

Q1. Given the production function $Q = f(K, L) = A[K^n + L^n]$ where A is the level of technology, K is capital and L is labor. Suppose that $n > 0$. Consider the following problem.

- a. To ensure that the above production function exhibits a *decreasing return to scale technology*, what additional restrictions do one need to place on n ?

$$Q = A[K^n + L^n]$$

$$\ln Q = \ln[A(K^n + L^n)]$$

The condition is $2n < 1$ to exhibit a decreasing return to scale.

- b. Under the assumption used in (a), show that the production function satisfies the law of diminishing returns.

$$MP_K = \frac{\partial f(K, L)}{\partial K} = AnK^{n-1}$$

$$\frac{\partial MP_K}{\partial K} = (n-1)AnK^{n-2} < 0$$

↳ negative according to a

; as K increased, MP_K falls due to law of diminishing marginal product.

$$MP_L = \frac{\partial f(K, L)}{\partial L} = AnL^{n-1}$$

$$\frac{\partial MP_L}{\partial L} = (n-1)AnL^{n-2} < 0$$

; as L increased, MP_L falls due to law of diminishing product.

- c. Calculate the marginal rate of technical substitution (MRTS) of labor (L) for capital (K).

$$MRTS = \frac{MP_L}{MP_K} = \frac{AnL^{n-1}}{AnK^{n-1}}$$

$$= \left(\frac{L}{K}\right)^{n-1}$$

- d. Show that MRTS is a decreasing function in L. That is, as labor increases, the value of MRTS decreases.

$$\frac{\partial MRTS}{\partial L} = n-1 \left(\frac{L}{K}\right)^{n-2} \cdot (1)$$

$2n < 1 \Rightarrow n < \frac{1}{2}$. So, $(n-1) < 0$ making MRTS falls as L rises.

- e. Under the condition(s) assumed in (a), is the production function satisfied with the *global concave property*?

$$H = \begin{bmatrix} f_{KK} & f_{KL} \\ f_{LK} & f_{LL} \end{bmatrix}$$

$$\ln Q = \ln[A(K^n + L^n)] = \ln(AK^n + L^n)$$

$$= \ln AK^n + \ln L^n$$

$$\text{foc} : d \ln AK^n + d \ln L^n$$

$$= [\ln A \cdot nK^{n-1} + K^n \ln A] + d \ln L^n$$

$$\text{SOC} : d \ln AnK^{n-1} + d \ln L^n$$

$$= \quad ??$$

∴ yes, it's satisfy global concave property.

Suppose that $K(t) = \frac{1}{2}t^2 + 2t + 3$ and $L(t) = e^t + 3$, where $t \geq 0$ is the number of periods from now. Consider the following problem

- f. Show that Q is increasing over time.
- g. Compute $\frac{dQ}{dt}$ when $t = 0$, i.e. growth of output in the initial period.

Total derivative

$$\frac{dQ}{dt} = Q$$

\swarrow $k \leftarrow t$
 \swarrow $L \leftarrow t$

$$\begin{aligned}
 f) \quad \frac{dQ}{dt} &= \frac{\partial Q}{\partial k} k'(t) + \frac{\partial Q}{\partial L} L'(t) \\
 &= Ank^{n-1} \cdot \underbrace{dk}_{t+2} + AnL^{n-1} \cdot \underbrace{dL}_{te^{t-1}} \\
 &= Ank^{n-1}(t+2) + AnL^{n-1}(te^{t-1}) \\
 &\therefore Q \text{ is increasing over time}
 \end{aligned}$$

$$\begin{aligned}
 g) \quad \frac{dQ}{dt} \Big|_{t=0} &\rightarrow t=0; \\
 k(t) &= \frac{1}{2}(0^2) + 2(0) + 3 = 3; \\
 L(t) &= e^0 + 3 = 4 \\
 \frac{dQ}{dt} \Big|_{t=0} &= Ank^{n-1}(t+2) + AnL^{n-1}(te^{t-1}) \\
 &= Ank^{n-1}(0+2) + AnL^{n-1}(0e^{0-1}) \\
 &= An(3)^{n-1} \cdot 2 + An(4)^{n-1} \cdot (0) \\
 &= 2An(3)^{n-1}
 \end{aligned}$$

