. In equation (7.2.1), both  $w$  and  $p_1$  increase; however,  $p_1$  rises proportionally more than  $w$  since the right-hand side decreases, leading to a decline in the real wage expressed in

terms of good  $q_1$ . In contrast, according to equation (7.2.2), the purchasing power in terms of good  $q_2$  increases because the wage rises while  $p_2$  remains constant.

Capital owners experience a welfare improvement. In equation (7.2.3), the purchasing power of the return to capital in terms of good  $q_1$  increases, since the right-hand side rises and therefore the left-hand side also increases (as noted previously,  $r_K$  increases while  $p_1$  also rises) making real return to capital increases. In equation (7.2.4), the purchasing power in terms of good  $q_2$  also increases because the return to capital rises while  $p_2$  remains constant.

Landowners experience a welfare loss. In equation (7.2.5), the return to land decreases while  $p_1$  increases, causing the real return to land measured in units of good  $q_1$  to decline. In equation (7.2.6), the return to land also decreases while  $p_2$  remains constant, leading to a decline in the real return to land measured in units of good  $q_2$ .

Figure 13: Increase in  $p_1$  in the Specific Factors model equilibrium



The central insight of the Specific Factors Model is that trade generates both aggregate gains and redistribution across factors. At the national level, the economy is unambiguously better off, as trade enables specialization and provides access to a broader set of consumption possibilities. Within the economy, however, specific factors are affected asymmetrically: owners of the factor tied to the expanding sector gain, whereas owners of the factor tied to the contracting sector lose. The welfare of the mobile factor is ambiguous, as its outcome depends on the composition of its consumption bundle.

This distributional conflict underscores the political economy dimension of trade. Although the economy as a whole benefits, opposition to trade may arise from groups whose incomes decline. The model therefore provides a theoretical foundation for understanding sector-based lobbying and political resistance to trade, as observed in practice.

## 7.4 Exercises

1. Within the framework of the Specific Factors Model, analyze the effects of the following scenarios on sectoral production, factor allocation, and the welfare of factor owners:
  1. A technological improvement in sector  $q_1$ .
  2. An increase in the endowment of the factor specific to sector  $q_2$ .
  3. A decrease in the relative price  $\frac{p_1}{p_2}$ .
  4. A reduction in the endowment of the mobile factor.
2. Consider the following production functions for sectors  $q_1$  and  $q_2$ :

$$q_1 = L_1^{\frac{1}{4}} K^{\frac{3}{4}}, \quad q_2 = L_2^{\frac{3}{4}} T^{\frac{1}{4}}$$

where the economy is endowed with  $\bar{L}$  units of labor,  $\bar{K}$  units of capital, and  $\bar{T}$  units of land.

1. Determine the allocation of factors across sectors.
2. Derive the level of output in each sector.
3. Compute the returns to each factor of production.
4. Suppose that all factor endowments are equal to one (normalized to 100%) and that prices are equal to one. Determine the allocation of factors, the output in each sector, and the returns to each factor. Illustrate the results using the diagram developed in this section.

## 8 The Neoclassical Model of International Trade and Offer Curve

### 8.1 The Neoclassical Model of International Trade

The neoclassical model of international trade extends the Ricardian framework by introducing multiple factors of production and incorporating the principle of diminishing marginal returns. In contrast to the Ricardian model, which explains trade solely through cross-country differences in labor productivity, the neoclassical approach highlights how variations in factor endowments and production technologies shape comparative advantage.

### 8.2 Introduction to the model

Consider a world economy composed of two countries,  $i$  and  $j$ , each producing two goods, denoted by  $q_{1z}$  and  $q_{2z}$ , where  $z = i, j$ . Production in each country requires two factors of production—labor ( $L$ ) and capital ( $K$ )—which are perfectly mobile across sectors within a country but immobile across countries. The aggregate factor endowment of country  $z$  is represented by  $(\bar{L}_z, \bar{K}_z)$ . Each good is produced according to a neoclassical production function that exhibits constant returns to scale and diminishing marginal returns with respect to each input. Moreover, sectors differ in their factor intensities, meaning that one good is relatively more labor-intensive while the other is relatively more capital-intensive. As a result, the Production Possibility Frontier (PPF) of each country is strictly concave to the origin, reflecting increasing opportunity costs.

Additionally, the utility function of the representative consumer in each country is assumed to be homothetic and strictly convex in consumption, resulting to concave indifference curves.

### 8.3 Tracing the PPF for an Economy with Two Factors and Two Sectors

In section 5.2, it was established that in a model with two goods and two factors, production efficiency requires the equality of the *marginal rate of technical substitution (MRTS)* across sectors. This condition defines the *contract curve* in factor space. Each allocation of labor and capital located on the contract curve represents an efficient distribution of resources, implying that an increase in the output of one good cannot occur without a reduction in the output of the other.

This concept serves as the basis for tracing the Production Possibility Frontier (PPF). For every feasible allocation of labor to one sector, there exists a corresponding level of capital that satisfies the efficiency condition along the contract curve. The remaining quantities of labor and capital are allocated to the other sector. Each efficient allocation determines the production levels of both goods and corresponds to a specific point on the PPF. Varying the allocation of labor across all feasible values traces the complete PPF of the country.

## 8.4 Autarky Equilibrium in the model

Additionally, in section 5.2, the autarky equilibrium is determined simultaneously in goods and factor markets. The demand side in the goods markets is driven by consumer preferences, expressed as

$$x_{1z} = x_{1z}(\bar{L}_z, \bar{K}_z, w, r, p_1, p_2) \quad (8.4.1)$$

$$x_{2z} = x_{2z}(\bar{L}_z, \bar{K}_z, w, r, p_1, p_2) \quad (8.4.2)$$

Equilibrium in the goods markets requires that

$$q_{1z} = x_{1z}(\bar{L}_z, \bar{K}_z, w, r, p_1, p_2) \quad (8.4.3)$$

$$q_{2z} = x_{2z}(\bar{L}_z, \bar{K}_z, w, r, p_1, p_2) \quad (8.4.4)$$

The conditional factor demands in each sector are given by

$$L_{1z} = L_{1z}(q_{1z}, w, r) \quad (8.4.5)$$

$$K_{1z} = K_{1z}(q_{1z}, w, r) \quad (8.4.6)$$

$$L_{2z} = L_{2z}(q_{2z}, w, r) \quad (8.4.7)$$

$$K_{2z} = K_{2z}(q_{2z}, w, r) \quad (8.4.8)$$

Equilibrium in the factor markets implies that

$$\bar{L}_z = L_{1z}(q_{1z}, w, r) + L_{2z}(q_{2z}, w, r) \quad (8.4.9)$$

$$\bar{K}_z = K_{1z}(q_{1z}, w, r) + K_{2z}(q_{2z}, w, r) \quad (8.4.10)$$

Since production functions exhibit constant returns to scale, the unit cost functions determine prices as follows:

$$p_{1z} = c_{1z}(w, r) \quad (8.4.11)$$

$$p_{2z} = c_{2z}(w, r) \quad (8.4.12)$$

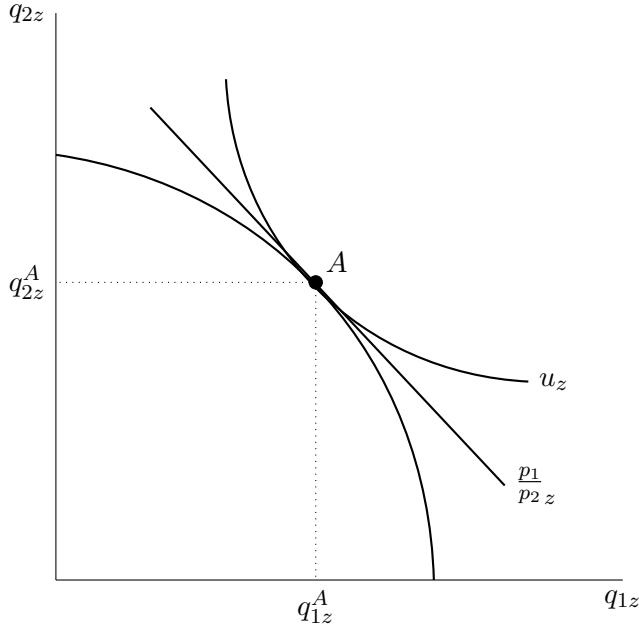
indicating that prices are equal to marginal costs.

Solving the system composed of equations (8.4.1), (8.4.2), (8.4.9), (8.4.10), (8.4.11), and (8.4.12) yields the autarky equilibrium for country  $z$ .

The autarky equilibrium is illustrated in Figure 14. Equilibrium occurs at the tangency point between the Production Possibility Frontier (PPF) and the highest attainable indifference curve. This point determines the equilibrium levels of production and consumption for both goods, as well as the relative autarky prices. The relative goods prices, in turn, determine the

relative factor prices, and together with the production levels, they define the allocation of factors between sectors. Point  $A$  represents the autarky equilibrium since, given the PPF, it yields the maximum attainable utility; any other point along the PPF would correspond to a lower indifference curve.

Figure 14: Autarky Equilibrium in the Neoclassical model



## 8.5 Trade Equilibrium in the Neoclassical model

The world relative price,  $\left(\frac{p_1}{p_2}\right)^W$ , will lie between the autarky relative prices of both countries. If  $\left(\frac{p_1}{p_2}\right)^W$  is below the lower autarky relative price, both countries will import  $q_1$  and export  $q_2$ , generating an excess demand for  $q_1$  and an excess of supply for  $q_2$ . Conversely, if  $\left(\frac{p_1}{p_2}\right)^W$  is above the higher autarky relative price, both countries will attempt to export  $q_1$  and import  $q_2$ , creating an excess supply of  $q_1$  and an excess demand for  $q_2$ .

When the world relative price  $\left(\frac{p_1}{p_2}\right)^W$  lies between the autarky relative prices, one country will export one good while the other will export the alternative good. If the world relative price  $\left(\frac{p_1}{p_2}\right)^W$  is higher than the autarky relative price, good  $q_1$  will be exported and good  $q_2$  imported. Conversely, if the world relative price is lower than the autarky relative price, good  $q_1$  will be imported and good  $q_2$  exported. A specific world relative price will equalize the desired export quantity of one country with the desired import quantity of the other. By *Walras' Law*, this price will also ensure equilibrium in the market for the remaining good.

