Lecture 2:
Technology, Population and Growth

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Goal

- Economists, Model and Data
  - Modeling ideas
- Modeling a Dynamic Economy
  - Isocost curve
  - Relative price
  - labor vs. energy intensive option of technology
- Malthusian Economics and Diminishing Product of Labor

Part 1. Basic Concept of a Model

- Note that an economy as a whole is a complicated mechanism where a lots of individuals and parties interact with one another. Consequences of one's action may not just be limited to oneself but may affect other innocent parties as well (externalities).
- What we want to do is say something about the economy. The platform for an economy need not be at a country level, it could be at a micro level starting from your household itself, where household members interact with one another and the outside sector. Modeling a household's behavior to the tiniest of detail is still complicated (even with so few people).
- You want the model to incorporate what is necessary but then throw away mundane little details that are unnecessary. Bigger picture!
- You can think of a map as an analogy of what a good model may look like. A map obviously does not capture the tiniest of details; if it did, then the map would be overwhelming and impossible to follow. Instead what a good map does is it captures prominent landmarks so that you can track your destination in relation to these landmarks. So, this "good map" is acting as a good model.

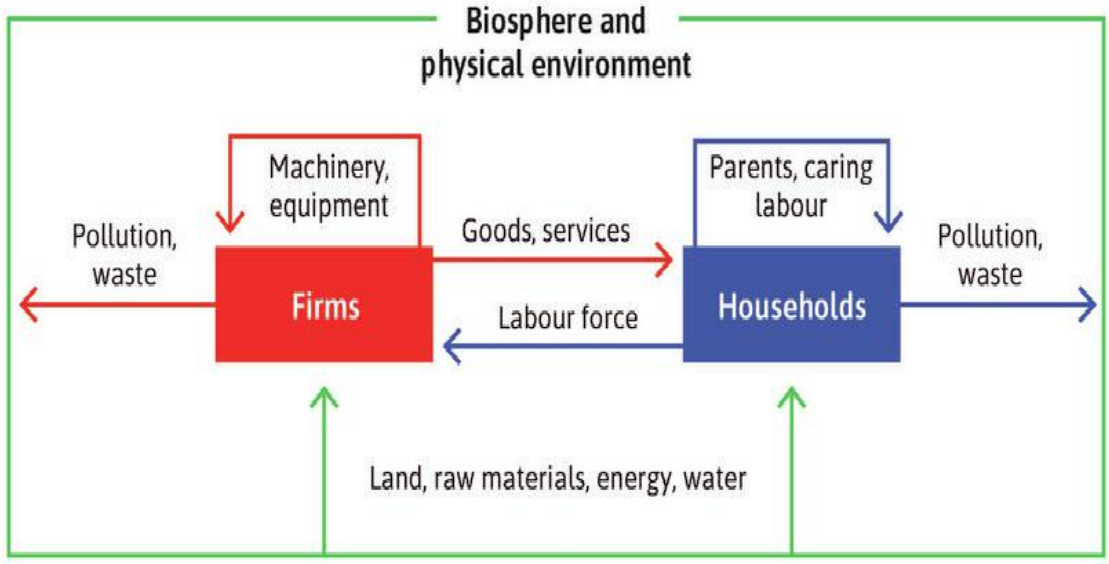
Model – Steps to Consider

1. Set up of the model: This is a simplified description of conditions under which individuals take actions.
2. Next, describe what determines the actions that people take.
3. How each action may affect one another.
4. Focus on outcome of the action (most often known as the equilibrium).
5. Try and gather more information as to how the equilibrium outcome might change if certain variables are changed in the model.

As a whole, a good model should be: *i*) clear and on point, *ii*) should help us understand useful concepts of the reality, *iii*) predictions of the model should be backed by empirical evidence, and *iv*) should be useful.

A Simple Economic Model

Figure 1: Model of Economy: Households, Firms and Biosphere



Picture taken from Core Economy project. Scientists often use figures, graphs and mathematical tools to depict models. The figure shows how participants in the economy, households and firms, interact with one another by exchanging their goods and services. Also, there is a constant interaction between the agent that makes up an economy and their biosphere.