Q2. A monopolist faces the market demand given by $P = Q^{-c}$ where "c" is a parameter with positive value, "P" is the price per unit output and "Q" is the amount of output. Suppose that monopolist's production technology is given by $Q = K^{\frac{1}{3}}L^{\frac{2}{3}}$ where "K" and "L" are the level of capital used and the number of labor employed, respectively. Assume that the unit price of K and L are set equal to "r" and "w", respectively. Consider the following problems.

a. What type of the return to scale technology does the production function exhibit?

From Cobb-Douglas production function $Q = K^{\alpha} L^{\beta}$

If $\alpha + \beta < 1$, there will be decreasing return to scale

If $\alpha + \beta = 1$, " constant "

If $\alpha + \beta > 1$, " increasing "

Consequently, $Q = K^{\frac{1}{3}} L^{\frac{2}{3}}$ $\alpha + \beta = \frac{1}{3} + \frac{2}{3} = 1$

\therefore The production function is constant return to scale.

From now on, assume that $c = \frac{1}{4}$. Consider the following problems.

b. Construct the profit function of the monopolist. (Hint: your profit function should be expressed in terms of K and L .)

$$P = Q^{-c} \quad Q = K^{\frac{1}{3}} L^{\frac{2}{3}}$$

from market demand : $P = Q^{-c}$

substitute $c = \frac{1}{4} \rightarrow P = Q^{-\frac{1}{4}}$

$$\text{Profit} = \text{Total Revenue} - \text{Total Cost}$$

$$\pi = P \cdot Q - [\text{Total Cost of capital} + \text{Total cost of labor}]$$

$$\pi = Q^{-\frac{1}{4}} \cdot Q - [Kr + wL]$$

The unit price of K is equal to $r \rightarrow$ 1 unit price = r
K unit price = Kr

The unit price of L is equal to $w \rightarrow$ 1 unit price = w
L unit price = wL

$$\pi = Q^{-\frac{1}{4}} \cdot Q^1 - [Kr + wL]$$

$$\pi = Q^{-\frac{1}{4}} \cdot Q^{\frac{4}{4}} - Kr - wL$$

$$\pi = Q^{\frac{3}{4}} - Kr - wL$$

$$\text{From } Q = K^{\frac{1}{3}} \cdot L^{\frac{2}{3}}$$

$$\pi = \left[K^{\frac{1}{3}} \cdot L^{\frac{2}{3}} \right]^{\frac{3}{4}} - Kr - wL$$

$$\pi = \left(K^{\frac{1}{3}} \right)^{\frac{3}{4}} \cdot \left(L^{\frac{2}{3}} \right)^{\frac{3}{4}} - Kr - wL$$

$$\pi = K^{\frac{1}{4}} \cdot L^{\frac{1}{2}} - Kr - wL$$

$$f(K, L) = K^{\frac{1}{4}} \cdot L^{\frac{1}{2}} - Kr - wL \quad \#$$

c. The firm wants to maximize profit and seek for combination of the two factor inputs. Derive the demand for factor inputs, capital and labor.

$$\text{F.O.C} \quad \frac{\partial f}{\partial K} = 0, \quad \frac{\partial f}{\partial L} = 0$$

$$\frac{\partial f}{\partial K} = \frac{1}{4} K^{-\frac{3}{4}} \cdot L^{\frac{1}{2}} - (1)r$$

$$\frac{\partial f}{\partial K} = \frac{1}{4} K^{-\frac{3}{4}} L^{\frac{1}{2}} - r$$

$$\frac{\partial f}{\partial K} = \frac{L^{\frac{1}{2}}}{4K^{\frac{3}{4}}} - r$$

$$0 = \frac{L^{\frac{1}{2}}}{4K^{\frac{3}{4}}} - r$$

$$r = \frac{L^{\frac{1}{2}}}{4K^{\frac{3}{4}}}$$

$$4r = \frac{L^{\frac{1}{2}}}{K^{\frac{3}{4}}} \quad \text{—————} \quad \textcircled{1}$$