Production under trade conditions is determined at the point where the slope of the Production Possibility Frontier (PPF) equals the world relative price, that is, where the *marginal rate of transformation (MRT)* corresponds to  $\left(\frac{p_1}{p_2}\right)^W$ . From equations (8.4.9), (8.4.10), (8.4.11), and

(8.4.12), the production levels under trade can be obtained for a given world relative price. Consumption under trade is determined by the condition that the *marginal rate of substitution* (*MRS*) equals the world relative price, expressed as

$$\frac{\frac{\partial U}{\partial q_{1z}}}{\frac{\partial U}{\partial q_{2z}}} = \left(\frac{p_1}{p_2}\right)^W \quad (8.5.1)$$

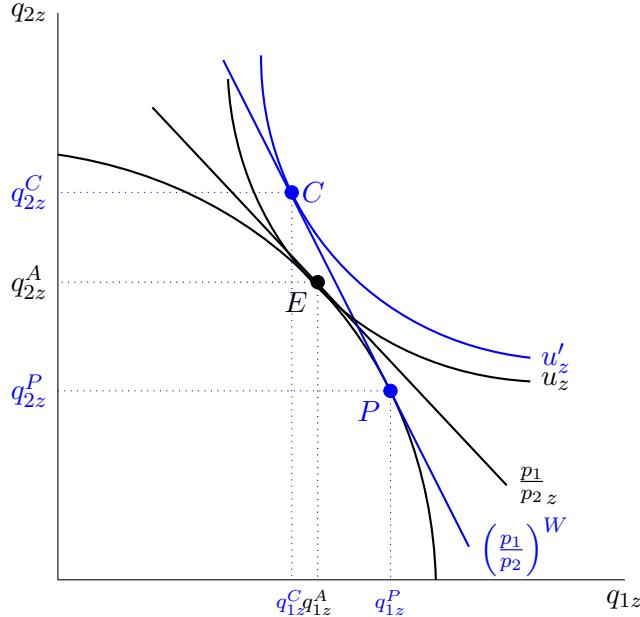
The consumer's budget constraint under trade is given by

$$\left(\frac{p_1}{p_2}\right)^W q_{1z}^P + q_{2z}^P = \left(\frac{p_1}{p_2}\right)^W q_{1z}^C + q_{2z}^C \quad (8.5.2)$$

where  $q_{1z}^P$  and  $q_{2z}^P$  represent the production of goods under trade, and  $q_{1z}^C$  and  $q_{2z}^C$  denote the corresponding consumption quantities. Equations (8.5.1) and (8.5.2) yield the consumption bundle under trade.

Figure 15 illustrates the trading equilibrium for the case in which the world relative price of good 1 is higher than its autarky level. The production point is denoted by  $P$ , while the consumption point is represented by  $C$ . Welfare increases relative to autarky, as the economy reaches a higher indifference curve. International trade enables countries to consume beyond their autarky production possibility frontier by exploiting differences in relative costs and factor endowments.

Figure 15: Equilibrium in the Neoclassical model with trade



The export and import quantities for each good can be derived once the economy engages in trade. Figure 16 illustrates exports and imports under trade. The difference between  $q_{1z}^P$  and  $q_{1z}^C$  represents the exports of  $q_1$ , whereas the difference between  $q_{2z}^C$  and  $q_{2z}^P$  corresponds to the

imports of  $q_2$ . In the figure, the height of the blue triangle represents the volume of imports, while the base corresponds to the volume of exports.

Figure 16: Exports and Imports in the Neoclassical model with trade

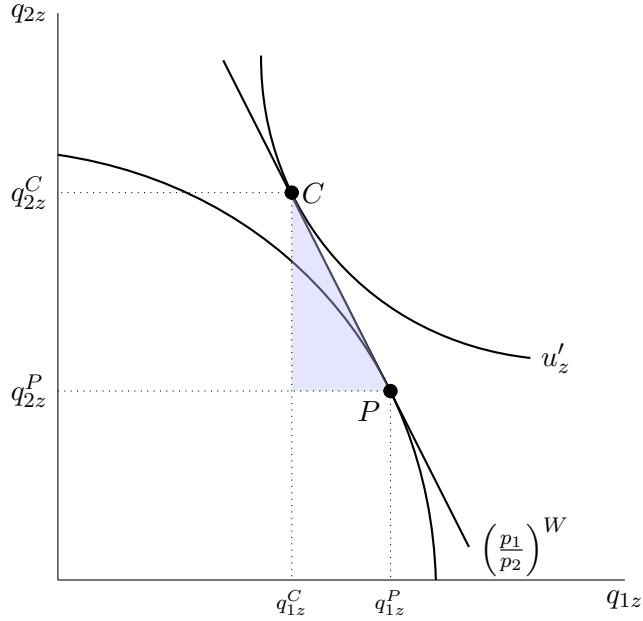


Figure 17 illustrates exports and imports under different world relative prices. It can be observed that larger deviations between the world relative price and the autarky relative price are associated with greater volumes of exports and imports.

Figure 17: Equilibrium in the Neoclassical model with trade at different terms of trade

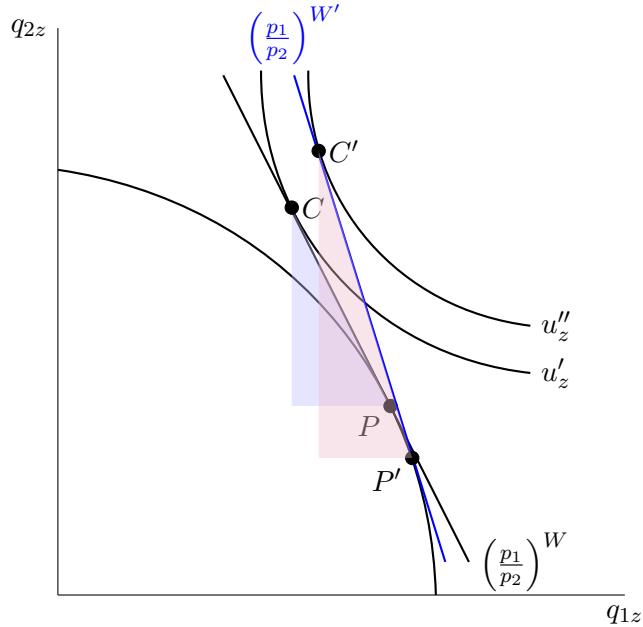


Figure 18 presents the offer curve ( $OC$ ) under the assumption that the world relative price of good 1 is higher than its autarky level. The horizontal axis represents the quantity of exports of  $q_1$ , while the vertical axis represents the corresponding imports of  $q_1$ . The offer curve illustrates the combinations of exports and imports associated with different relative prices. The origin, where exports and imports are both equal to zero, corresponds to the autarky relative price.

Figure 18: Offer curve for country  $z$

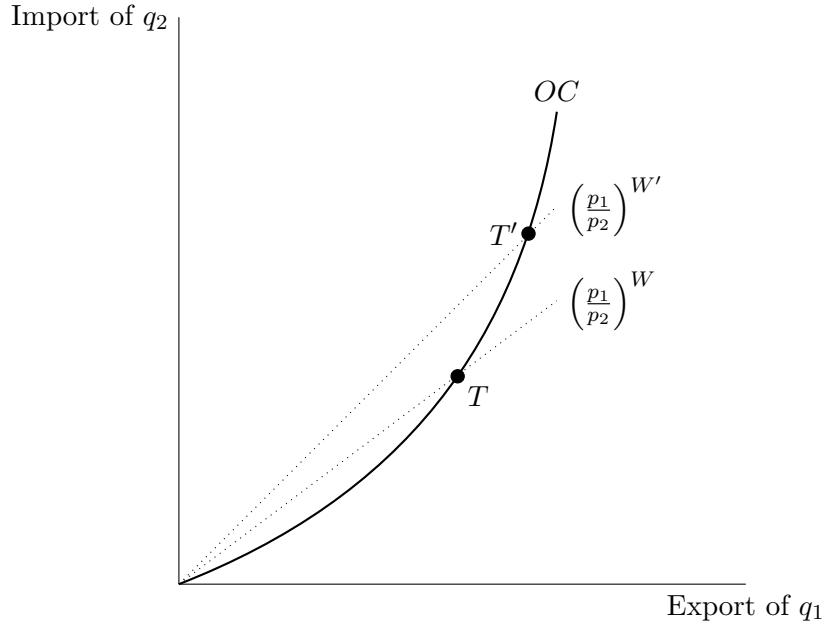
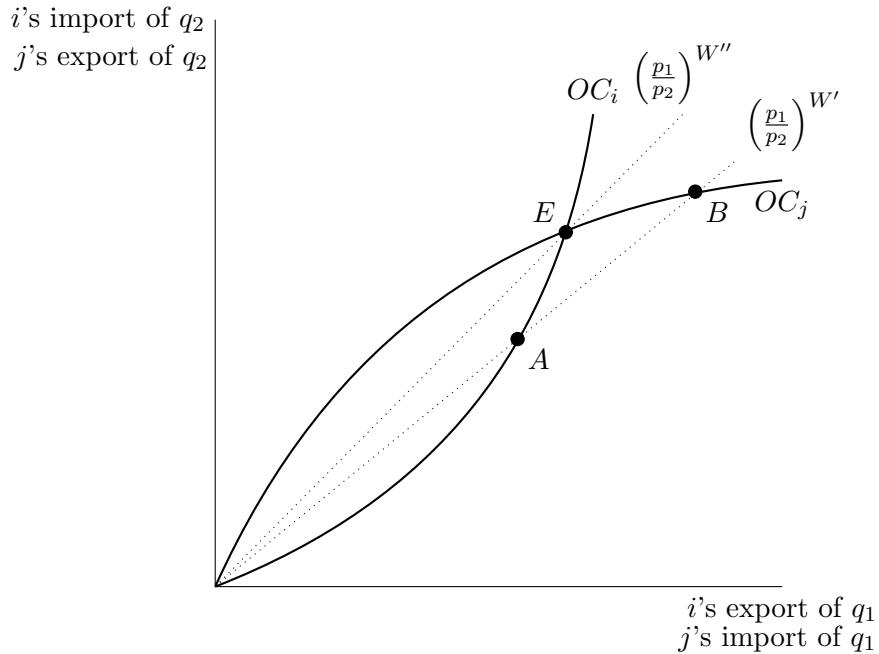


Figure 19 depicts the offer curves for countries  $i$  and  $j$ , assuming that the world relative price is higher than country  $i$ 's autarky relative price but lower than that of country  $j$ . As previously discussed, the trading equilibrium occurs at a world relative price  $(\frac{p_1}{p_2})^{W''}$ , where country  $i$ 's imports of good  $q_2$  are exactly equal to country  $j$ 's exports of  $q_2$  and the analogous condition holds for  $q_1$ .

Figure 19: Trade Equilibrium



## 8.6 Minimum conditions to Trade

The minimum condition for trade to occur is that countries possess different autarky relative prices. When this condition is met, both countries benefit from trade through specialization following the opening of international markets.

In section 5.2, it was established that the autarky relative price is determined simultaneously in two markets: (i) the goods market and (ii) the factor markets. In the goods market, demand is determined by consumer preferences, represented by the utility function, while supply depends on the production technology, represented by the production functions. In the factor markets, the supply of factors is defined by the endowments, whereas factor demand depends on the production functions and the level of production, which in turn depends on consumption.

These three components—(i) the utility function, (ii) the production functions, and (iii) the factor endowments—jointly determine the autarky relative price. If at least one of these elements differs across countries, their autarky relative prices will diverge, thereby creating the conditions for mutually beneficial trade

Figure 20 illustrates the case in which both countries share identical production functions and identical factor endowments. Consequently, they exhibit the same Production Possibility Frontier (PPF). However, the countries differ in consumer preferences, represented by distinct utility functions, which lead to different autarky relative prices.

In figure 20, points  $A$  and  $B$  represent the autarky equilibria for countries  $i$  and  $j$ , respectively. A world relative price lying between these autarky relative prices (shown in red) results in production under trade at point  $E$  for both countries. Under these conditions, consumption

occurs at points  $C$  and  $D$ , each located on a higher indifference curve, indicating welfare gains from trade.

