

The Digital Economist

Lecture 2 -- Production and Production Possibilities

An ideal place to start our discussion about economics is with the concept of production and production technology. Before there are any goods available for trade among individuals or for individual consumption, these good must be produced using available resources and technology.

THE PRODUCTION FUNCTION

Production refers to the conversion of inputs, the **factors of production**, into desired output. This relationship is about making efficient use of the available technology and is often written as follows:

$$X_i = f(L,K,M,R)$$

where X_i is the quantity produced of a particular (i^{th}) good or service and:

- **L** represents the quantity of labor input available to the production process.
- **K** represents capital input, machinery, transportation equipment, and other types of intermediate goods.
- **M** represents land, natural resources and raw material inputs for production, and
- **R** represents entrepreneurship, organization and risk-taking.

A positive relationship exists among these inputs and the output such that greater availability of any of these factors will lead to a greater potential for producing output. In addition, all factors are assumed to be essential for production to take place. The functional relationship $f(\cdot)$ represents a certain level of technology and know how, that presently exists, for conversion these inputs into output such that any technological improvements can also lead to the production of greater levels of output.

Production in the Short Run

In order to better understand the technological nature of production, we distinguish between **short run** production relationships: where only one factor input may vary (typically labor) in quantity holding the other factors of production constant (i.e., capital and/or materials) and the **long run**: where all factors of production may vary. The short run allows for the development of a simple two variable model to understand the behavior between a single variable input and the corresponding level of output. Thus we can write:

$$X_i = f(L;K,M,R)$$

or

$$X_i = f(L)$$

For example we could develop a short run model for agricultural production where the output is measured as kilograms of grain and labor is the variable input. The fixed factors of production include the following:

- 1 plow
- 1 tractor.... capital
- 1 truck
- 1 acre of land
- 10 kilograms of seed grain

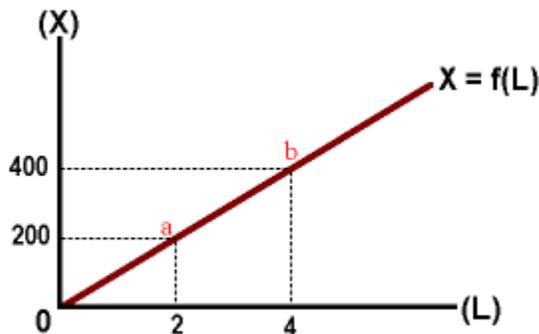
We might hypothesize the production relationship to be as follows:

Table 1, Production (*Constant Marginal Productivity*)

Input (L)	Output (X_{grain})	MP_L
0	0 kg	-
1	100	100
2	200	100
3	300	100
:	:	100
10	1000	100

In this example we find that each time we add one more unit of labor, output increases by 100 kg. The third column MP_L defines this relationship. This column measures the **marginal productivity of labor** -- a measure of *the contribution of each additional unit of labor input to the level of output*. In this case, we have a situation of **constant marginal productivity** that is unrealistic with production in the short run. Constant marginal productivity implies that as labor input increases, output always increases without bound -- a situation difficult to imagine with limited capital and one acre of land.

Figure 1, A Production Function (*Constant Marginal Productivity*)



A more realistic situation would be that of **diminishing marginal productivity** where increasing quantities of a single input lead to *less and less* additional output. This property is just an acknowledgment that it is impossible to produce an infinite level of output when some factors of production (machines or land) fixed in quantity. Numerically, we can model diminishing marginal productivity as follows:

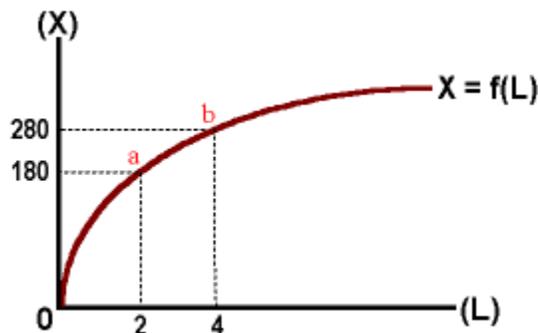
Table 2, Production (*Diminishing Marginal Productivity*)

Input (L)	Output (X_{grain})	MP_L
0	0 kg	-
1	100	100
2	180	80
3	240	60
4	280	40
5	300	20
6	300	0

In this case, additional labor input results in additional output. However, the contribution of each additional unit of labor is less than previous units such that the sixth unit of labor contributes nothing to output. With 5 or 6 workers, the available amount of land cannot support additional output.

