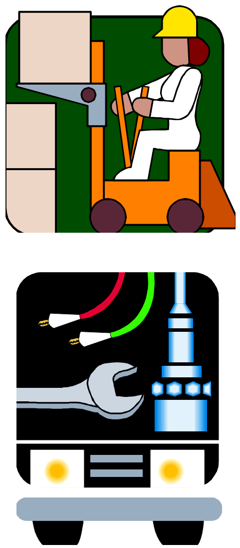
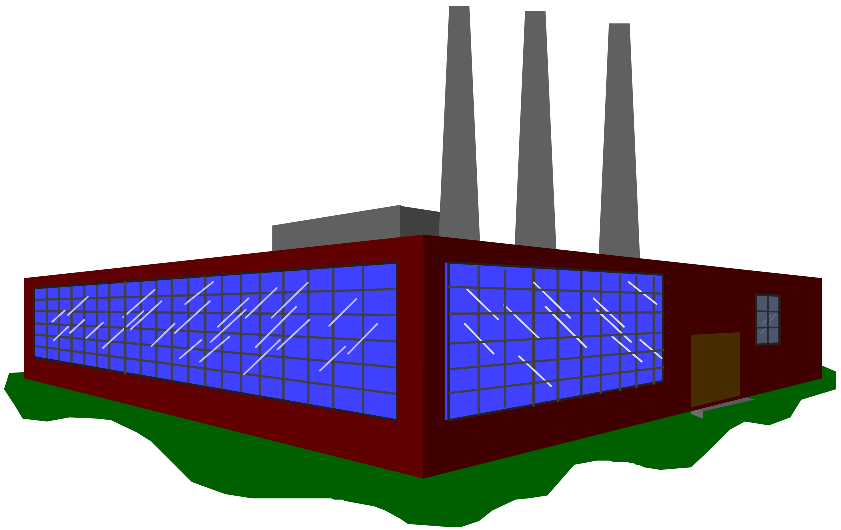
# Theory of Production

# Production





Inputs:
Labour, Capital

Production:
The Firm

Outputs:
Goods

# THE THEORY OF PRODUCTION

- Production theory forms the foundation for the theory of supply

- Managerial decision making involves four types of production decisions:
    1. Whether to produce or to shut down
    2. How much output to produce
    3. What input combination to use
    4. What type of technology to use

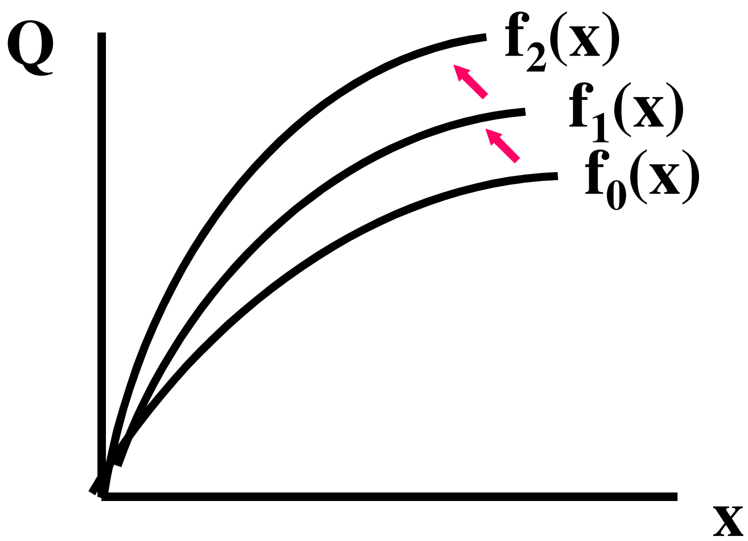
# Two Concepts of Efficiency

- Economic efficiency:
  - occurs when the cost of producing a given output is as low as possible

- Technological efficiency:
  - occurs when it is not possible to increase output without increasing inputs

# Production Function

- A *production function* is a table or a mathematical equation showing the maximum amount of output that can be produced from any specified set of inputs, given the existing technology




**Improvement of technology**

**$f_0(x)$ - $f_2(x)$**

**Q = output**

**x = inputs**

# Production Function continued

$$Q = f(X_1, X_2, \ldots, X_k)$$

where

$Q$ = output

$X_1, \ldots, X_k$ = inputs

For our current analysis, let's reduce the inputs to two, capital (K) and labor (L):

$$Q = f(L, K)$$

# Background to Supply

The Short-run Theory of Production

# SHORT-RUN THEORY OF PRODUCTION

- The law of diminishing returns
- The short-run production function:
  - total physical product (*TPP*)
  - average physical product (*APP*)

    $APP = TPP/Q_V$
  - marginal physical product (*MPP*)

    $MPP = \Delta TPP/\Delta Q_V$

# Wheat production per year from a particular farm (tonnes)

| Number of Workers (Lb) | TPP |
|---|---|
| 0 | 0 |
| 1 | 3 |
| 2 | 10 |
| 3 | 24 |
| 4 | 36 |
| 5 | 40 |
| 6 | 42 |
| 7 | 42 |
| 8 | 40 |

## Wheat production per year from a particular farm (tonnes)

| Number of Workers (Lb) | TPP | APP (=TPP/Lb) |
|---|---|---|
| 0 | 0 | - |
| 1 | 3 | 3 |
| 2 | 10 | 5 |
| 3 | 24 | 8 |
| 4 | 36 | 9 |
| 5 | 40 | 8 |
| 6 | 42 | 7 |
| 7 | 42 | 6 |
| 8 | 40 | 5 |