Figure 20: Trade between countries with identical PPP and endowments

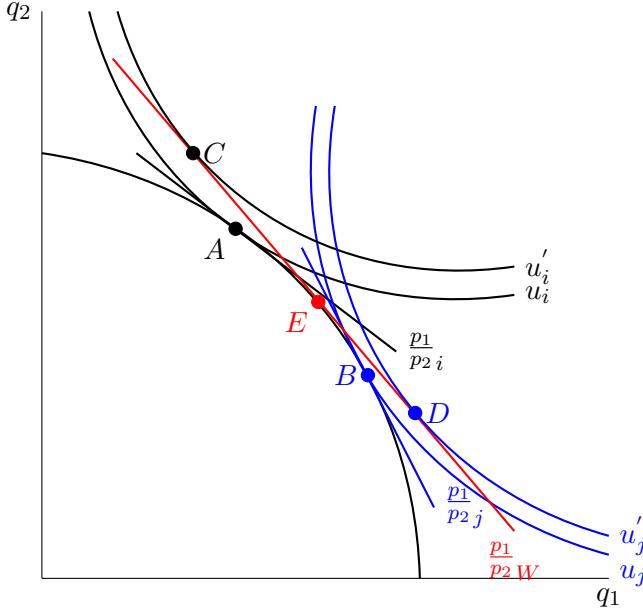
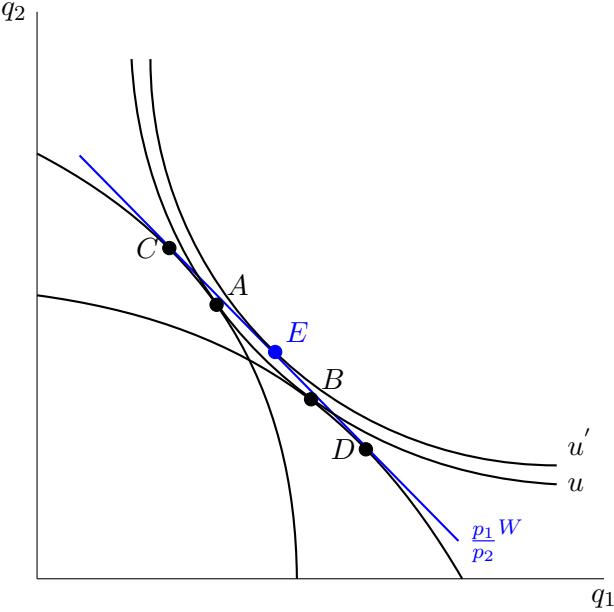


Figure 20 illustrates the case in which both countries possess identical factor endowments and identical preferences, represented by the same utility function. However, the countries differ in production technology, as reflected in distinct production functions. Because production technologies vary across countries, their Production Possibility Frontiers (PPFs) differ, leading to distinct autarky relative prices.

In figure 20, one country's maximum attainable output of good  $q_2$  exceeds that of the other, while the other country can produce a higher maximum quantity of good  $q_1$ . This representation is merely illustrative; the specific shape and position of each PPF depend on the functional form of the underlying production technologies.

Figure 21: Trade between countries with identical preferences and endowments



If both countries share identical technologies (production functions) and identical preferences (utility functions) but differ in their relative factor endowments, they will still exhibit different autarky relative prices. Consequently, their Production Possibility Frontiers (PPFs) will also differ.<sup>6</sup>

The specific configuration of the PPFs across countries depends on the respective factor endowments. For instance, if one country is relatively abundant in one factor while the other is relatively abundant in the alternative factor, the scenario resembles that depicted in Figure 20. Conversely, if one country possesses larger quantities of both factors, its PPF will completely encompass that of the other country.

This last case corresponds precisely to the **Heckscher–Ohlin Model**. In this model, two countries produce two goods using two factors of production. Both countries share identical production technologies and identical preferences. However, even under these conditions, differences in relative factor endowments lead to distinct autarky relative prices. As a result, countries engage in trade and achieve higher levels of welfare through specialization according to their comparative advantage.

## 8.7 Equilibrium in the Neoclassical $2 \times 2 \times 1$ model

In an economy with two countries and two goods but only one factor of production, the autarky equilibrium has the same graphical representation as in Figure 14. However, solving for the autarky equilibrium in this case is simpler, as the Production Possibility Frontier (PPF) can

<sup>6</sup>If endowments differ in absolute terms but relative endowments are identical across countries, PPFs will differ while autarky relative prices will remain the same. In this case, there would be no incentive to engage in trade. In particular, one country's PPF will encompass that of the other.

be obtained explicitly. In section 8.3, the Production Possibility Frontier (PPF) was derived implicitly by considering that each point on the contract curve represents an efficient allocation of factors and, therefore, corresponds to a point on the PPF. Different allocations of factors can thus be used to determine the implicit form of the PPF.

The optimal consumption and production in autarky occur where the *marginal rate of transformation* (MRT) equals the *marginal rate of substitution* (MRS). Given that the PPF is expressed explicitly, the equilibrium condition can be solved as

$$\frac{\partial q_{2z}}{\partial q_{1z}} = \frac{\frac{\partial U}{\partial q_{1z}}}{\frac{\partial U}{\partial q_{2z}}} \quad (8.7.1)$$

where the left-hand side of equation (8.7.1) represents the MRT, and the right-hand side represents the MRS.

Using equation (8.7.1) and the explicit form of the PPF, the autarky equilibrium can be readily determined.

When the economy opens to trade, production is determined at the point where the MRT equals the world relative price, that is,

$$\frac{\partial q_{2z}}{\partial q_{1z}} = \left( \frac{p_1}{p_2} \right)^W \quad (8.7.2)$$

The optimal consumption under trade is characterized by the same condition described in equation (8.5.1)

## 8.8 Case study

Consider an economy composed of two countries, denoted by  $i$  and  $j$ , and two production factors: labor ( $L$ ) and capital ( $K$ ). Both countries share identical production technologies, defined as

$$q_{1z} = L_{1z}^{\frac{1}{4}} K_{1z}^{\frac{3}{4}}, \quad q_{2z} = L_{2z}^{\frac{3}{4}} K_{2z}^{\frac{1}{4}}, \quad z = i, j \quad (8.8.1)$$

The representative consumer in each country has preferences with the following utility function:

$$U_z = \sqrt{x_{1z} x_{2z}} \quad (8.8.2)$$

The factor endowments of each country are given by  $(\bar{L}_i, \bar{K}_i) = (100, 200)$  for country  $i$ , and  $(\bar{L}_j, \bar{K}_j) = (200, 100)$  for country  $j$

### 8.8.1 Production Possibility Frontier (PPF)

The contract curve is given by

$$K_{1z} = \frac{9\bar{K}_z L_{1z}}{\bar{L}_z + 8L_{1z}}, \quad z = i, j \quad (8.8.3)$$

Each point on the contract curve corresponds to an efficient allocation of factors and, therefore, to a point on the Production Possibility Frontier (PPF). The PPF can thus be expressed as

$$\text{PPF}_z = \left\{ (q_{1z}, q_{2z}) : \exists L_{1z} \in [0, \bar{L}_z], \quad q_{1z} = L_{1z}^{\frac{1}{4}} \left( \frac{9\bar{K}_z L_{1z}}{\bar{L}_z + 8L_{1z}} \right)^{\frac{3}{4}}, \right. \\ \left. q_{2z} = (\bar{L}_z - L_{1z})^{\frac{3}{4}} \left( \bar{K}_z - \frac{9\bar{K}_z L_{1z}}{\bar{L}_z + 8L_{1z}} \right)^{\frac{1}{4}} \right\} \quad (8.8.4)$$

Equation (8.8.4) characterizes the PPF. For each feasible allocation of  $L_{1z}$ , the contract curve determines the corresponding optimal amount of  $K_{1z}$ . These two values simultaneously define the remaining factor allocations,  $L_{2z}$  and  $K_{2z}$ , which together determine the output levels of both sectors

### 8.8.2 Autarky

From equations (8.4.3) and (8.4.4), the equilibrium in the goods markets is given by

$$q_{1z} = \frac{(w\bar{L}_z + r\bar{K}_z)}{2p_1}, \quad q_{2z} = \frac{(w\bar{L}_z + r\bar{K}_z)}{2p_2}, \quad z = i, j \quad (8.8.5)$$

From equations (8.4.9) and (8.4.10), the equilibrium in the factor markets can be expressed as

$$\bar{L}_z = 3^{-\frac{3}{4}} q_{1z} \left( \frac{r}{w} \right)^{\frac{3}{4}} + 3^{\frac{1}{4}} q_{2z} \left( \frac{r}{w} \right)^{\frac{1}{4}} \quad (8.8.6)$$

$$\bar{K}_z = 3^{\frac{1}{4}} q_{1z} \left( \frac{w}{r} \right)^{\frac{1}{4}} + 3^{-\frac{3}{4}} q_{2z} \left( \frac{w}{r} \right)^{\frac{3}{4}} \quad (8.8.7)$$

In addition, from equations (8.4.11) and (8.4.12), the unit cost functions imply that

$$p_1 = \left( 3^{-\frac{3}{4}} + 3^{\frac{1}{4}} \right) w^{\frac{1}{4}} r^{\frac{3}{4}} \quad (8.8.8)$$

$$p_2 = \left( 3^{-\frac{3}{4}} + 3^{\frac{1}{4}} \right) w^{\frac{3}{4}} r^{\frac{1}{4}} \quad (8.8.9)$$

Combining equations (8.8.8) and (8.8.9) yields the relative factor price relationship:

$$\frac{r}{w} = \left( \frac{p_1}{p_2} \right)^2 \quad (8.8.10)$$

Equation (8.8.10), together with the goods and factor market equilibrium conditions, allows the determination of the autarky relative price:

$$\frac{p_1}{p_2} = \sqrt{\frac{\bar{L}_z}{\bar{K}_z}} \quad (8.8.11)$$

Once the autarky relative price equilibrium has been determined, the corresponding equilibrium

factor prices, levels of consumption and production, and the allocation of factors across sectors can be derived by substitution into the preceding equations.

### 8.8.3 Trade Equilibrium

Substituting equation (8.8.10) into equations (8.8.6) and (8.8.7) defines the production levels of each sector when the economy is open to trade and faces relative prices equal to  $\left(\frac{p_1}{p_2}\right)^W$ :

$$\bar{L}_z = 3^{-\frac{3}{4}} q_{1z} \left(\frac{p_1}{p_2} W\right)^{\frac{3}{2}} + 3^{\frac{1}{4}} q_{2z} \left(\frac{p_1}{p_2} W\right)^{\frac{1}{2}} \quad (8.8.12)$$

$$\bar{K}_z = 3^{\frac{1}{4}} q_{1z} \left(\frac{p_1}{p_2} W\right)^{-\frac{1}{2}} + 3^{-\frac{3}{4}} q_{2z} \left(\frac{p_1}{p_2} W\right)^{-\frac{3}{2}} \quad (8.8.13)$$

Given the representative consumer preferences, equation (8.5.1) can be expressed as

$$\frac{x_{2z}}{x_{1z}} = \frac{p_1 W}{p_2} \quad (8.8.14)$$

Substituting equation (8.8.14) into the budget constraint (8.5.2) and solving yields

$$x_{1z} = \frac{1}{2} \left( q_{1z} + \frac{p_2 W}{p_1} q_{2z} \right) \quad (8.8.15)$$

$$x_{2z} = \frac{1}{2} \left( \frac{p_1 W}{p_2} q_{1z} + q_{2z} \right) \quad (8.8.16)$$

Solving for  $q_{1z}$  and  $q_{2z}$  in equations (8.8.12) and (8.8.13), and substituting the results into equations (8.8.15) and (8.8.16), yields the consumption levels under trade. The relative offer curve can then be derived by considering different values of the world relative price.