A short run production relationship can be modeled in the diagram below. In this example, labor is the variable factor input and land, capital, and entrepreneurship are fixed in quantity. There is a positive relationship between labor input and output levels. However, as additional labor is used, less and less additional output is produced. The shape of this production function is consistent with the law of diminishing marginal productivity.

Figure 2, A Production Function (*Diminishing Marginal Productivity*)



PRODUCTION POSSIBILITIES

If we extend our model of production to two (or several) goods, we can develop a more realistic notion of production relationships. In a world of scarce resources, business firms producing different goods are competing for the same pool of factor inputs. In the short run labor is available for the production of one or a combination of goods. However, the desire to increase production of one good 'X' will come at the expense of another good 'Y' as labor or other resources are reallocated from the first good to the second.

In the table below, we can model this competition for resources between two goods: Apples and Bread. In this example, additional units of labor directed to bread production allows for producing in the range of 0 – 210 units of bread. Separately, additional units of labor applied to apple production allows for producing in the range of 0 - 260 units of apples.

Table 3, Production Possibilities: Bread and Apples
(7 units of Labor available)

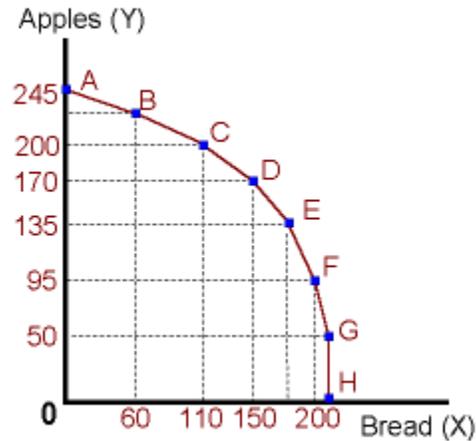
Pt.	X _{Bread}	MP _{L,Bread}	Pt.	Y _{Apples}	MP _{L,Apples}
A	0	-	H	0	-
B	60	60	G	50	50
C	110	50	F	95	45
D	150	40	E	135	40
E	180	30	D	170	35
F	200	20	C	200	30
G	210	10	B	225	25
H	210	0	A	245	20
	200	-10		260	15

Working with an assumption that the amount of labor input is fixed in supply at 7 units, this labor must be shared between bread and apple production. If we happen to be producing 245 units of apples (point A), then all 7 units of labor are being used for this purpose. The desire to produce bread requires a reallocation of labor from apple production to bread production. In the table above, we can show this as a movement from point A to point B. We are able to produce 60 units of bread (0-60 units) but at the sacrifice of producing 20 apples (245-225 units). These 20 apples represent the **opportunity cost** of bread production (i.e., *each unit of bread costs 20/60 unit or 1/3 apple*). If we move from point B to point C, the additional 50 units of bread (60-110), come at the “cost” of 25 apples (225-200 units) – *each bread costs 25/50 or 1/2 apple*. Because of diminishing marginal productivity in production of these two goods, the production of additional units of bread requires that more and more apples are given up. Stated differently, we can say that the opportunity cost of producing bread is increasing. This is known as the **Law of Increasing (Opportunity) Costs**.

The diagram below summarizes the numbers in the above table. Points on the maroon curve -- the **Production Possibilities Frontier** represent an efficient use of resources.

Points within the curve represent inefficient production levels -- resources and technology allow for producing more of good X, good Y, or more of both. Movements along the curve imply that a tradeoff exists in production when resources are scarce or fixed in supply. Finally points (combinations of the two goods) beyond the frontier are unattainable with existing levels of technology and resource availability.

Figure 3, The Production Possibilities Frontier



The Marginal Rate of Transformation

The diagram above helps us observe the slope of the PPF between any two points. This slope, is known as the Marginal Rate of Transformation (MRT), is a measure of the ratio of marginal productivity for each of the two goods.