## Wheat production per year from a particular farm (tonnes)

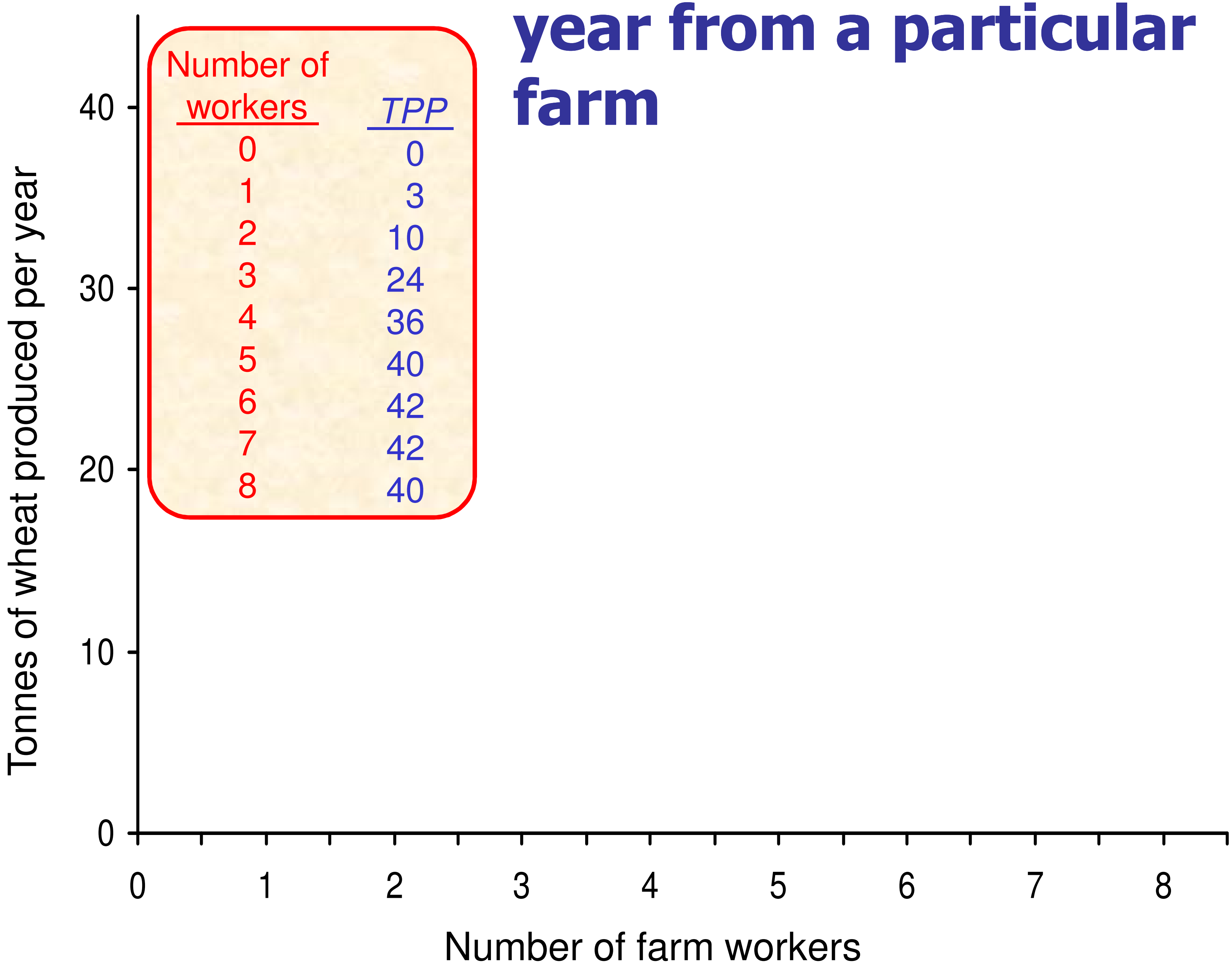
| Number of Workers (Lb) | TPP | APP (=TPP/Lb) | MPP (=∆TPP/∆Lb) |
|---|---|---|---|
| 0 | 0 | - | |
| | | | 3 |
| 1 | 3 | 3 | |
| | | | 7 |
| 2 | 10 | 5 | |
| | | | 14 |
| 3 | 24 | 8 | |
| | | | 12 |
| 4 | 36 | 9 | |
| | | | 4 |
| 5 | 40 | 8 | |
| | | | 2 |
| 6 | 42 | 7 | |
| | | | 0 |
| 7 | 42 | 6 | |
| | | | -2 |
| 8 | 40 | 5 | |

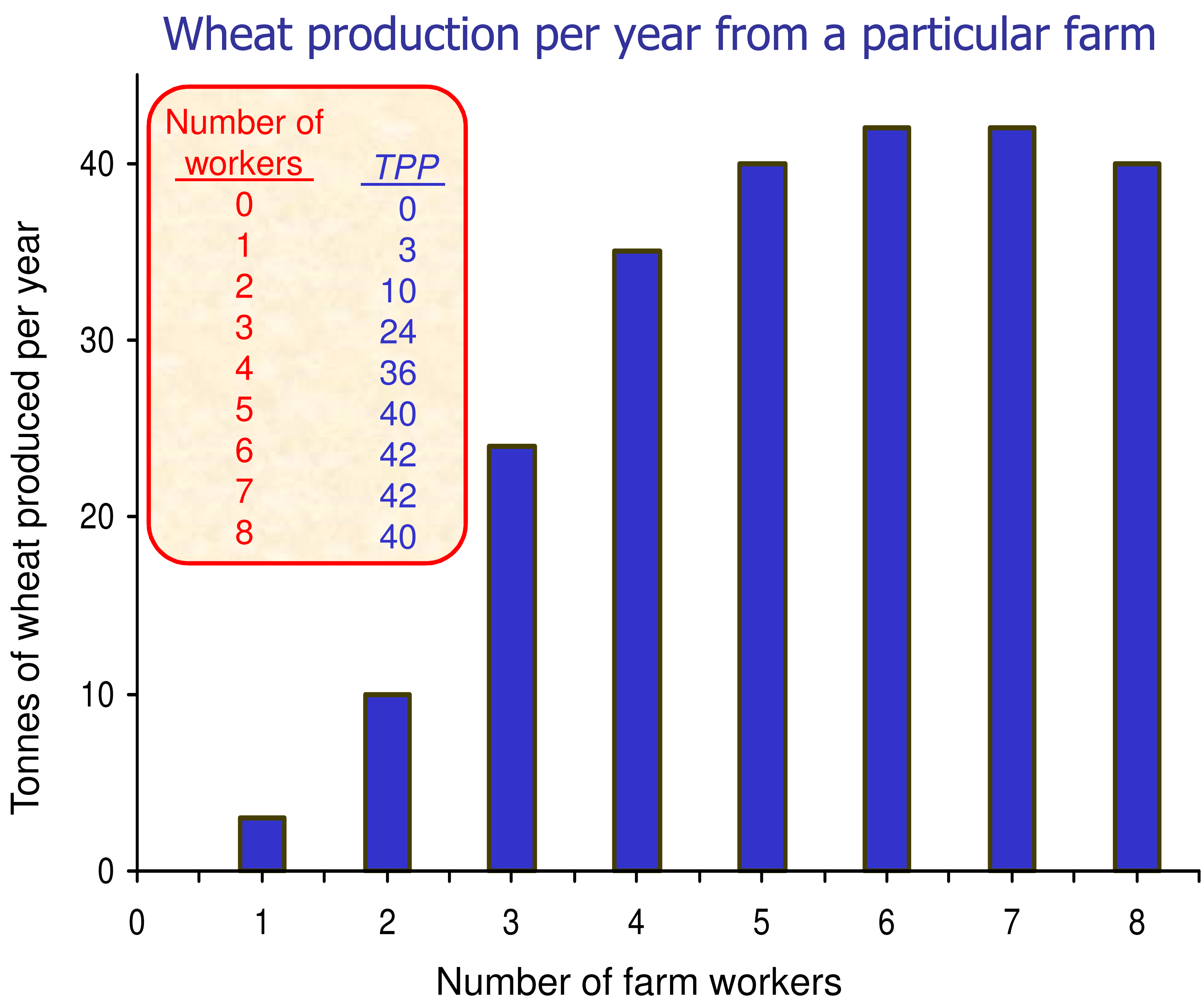
## Wheat production per year from a particular farm (tonnes)

