Chapter 4

Production and Cost

(1) Definitions

First thing first, we do need to know what are the composition of production.

› Firm or producer
An organization accumulating resources to create products or services to be sold in products market.

› Factors of production
Including land, labor, capital and entrepreneur.

› Production
A process of transforming factors of production into products.

(1) Definitions

Let’s come up with some examples of production.

Product	Owners of factor	Market	Production

(1) Definitions

The production process is simplified into a production function, which is defined as follows.

Definition 4.1

Production function *is a mathematical function which transforms resources into goods or services. It indicates the highest output q that a firm can produce for every specified combination of inputs. For simplicity, we assume that*

› $q = f(K, L)$

(2) Assumptions

Before we move on, some assumptions must be posed.

› Firm is assumed to be rational with its aim to maximize profit.

› Every unit of factors of production is considered equally in quality.

› Each factor of production can be indefinitely separable. (Continuous)

› In the long-run, if budget or cost is limited, the analysis will consider only the part where the satiation of production has not been reached.

› Ceteris paribus.

(1) Difference between short and long-run

Short and long-run production is not categorized by time frame of production. Instead, short run of production means that there is **at least one fixed factor** utilized, a factor which is assumed to be constant in the short-run.

Therefore, we usually assume that capital is a fixed factor while labor is a variable factor, a factor that firm can adjust its amount. The production function becomes

› $q = f(\overline{K}, L)$

Also note that return or compensation for capital is interest (r), while for labor is wage (w).

Since capital is assumed to be fixed in the short-run, the focus here is on the relation between **labor hired and number of output** ($L \Rightarrow q$).

(2) Short-run product

Definition 4.2

Total product *is total output produced from a production process and a set of input, denoted by* ***TP*** *or* ***q****.*

Average product *is the average output per variable factor, denoted by* ***AP****.*

› $AP = \frac{TP}{L}$

Average product *is the additional output from adding 1 more unit of variable factor into the production, denoted by MP.*

› $MP = TP_n - TP_{n-1} = \frac{\Delta TP}{\Delta L} = \frac{\partial TP}{\partial L}$

Each type of output is related in the following table.

(2) Short-run product

Labor (L)	Total product (TP or q)	Average Product (AP)	Marginal Product (MP)
0	0	-	-
1	3		
2	8		
3	12		
4	14		
5	14		
6	12		

From the chart, we can see that when a firm decides to add more variable factor, marginal product increases at first and then decreases later on. This nature of short-run production is governed by the law of diminishing marginal product.

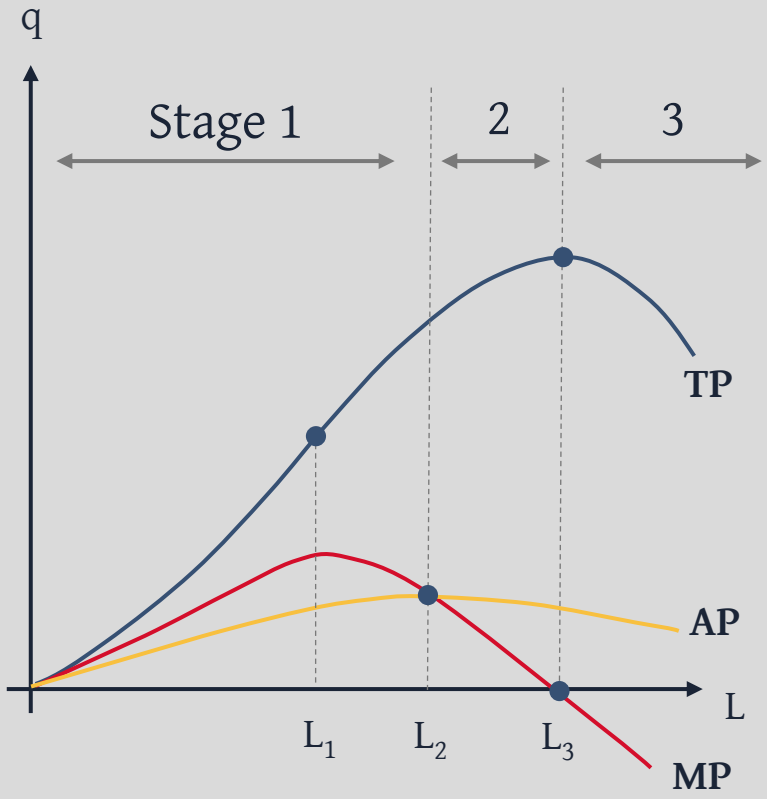
(3) Diminishing marginal product

Definition 4.3

Law of diminishing marginal product *states that in short-run, when firm increases variable factor, marginal product will increase at first then decrease until it becomes 0 and negative. The reason of diminishing marginal product is because of disproportionated use of factors of production due to the constant number of fixed factor.*

Let's consider an example.

(3) Diminishing marginal product



› What should we notice in each stage of production?