Specifically:

$$MRT = MP_y / MP_x = \text{Marginal Cost}_x / \text{Marginal Cost}_y$$

$$\text{given that: } \text{Marginal Cost}_i = \text{wage rate} / MP_i$$

This ratio measures the opportunity cost of using resources in producing one good in terms of the alternative use of those resources used in the production of other goods. Given the role of diminishing marginal productivity; as resources are allocated away from good Y towards good X, the opportunity cost (|MRT|), of producing more of good X, increases.

If resources were to be allocated in the opposite direction, the same would be true -- the opportunity cost of producing more of good Y would also increase in terms of foregone production of good X.

See: *The Digital Economist*: http://www.digitaleconomist.com/ppf_4010.html#1

Opportunity Costs and Relative Prices

Suppose that we are producing at point **C** in the diagram below (left). If we transfer one unit of labor away from apple production to bread production, we must give up 30 units of apples and gain 40 units of bread. Thus the opportunity cost of each unit of bread is $3/4$ (0.75) of an apple. Bringing **relative prices** into the picture, we might find that the price of apples ' P_{apples} ' is \$2.00 and the price of bread ' P_{bread} ' is \$3.00. Or,

$$P^R = [P_x / P_y] = [P_{\text{bread}} / P_{\text{apples}}] = 1.50.$$

Stated differently, (as a **Terms of Trade**), we find that we are willing to trade 1 unit of bread for \$3.00 and with that \$3.00, we could then acquire 1.5 units of apples. Or, one unit of bread is *worth* 1.5 units of apples given these prices.

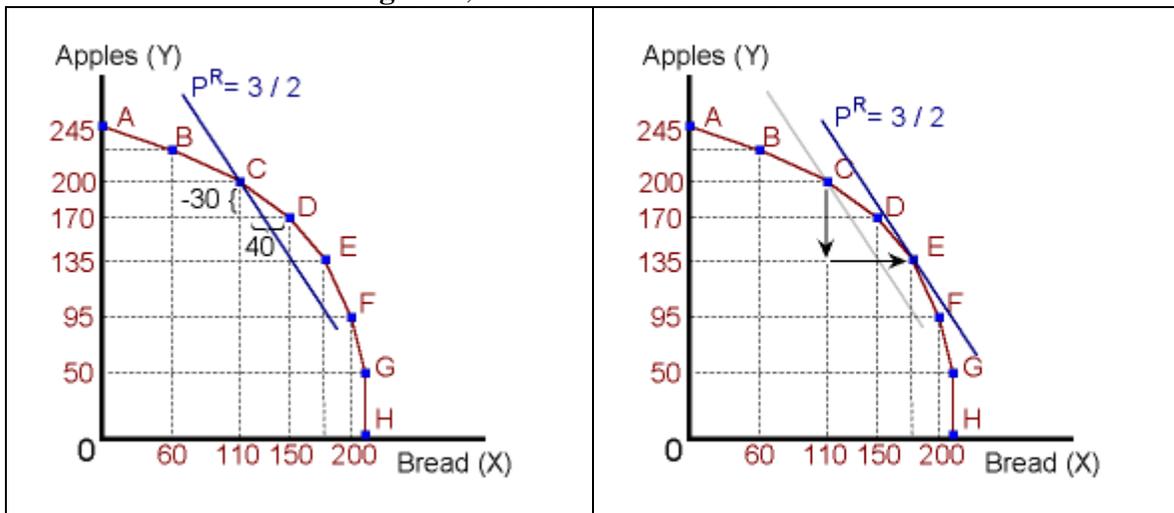
If we compare the relative price (value) of bread to the opportunity cost of bread, we find that the value of bread in terms of apples, at point **C**, is greater than the opportunity cost of producing bread:

One bread is *worth* 1.5 apples
 One bread “costs” 0.75 apples.

or

$$P_{\text{bread}} / P_{\text{apples}} > \text{MRT}$$

Figure 4, the PPF and Relative Prices



From a social point of view, we should be allocating more resources towards bread production and away from apple production. With the reallocation of resources, the opportunity cost of bread production will rise. This reallocation should continue until the following is true:

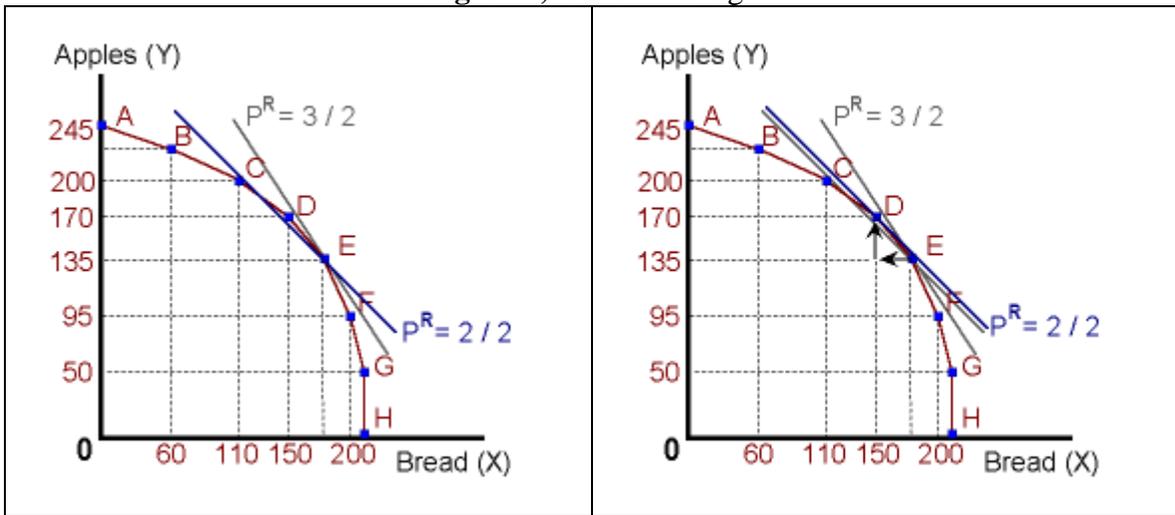
$$P^R = \text{MRT}$$

or

$$P_{\text{bread}} / P_{\text{apples}} = \text{MC}_{\text{bread}} / \text{MC}_{\text{apples}}$$

If the price of bread were to fall, say to \$2.00 per unit, then the relative price of bread would be equal to 1.0 (i.e., each unit of bread is exactly equal to the value of one unit of apples) and $P^R \downarrow$. With this change, the value of bread, in terms of apples, is less than the opportunity costs of producing bread. In this case we should allocate resources away from bread production. This reallocation will cause the opportunity cost of bread to fall until it is just equal to the prevailing relative price.

Figure 5, A Price Change



The Digital Economist

Worksheet #1: Production and Production Possibilities

1. Given the following production data, complete the following table:

Labor (L)	Rice Kilograms	Marginal Product	Labor (L)	Houses Units	Marginal Product
0	0	_____	0	0	_____
1	40	_____	1	2	_____
2	75	_____	2	4	_____
3	105	_____	3	6	_____
4	130	_____	4	8	_____
5	150	_____	5	10	_____
6	165	_____	6	12	_____
7	175	_____	7	14	_____
8	180	_____	8	16	_____
9	180	_____	9	18	_____
10	175	_____	10	20	_____

b. Graph these two production functions below:

Rice



Houses

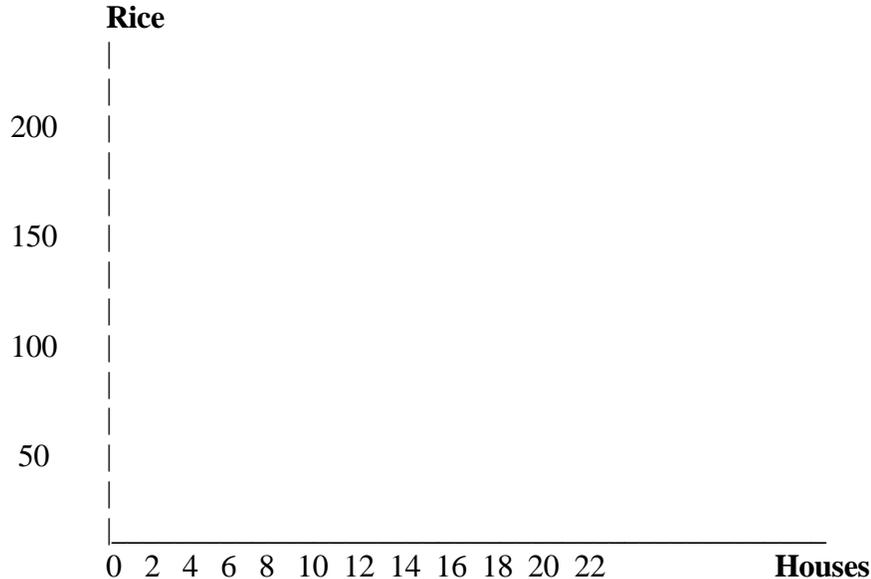


c. How would you characterize the production function for rice (diminishing, constant, or increasing marginal productivity)? _____ How about the production function for houses? _____

d. Is it possible (in the short run) to produce 200 kg of rice? _____ Why or why not?

Worksheet #1, page 2

2. Given the production data on page 1, plot a production possibilities frontier for 6 units of labor to be allocated between rice and housing production.



b. What economic law determines leads to the curvature of the above production possibilities curve? _____

c. Given that only 6 units of labor is available to be allocated between rice and housing production, is it possible to produce 100 kg. of rice and 5 houses? _____ Why or why not? _____ Does this combination of rice and housing production represent an efficient use of resources? _____

d. Assuming that we are currently producing 130 kg. of rice (using 4 units of labor) and 4 houses (using the remaining 2 units of labor). How many kg. of rice must be given up if we transfer one unit of labor away from rice production towards housing production? _____ How many additional houses could we build? _____ What is the *opportunity cost* of each additional house? _____ How are these *opportunity costs* measured? _____

e. Suppose that society values a kg of rice at \$1,000 and values a house at \$15,000. What is the relative price of a house as compared to rice (what is the *rice-value* of a house)? _____

f. Given the opportunity costs of an additional house (in part d) and the relative price of a house (in part e), should resources be allocated towards or away from rice production? _____

g. Show the impact of an increase in the size of the labor force from 6 to 10 workers on the above production possibilities curve.

COMPARATIVE ADVANTAGE AND THE GAINS FROM TRADE

For many years, economists sought to understand the motivations behind the trading and exchange of goods and services among individuals, regions, and nations.

It was first thought that trade was the result of a given nation exploiting its Absolute Advantage in production of goods relative to the productive ability of other nations. A country is said to have the **Absolute Advantage** in production if it can produce the same amount of output with *less input* relative to other countries. For example, given the following data:

	1 kg. of Rice	1 kg. of Tea
Indonesia	5 hrs. labor	2 hrs. labor
Thailand	3 hrs. labor	6 hrs. labor

In this case, Indonesia has the absolute advantage in tea production and Thailand the absolute advantage in rice production. Based on this concept of absolute advantage, one would conclude that Indonesia should devote its resources to and specialize in tea production. Thailand should specialize in rice production and export some of this rice in trade for Indonesia's tea.

However, it was often observed that one country possessed the absolute advantage in the production of both (all) goods. For example:

	1 kg. of Rice	1 kg. of Tea
Indonesia	4 hrs. labor	2 hrs. labor
Thailand	5 hrs. labor	15 hrs. labor

We might expect that in such a case, this country (Indonesia in the above example) would find it more efficient to engage in production of all goods to meet domestic consumption needs and avoid relationships with its economic partners. In reality, trade still takes place among nations, even though one country lacks an absolute advantage in the production of any good.

Comparative Advantage

Trade, and the gains from trade, is better explained by the concept of **Comparative Advantage**. This concept is based on the notion of *opportunity costs* within one country as compared to its economic partners. For example, in table 5 above we find that in Indonesia, in order to produce one more unit of rice, resources must be pulled from their next best use -- tea production. Specifically,

1 unit of rice will require the sacrifice of **2 units of tea**

since 1 kg. of rice requires 4 hours of labor input that must be drawn from tea production.