## 8.9 Exercises

1. Consider an economy in which labor is the only factor of production. There are two countries,  $i$  and  $j$ , each endowed with  $L_i$  and  $L_j$  units of labor, respectively. Both countries share the same production technology given by

$$q_{1k} = \sqrt{L_{1k}}, \quad q_{2k} = \sqrt{L_{2k}}, \quad k = i, j$$

However, preferences differ across countries and are represented by the following utility functions:

$$U_i = x_{1i}^2 x_{2i}, \quad U_j = x_{1j} x_{2j}^2$$

1. Derive the Production Possibility Frontier (PPF) for each country and determine their respective Marginal Rates of Transformation (MRT).
2. Determine the autarky equilibrium for each country.
3. Compute production and consumption levels for each country when trade is allowed, given a world relative price  $\frac{p_1}{p_2}W$ .
4. Derive an expression for the world relative price in equilibrium under free trade.
5. Assume both countries have identical labor endowments, each equal to 100. Demonstrate that both countries gain from trade and explain the intuition behind this result, given that they share the same technology and labor endowments. Determine the equilibrium world relative price and demonstrate that it lies between the autarky relative prices of both countries.
2. Considering the example proposed in [Section 8.8](#) and using Excel (all computations must be performed in Excel), for each country:
  1. Plot the Production Possibility Frontier (PPF).
  2. Estimate an approximate Marginal Rate of Transformation (MRT).
  3. Determine explicitly the autarky equilibrium, including relative goods prices, relative factor prices, consumption, production, and the allocation of factors across sectors.
  4. Demonstrate that in equilibrium, the autarky relative price approximates the MRT estimated previously.
  5. Show that, in equilibrium, no higher level of utility can be attained.
  6. Approximate and plot the offer curve when both countries are opened to trade.
  7. Determine the world relative price<sup>7</sup> and the equilibrium for each country. Verify that both world markets are in equilibrium at that relative price.
  8. Demonstrate that both countries achieve higher welfare when engaging in trade.

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<sup>7</sup>This can be computed using the *Solver* tool in Excel.

3. Based on the neoclassical model, consider an increase in country  $i$ 's preference for good  $q_2$ . Assume that under trade, country  $i$  imports  $q_1$  both before and after the change in preferences.
  1. Using Figures 14 and 15, illustrate the new production and consumption points under autarky and trade. Provide the economic intuition for the resulting changes.
  2. Using Figure 18, illustrate how country  $i$ 's offer curve shifts. Explain how this shift reflects a change in the willingness to trade and interpret the underlying intuition.
  3. Using Figure 19, analyze how the world relative price equilibrium may change. Provide the economic intuition for this result.
  4. Assess whether it is possible for country  $i$  to become an exporter of  $q_1$  following the preference change. Specify the conditions under which this could occur and justify your reasoning.
  5. Discuss how your previous answers would change if the preference shift were instead toward good  $q_1$ .

## 9 The Heckscher–Ohlin–Vanek Model

### 9.1 Introduction

This chapter builds on the fundamental concepts developed in [Chapter 5](#) and [Chapter 8](#). As discussed in [Section 8.6](#), the Heckscher–Ohlin model constitutes a particular case of the neoclassical framework in which countries share identical technologies (production functions) and preferences (utility functions) but differ in their relative factor endowments—and consequently in their absolute endowments. This model highlights the role of factor endowments, rather than technological differences, as the fundamental source of comparative advantage. Vanek later extended and generalized this framework to encompass  $n$  factors and  $n$  goods.

In this chapter, an additional assumption is introduced: **relative prices are exogenous**. This implies that the country under analysis takes the relative prices of goods as given and exerts no influence over their determination. This assumption can be interpreted as the country being sufficiently small relative to the rest of the world so that its actions have no effect on world relative prices.

It should be noted that in [Chapter 8](#), where there were two countries, each country influenced the determination of the world relative prices, making them endogenous to the model. In fact, as illustrated in the offer curve equilibrium in [Figure 19](#), the equilibrium world relative price is determined by the intersection of both countries' offer curves.

The Heckscher–Ohlin–Vanek (HOV) model represents the natural multi-good, multi-factor extension of the canonical Heckscher–Ohlin framework. Its central prediction is that the pattern of trade can be described in terms of the factor content of net exports, thereby linking observed trade flows directly to relative factor endowments across countries. This formulation generalizes the Heckscher–Ohlin theorem and provides a tractable empirical framework for testing the relationship between factor abundance and trade patterns.

### 9.2 The model

Consider a world economy composed of  $m$  countries, each endowed with a given quantity of the  $n$  factors of production. The relative factor endowments of each country differ from the world relative endowments. All countries produce  $n$  goods using identical, concave production functions that exhibit constant returns to scale. Sectors differ in their factor intensities. Preferences are identical and homothetic across countries, ensuring that demand patterns depend solely on relative prices.

### 9.3 Prices Equal its Marginal Cost

As discussed in [Chapter 5](#)—and implicitly applicable to [Chapter 8](#)—the condition that prices equal marginal costs for the case of two factors and two goods can be expressed as

$$\begin{cases} p_1 = w a_{L1} + r a_{K1}, \\ p_2 = w a_{L2} + r a_{K2} \end{cases} \quad (9.3.1)$$

In matrix form, this relationship generalizes to

$$\begin{bmatrix} p_1 \\ p_2 \\ \vdots \\ p_n \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{bmatrix} \quad (9.3.2)$$

where  $a_{ij}$  denotes the quantity of factor  $i$  required to produce one unit of good  $j$ —that is, the conditional factor demand per unit of output.

The factor requirement can also be derived from Shephard's Lemma:

$$a_{ij}(w_1, \dots, w_n) = \frac{\partial c_j(w_1, \dots, w_n)}{\partial w_i} \quad (9.3.3)$$

Hence, equation (9.3.2) can be written more compactly as

$$\mathbf{P} = \mathbf{AW} \quad (9.3.4)$$

where  $\mathbf{P}$  is the  $n \times 1$  vector of goods prices,  $\mathbf{A}$  is the  $n \times n$  matrix of factor requirements, and  $\mathbf{W}$  is the  $n \times 1$  vector of factor prices.

## 9.4 Equilibrium in the Factor Markets

As discussed in Chapter 5—and equally applicable to Chapter 8—the equilibrium conditions in the factor markets for the case of two factors and two goods can be expressed as

$$\begin{cases} \bar{L} = a_{Li}q_i + a_{Lj}q_j, \\ \bar{K} = a_{Ki}q_i + a_{Kj}q_j \end{cases} \quad (9.4.1)$$

In matrix form, this relationship generalizes to

$$\begin{bmatrix} \bar{e}_{1i} \\ \bar{e}_{2i} \\ \vdots \\ \bar{e}_{ni} \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \begin{bmatrix} q_{1i} \\ q_{2i} \\ \vdots \\ q_{ni} \end{bmatrix} \quad (9.4.2)$$

Equation (9.4.2) can be written more compactly as

$$\mathbf{E}_i = \mathbf{AQ}_i \quad (9.4.3)$$

where  $\mathbf{E}_i$  denotes the  $n \times 1$  vector of factor endowments for country  $i$ , and  $\mathbf{Q}_i$  represents the  $n \times 1$  vector of outputs for the same country. As these quantities vary across countries, the subscript  $i$  is used to identify the respective country.

This relationship also holds at the world level:

$$\mathbf{E}_W = \mathbf{AQ}_W \quad (9.4.4)$$

If the matrix of factor requirements,  $\mathbf{A}$ , is invertible, equation (9.4.3) and (9.4.4) can be rewritten as

$$\mathbf{Q}_k = \mathbf{A}^{-1}\mathbf{E}_k, \quad k = i, W \quad (9.4.5)$$

## 9.5 Factor Price Equalization

If countries share identical technologies (production functions), are open to trade, and face the same world relative prices, then factor prices will be equalized across countries. The intuition behind this result is that, as factor prices are determined by equation (9.3.2), identical production technologies imply identical marginal costs across sectors. Because all countries face the same world relative prices, they will consequently have identical factor prices.

It should be noted that equation (9.3.4) applies uniformly to all countries. No country-specific subscript is required, as the vector of goods prices  $\mathbf{P}$  is identical across countries, the factor requirement matrix  $\mathbf{A}$  is the same due to identical production technologies, and the vector of factor prices  $\mathbf{W}$  is equalized across countries by the *Factor Price Equalization* theorem.

## 9.6 Consumption Allocation

Under identical and homothetic preferences, each country's share of world income determines its share in world consumption. Let  $\alpha_i$  denote the share of country  $i$  in world income, with  $\sum_{i=1}^m \alpha_i = 1$ . This share can be measured as

$$\alpha_i = \frac{\mathbf{P}^\top \mathbf{Q}_i}{\mathbf{P}^\top \mathbf{Q}_W} \quad (9.6.1)$$

Consumption in country  $i$  can therefore be expressed as

$$\mathbf{X}_i = \alpha_i \mathbf{X}_W \quad (9.6.2)$$

where  $\mathbf{X}_i$  is the vector of country  $i$ 's consumption and  $\mathbf{X}_W$  represents world consumption. In equilibrium, world consumption equals world production,  $\mathbf{X}_W = \mathbf{Q}_W$ . Hence, equation (9.6.2)

can be rewritten as

$$\mathbf{X}_i = \alpha_i \mathbf{Q}_W \quad (9.6.3)$$

## 9.7 Factor Content of Trade

The factor content of trade is defined as the factor embodied in a country's net exports. The factor content vector of trade for country  $i$  is

$$A\mathbf{T}_i = A(\mathbf{Q}_i - \mathbf{C}_i) \quad (9.7.1)$$

Note that  $\mathbf{T}_i$  denotes the vector of net exports for country  $i$ , expressed in units of goods. When premultiplied by matrix  $A$ , that is,  $A\mathbf{T}_i$ , the expression is measured in terms of factors. Equation (9.7.2) can be expressed as

$$A\mathbf{T}_i = \mathbf{E}_i - \alpha_i \mathbf{E}_W \quad (9.7.2)$$

Thus the factor content of trade equals the difference between a country's factor endowment and its consumption share of world factor endowments.

## 9.8 The Heckscher–Ohlin–Vanek Theorem

The Heckscher–Ohlin Theorem states that, in the  $2 \times 2 \times 2$  model, if a country is relatively abundant in factor  $i$ , it will export the good that is intensive in the use of that factor and import the other good. In this context, a country is considered labor-abundant if its relative labor endowment (with respect to capital) exceeds that of the other country—or, equivalently, if it exceeds the world's relative labor endowment; otherwise, it is capital-abundant. It should be noted that for this theorem to hold, countries must differ in their relative factor endowments, and sectors must differ in their factor intensities.