(4) Costs in the short-run

Even though we learned that marginal product is diminishing in the short-run, seeking to maximize output is not firm's goal. (**MAXIMIZING PROFIT**)

Therefore, we need to further cost structure in the short-run. Cost is a value that one gives up to get another thing in return. For the production concept, production cost can be interpreted as **compensation or opportunity cost** for those factors since they are used for production and not otherwise.

Since we have fixed and variable cost, both are separated. We are going to consider these costs from three aspects, or term, as

(1) Total term: Total fixed cost (TFC), Total variable cost (TVC), and total cost (TC or STC)

(2) Average term: Average fixed cost (AFC), Average variable cost (AVC), and Average total cost (ATC or SAC)

(3) Marginal term: Marginal cost (MC or SMC)

(4) Costs in the short-run

Definition 4.4

Total fixed cost *is the total cost for fixed factor, denoted by* ***TFC****.*

Total variable cost *is the total cost for variable factor, denoted by* ***TVC****.*

Total cost *is both fixed and variable cost combined, denoted by* ***TC*** *or* ***STC****.*

› $TC = TFC + TVC$

(4) Costs in the short-run

Definition 4.5

Average fixed cost *is the cost of fixed factor per one unit of output, denoted by* **AFC**.

› $AFC = \frac{TFC}{q}$

Average variable cost *is the cost of variable factor per one unit of output, denoted by* **AVC**.

› $AVC = \frac{TVC}{q}$

Average cost *is the total cost per one unit of output, denoted by* **AC** *or* **SAC**.

› $AC = \frac{TC}{q} = \frac{TFC}{q} + \frac{TVC}{q} = AFC + AVC$

(4) Costs in the short-run

Definition 4.6

Marginal cost *is the additional cost when one more unit of output is produced, denoted by* ***MC*** *or* ***SMC****.*

› $MC = TC_n - TC_{n-1} = \frac{\Delta TC}{\Delta q} = \frac{dTC}{dq}$

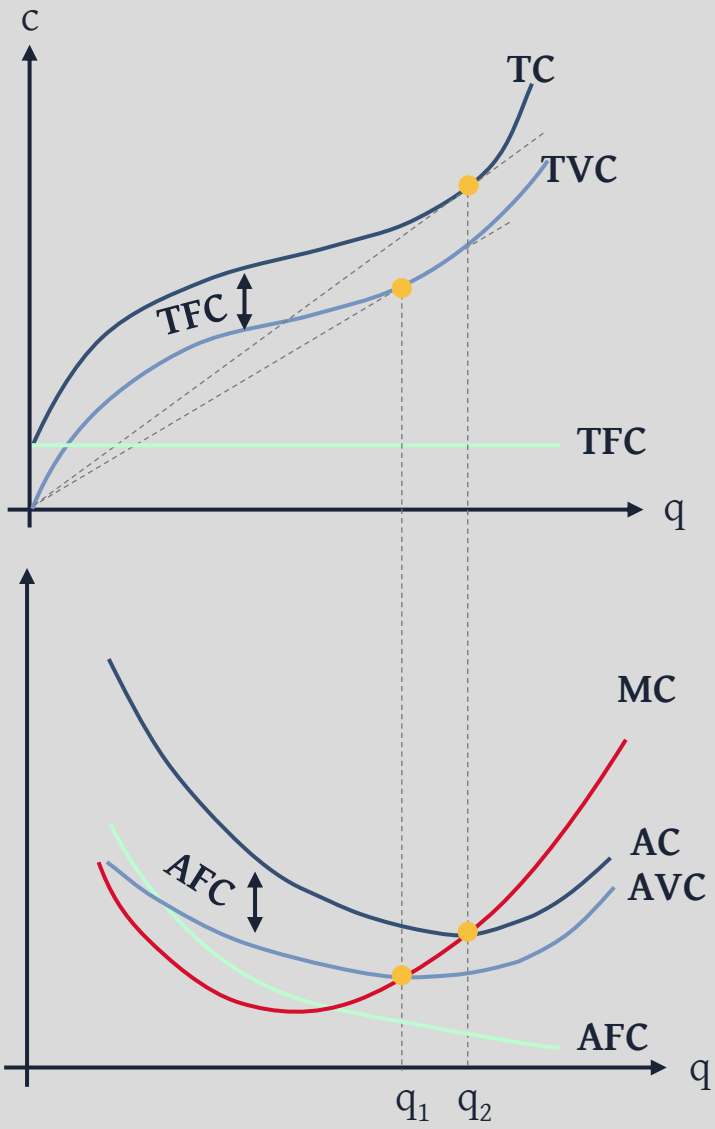
We can prove that $MC = \frac{dTVC}{dq}$

Studying cost, on the other hand, focuses on relation between **output and cost** ($q \Rightarrow c$). Now let's look at the table.