Some Necessary Elements

- Incentive: All economic models in a way is designed such that they incorporate human actions in reponse to incentives. Given the choices available, people try and do as well as they can. In other words, they pick the choice that makes them better. If a choice is incentivized, in many situations, humans are more likely to pick that choice compared to its alternative.
- Relative Price: Generally, it is not the absolute price but the relative price that matters. Now, when you go shopping at a grocery store A, you not only are concerned about the absolute price in store a but you are comparing the relative price of goods between store A and grocery store B.
- Economic rent: Economic rent is the benefit that you get from choosing the best possible option compared to the second best option.

$$\begin{aligned}\text{Economic Rent from option A} &= \text{Benefit from option A} \\ &\quad - \text{Benefit from the next best option}\end{aligned}$$

Economic Rent and Decision Criteria

- Note that Economic Rent is very different from the rent you actually pay your landlord.
- The concept of Economic Rent brings up the following decision rules:
  - if option A gives you economic rent and if taking that option is not hurting anyone, then pick option A.
  - if you have already picked option A, then keep picking option A.
- Consider an intuitive example. You are presented with three options to conduct in your free time: *i*) playing soccer, *ii*) playing guitar, and *iii*) going hiking. You like option *i*) more than option *ii*) and option *ii*) more than option *iii*). If your action does not affect anyone else (including the Biosphere), you would play soccer during your free time. Playing soccer provides you with economic rent.

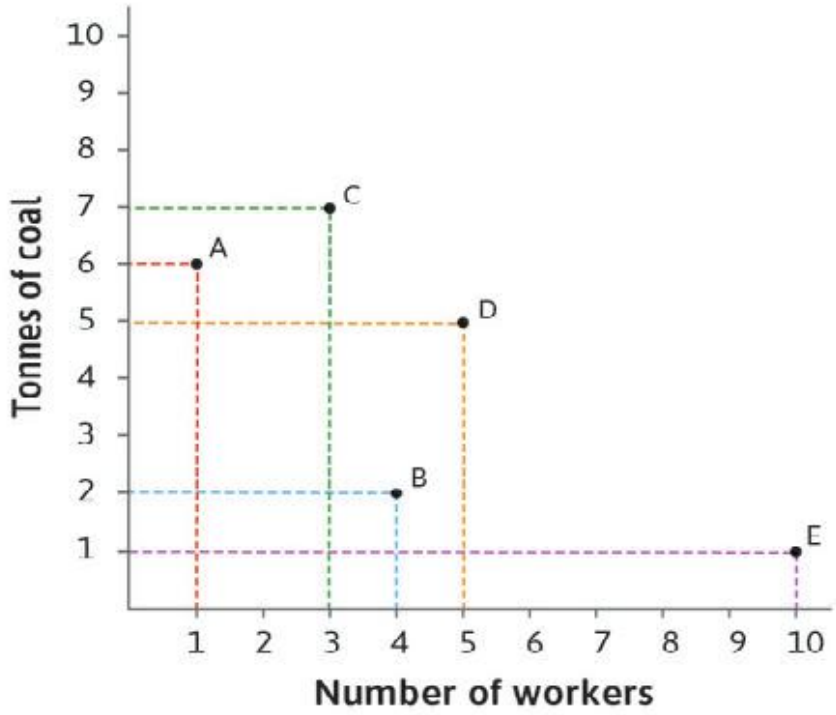
Part 2. Modelling a Dynamic Economy – Technology and Cost

- Suppose you are an expert in cloth making and I ask you of different combinations of technology available to produce a 100m long cloth. You give me the following technological options based on which I have to decide on which option to pick.

Technology option	Number of workers	Coal required (tonnes)
A	1	6
B	4	2
C	3	7
D	5	5
E	10	1

Using Graphs

Figure 2: Technology options for producing 100m of cloth



This graph gives a general idea about which option I should be picking. My first thought is to throw aways options that does not make sense. In other words, find options that are dominated by other options in both inputs. From the figure option B dominates option D and option A dominates option C (same amount of cloth can be produced by using technology A, compared to C). So general rule will help eliminate options D and C. Now my pick would be between A, B, and E. From this point, which option to pick depends on my objective. Say my objective is to maximize profit. This can be done by minimizing cost. So, out of options A, B and E, pick one that is least costly.