| | Number of Workers (Lb) | TPP | APP (=TPP/Lb) | MPP (=$\Delta$TPP/$\Delta$Lb) |
|---|---|---|---|---|
| (a) | 0 | 0 | - | |
| | | | | 3 |
| | 1 | 3 | 3 | |
| | | | | 7 |
| | 2 | 10 | 5 | |
| (b) | | | | 14 |
| | 3 | 24 | 8 | |
| | | | | 12 |
| (c) | 4 | 36 | 9 | |
| | | | | 4 |
| | 5 | 40 | 8 | |
| | | | | 2 |
| | 6 | 42 | 7 | |
| (d) | | | | 0 |
| | 7 | 42 | 6 | |
| | | | | -2 |
| | 8 | 40 | 5 | |

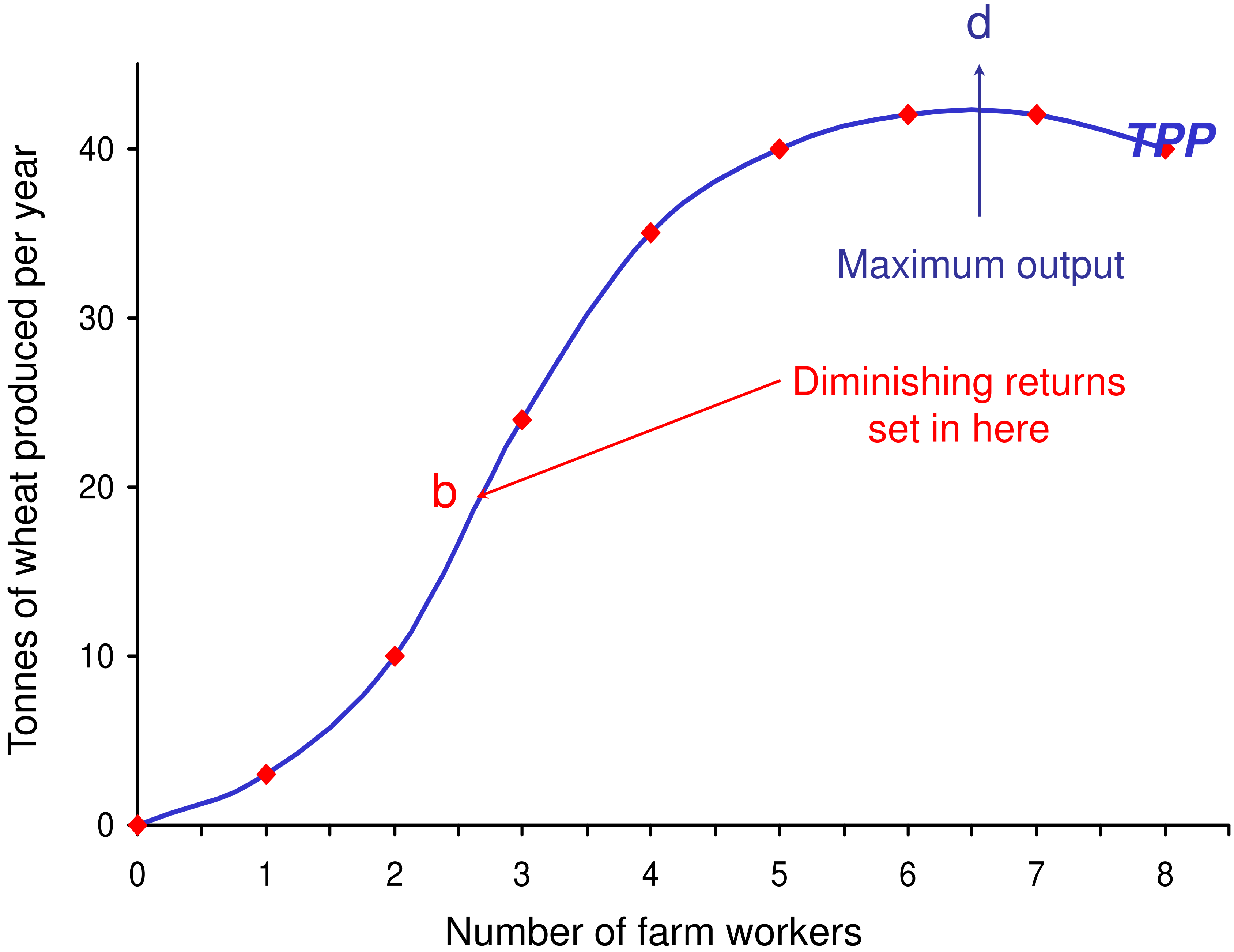
# Wheat production per year from a particular farm

| Number of workers | *TPP* |
|---|---|
| 0 | 0 |
| 1 | 3 |
| 2 | 10 |
| 3 | 24 |
| 4 | 36 |
| 5 | 40 |
| 6 | 42 |
| 7 | 42 |
| 8 | 40 |