(4) Costs in the short-run

(1) q	(2) TFC	(3) TVC	(4) TC	(5) AFC	(6) AVC	(7) AC	(8) MC
0		0					
1		12					
2	25	18					
3		20					
4		24					
5		35					

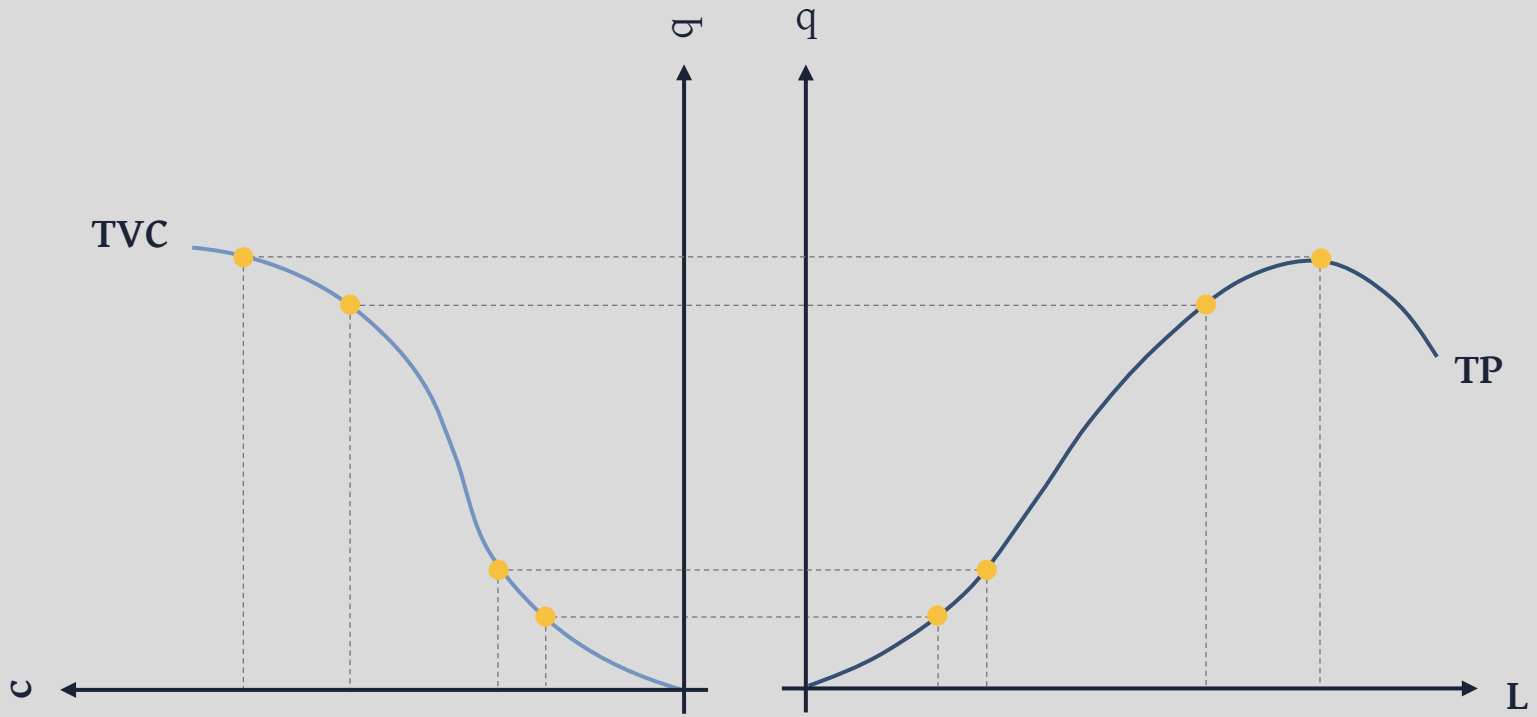
(4) Costs in the short-run



› What should we notice in costs graphs?

(4) Costs in the short-run

Now consider why MC rises, which results in TVC convexity.



(5) Summary of short-run production

› Short-run production ($L \Rightarrow q$) means at least a fixed factor is utilized.

› Increasing variable factor into the production causes marginal product to diminish due to disproportionated combination of fixed and variable factor.

› Diminishing marginal product makes it costlier ($q \Rightarrow c$) to produce one more output when firm keeps adding more variable factor.

› Diminishing marginal product causes marginal cost to rise, also total variable cost, total cost ,average variable cost, and average cost to later rise.

Again, firm's objective is not to minimize cost. We then need to study firm's revenue in order to complete producer part. However, firm's revenue varies by market structure (or competitiveness). Hence, we will study firm's revenue and profit in the products market section.

(1) Production in the long-run

On the other hand, long-run production occurs when a firm can adjust the amount of all factors of production. Production function is then represented in this form

› $q = f(K, L)$

Since firm can freely select an amount of all factors of production, the topic then shifts to how can firm select optimal combination for each level of output?