Calculating cost of production

- Cost of production
  Cost=price of labor×number of labors+price per ton×tonnes of coal
- Now say that price per worker is £10 and price per ton of coal is £20. Next, we calculate cost for all three options A, B and E.

Technology	workers	Coal (tonnes)	Cost of Technology(£)
A	1	6	$= 1 \times 10 + 6 \times 20 = 130$
B	4	2	$= 4 \times 10 + 2 \times 20 = 80$
E	10	1	$= 10 \times 10 + 1 \times 20 = 120$

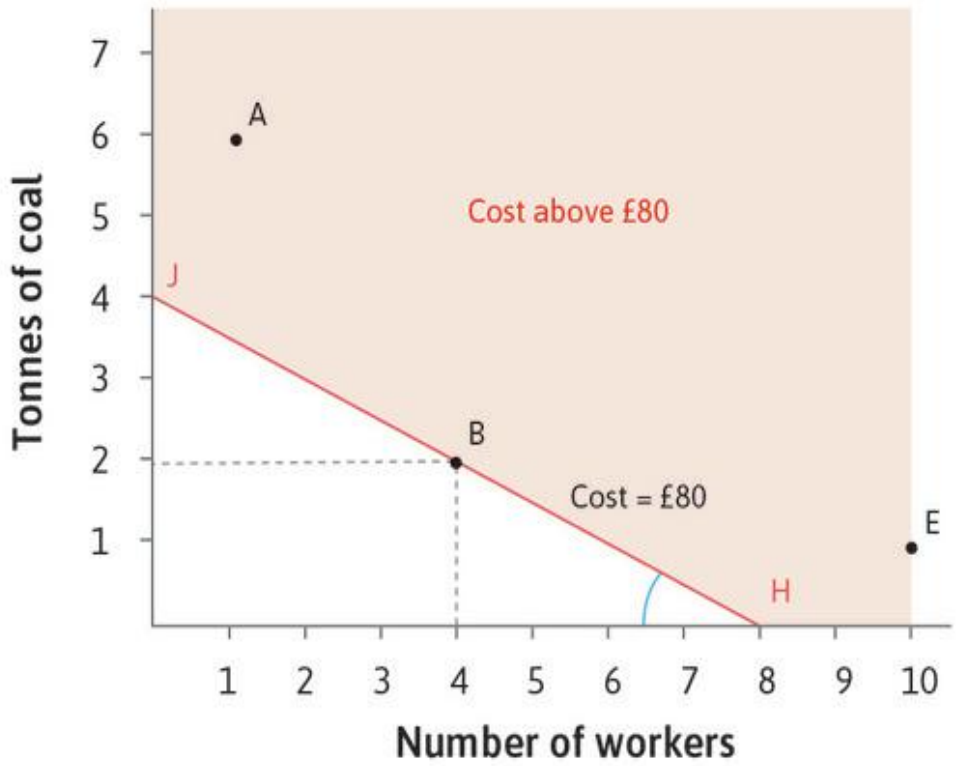
From this calculation, I would pick technology option B as option B is as efficient as other options (note that all options produce 100m cloth, but option B does it at a cheaper price.)

Isocost curve

- This is a curve that shows various combinations of technology with the same exact cost.
- c=w×L+p×R, where w is wage per worker, L is the number of workers, p is price per ton of coal, and R is the tons of coal. c is the total cost of technology.
- Rearranging, R=$\frac{c}{p}$-$\frac{w}{p}$×L, which is the equation of the isocost curve. Now, compare this to y=bx+a
  - $\frac{c}{p}$ = a, which is the y-intercept
  - -$\frac{w}{p}$=b, which is the slope
- What is the y-intercept of an isocost curve, when cost c = £80 (for technology B).
  - R=$\frac{80}{20}$-$\frac{w}{p}$×0, note that L=0 when finding the y-intercept. So, the y-intercept of the isocost is $\frac{80}{20}$=4.
- The slope of the isocost is: -$\frac{w}{p}$=-$\frac{10}{20}$=-$\frac{1}{2}$. This is also the relative price of two technologies.
- So, you can re-write the isocost equation as R=4-$\frac{1}{2}$×L, when c = £80.
  - Note that we are just replacing $\frac{c}{p}$ = 4 and -$\frac{w}{p}$=-$\frac{1}{2}$.