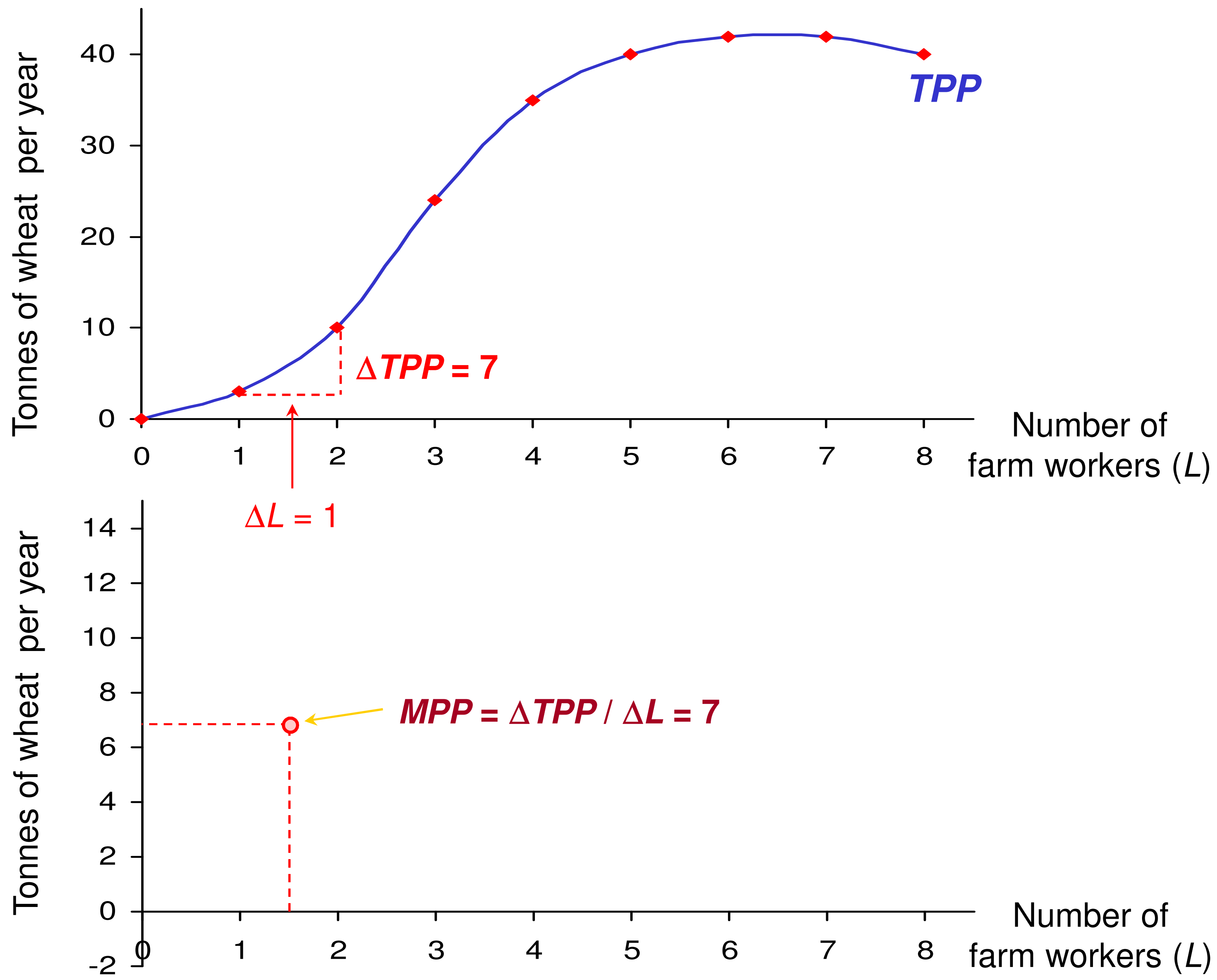



Wheat production per year from a particular farm
Number of workers
TPP
0 0
1 3
2 10
3 24
4 36
5 40
6 42
7 42
8 40
Tonnes of wheat produced per year
0
10
20
30
40
0
1
2
3
4
5
6
7
8
Number of farm workers

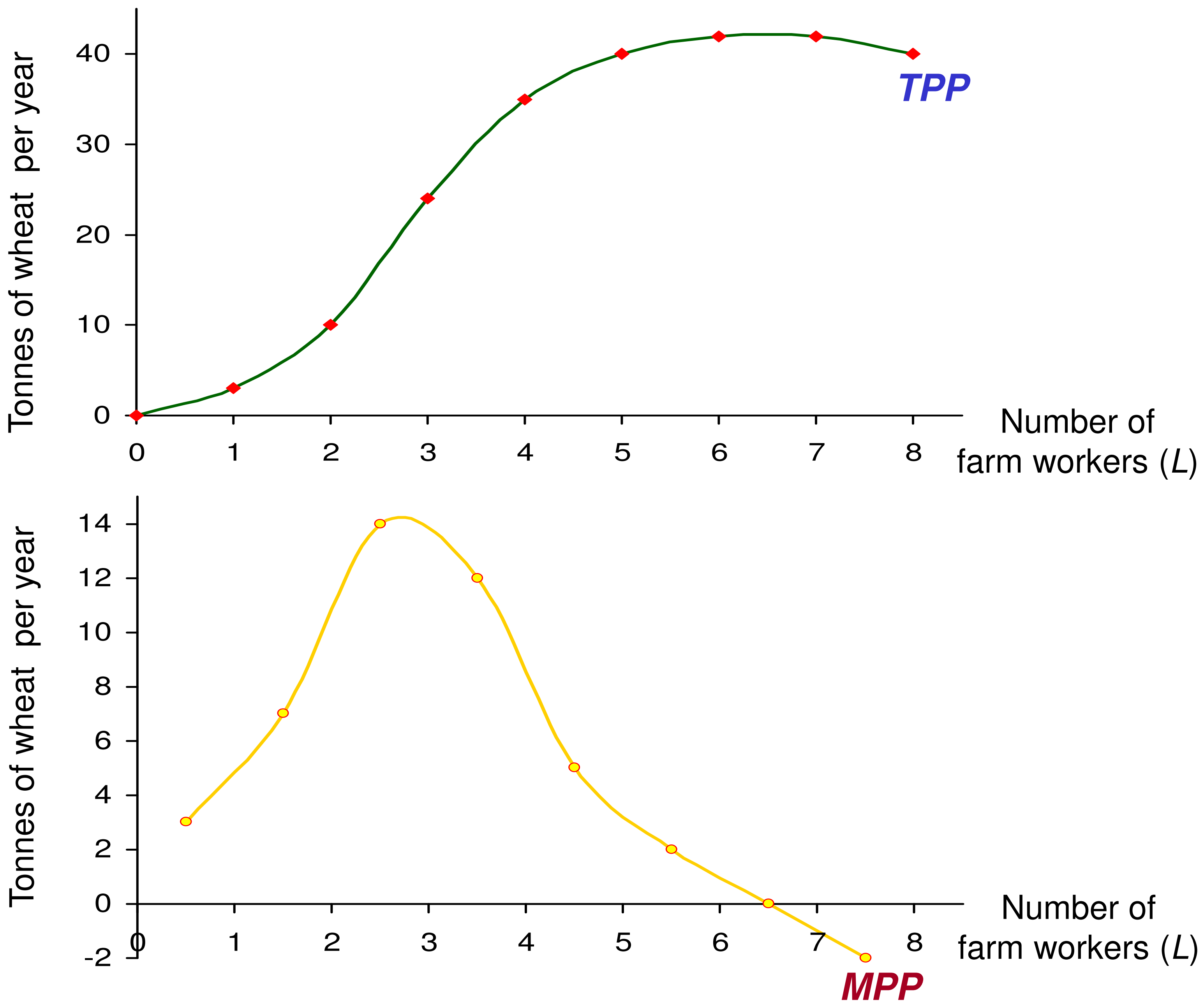
# Wheat production per year from a particular farm