(1) Production in the long-run

Output	Capital	Labor
10	1	5
10	3	3
10	5	1
20	2	7
20	4	4
20	6	2

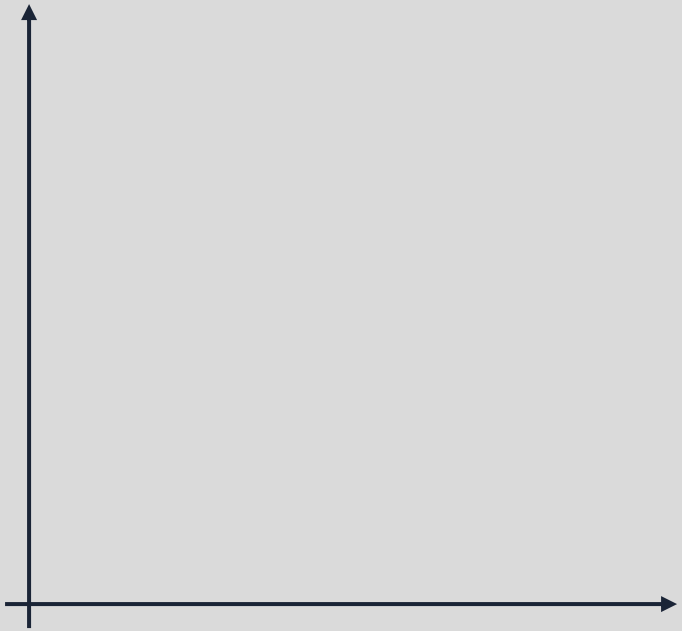
Supposed that only capital (K) and labor (L) are utilized in a production, a firm considers to produce $q = 10$ or $q = 20$, the question is how many units of capital or labor should firm utilize at each q or what is (K^*, L^*).

The table on the left-hand side illustrates many bundles that can lead to the same result.

The quick answer would be (K^*, L^*) that **minimize cost** for each particular level of q. So, we need to consider **capital and labor price** (r and w).

The tools that we are going to use to analyze is called **Isoquant** and **Isocost**.

(2) Isoquant



Characteristics

› Factors bundles

› Level of output yield

› Isoquant cannot intersect.

› Isoquant has negative slope and convex to the origin

(2) Isoquant

Definition 4.7

Marginal rate of technical substitution *is a ratio of substitution between two types of factor on a point of an isoquant that yield the same level of output.*