Isocost curve when c=£80.

Figure 3: Isocost curve when cost of technology is £80



The figure above shows plots the equation of the line given by $R = 4 - \frac{1}{2} \times L$. This is the case when cost is £80. So the line shows combination of tonnes of coal and the number of workers that yield the cost £80. As shown, technology option of B is just one point on the line.

Practice Problem 2.1, Isocost lines

- Say that the wage is £10 but the price of coal is £5.

1. What is the relative price of labor?
2. Using demonstrations in the previous slide, write down the equation of an isocost line for cost c=\$60 in the standard form of y=a+bx.
3. Rewrite the equation in problem 2, but use cost c=£90.
4. Plot equations from problems 2 and 3 on a graph.

The Isocost Curve and Relative Price

- Note that when looking at the equation of the isocost line R=$\frac{c}{p}$-$\frac{w}{p}$×L from the previous slide, the slope of the isocost is -$\frac{w}{p}$, which is the relative price of labor. This fraction gives the price for labor when price for other technology (coal) is \$1.
  - So when w=\$10 and p=\$20, labor is half times cheaper than cost is.
- Note that changes in relative price changes the slope of the isocost line.
- So, initially when w=\$10 and p=\$20 we found that the cheapest technology is B. But what happens if w remains at \$10 but p falls to \$5.

Technology	workers	Coal (tonnes)	Cost of Technology(£)
A	1	6	$= 1 \times 10 + 6 \times 5 = 40$
B	4	2	$= 4 \times 10 + 2 \times 5 = 50$
E	10	1	$= 10 \times 10 + 1 \times 5 = 105$

From this calculation, B is no longer the cheapest option as before. The cheapest option now is A. So, as price of energy falls, the firm substitutes labor intensive technology for energy intensive technology, i.e. go from technology option B to A. Change in profit now is: change in revenue from switching B to A - change in cost from switching B to A. = 0 - (40-50)=10.