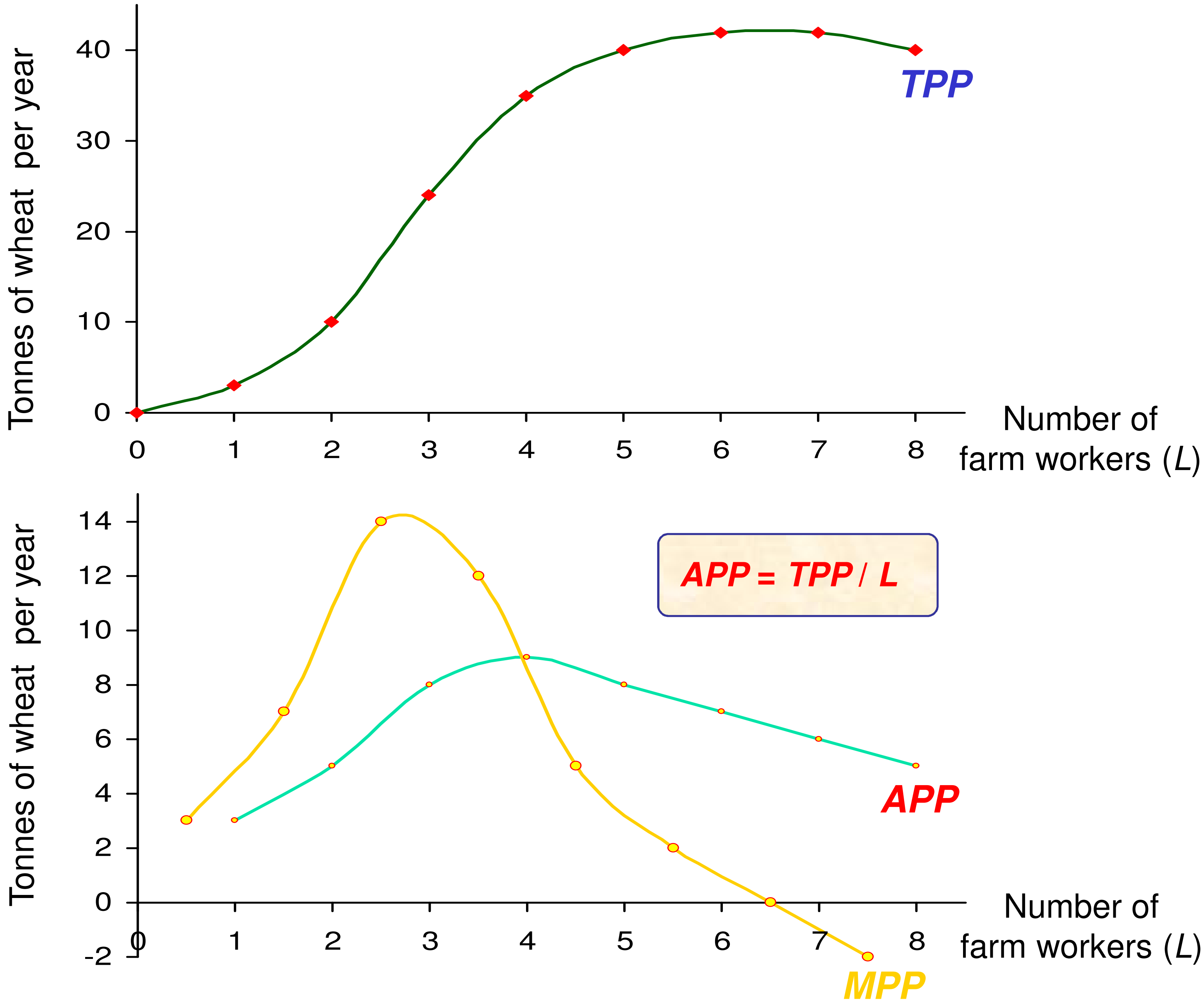
# Wheat production per year from a particular farm