› $MRTS_{LK} = \frac{\Delta K}{\Delta L}$

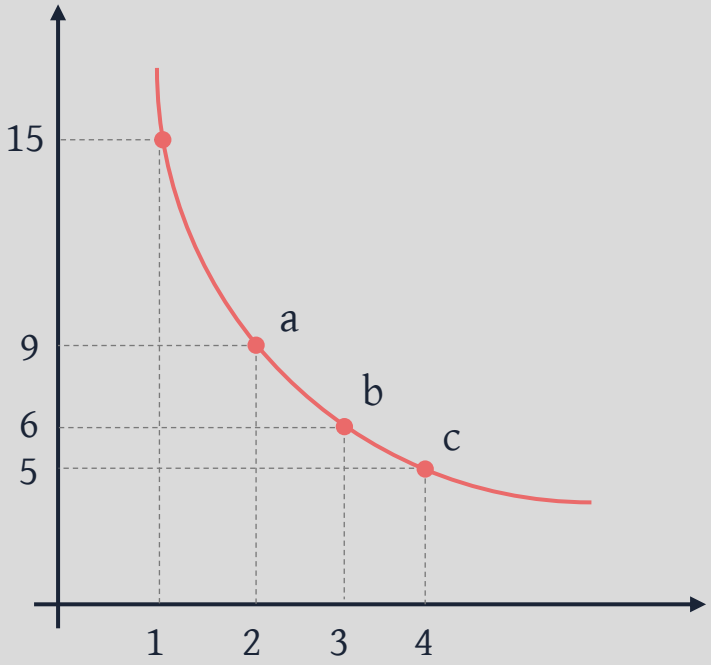


Figure out these MRTS_{LK}

› $\text{MRTS}_{LK(\text{a})} =$

› $\text{MRTS}_{LK(\text{b})} =$

› $\text{MRTS}_{LK(\text{c})} =$

(2) Isoquant

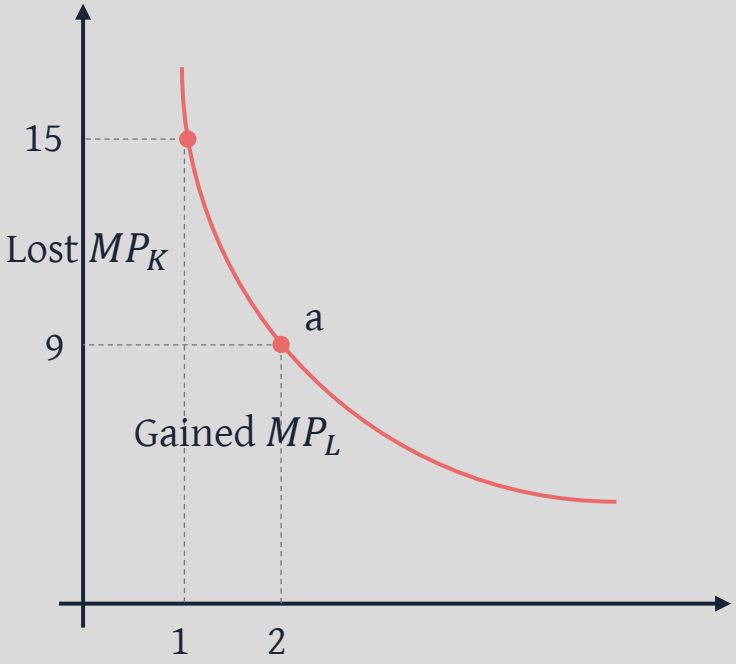
As we learned that, in case of two substitutable factors, MRTS is the ratio of substituting two factors, resulting in the same amount of output, it also means that.

› $|MRTS_{LK}| = \left|\frac{\Delta K}{\Delta L}\right| = \frac{MP_L}{MP_K}$

where MP_L and MP_K are marginal product of labor and marginal product of capital, respectively.

Consider an example here.

(2) Isoquant



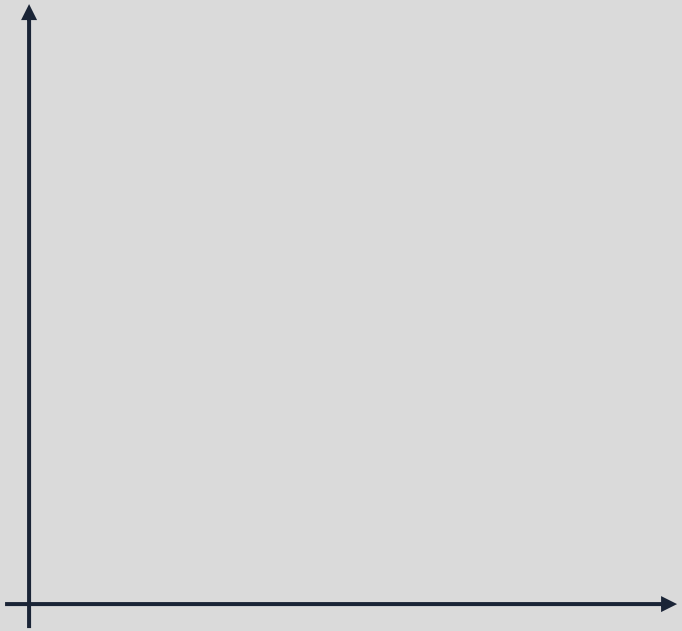
› Supposed that the MRTS at one point is -6, it means that when giving up 6 of K while adding 1 unit of L into the production result in yielding the same amount of product. (or it can be 12 of K and 2 of L which is the same ratio)

› When a firm gives up 6 of K, this firm loses an amount of marginal product of capital (MP_K). We do not know how many.

› When the firm adds 1 more unit of L, this firm gains an amount of product that was lost from MP_K. Again we do not know how many but it is the marginal product of labor (MP_L) from that 1 L.

› Those MP_K and MP_L must be equal since changing factors bundle on the same isoquant results in the same amount of output. Therefore, it means that 1 unit of L can produce equal MP of 6 units of K. That makes MP_L 6 times larger than MP_K.

(3) Isocost



Isocost is, once again, very similar to the budget line. Consider an example here.

Given that a labor costs 25 baht a day and a unit of capital costs 50 baht a day, a firm can bear 200 baht cost per day. Draw the isocost.

(3) Isocost

Isocost shows combinations of capital and labor that cost equally. Assumed that production function consists of capital and labor, total cost (TC) equals interest multiply by number of capital plus with wage multiply by number of labor or $TC = rK + wL$

Isocost has a fixed slope if, during the analysis, price of labor and capital do not change. The slope can be defined as follows.

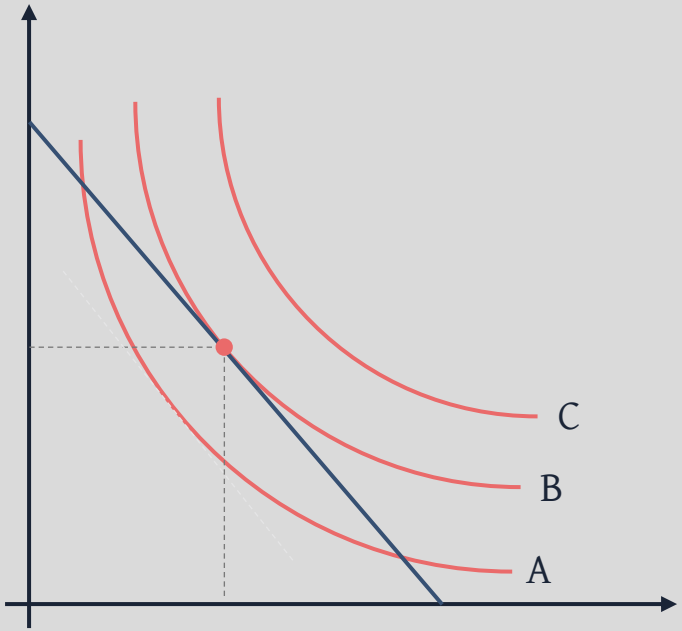
Definition 4.8

Marginal rate of market substitution *is the substitution rate of two factors given by their price or the slope of isocost.*