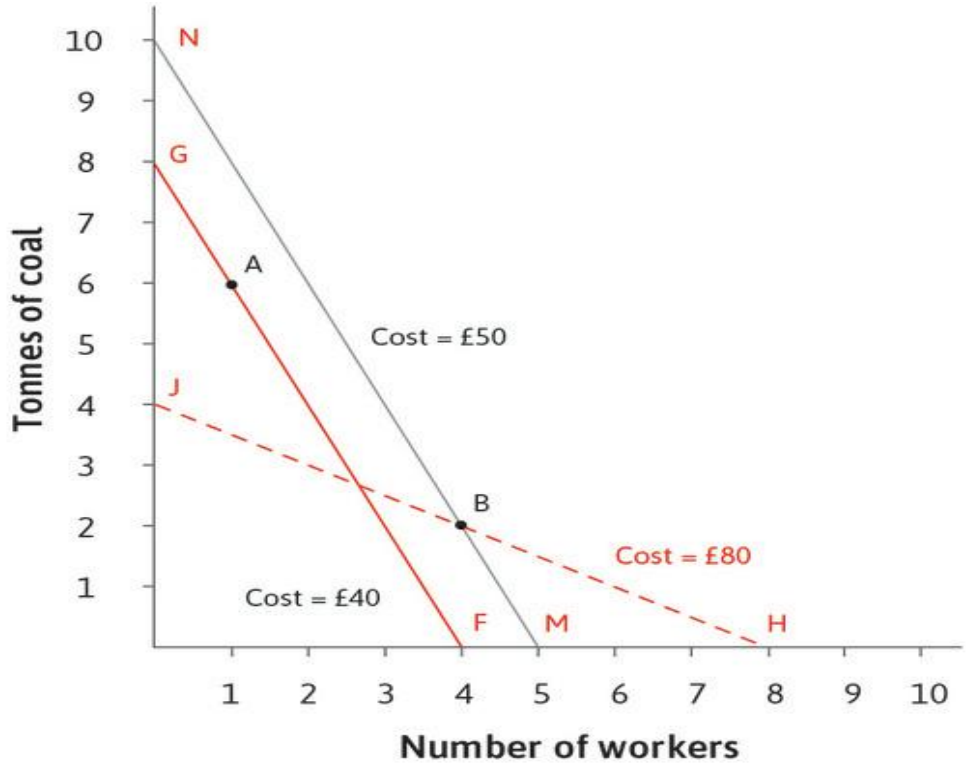
Practice Problem 2.2

- Consider different isocost lines as shown in the figure (in the next slide). Based on these isocost curves, what can we conclude?

1. When the wage is £10 and the price of coal is £5, the combination of inputs at point N is more costly than the inputs at point B.
2. Isocosts MN and FG represent the same price ratio (wage/price of coal) but different total costs of production.
3. Isocost HJ represents a higher (wage/price of coal) ratio than isocost FG.
4. Isocost HJ represents all points that can produce 100 metres of cloth at a particular price ratio.

Figure for practice problem 2.2

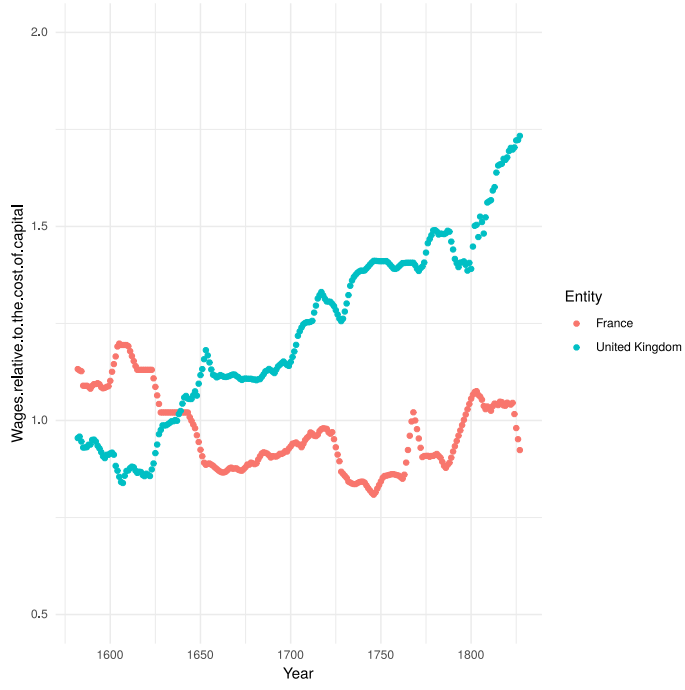
Figure 4: Isocost curves for different cost of technology



The figure above shows plots several isocost lines. Use the figure to answer practice problem 2.2 in prior slide.

The British Exposure to the Industrial Revolution and Relative Price

Figure 5: Relative price of labor to capital in Britain and France



The figure above shows plots relative price between labor and energy for Britain and France. It can be seen that the relative price in two countries were quite similar in 1600s. However, starting 1700s the relative price between labor and energy increased in Britain, particularly as price of energy decreased. Note that the period of increase in relative price in Britain coincides with the industrial revolution. Such increases in price of labor compared to energy (or machines) causes firms to replace energy (machines) for labor. A reduction in price for energy (machines) can take place due to technologial advancements and innovation.