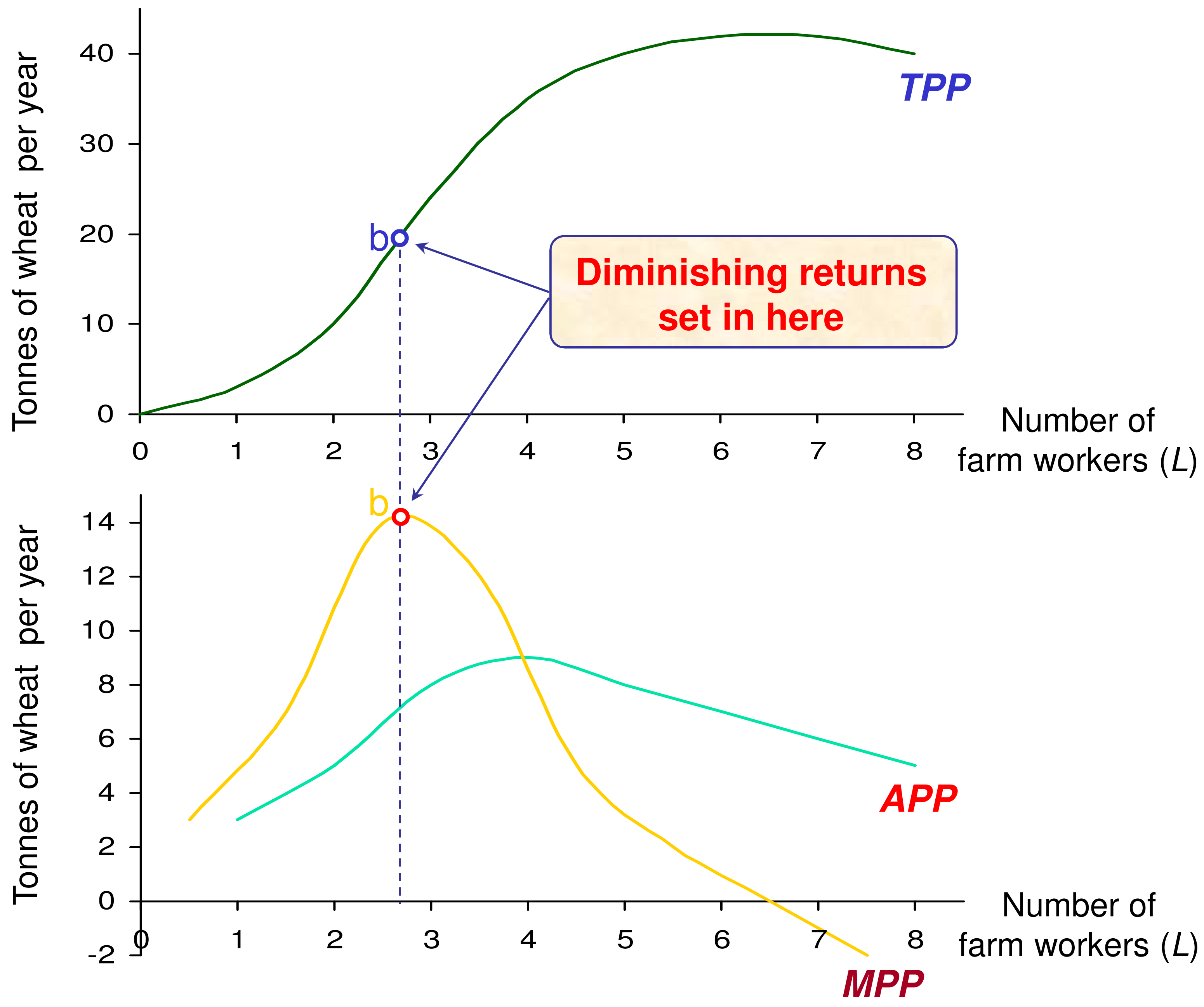
# Wheat production per year from a particular farm



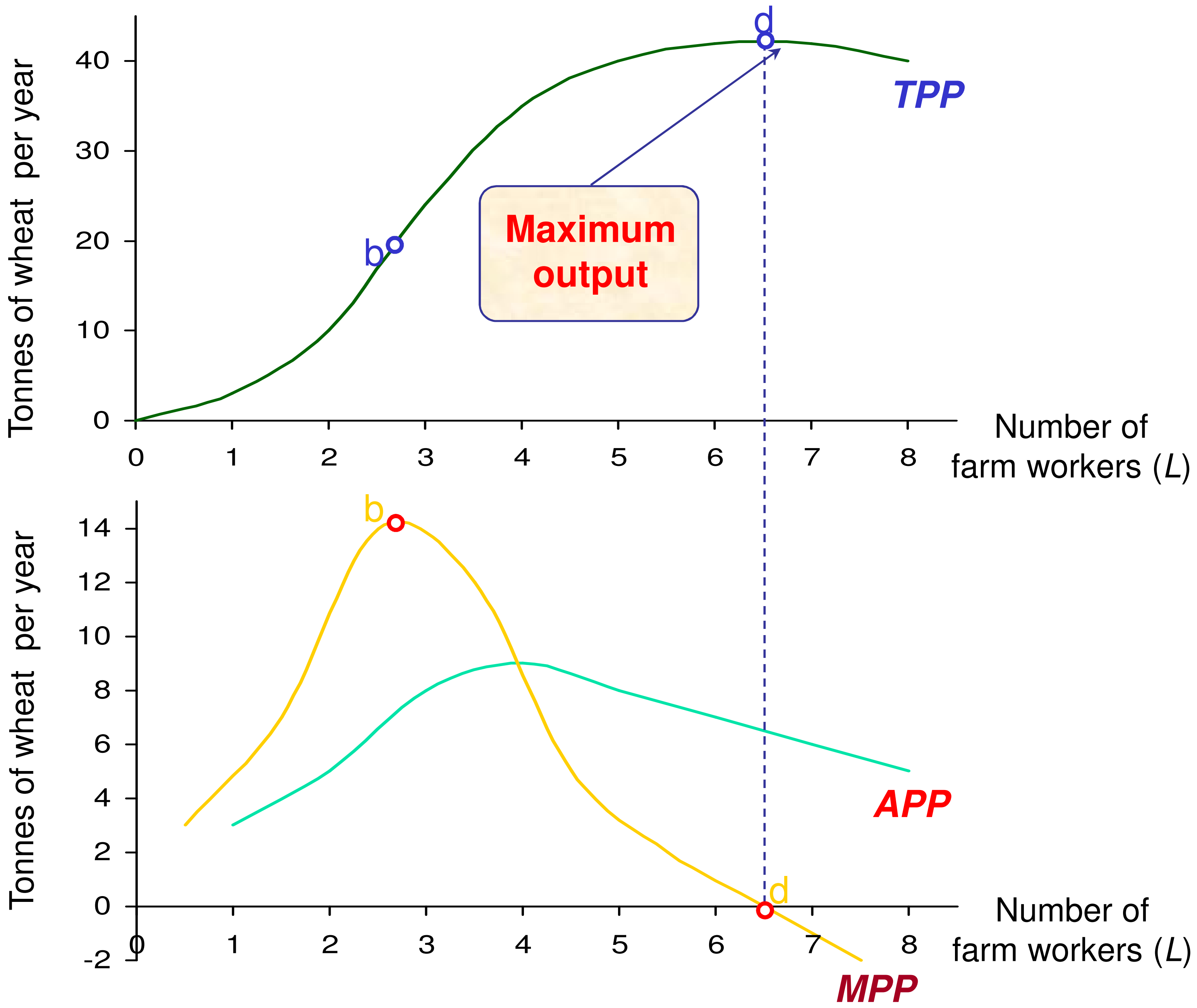
# Wheat production per year from a particular farm