› $|MRMS_{LK}| = \left|\frac{\Delta K}{\Delta L}\right| = \frac{w}{r}$

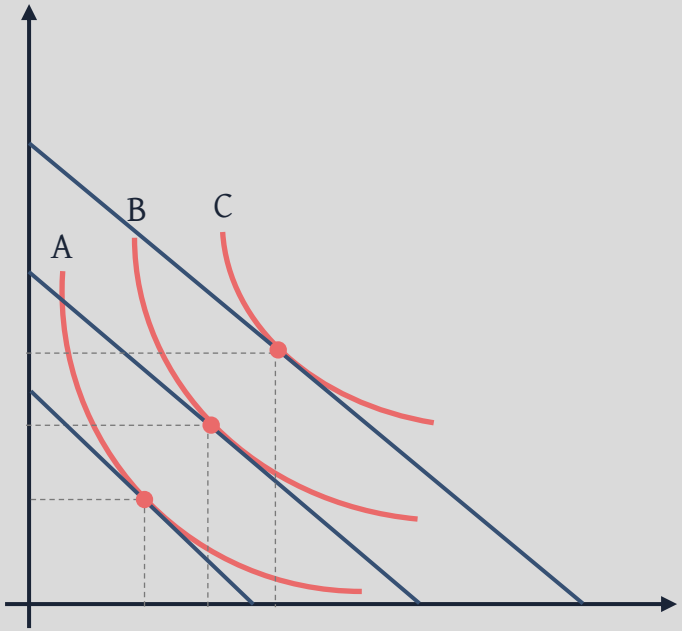
Change in isocost can be caused by change in a firm's budget, extending or shrinking isocost, and change in factor price, tilting the isocost the same way as budget line.

(4) Firm's equilibrium



For each level of output on each isoquant, a b or c, there is a specific combination between K and L that will minimize cost (K^*, L^*), which makes

(4) Firm's equilibrium



When firm can bear more cost, the number of factors of production that minimize cost can be increased to the point where new isocost tangent with new isoquant. If we draw a line connecting between each equilibrium, we will get an **expansion path**.

This expansion path is the set of optimal combinations. Each combination indicates a pair of c and q, which this c is minimized with respect to given q. We can then plot relation between c and q in the long-run production.

(5) Costs in the long-run

For every combination of c and q that minimize cost for a firm, we can derive long-run costs from the expansion path.

Definition 4.9

Long-run total cost *is the cost of all variable costs combined, denoted by* ***LTC.***

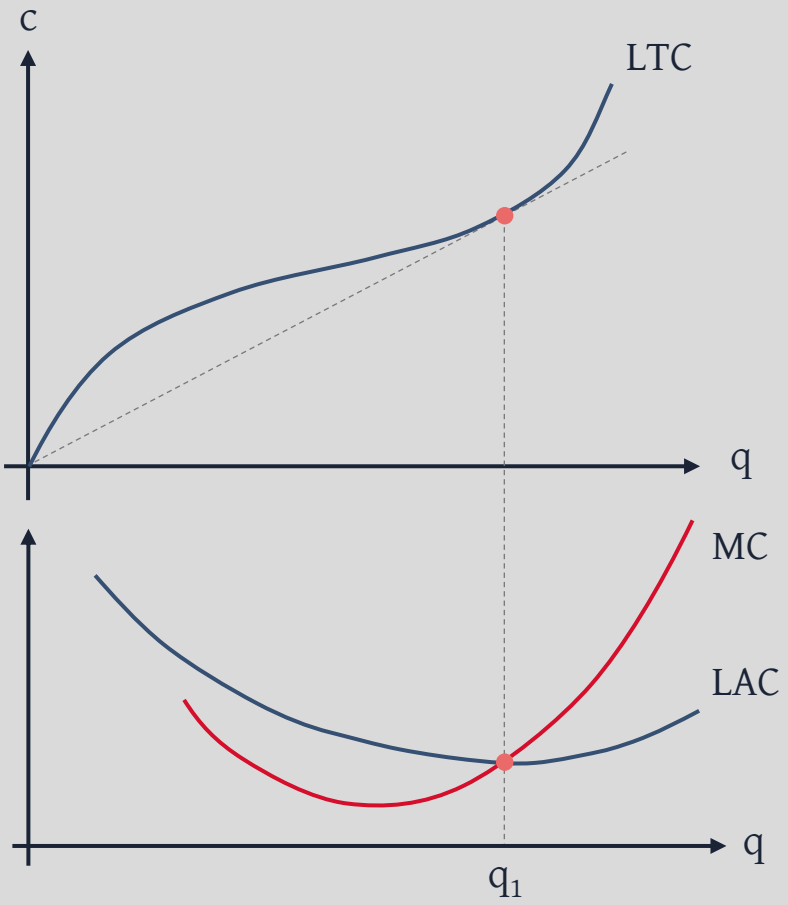
Long-run average cost *is the average of total cost per one output, denoted by* ***LAC.***