Extending this logic to the case of  $n$  factors and  $n$  goods, the Heckscher–Ohlin–Vanek Theorem states that country  $i$  will be a net exporter of the services of factors in which it is relatively abundant and a net importer of the services of factors in which it is relatively scarce. Formally,

$$A\mathbf{T}_i = \mathbf{E}_i - \alpha_i \mathbf{E}_W \quad (9.8.1)$$

Each element of the resulting vector  $A\mathbf{T}_i$  represents the quantity of factor services embodied in net exports for country  $i$ , where a positive entry indicates a net export and a negative entry indicates a net import of the corresponding factor.

Suppose factors are ordered from the most to the least relatively abundant (compared to the world). All factors whose relative endowment ratio exceeds the country's share of world income are net exported, while those below that threshold are net imported. Formally,

$$\frac{e_{ji}}{e_{jW}} \geq \dots \geq \alpha_i \geq \dots \geq \frac{e_{ki}}{e_{kW}} \quad (9.8.2)$$

Hence, factor  $j$  will be a net export (its corresponding entry in  $\mathbf{AT}_i$  is positive) if country  $i$ 's relative endowment exceeds  $\alpha_i$ , whereas factor  $k$  will be a net import (its corresponding entry in  $\mathbf{AT}_i$  is negative) if it falls below this value.

## 9.9 Stolper–Samuelson Theorem

Since countries take prices as exogenous, in an economy with two goods and two factors, the *Stolper–Samuelson Theorem* applies exactly as described in [Chapter 5](#).

For the general case of  $n$  factors and  $n$  goods, the relationship can be expressed in matrix form as

$$\Delta \mathbf{P} = \mathbf{A} \Delta \mathbf{W} \quad (9.9.1)$$

The generalized result for  $n$  factors is that a change in goods prices benefits the factors used intensively in the production of goods whose prices increase, and harms the factors used intensively in the production of goods whose prices decline. Consequently, trade-induced changes in relative prices generate redistributive effects across factors, consistent with the HOV prediction that countries export the goods of their relatively abundant factors.

## 9.10 Rybczynski Theorem

In an economy with two goods and two factors, the *Rybczynski Theorem* applies exactly as described in [Chapter 5](#). As previously discussed, the Rybczynski Theorem analyzes the effect of changes in factor endowments on output levels under fixed goods prices. In this setting, factor prices  $\mathbf{W}$  remain constant, ensuring that the input coefficients  $a_{fi}$  are fixed.

In matrix form, the *Rybczynski Theorem* can be expressed as

$$\Delta \mathbf{E}_i = \mathbf{A} \Delta \mathbf{Q}_i \quad (9.10.1)$$

If the matrix of factor requirements  $\mathbf{A}$  is invertible, equation (9.10.1) can be rewritten as

$$\Delta \mathbf{Q}_i = \mathbf{A}^{-1} \Delta \mathbf{E}_i \quad (9.10.2)$$

The Rybczynski Theorem then states that an increase in the endowment of factor  $j$  expands the output of the good that uses factor  $j$  intensively and contracts the output of other goods. This result highlights how changes in factor endowments influence the composition of production, even when goods prices remain constant.

## 9.11 Exercises

1. Using the matrix approach developed in this chapter, suppose country  $i$  is endowed with  $(\bar{L}_i, \bar{K}_i) = (0.4, 0.6)$ , while the world is endowed with  $(\bar{L}_W, \bar{K}_W) = (1, 1)$ . World prices are given by  $(p_1, p_2) = (1, 1)$ . The total cost functions for each sector are

$$CT_1 = 2q_1 \left( \frac{w}{\frac{1}{3}} \right)^{\frac{1}{3}} \left( \frac{r}{\frac{2}{3}} \right)^{\frac{2}{3}}, \quad CT_2 = 2q_2 \left( \frac{w}{\frac{2}{3}} \right)^{\frac{2}{3}} \left( \frac{r}{\frac{1}{3}} \right)^{\frac{1}{3}}$$

1. Determine the vector of factor prices,  $\mathbf{W}$ .
  2. Compute the vector of production for country  $i$ ,  $\mathbf{Q}_i$ .
  3. Compute the world production vector,  $\mathbf{Q}_W$ .
  4. Determine the consumption vector for country  $i$ ,  $\mathbf{X}_i$ .
  5. Derive the vector of net exports for country  $i$ ,  $\mathbf{T}_i$ .
  6. Verify that the Heckscher–Ohlin theorem holds.
  7. Verify that the *Factor Price Equalization Theorem* holds.
2. Considering the example developed in Section 8.8:
    1. Demonstrate that equation (9.8.1) holds.
    2. Verify that the Heckscher–Ohlin–Vanek (HOV) theorem is satisfied.
  3. Suppose an economy with three factors (labor, capital, and land) and three sectors. World prices are equal to 1 for all goods. Country  $i$  is endowed with 10, 20, and 30 units of labor, capital, and land, respectively, while the world endowment for each factor is 100. The production functions are given by

$$q_1 = \min\{3L_1, 2K_1, T_1\}$$

$$q_2 = \min\{L_2, K_2, T_2\}$$

$$q_3 = \min\{L_3, 2K_3, 3T_3\}$$

1. Determine  $\mathbf{E}_i$  and  $\mathbf{E}_W$ .
2. Compute  $\mathbf{AT}_i$ .
3. Verify that the HOV theorem holds.
4. Suppose the land endowment of country  $i$  increases by 10%. Determine  $\mathbf{Q}'_i$  and demonstrate that the *Rybczynski Theorem* holds.
5. Suppose  $p_3$  increases to 2, while all other prices remain unchanged. Determine the new vector of factor prices,  $\mathbf{W}'$ , and demonstrate that the *Stolper–Samuelson Theorem* holds.

## 10 The Input–Output Model

The Input–Output (I–O) model, originally developed by Leontief, constitutes a fundamental analytical framework in international economics for examining the interdependence among industries and the transmission of trade shocks across sectors. It provides a systematic approach to understanding how final demand and production structures jointly determine output levels within an economy. The model is particularly valuable for identifying and quantifying both the direct and indirect effects of changes in demand.

### 10.1 The Model

Consider an economy composed of  $n$  productive sectors. Each sector produces a good that can be used either as an intermediate input by other sectors or as a final good consumed domestically or exported. Let  $x_i$  denote the total output of sector  $i$ ,  $z_{ij}$  the quantity of good  $i$  used as an intermediate input by sector  $j$ , and  $b_i$  the final demand for good  $i$ . The final demand comprises household consumption, government expenditure, inventory accumulation or capital formation, and foreign demand. Market clearing for each good requires

$$x_i = \sum_{j=1}^n z_{ij} + b_i, \quad j = 1, \dots, n \tag{10.1.1}$$

Additionally, it is assumed that the total output of sector  $i$  equals the total value of its inputs, which include all intermediate inputs used by sector  $i$  and the value added generated within the sector. This relationship can be expressed as

$$x_i = \sum_{j=1}^n z_{ji} + v_i, \quad j = 1, \dots, n \tag{10.1.2}$$

where  $v_i$  in equation (10.1.2) represents the value added by sector  $i$ , which may include the returns to labor, capital, and land, as well as taxes and profits.

Table 2 presents the Input–Output table for an economy with three sectors. In practice, each entry in Table 2 is measured in monetary units, ensuring that all values in the table are expressed in the same currency

Table 2: The Input-Output table for three sectors

		Sectors				
		1	2	3	b	Total input
Sectors	1	$z_{11}$	$z_{12}$	$z_{13}$	$b_1$	$x_1$
	2	$z_{21}$	$z_{22}$	$z_{23}$	$b_2$	$x_2$
	3	$z_{31}$	$z_{32}$	$z_{33}$	$b_3$	$x_3$
Value added		$v_1$	$v_2$	$v_3$		
Total input		$x_1$	$x_2$	$x_3$		

Defining the input coefficients as  $a_{ij} = \frac{z_{ij}}{x_j}$ , which represent the quantity of good  $i$  required per unit of output in sector  $j$ <sup>8</sup>, the system can be expressed compactly in matrix form. Let  $\mathbf{x}$  denote the  $n \times 1$  vector of total outputs,  $\mathbf{b}$  the  $n \times 1$  vector of final demands, and  $A = [a_{ij}]$  the  $n \times n$  matrix of technical coefficients. Then

$$\mathbf{x} = A\mathbf{x} + \mathbf{b} \quad (10.1.3)$$

Rearranging equation (10.1.3) yields to

$$(I - A)\mathbf{x} = \mathbf{b} \quad (10.1.4)$$

If the inverse of the matrix  $(I - A)$  exists, total output can be expressed from equation (10.1.4) as

$$\mathbf{x} = (I - A)^{-1}\mathbf{b} \quad (10.1.5)$$

The matrix  $(I - A)^{-1}$ , known as the *Leontief inverse*, captures both the direct and indirect production requirements within the economy. Each element  $(i, j)$  of this matrix represents the total output from sector  $i$  required to satisfy one additional unit of final demand in sector  $j$ , taking into account the entire network of intermediate linkages across sectors.

## 10.2 Comparative Statics in the I–O Model

The input–output framework is particularly well suited for comparative static analysis of demand shocks. Consider a marginal change  $\Delta\mathbf{b}$  in final demand. The corresponding change in total output is given by

$$\Delta\mathbf{x} = (I - A)^{-1}\Delta\mathbf{b}. \quad (10.2.1)$$

Equation (10.2.1) implies that any disturbance to final demand is proportionally transmitted throughout the production network. Specifically, an increase in the final demand for sector  $i$

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<sup>8</sup>If the entries of the Input–Output table are measured in monetary units,  $a_{ij}$  represents the amount of monetary units spent in sector  $i$  by sector  $j$  to generate one monetary unit of output.

leads to a more than proportional rise in its total output, as sector  $i$  requires intermediate inputs from other sectors, which in turn demand additional inputs from sector  $i$ , and so on. The same mechanism applies in the case of a decrease in final demand, generating a proportional contraction that propagates through the different sectors.

Furthermore, the new output vector can be expressed using equation (10.1.5) as

$$\mathbf{x}' = (I - A)^{-1} \mathbf{b}' \quad (10.2.2)$$

### 10.3 Case Study

Consider the following Input–Output table for an economy composed of two sectors: goods and services

Table 3: Input–Output example for an economy with goods and services sectors

	Goods	Services	Final demand
Goods	1	3	6
Services	2	4	5
Labor	7	4	

It follows that the production vector is

$$\mathbf{x} = \begin{bmatrix} 10 \\ 11 \end{bmatrix}$$

The corresponding matrix of technical coefficients,  $A$ , is given by

$$A = \begin{bmatrix} \frac{1}{10} & \frac{3}{11} \\ \frac{2}{10} & \frac{5}{11} \end{bmatrix}$$

The Leontief inverse matrix,  $(I - A)^{-1}$ , is

$$(I - A)^{-1} = \begin{bmatrix} 1.23 & 0.53 \\ 0.39 & 1.74 \end{bmatrix}$$

Using equation (10.1.5), it can be verified that

$$(I - A)^{-1} \mathbf{b} = \begin{bmatrix} 1.23 & 0.53 \\ 0.39 & 1.74 \end{bmatrix} \begin{bmatrix} 6 \\ 5 \end{bmatrix} = \begin{bmatrix} 10 \\ 11 \end{bmatrix} = \mathbf{x}$$

Suppose now that final demand in the goods sector decreases by two units. The corresponding change in final demand is

$$\Delta \mathbf{b} = \begin{bmatrix} -2 \\ 0 \end{bmatrix}$$

Using equation (10.2.2), the resulting change in the production vector is obtained as

$$(I - A)^{-1} \Delta \mathbf{b} = \begin{bmatrix} 1.23 & 0.53 \\ 0.39 & 1.74 \end{bmatrix} \begin{bmatrix} -2 \\ 0 \end{bmatrix} = \begin{bmatrix} -2.46 \\ -0.77 \end{bmatrix} = \Delta \mathbf{x}$$

It is noteworthy that, even though the final demand for the services sector remains unchanged, its output decreases because the goods sector reduces its use of intermediate inputs from services as a result of the decline in goods output.