# Wheat production per year from a particular farm



# Wheat production per year from a particular farm



# Short-Run and Long-Run Production

- In the short run some inputs are fixed and some variable
  - e.g. the firm may be able to vary the amount of labor, but cannot change the capital
  - in the short run we can talk about *factor productivity*

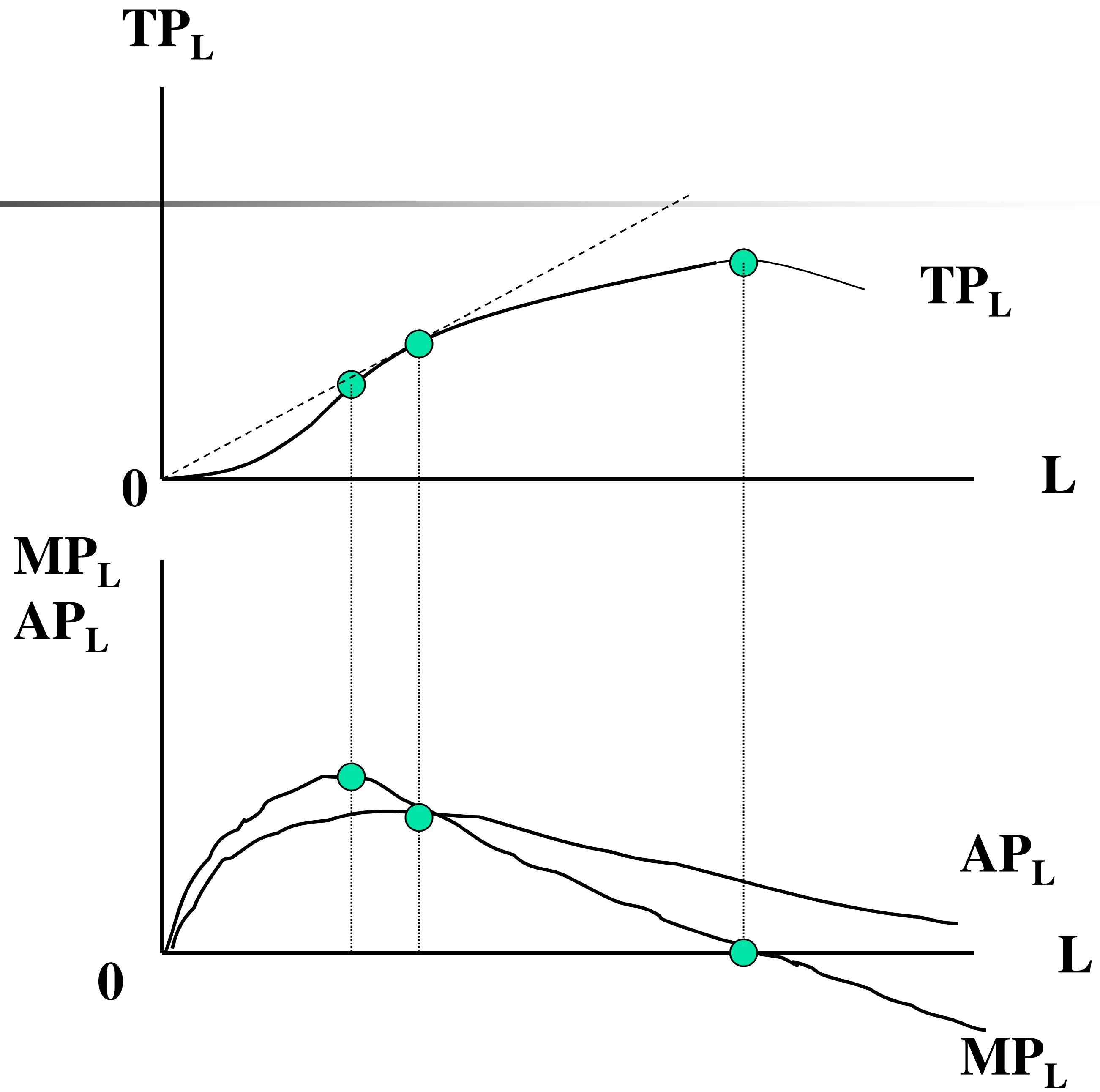
- In the long run all inputs become variable
  - e.g. the long run is the period in which a firm can adjust *all* inputs to changed conditions
  - in the long run we can talk about *returns to scale*

# How to Determine the Optimal Input Usage

- We can find the answer to this from the concept of derived demand
- The firm must know how many units of output it could sell, the price of the product, and the monetary costs of employing various amounts of the input L
- Let us for now assume that the firm is operating in *a perfectly competitive market* for its output and its input