Pulling 4 labor hours away from tea, means giving up the production of 2 kg. of tea (each 'kilo' of tea requiring 2 labor hours). This sacrifice of tea represents the opportunity "cost" of producing each additional unit of rice. Thus in the case of Indonesia

1 unit of rice will "cost" 2.0 units of tea

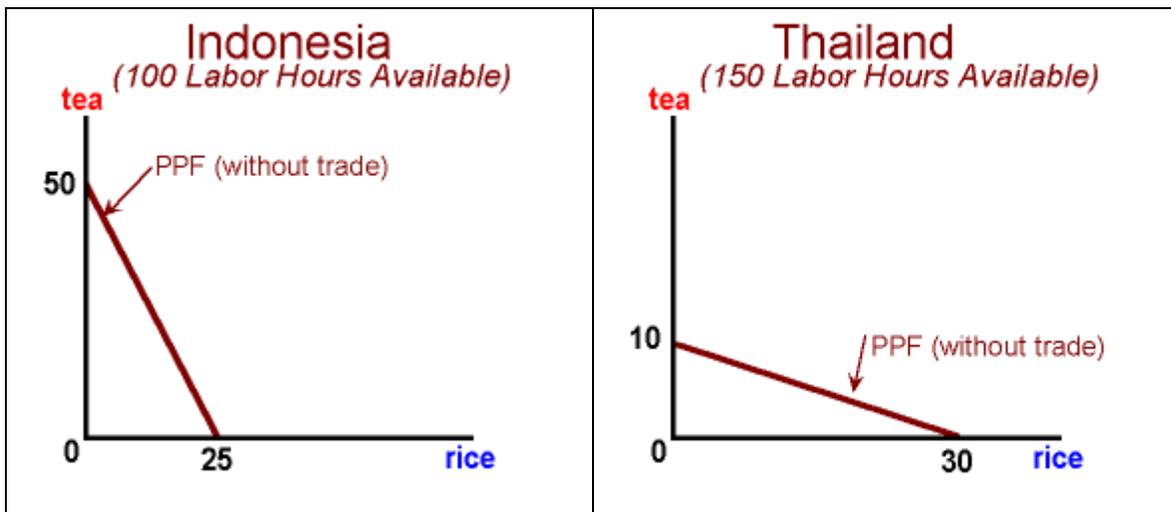
1 unit of tea will "cost" 0.5 units of rice

and in the case of Thailand

1 unit of tea will "cost" 3.0 units of rice

1 unit of rice will "cost" 0.333 units of tea

Thus the *opportunity costs* of rice production (1 kg.) are lower in Thailand [0.333 kg. of tea rather than 2.0 kgs. of tea]. Thailand has the *comparative advantage* in rice production and should specialize in production of that good.



In Indonesia, the *opportunity costs* of tea production (1 kg.) are lower than in Thailand [0.50 kg. of rice rather than 3.0 kgs. of rice]. Indonesia has the *comparative advantage* in tea production and should specialize in production of that good.

The Gains from Trade

Suppose that Indonesia does specialize in tea production and Thailand specializes in rice production. Chances are that consumers in both countries would like to be able to consume both goods. Thus Indonesia would like to import some rice in trade for tea and Thailand would like to import tea in trade for rice.

It would be necessary for these two countries to agree on a **Terms of Trade** (ToT) to allow the exchange process to go forward.

Suppose that these two countries agree on a ToT of:

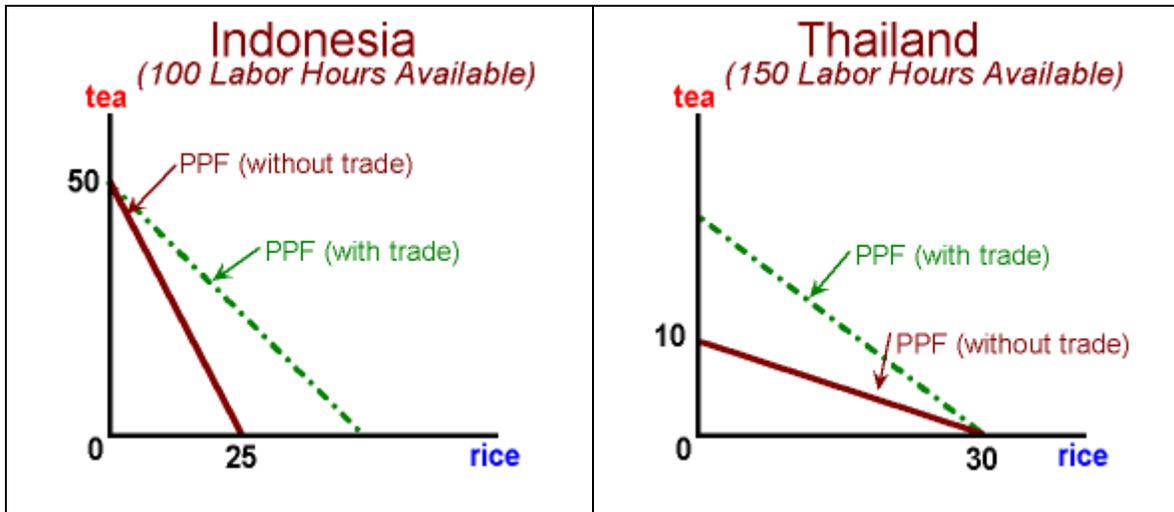
$$1 \text{ rice} = 1 \text{ tea.}$$

Indonesia would benefit since that country could now acquire 1 rice at a trading cost of 1 tea which is less than the domestic opportunity costs of 2.0 kg's. of tea.

Thailand would benefit since that country could now acquire 1 tea at a trading cost of 1 rice which is less than the domestic opportunity costs of 3.0 kg's. of rice.

As long as the ToT is less than domestic opportunity costs in each country, an incentive for trade will exist. For the case of Indonesia and Thailand the ToT (tea : rice) will fall in the following interval:

$$\{\text{Thailand's opp. costs}\} 1:3 < \text{ToT} < 2:1 \{\text{Indonesia's opp. costs}\}$$



See also:

The Digital Economist: http://www.digitaleconomist.com/comparative_advantage.html

The Commanding Heights: http://www.pbs.org/wgbh/commandingheights/lo/story/ch_menu_03.html

- **Episode 3:** Chapters 2, 3, 4, & 5.

The Digital Economist

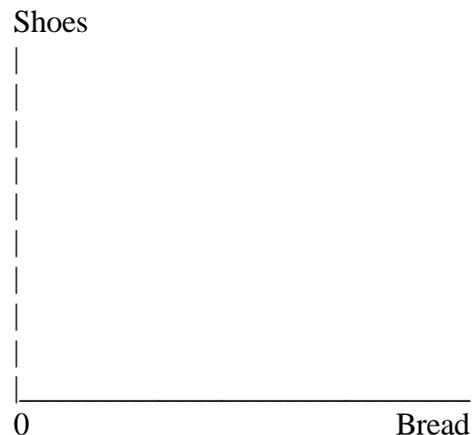
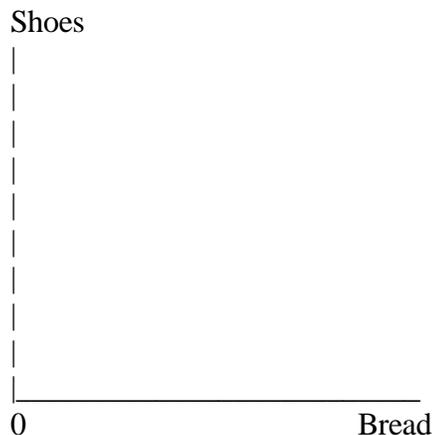
Worksheet #2: Comparative Advantage and Gains from Trade

1. Given the following production data for John and Mary:

Mary can produce 3 loaves of Bread per hour of work *or* she can produce 6 pairs of shoes per hour of work.

John can produce 5 loaves of bread per hour of work *or* he can produce 3 pairs of shoes per hour of work.