› $LAC = \frac{LTC}{Q}$

Long-run marginal cost *is the additional cost when firm produces one more unit of output, denoted by* ***LMC.***

› $LMC = \frac{\Delta LTC}{\Delta Q} = \frac{dLTC}{dQ}$

(5) Costs in the long-run



Graphing the long-run costs curve will result in the illustration on the left-hand side.

From the expansion path and long-run cost, we can further study multiple topics. The law of returns to scale is one of them to understand proportional return of output to input.

(6) Law of Returns to Scale

Definition 4.10

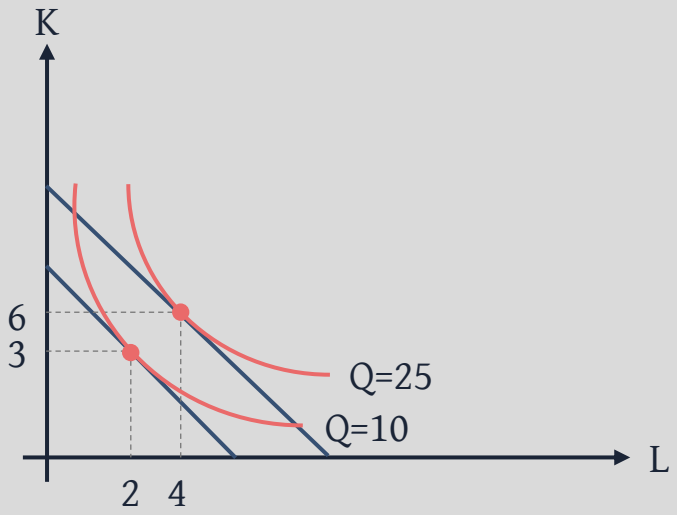
Law of returns to scale *states that when firm increases all factors proportionally, the return will be one or another as stated below (we cannot consider the case that each factor increase unequally)*

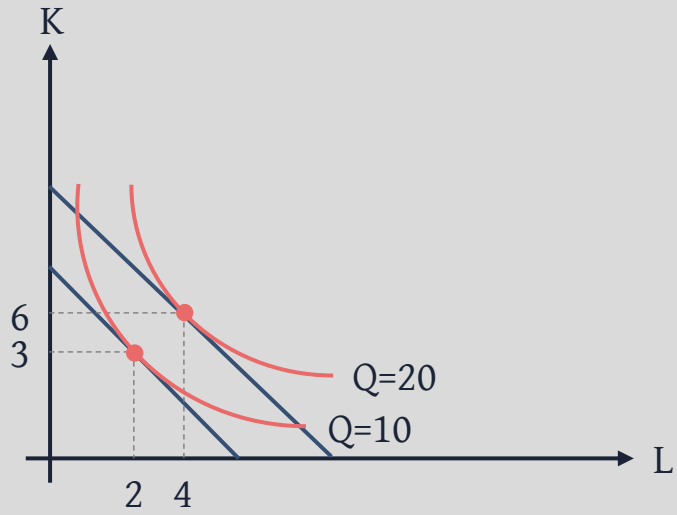
› *Increasing returns to scale (IRS) is the case that proportion of output increases more than proportion of production factors.*

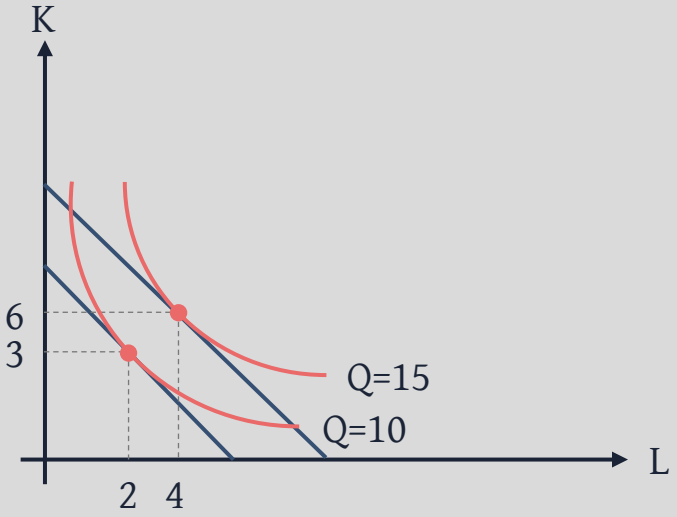
› *Constant returns to scale (CRS) is the case that proportion of output increases equally to proportion of production factors.*