## 10.4 Exercises

1. Consider a country that categorizes its production into three sectors. The technical coefficients matrix is given by

Table 4: Technical coefficients matrix  $A$

	Sector 1	Sector 2	Sector 3
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Sector 1	0.15	0.09	0.12
Sector 2	0.03	0.09	0.08
Sector 3	0.03	0.03	0.12

The vector of final demand (in local currency) is

Table 5: Final demand vector  $b$  (local currency)

	Household demand	Government demand	Foreign demand
Sector 1	9	6	7
Sector 2	8	10	9
Sector 3	6	7	7

1. Determine the total output vector  $x$  for the country.
2. Determine the value added generated by each sector.
3. Suppose the government seeks to raise total output by increasing public expenditure. The targeted increases in sectoral output are 30%, 15%, and 15% for sectors 1, 2, and 3, respectively. Determine the required increase in government spending by sector to achieve these targets.

## 11 The Leontief Paradox Reconsidered

### 11.1 Leontief's approach

This chapter is based on Leamer (1980), which seeks to address the *Leontief Paradox*. Leontief (1954) argued that a country is relatively well endowed with capital if the capital–labor ratio embodied in its exports exceeds that embodied in its imports; otherwise, the country is relatively well endowed with labor. Let  $\lambda$  denote Leontief's statistic. According to Leontief, a country is considered capital-abundant if:

$$\lambda = \frac{\frac{K_x}{L_x}}{\frac{K_m}{L_m}} > 1 \quad (11.1.1)$$

where  $K_x$  and  $K_m$  denote the amounts of capital embodied in exports, imports;  $L_x$  and  $L_m$  represent the corresponding quantities of labor.

Leontief tested this hypothesis using data for the United States in 1947, summarized in the following table

Table 6: Domestic capital and labor requirements per million dollars of United States exports and of competitiveness import replacements

Input	Exports	Imports
Capital (\$, 1947 prices)	2550780	3091339
Labor (man-years)	182.313	170.004

It is straightforward to compute from equation (11.1.1) and Table 6 that Leontief's statistic is approximately 0.77. Since this value is less than 1, it suggests that the United States in 1947 was relatively well endowed with labor rather than capital. This result contradicted the prevailing belief that the United States was capital-abundant, giving rise to what became known as the *Leontief Paradox*.

Following the emergence of the paradox, numerous studies were written in an attempt to explain it. However, the paper that most convincingly offered a resolution was published by Edward Leamer in 1980. Leamer (1980) argued that the paradox originated from a fundamental conceptual misunderstanding in Leontief's analysis.

In this chapter, it is assumed that the factor services embodied in net exports are equal to the factor services embodied in exports minus those embodied in imports. Formally,

$$K_T = K_x - K_m, \quad L_T = L_x - L_m$$

where  $K_T$  and  $L_T$  denote the capital and labor services contained in net exports, respectively.

## 11.2 Leamer's approach

Leamer (1980) proposed that a country is revealed to be relatively well endowed with capital if one of the following three conditions is satisfied:

$$K_x - K_m > 0, \quad L_x - L_m < 0 \quad (11.2.1)$$

$$K_x - K_m > 0, \quad L_x - L_m > 0, \quad \frac{K_x - K_m}{L_x - L_m} > \frac{K_c}{L_c} \quad (11.2.2)$$

$$K_x - K_m < 0, \quad L_x - L_m < 0, \quad \frac{K_x - K_m}{L_x - L_m} < \frac{K_c}{L_c} \quad (11.2.3)$$

where  $K_c$  denotes the amount of capital embodied in consumption, and  $L_c$  represents the amount of labor embodied in consumption.

The above conditions indicate that a country is relatively well endowed with capital if one of the following holds:

- i. From (11.2.1), the country is a net exporter of capital and a net importer of labor.
- ii. From (11.2.2), the country is a net exporter of both capital and labor, but the capital–labor ratio embodied in net exports exceeds that embodied in consumption.
- iii. From (11.2.3), the country is a net importer of both capital and labor, but the capital–labor ratio embodied in net exports is lower than that embodied in consumption.

Leontief's data for the United States in 1947 satisfy the second condition, indicating that the country is, in fact, revealed by its trade pattern to be capital abundant.

### 11.2.1 From the *Heckscher–Ohlin–Vanek* model with $n$ commodities

This section provides a concise overview of the *Heckscher–Ohlin–Vanek* (HOV) model extended to  $n$  commodities studied in Chapter 9, following the notation used by Leamer (1980) to maintain consistency with the original paper on which this chapter is based.

Assume the following:

- There are  $n$  commodities that are freely traded internationally.
- There are  $n$  factors of production that are perfectly immobile internationally.
- All individuals have identical and homothetic preferences.
- Production functions are identical across countries and exhibit constant returns to scale.
- Goods and factor markets are perfectly competitive.
- Factor prices are equalized across countries, consistent with the *Factor Price Equalization Theorem*.

Under these assumptions, the following relationship holds:

$$\mathbf{AT}_i = \mathbf{E}_i - \alpha_i \mathbf{E}_W \quad (11.2.4)$$

where  $\mathbf{A}$  is the matrix of total factor requirements,  $\mathbf{T}_i$  is the vector of net exports of country  $i$ ,  $\mathbf{E}_i$  is the vector of total factor endowments of country  $i$ , and  $\mathbf{E}_W$  is the vector of total world endowments (such that  $\mathbf{E}_W = \sum_i \mathbf{E}_i$ ). The term  $\alpha_i$  denotes the share of world income accruing to country  $i$ .

Equation (11.2.4) can be derived as follows. Let  $\mathbf{Q}_i$  denote the vector of outputs in country  $i$  and  $\mathbf{Q}_W$  the vector of world outputs. In equilibrium, factor market clearing requires that factor demand equals factor supply, i.e.,  $\mathbf{AQ}_i = \mathbf{E}_i$  and  $\mathbf{AQ}_W = \mathbf{E}_W$ . With identical and homothetic preferences, the consumption vector  $\mathbf{C}_i$  for each country is proportional to world output, such that  $\mathbf{C}_i = \alpha_i \mathbf{Q}_W$ . Therefore, country  $i$ 's trade vector is given by  $\mathbf{T}_i = \mathbf{Q}_i - \mathbf{C}_i$ , and the factors embodied in trade are

$$\mathbf{AT}_i = \mathbf{A}(\mathbf{Q}_i - \mathbf{C}_i) = \mathbf{E}_i - \alpha_i \mathbf{AQ}_W = \mathbf{E}_i - \alpha_i \mathbf{E}_W$$

which corresponds to equation (11.2.4).

Each element of equation (11.2.4) is measured in factor units. For example, the first entry of  $\mathbf{AT}_i$  represents the net export of factor 1, the first entry of  $\mathbf{E}_i$  represents the total endowment of factor 1 in country  $i$ , and the first entry of  $\alpha_i \mathbf{E}_W$  represents the amount of factor 1 embodied in country  $i$ 's consumption. Accordingly, the expressions for capital and labor can be written as:

$$K_T = K_i - \alpha_i K_W \quad (11.2.5)$$

$$L_T = L_i - \alpha_i L_W \quad (11.2.6)$$

Country  $i$  is said to be relatively abundant in capital (compared with labor) if and only if the share of the world's capital stock located in country  $i$  exceeds the share of the world's labor force, that is,

$$\frac{K_i}{K_W} > \frac{L_i}{L_W} \quad (11.2.7)$$

Finally, the vector of factors embodied in the vector of commodities  $\mathbf{z}$  is given by  $\mathbf{Az}$ . Therefore, equation (11.2.4) can be expressed in terms of commodities as:

$$\mathbf{T}_i = \mathbf{Q}_i - \mathbf{C}_i \quad (11.2.8)$$

### 11.3 Corollaries

- **Corollary 1:** Using equations (11.2.5) and (11.2.6), and acknowledging equation (11.2.7), capital is revealed by trade to be abundant relative to labor if and only if

$$\frac{K_i}{L_i} > \frac{K_T - K_i}{L_i - L_T} \quad (11.3.1)$$

Because the factor endowment net of trade equals the amount of the factor embodied in consumption—that is,  $K_c = K_i - K_T$  and  $L_c = L_i - L_T$ —equation (11.3.1) can alternatively be expressed as

$$\frac{K_i}{L_i} > \frac{K_c}{L_c} \quad (11.3.2)$$

Under the assumption that  $L_T > 0$  and  $K_T > 0$ , equation (11.3.1) can be equivalently expressed as

$$\frac{K_T}{L_T} > \frac{K_i}{L_i} \quad (11.3.3)$$

Yet another way to express equation (11.3.1), by combining equations (11.3.2) and (11.3.3), is

$$\frac{K_T}{L_T} > \frac{K_c}{L_c} \quad (11.3.4)$$

Equation (11.3.2) states that country  $i$  is relatively capital abundant if its endowment of capital per worker exceeds the capital–labor ratio embodied in consumption. This implies that the capital–labor ratio embodied in net exports is higher than that embodied in the domestic endowment (equation (11.3.3)). Equation (11.3.4) indicates that country  $i$  is relatively capital abundant if the capital–labor ratio embodied in its net exports exceeds that embodied in its consumption.

If  $L_T < 0$  and  $K_T < 0$ , equations (11.3.3) and (11.3.4) should be modified, respectively, as follows:

$$\frac{K_T}{L_T} < \frac{K_i}{L_i}, \quad (11.3.5)$$

$$\frac{K_T}{L_T} < \frac{K_c}{L_c}. \quad (11.3.6)$$

- **Corollary 2:** If the net exports of capital and labor services have opposite signs, the factor with positive net exports is revealed to be the relatively abundant factor. This corresponds to equation (11.2.1).
- **Corollary 3:** If the net exports of capital and labor services have opposite signs, then the capital–labor ratio embodied in exports,  $\frac{K_x}{L_x}$ , exceeds that embodied in imports,  $\frac{K_m}{L_m}$ , if and only if the country is relatively capital abundant, i.e.,  $\frac{K_i}{K_W} > \frac{L_i}{L_W}$ . **This implies that the Leontief statistic is valid only when a country is a net exporter of one factor and a net importer of the other.**

A significant practical limitation of Corollary 3 is that it assumes  $K_T$  and  $L_T$  have opposite signs. However, according to Leontief's 1947 data, both  $K_T$  and  $L_T$  are positive—the United States was a net exporter both capital and labor services. In this case, the ordering  $\frac{K_T}{L_T} < \frac{K_m}{L_m}$  provides no information about the relative magnitudes of  $\frac{K_i}{K_W}$  and  $\frac{L_i}{L_W}$ .