- Who has the *Absolute Advantage* in Bread production? _____
 - Who has the *Absolute Advantage* in Shoe production? _____
 - Who has the *Comparative Advantage* in Bread Production? _____
 - What is the *opportunity cost* of producing bread for this individual? _____
 - Who has the *Comparative Advantage* in Shoe production? _____
 - What is the *opportunity cost* of producing shoes for this individual? _____
 - Who should specialize in Bread production? _____
- h. On the diagrams below, draw a production possibilities curve based on each person (Mary and John) working a single 8-hour day. On the left diagram assume that these two individuals produce both goods individually (i.e., draw a separate PPC for each individual in the same diagram). On the right diagram assume that these two individuals take advantage of their respective comparative advantages and draw the combined PPC.



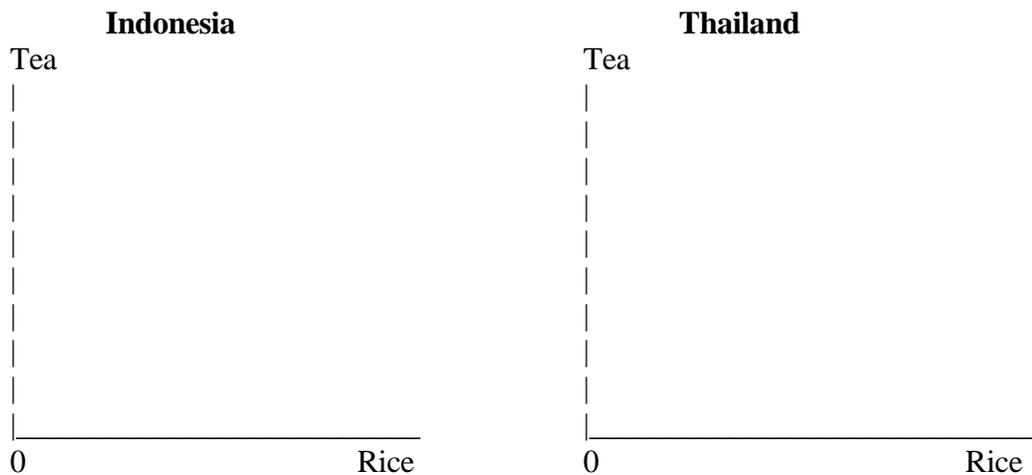
Worksheet #2, page 2

2. Given the following production data for two countries, **Indonesia** and **Thailand**:

	Indonesia	Thailand
<i>Production of:</i>		
one unit of rice requires:	4 labor hours	2.5 labor hours
one unit of tea requires:	2 labor hours	7.5 labor hours

a. Calculate the opportunity costs of Rice and Tea production in both countries and define which country has the *Comparative Advantage* in Rice production and which country has the *Comparative Advantage* in Tea production.

b. Plot a production possibilities curve for each country assuming that **Indonesia** has 100 labor hours available and **Thailand** has 150 labor hours available:



c. On each diagram, plot a **Terms of Trade** line corresponding to 1 unit of Rice for 1 unit of Tea assuming that each country specializes in that product where they have a Comparative Advantage.

Be sure that you understand the following concepts and terms:

- Production Function
 - Production Technology
 - Factors of Production
 - Production in the Short run
 - Production in the Long Run
 - Fixed Factors of Production
 - Variable Factors of Production
 - Marginal Productivity (of Labor)
 - Constant Marginal Productivity
 - Diminishing Marginal Productivity
 - Production Possibilities
 - Production Possibilities Frontier (PPF)
 - Relative Prices
 - Opportunity Costs
 - Marginal Rate of Transformation
 - Absolute Advantage
 - Comparative Advantage
 - Terms of Trade
 - Gains from Trade
-

Suggested Readings:

- Greider, William, *One World, Ready or Not, the manic logic of global capitalism* 1997, Touchstone Books.
 - Stiglitz, Joseph E., *Globalization and its Discontents*, 2002, W.W. Norton & Co.
 - Yergin, Daniel, and Joseph Stanislaw, *The Commanding Heights, the Battle for the World Economy*, 1998, Touchstone Books.
-

See also:

www.pbs.org/commandingheights/ -- The Commanding Heights, the Battle for the World Economy –
Episode 3.