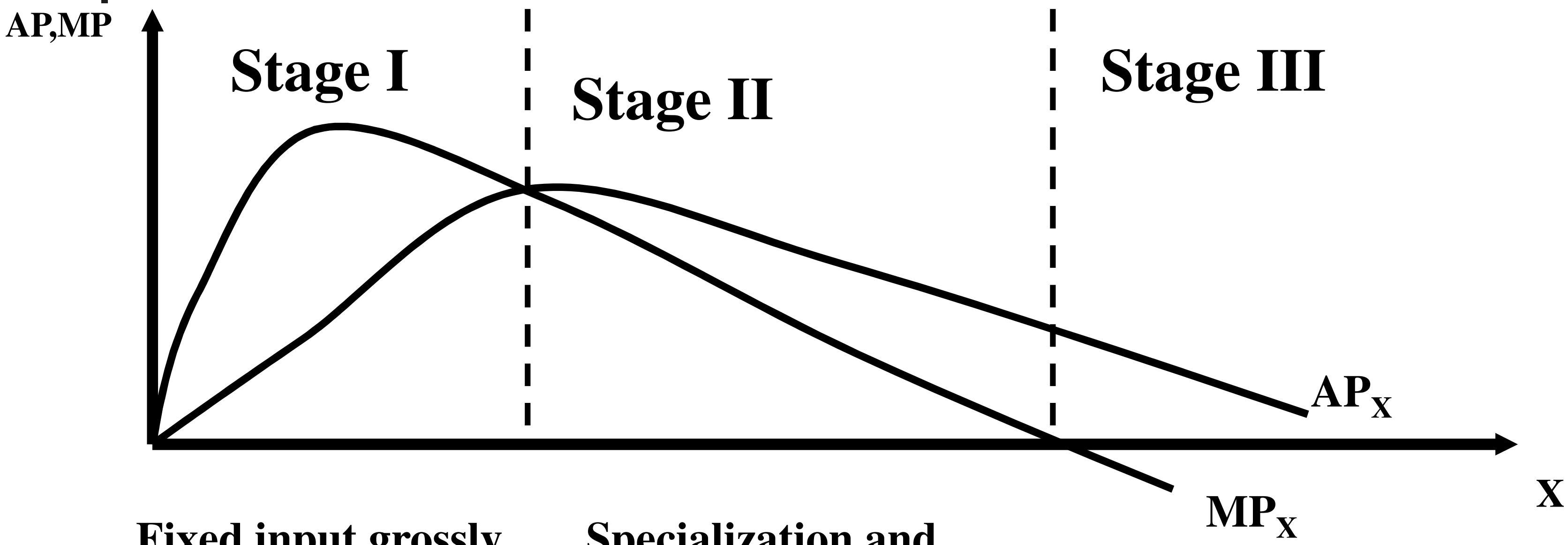
# So let's Plot $TP_L$, $MP_L$ and $AP_L$ at one Graph

| $Q_L$ | $TP_L$ | $MP_L$ | $AP_L$ |
|---|---|---|---|
| 1 | 10 | 10 | 10 |
| 2 | 25 | 15 | 12.5 |
| 3 | 35 | 10 | 11.67 |
| 4 | 40 | 5 | 10 |
| 5 | 40 | 0 | 8 |
| 6 | 35 | -5 | 5.83 |



TP_L
TP_L
0
L
MP_L
AP_L
AP_L
L
0
MP_L

# Three Stages of Production




Fixed input grossly underutilized; specialization and teamwork cause AP to increase when additional X is used

Specialization and teamwork continue to result in greater output when additional X is used; fixed input being properly utilized

Fixed input capacity is reached; additional X causes output to fall

# Stages of Production

- Stage I - $MP > AP$ and AP is rising,
- Stage II - $MP < AP$ and AP is falling; $MP > 0$, and
- Stage III - AP is still falling; $MP < 0$.

- Which stage do you think the typical firm will seek?

# Law of Diminishing Returns (Diminishing Marginal Product)

Holding all factors constant except one, the law of diminishing returns says that:

- beyond some value of the variable input, further increases in the variable input lead to steadily decreasing marginal product of that input
  - e.g. trying to increase labor input without also increasing capital will bring diminishing returns

# Short Run Production Function

| Units of Capital | Units of Labour | Total Output |
|---|---|---|
| 20 | 0 | 0 |
| 20 | 1 | 30 |
| 20 | 2 | 40 |
| 20 | 3 | 47 |
| 20 | 4 | 53 |
| 20 | 5 | 58 |
| 20 | 6 | 62 |
| 20 | 7 | 65 |

# Marginal Physical Product

- MPP is the *extra* output that can be produced by using one more unit of an input, *holding all other inputs constant*.

$$MPP_L = \frac{\Delta Q}{\Delta L}$$

# Example: MPP of Labour

| Units of Capital | Units of Labour | Output | Marginal Physical Product |
|---|---|---|---|
| 20 | 0 | 0 | |
| 20 | 1 | 30 | 30 |
| 20 | 2 | 40 | 10 |
| 20 | 3 | 47 | 7 |
| 20 | 4 | 53 | 6 |
| 20 | 5 | 58 | 5 |
| 20 | 6 | 62 | 4 |
| 20 | 7 | 65 | 3 |

Diminishing returns to labour

# Example:

Note:

P = Product Price = $2
W = Cost per unit of labor = $10000
MRP = MP x P
TLC = X x W
MLC = ΔTLC / ΔX

**Table 7.6 Combining Marginal Revenue Product (MRP) with Marginal Labor Cost (MLC)**

| Labor Unit (X) | Total Product (Q or TP) | Average Product (AP) | Marginal Product (MP) | Total Revenue Product (TRP) | Marginal Revenue Product (MRP) | Total Labor Cost (TLC) | Marginal Labor Cost (MLC) | TRP-TLC | MRP-MLC |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | | 0 | 0 | | 0 | | 0 | 0 |
| 1 | 10000 | 10000 | 10000 | 20000 | 20000 | 10000 | 10000 | 10000 | 10000 |
| 2 | 25000 | 12500 | 15000 | 50000 | 30000 | 20000 | 10000 | 30000 | 20000 |
| 3 | 45000 | 15000 | 20000 | 90000 | 40000 | 30000 | 10000 | 60000 | 30000 |
| 4 | 60000 | 15000 | 15000 | 120000 | 30000 | 40000 | 10000 | 80000 | 20000 |
| 5 | 70000 | 14000 | 10000 | 140000 | 20000 | 50000 | 10000 | 90000 | 10000 |
| 6 | 75000 | 12500 | 5000 | 150000 | 10000 | 60000 | 10000 | 90000 | 0 |
| 7 | 78000 | 11143 | 3000 | 156000 | 6000 | 70000 | 10000 | 86000 | -4000 |
| 8 | 80000 | 10000 | 2000 | 160000 | 4000 | 80000 | 10000 | 80000 | -6000 |

# Optimal Use of the Variable Input

| | |
|---|---|
| Marginal Revenue Product of Labor | $MRP_L = (MP_L)(MR)$ |
| Marginal Resource Cost of Labor | $MRC_L = \frac{\Delta TC}{\Delta L}$ |
| Optimal Use of Labor | $MRP_L = MRC_L$ |

# Optimal Decision Rule:

A profit maximizing firm operating in perfectly competitive output and input markets will be using optimal amount of an input at the point at which the monetary value of the input's marginal product is equal to the additional cost of using that input (L)

- in other words, when MRP = MLC