- **Corollary 4:** When there are more than two commodities, the ordering of exports and imports by factor intensity (e.g.,  $\frac{K_x}{L_x} > \frac{K_m}{L_m}$ ) is compatible with either ordering of factor abundance,  $\frac{K_i}{K_W} > \frac{L_i}{L_W}$  or  $\frac{K_i}{K_W} < \frac{L_i}{L_W}$ . This means that the Leontief statistic is not valid when there are more than two commodities (and therefore more than two factors).
- **Corollary 5:** If there are only two commodities and one is exported while the other is imported, the ordering of exports and imports by capital intensity coincides with the ordering of factor abundance; that is,  $\frac{K_x}{L_x} > \frac{K_m}{L_m}$  if and only if  $\frac{K_i}{K_W} > \frac{L_i}{L_W}$ . This implies that country  $i$  is capital abundant if it exports the capital-intensive good. Moreover, this corollary shows that even if country  $i$  is a net exporter of both factors, the Leontief statistic would be valid as long as one good is exported and the other is imported.

In summary, the Leontief statistic would have been valid if there were only two commodities and the United States had been a net exporter in one factor and net importer in the other factor, or if it had exported one good and imported the other.

## 11.4 Case study

Let the matrix of factor requirements be given by

$$A = \begin{bmatrix} 4 & 1 & 1 \\ 3 & 2 & 0.5 \\ 1 & 0 & 3 \end{bmatrix}$$

The first row corresponds to capital inputs, the second row to labor inputs and the third row to land inputs.

Suppose the output vectors are

$$Q_i = \begin{bmatrix} 8 \\ 16 \\ 5 \end{bmatrix}, \quad Q_W = \begin{bmatrix} 12 \\ 68 \\ 52 \end{bmatrix}$$

The corresponding endowment vectors are

$$AQ_i = E_i = \begin{bmatrix} 53 \\ 58.5 \\ 23 \end{bmatrix}, \quad AQ_W = E_W = \begin{bmatrix} 168 \\ 198 \\ 168 \end{bmatrix}$$

If the prices of all commodities are one, the share of world income accruing to country  $i$  is equal to

$$\alpha_i = \frac{29}{132} \approx 0.22$$

The factor content of trade is equal to

$$AT_i = E_i - \alpha_i E_W = \begin{bmatrix} 53 \\ 58.5 \\ 23 \end{bmatrix} - 0.22 \begin{bmatrix} 168 \\ 198 \\ 168 \end{bmatrix} = \begin{bmatrix} 16.04 \\ 14.94 \\ -13.96 \end{bmatrix}$$

Hence, country  $i$  is a net exporter of the services of capital and labor, and a net importer of the services of land.

The implied commodity trade vector is

$$T_i = \begin{bmatrix} 5.36 \\ 1.04 \\ -6.44 \end{bmatrix}$$

Partitioning this into export ( $X_i$ ) and import ( $M_i$ ) vectors yields

$$X_i = \begin{bmatrix} 5.36 \\ 1.04 \\ 0 \end{bmatrix}, \quad M_i = \begin{bmatrix} 0 \\ 0 \\ 6.44 \end{bmatrix}$$

The factor contents of exports and imports are then

$$AX_i = \begin{bmatrix} 22.48 \\ 18.16 \\ 5.36 \end{bmatrix}, \quad AM_i = \begin{bmatrix} 6.44 \\ 3.22 \\ 19.32 \end{bmatrix}$$

For instance, country  $i$  exports 22.48 units of capital and imports 6.44 units, while it exports 18.16 units of labor and imports 3.22 units. The resulting *Leontief statistic* is therefore approximately 0.62, leading to the erroneous conclusion that country  $i$  is relatively labor-abundant.

However, the true ordering of factor abundance is determined by the ratio of country  $i$ 's

endowments to the world's endowments:

$$\frac{K_i}{K_W} = 0.315, \quad \frac{L_i}{L_W} = 0.295$$

This ranking reveals that country  $i$  is, in fact, *relatively capital-abundant*. It is worth noting that this inconsistency between the *Leontief statistic* and the true factor abundance ordering is precisely the issue highlighted in *Corollary 4*.

Finally, according to the *Heckscher–Ohlin–Vanek Theorem*, since  $\frac{T_i}{T_W} \approx 0.14 < \alpha_i \approx 0.22$ , country  $i$  is a net importer of land services, as previously noted.

## 11.5 Leontief's Data Revisited

Table 6 presents Leontief's original summary data, showing that  $\lambda = \frac{(K_x/L_x)}{(K_m/L_m)} < 1$ .

As reported in Table 7, the United States in 1947 was a net exporter of both capital and labor services. Consequently, the *Leontief statistic* fails to correctly reveal the country's relative factor abundance between capital and labor.

Table 7: Additional information on trade and endowments

Trade or Factor	Value
Exports	\$16678.4 million
Imports (competitive)	\$6175.7 million
Net exports of capital services ( $K_T$ )	\$23450 million
Net exports of labor services ( $L_T$ )	1.990 million man-years
Capital-labor intensity of trade ( $\frac{K_T}{L_T}$ )	11783

The appropriate comparison is presented in Table 7. Since net exports are substantially more capital-intensive than consumption, the United States is revealed by its trade pattern to be relatively well endowed with capital compared to labor. Notably, applying any of equations (11.3.2), (11.3.3), or (11.3.4) to the data in Table 7 yields the same conclusion.

Table 8: Capital intensity of consumption, production and trade

Trade or Factor	Production	Net Exports	Consumption
Capital	\$328519 million	\$23450 million	\$305069 million
Labor	47.273 million man-years	1.99 million man-years	45.28 million man-years
Capital/labor	6949	11783	6737

## 11.6 Exercises

1. Consider the following

$$Q_W = \begin{bmatrix} 76 \\ 83 \\ 79 \end{bmatrix}, \quad C_i = \begin{bmatrix} 2.28 \\ 2.49 \\ 2.37 \end{bmatrix}, \quad T_i = \begin{bmatrix} 0.32 \\ 0.06 \\ -0.07 \end{bmatrix}$$

The total factor requirements matrix is

$$A = \begin{bmatrix} 0.3 & 0.2 & 0.2 \\ 0.1 & 0.2 & 0.2 \\ 0.1 & 0.2 & 0.3 \end{bmatrix}$$

1. Compute the share of world income accruing to country  $i$ .
  2. Determine the production vector for country  $i$ .
  3. Calculate the factor content of net exports for country  $i$ .
  4. Identify which factor country  $i$  is relatively abundant in. Would the *Leontief statistic* be consistent in this case?
2. Consider the following endowments:

$$E_i = \begin{bmatrix} 30.45 \\ 15.25 \\ 43.05 \end{bmatrix}, \quad E_W = \begin{bmatrix} 823 \\ 847 \\ 1050 \end{bmatrix}$$

Prices are given by  $\mathbf{P} = (1, 2, 3)$ , and the matrix of factor requirements is

$$A = \begin{bmatrix} 5 & 4 & 10 \\ 6 & 6 & 2 \\ 9 & 4 & 4 \end{bmatrix}$$

1. Determine the production vector for country  $i$  and for the world.
  2. Compute the production vector for country  $i$ .
  3. Derive the export and import vectors.
  4. Identify the factors in which country  $i$  is a net exporter and a net importer. Does your answer align with the predictions of the Heckscher–Ohlin–Vanek Theorem?
3. Considering the example developed in [Section 8.8](#):

1. Compute the *Leontief statistic*. Assess whether it is valid to infer the country's relative factor abundance in capital or labor based on this statistic.

## 12 Increasing Returns, Monopolistic Competition, and International Trade

Traditional trade theory, as developed through the Ricardian and Heckscher–Ohlin models, explains the gains from trade in terms of *comparative advantage* arising from differences in technology or factor endowments. However, empirical evidence—most notably the substantial volume of *intra-industry trade* observed among similar, high-income economies—cannot be fully accounted for within these classical frameworks.

The advent of *new trade theory*, pioneered by Krugman (1979), expanded the analytical foundations of international trade by introducing *increasing returns to scale* and *monopolistic competition* into the theoretical structure. These models demonstrate that even countries identical in technologies, endowments, and preferences can gain from trade through specialization and an expansion in the range of available products.

### 12.1 The model

Consider an economy with a single scarce factor of production, labor. The economy is capable of producing a large number of goods, indexed by  $i$ . Goods are ordered such that those actually produced are numbered from 1 to  $n$ , where  $n$  is assumed to be large.

#### 12.1.1 The Consumer side

All residents are assumed to share a common, symmetric, and additively separable utility function given by

$$U = \sum_{i=1}^n u(x_i), \quad u'_i(x_i) > 0, \quad u''_i(x_i) < 0 \quad (12.1.1)$$

where  $x_i$  denotes the consumption of the  $i$ th good,  $u'_i(x_i)$  is the marginal utility of good  $i$ , and  $u''_i(x_i)$  is the derivative of the marginal utility of good  $i$  with respect to  $x_i$ .

Given a budget constraint, the maximization problem yields the following first-order condition:

$$\lambda = \frac{u'_i(x_i)}{p_i} \quad (12.1.2)$$

Defining the price elasticity of consumption for good  $i$ , and using equation (12.1.2), this relationship can be expressed as

$$\varepsilon_i(x_i) \equiv \frac{\partial x_i}{\partial p_i} \cdot \frac{p_i}{x_i} = -\frac{u'_i(x_i)}{x_i \cdot u''_i(x_i)} \quad (12.1.3)$$

and where it is assumed that  $\frac{\partial \varepsilon_i}{\partial x_i} < 0$ . The term  $\varepsilon_i$ <sup>9</sup> will turn out to represent the elasticity of

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<sup>9</sup>This elasticity is expressed in absolute value. Therefore, equation (12.1.3) includes a negative sign to ensure a positive expression, since  $u''_i < 0$ .

demand faced by an individual producer.

### 12.1.2 Firm's side

Each firm produces a unique variety of the good, but all goods belong to the same industry. Consequently, each firm possesses some degree of market power due to product differentiation, implying monopolistic competition. It is assumed that all firms share the same technology and, therefore, the same production and cost functions.

Labor input required to produce each variety is assumed to be a linear function of output:

$$l_i = \alpha + \beta q_i, \quad \alpha, \beta > 0 \quad (12.1.4)$$

where  $l_i$  denotes the labor used in producing good  $i$ ,  $q_i$  is the output of good  $i$ , and  $\alpha$  represents the fixed labor requirement. Note that equation (12.1.4) can be rewritten as

$$q_i = \frac{l_i - \alpha}{\beta} \quad (12.1.5)$$

Thus,  $\frac{\alpha}{\beta}$  represents the fixed amount of labor required to initiate production (e.g., administrative or setup labor), while  $\beta$  denotes the variable labor requirement per additional unit of output  $q_i$ . In other words, firms operate under decreasing average costs and constant marginal costs. Market equilibrium requires that the total production of each good equals the sum of individual consumptions. Identifying individuals with workers, aggregate production must therefore equal the consumption of a representative individual multiplied by the labor force:

$$q_i = Lx_i \quad (12.1.6)$$

The equilibrium in the labor market requires that total labor demand across all firms equals the available labor supply:

$$L = \sum_{i=1}^n l_i = \sum_{i=1}^n (\alpha + \beta q_i) \quad (12.1.7)$$

There are three variables to be determined in the model: the price of each good relative to wages,  $\frac{p_i}{w}$ ; the output per good,  $q_i$ ; and the number of goods produced,  $n$ .