› *Decreasing returns to scale (DRS) is the case that proportion of output increases less than proportion of production factors.*

(6) Law of Returns to Scale







(7) Economy of Scale

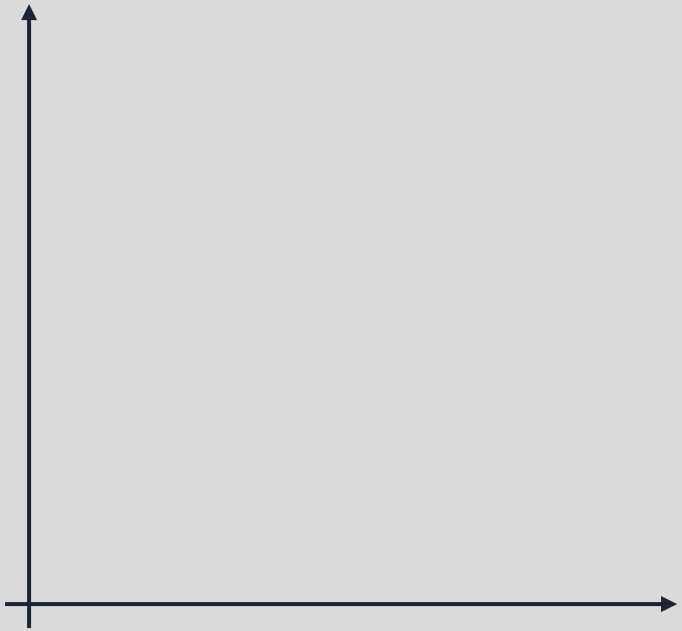
As we can see from the graph, even in the long-run, firms still encounter both decreasing and increasing marginal cost and average cost. To understand this, let's explore relationship between short and long-run first.

In the real-world scenario, firms mostly are in short-run production. Long-run production only occurs for a short period of time when firms decide to expand their production capability.

A metaphor for the situation is factory size. For example, for any industrial production, there must be some factors that cannot be adjusted immediately such as large and expensive machines or production building, setting up a new factory to expand production, or some made-by-order capital goods.

Therefore, the factory in the short-run production is when there is a capital good that cannot be adjusted, while in the long-run production is when the factory is actually expanding.

(7) Economy of Scale

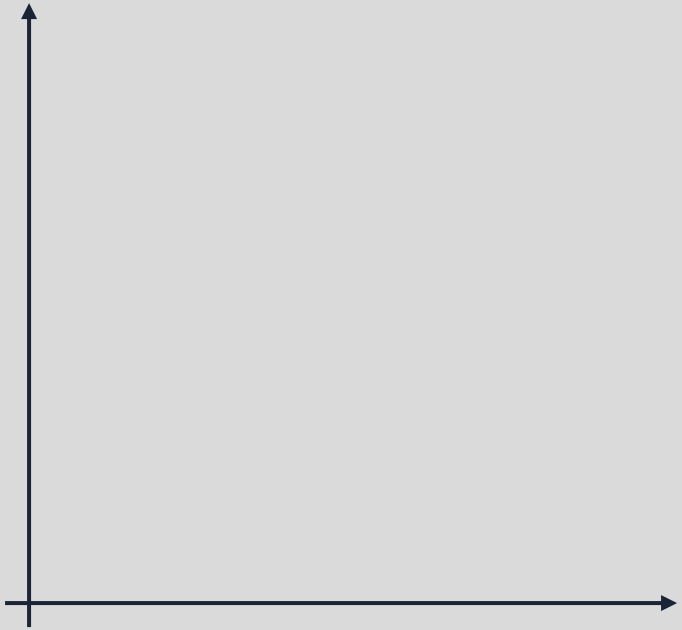


Both production stages are like the factory expansion as shown above. The short-run average cost of each line is the range that cannot be extended.

If the firm can choose unlimited factory sizes, when producing up to the lowest point of the short-run average cost, one will expand the new plant, causing the average cost to shift to another line which may result in lower the average cost level.

Therefore, the long-run average cost line is drawn from the lowest point of the average cost line.

(7) Economy of Scale



A firm gains cost advantage or economies of scale when the quantity produced is 'not too much' depending on each type of good or service, is a result from specialization, bulk order and other efficiency such as low search cost for material and specialized labor.

However, when firm produces 'too much', the opportunity cost can become higher such as search cost for labor and capital, cost of management, cost of monitoring, etc. This is the phase when a firm loses its advantage or diseconomies of scale.

(8) Summary of long-run production

› Long-run production $(K, L \Rightarrow q)$ means all factors are variable.

› To come up with long-run cost curves, it is based on a firm's decision to minimize cost for each level of q by choosing (K^*, L^*)

› Marginal and average long-run cost curves $(q \Rightarrow c)$ still rise even in the long-run production due to economies of scale.

› Returns to scale and economies of scale are related.

› Diminishing marginal product causes marginal cost to rise, also total variable cost, total cost ,average variable cost, and average cost to later rise.