Part 3. Malthusian Economics and Diminishing Product of Labor

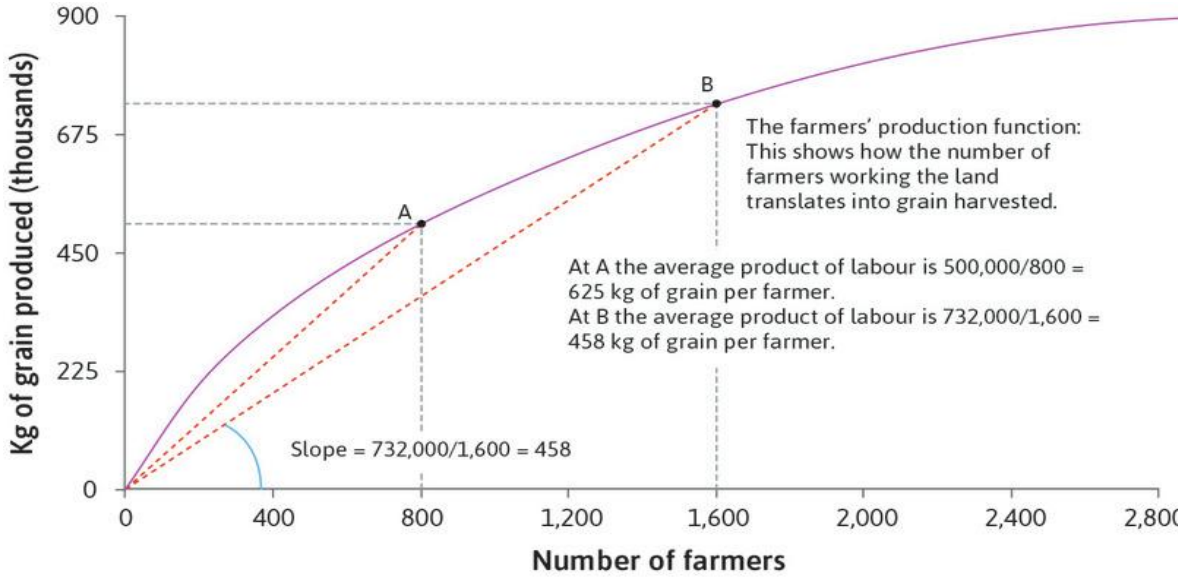
- Malthus came up with a model to explain the flat part of the hockey stick graph that we saw in Lecture 1 using a very important and widely used concept in economics called the diminishing average product of labor.
- Lets take an example.
  - Say, an economy only produces grain (an assumption)
  - Only uses land and labor to produce grain. These are also known as the factors of production, which are the inputs used to produce the product (grain).
  - You put these inputs into a production function defined as f such that Y=f(X), where Y is the output, X are inputs, and f is the production function that maps inputs to the output.
  - Now, consider that land (one of the inputs) is held constant and the only input that can vary is labor.
- Next, lets take the following table that shows the relationship between the number of labor input into the production function and output (grain produced).

Labor input and grain produced

Labor (number of workers)	Grain output (kg)	Average product of labor
200	200,000	$=\frac{200{,}000}{200} = 1{,}000$
400	330,000	825
600	420,000	700
800	500,000	625
1000	570,000	570
1200	630,000	525
1400	684,000	490
1600	732,000	458
1800	774,000	430
2000	810,000	405
2200	840,000	382
2400	864,000	360
2600	882,000	340
2800	894,000	319
3000	900,000	300

Let's plot the production function.

Figure 6: Production Function and Diminishing Average Product of Labor



The figure is taken from the core porject. The curve is bowed towards the outside (concave).Note that the slope of the line OA is steeper than the slope of the line OB. The slope in this case is also the average product of labor. Hence, production per labor is higher at point A compared to point B. You can also see this by drawing tangent lines on point A and point B. The slope of the tangent line at point A should be steeper than the slope of the tangent line on B. This graph allows us to present Malthus's hypothesis. Now, given that fertility rate is increasing, increases in population will yeild lesser grains per work, and this value drops as the population size keeps increasing. Malthus's worry was that given this phenomenon of diminishing average product of labor, production would not be able to sustain increases in fertility.

The other part of Malthus's model is that population rises as living standard increases and shinks otherwise. Now if you put this hypothesis along with the idea of diminishing average product of labor you begin to realize some sort of equilibrium approaching. Can you explain what might happen? Hint: start with the condition that living standards are increasing, this increases fertility, ...Here is a video to guide your explanation https://youtu.be/iEHQR1fGO_g

Conclusion I

- Firms choice depends on relative price of inputs as shown by the model
- We looked at a simple model to get an idea of how economists explain ideas with models
- We introduced the concept of production function, which will be expanded later on
- We took a look at Malthusian model, and how the concept of population growth coupled with diminishing average product of labor can explain stagnation before Industrial Revolution.
- This highlights the importance of economic rent through innovation during the period of industrial revolution.