Because all individuals share identical preferences across goods and all goods are produced with the same technology, symmetry ensures that every good produced will have the same price and be produced in the same quantity.

$$p = p_i, \quad q = q_i, \quad \forall i = 1, \dots, n \quad (12.1.8)$$

Each individual firm, being small relative to the entire economy, takes the behavior of other firms as given and ignores the effects of its own decisions on theirs. Owing to the symmetry established earlier, subscripts can be dropped. The representative firm then chooses its price

to maximize profits:

$$\pi = p(q) \cdot q - w(\alpha + \beta q) \quad (12.1.9)$$

The first order condition is given by

$$\frac{\partial p(q)}{\partial q} \cdot q + p(q) - \beta w = 0 \quad (12.1.10)$$

Equation (12.1.10) can be expressed as

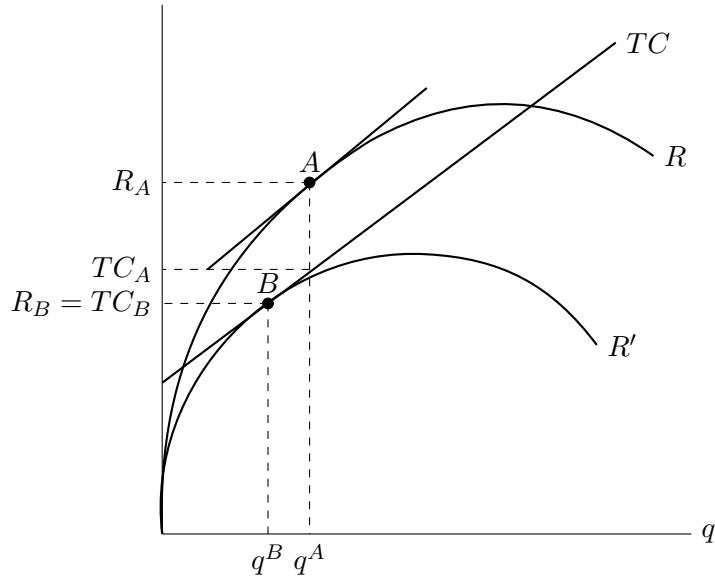
$$p = \frac{\varepsilon_i}{\varepsilon_i - 1} \beta w \quad (12.1.11)$$

Note that in equation (12.1.11), the price exceeds marginal cost since  $\frac{\varepsilon_i}{\varepsilon_i - 1} > 1$ , reflecting firms' market power under monopolistic competition. Equation (12.1.11) thus represents the first fundamental relationship of this model.

In the long run, however, profits are driven to zero by the entry of new firms, giving rise to the second key relationship of the model. The horizontal axis in Figure 22 measures the output of the representative firm, while the vertical axis measures revenue and cost in wage units. Total cost is represented by the  $TC$  curve, and  $OR$  and  $OR'$  denote revenue functions.

Initially, given the number of firms in the market, each firm faces a revenue function  $OR$ . The firm chooses its output to equate marginal revenue with marginal cost at point  $A$ . At this point, price (average revenue) exceeds both marginal and average cost, generating positive profits. These profits attract new entrants, increasing the number of firms in the market. As entry continues, the elasticity of demand faced by each firm rises, reducing its market power and shifting the revenue function inward to  $OR'$ . Equilibrium is ultimately reached at point  $B$ , where marginal revenue equals marginal cost, average revenue equals average cost, and profits are zero.

Figure 22: Equilibrium in Monopolistic Competition  
Revenue, total cost



Based on the previous discussion, imposing the zero-profit condition in the long run, that is, setting equation (12.1.9) equal to zero, yields the second fundamental relationship of the model.

$$p = \left( \frac{\alpha}{q} + \beta \right) w \quad (12.1.12)$$

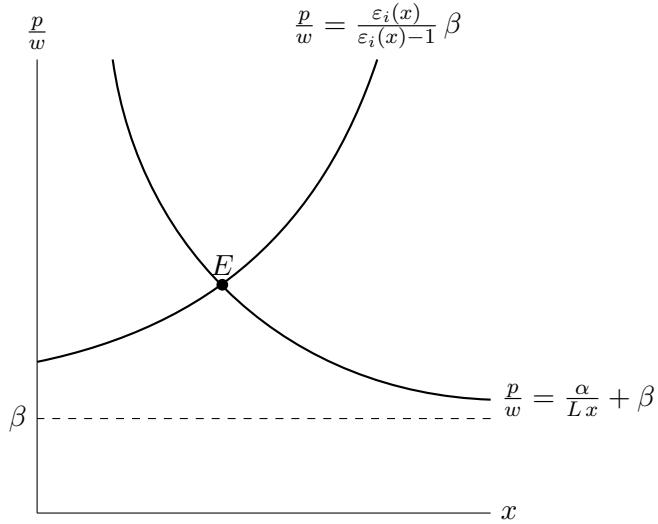
Equation (12.1.12) can be expressed in terms of consumption by substituting equation (12.1.6). Furthermore, both equations (12.1.11) and (12.1.12) can be rewritten in wage units.

$$\frac{p}{w} = \frac{\varepsilon_i(x)}{\varepsilon_i(x) - 1} \beta \quad (12.1.13)$$

$$\frac{p}{w} = \frac{\alpha}{Lx} + \beta \quad (12.1.14)$$

Equilibrium in the model is achieved when equations (12.1.13) and (12.1.14) intersect. This condition determines the equilibrium consumption per good (which is identical across goods due to symmetry) and the relative price expressed in wage units. The equilibrium is illustrated in Figure 23.

Figure 23: Equilibrium in the model



From equation (12.1.7), and given the symmetry assumption, the equilibrium number of goods is determined as

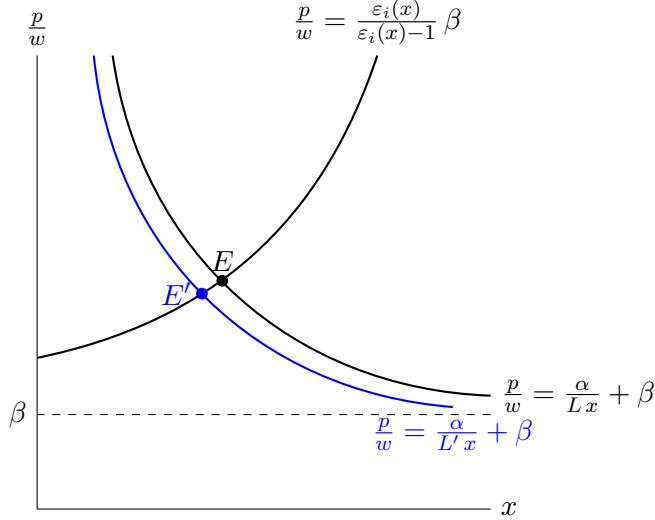
$$n = \frac{L}{\alpha + \beta q^*} \quad (12.1.15)$$

## 12.2 Case study: An increase in labor endowment

When the labor endowment increases, equation (12.1.13) remains unchanged, whereas in equation (12.1.14), for each level of  $x$ , the ratio  $\frac{p}{w}$  rises as  $L$  increases. This causes the zero-profit curve to shift downward, leading to a decrease in both  $\frac{p}{w}$  and  $x$  in the new equilibrium, as illustrated in Figure 24.

Solving for  $q$  in equation (12.1.12) shows that output per firm ( $q$ ) increases with higher relative wages. From equation (12.1.15), both the numerator and denominator increase with  $L$ , but the numerator rises proportionally more, implying that the number of varieties ( $n$ ) expands. Consequently, welfare improves because real wages ( $\frac{w}{p}$ ) increase and product variety also rises. An increase in labor endowment expands the size of the market. As a result, firms are able to produce a larger output ( $q$ ), allowing fixed costs to be spread over a greater production scale. This reduces average costs and, consequently, lowers the relative price ( $\frac{p}{w}$ ).

At the same time, the increase in market size encourages entry, leading to a higher number of firms ( $n$ ). Consumers therefore allocate their expenditure across a wider range of varieties, so that consumption per variety ( $x$ ) decreases, even though the relative price of each good declines.

Figure 24: Effect of an increase in  $L$  in the model


### 12.3 Effects of Trade

Suppose there exist two economies that are initially unable to trade. To highlight the main argument, assume that both countries share identical preferences and technologies. Since this is a one-factor model, differences in relative factor endowments does not apply here. In a conventional trade framework, there would be no reason for trade to occur between these economies, nor any potential gains from doing so. In this model, however, trade and welfare gains will both arise.

Consider the case in which trade is opened between the two countries at zero transportation cost. Symmetry ensures that wage rates are equalized across countries and that the price of any good produced in either economy is identical. The effect of trade is therefore equivalent to an expansion in each country's labor force, leading to an increase in both the scale of production ( $q$ ) and the range of goods available for consumption ( $n$ ). Consequently, welfare rises in both countries, driven by higher real wages ( $w/p$ ) and greater product diversity. Goods  $1, \dots, n$  are produced in the home country, while goods  $n+1, \dots, n+n^*$  are produced in the foreign country. Each individual maximizes their utility function, which can be expressed as a function of consumption of home-produced and foreign-produced goods, given by

$$U = \sum_{i=1}^n v(x_i) + \sum_{i=n+1}^{n+n^*} v(x_i^*), \quad (12.3.1)$$

The number of goods produced in each country is proportional to its labor force:

$$n = \frac{L}{\alpha + \beta x}, \quad n^* = \frac{L^*}{\alpha + \beta x}. \quad (12.3.2)$$

Note that in equation (12.3.2), the denominator is identical for both countries, since under

trade they face the same prices and wage rate. Consequently, consumption of each type of good will also be identical across countries.

Since all goods have identical prices and consumption levels, expenditures on each country's goods will be proportional to the size of its labor force. The share of imports in the home country's total expenditure is given by  $n^*/(n + n^*)$ . The value of imports for each country equals national income multiplied by the import share, which, using equation (12.3.2), can be expressed as

$$M = wL \cdot \frac{L^*}{L + L^*}, \quad M^* = wL^* \cdot \frac{L}{L + L^*} \quad (12.3.3)$$

If both countries have identical labor endowments, the value of imports for each country will equal one-half of national income, and each country's income will represent one-half of world income. The key insight from this model is that economies of scale alone can generate both trade and gains from trade, even in the absence of international differences in preferences, technology, or factor endowments.

## 12.4 Exercises

1. Consider a country with a population of one million individuals. All firms operate under monopolistic competition within the same industry. Each firm requires 1000 workers as a fixed labor cost to start production, and an additional 50 workers per unit of output. Consumers share identical additive preferences, where utility derived from consumption of good  $i$  is given by

$$u(x_i) = x_i - \frac{x_i^2}{2}$$

1. Determine the relative price, consumption per good, and the equilibrium number of goods.
  2. Illustrate the equilibrium. Demonstrate the slope and concavity of each curve in the model.
  3. Compute the elasticity of consumption in equilibrium.
  4. Suppose there exists another country identical in every respect except that its population is two million. Determine the equilibrium for this second country.
2. Based on the model studied in this chapter, analyze how the relative price, consumption per good, production per good, number of goods, and welfare change in each of the following cases:
  1. A decrease in the labor endowment.
  2. An increase in total fixed costs, with variable costs unchanged.
  3. An increase in total variable costs, with fixed costs unchanged.

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