$$\frac{\partial f}{\partial L} = K^{\frac{1}{4}} \cdot \left[\frac{1}{2} L^{-\frac{1}{2}} \right] - 0 - w \quad (1)$$

$$\frac{\partial f}{\partial L} = K^{\frac{1}{4}} \cdot \frac{1}{2} L^{-\frac{1}{2}} - w$$

$$\frac{\partial f}{\partial L} = K^{\frac{1}{4}} \left(\frac{1}{2L^{\frac{1}{2}}} \right) - w$$

$$0 = \frac{K^{\frac{1}{4}}}{2L^{\frac{1}{2}}} - w$$

$$2w = \frac{K^{\frac{1}{4}}}{L^{\frac{1}{2}}} \quad \text{—————} \quad \textcircled{2}$$

$$\textcircled{1} \times \textcircled{2} ; \left[\frac{L^{\frac{1}{2}}}{K^{\frac{3}{4}}} \right] \left[\frac{K^{\frac{1}{4}}}{L^{\frac{1}{2}}} \right] = (4r)(2w)$$

$$\frac{K^{\frac{1}{4}}}{K^{\frac{3}{4}}} = 8rw$$

$$K^{\frac{1}{4} - \frac{3}{4}} = 8rw$$

$$K^{-\frac{2}{4}} = 8rw$$

$$K^{-\frac{1}{2}} = 8rw$$

$$\frac{1}{8rw} = K^{\frac{1}{2}}$$

$$\left(K^{\frac{1}{2}} \right)^2 = \left(\frac{1}{8rw} \right)^2$$

$$K = \frac{1}{64r^2w^2}$$

③

Then substitute K in ①

$$\frac{L^{\frac{1}{2}}}{K^{\frac{3}{4}}} = 4r$$

$$L^{\frac{1}{2}} = K^{\frac{3}{4}} (4r)$$

$$L^{\frac{1}{2}} = \left[\frac{1}{64r^2w^2} \right]^{\frac{3}{4}} (4r)$$

$$L^{\frac{1}{2}} = \frac{1}{(64)^{\frac{3}{4}} (r^2)^{\frac{3}{4}} (w^2)^{\frac{3}{4}}} \cdot 4r$$

$$L^{\frac{1}{2}} = \frac{4r}{(2^6)^{\frac{3}{4}} \cdot r^{\frac{3}{2}} \cdot w^{\frac{3}{2}}}$$

$$L^{\frac{1}{2}} = \frac{4r}{2^{\frac{9}{2}} \cdot r^{\frac{3}{2}} \cdot w^{\frac{3}{2}}}$$

$$\left(L^{\frac{1}{2}} \right)^2 = \left(\frac{4r}{2^{\frac{9}{2}} \cdot r^{\frac{3}{2}} \cdot w^{\frac{3}{2}}} \right)^2$$

$$L = \frac{16r^2}{2^9 \cdot r^3 \cdot w^3}$$

$$L = \frac{\cancel{2^4} \cdot \cancel{r^2}}{\cancel{2^5} \cdot \cancel{r^3} \cdot w^3}$$

$$L = \frac{1}{32rw^3} \quad \text{④}$$

from the production function $Q = K^{\frac{1}{3}} L^{\frac{2}{3}}$

$$Q = \left(\frac{1}{64r^2w^2} \right)^{\frac{1}{3}} \left(\frac{1}{32rw^3} \right)^{\frac{2}{3}}$$

$$Q = \frac{1}{(64)^{\frac{1}{3}} (r^2)^{\frac{1}{3}} (w^2)^{\frac{1}{3}} \cdot (32)^{\frac{2}{3}} (r)^{\frac{2}{3}} \cdot w^2}$$

$$Q = \frac{1}{4 \cdot r^{\frac{2}{3}} \cdot w^{\frac{2}{3}} \cdot \sqrt[3]{32 \cdot 32} \cdot r^{\frac{2}{3}} \cdot w^2}$$

$$Q = \frac{1}{4 r^{\frac{4}{3}} w^{\frac{8}{3}} \cdot \sqrt[3]{8 \cdot 4 \cdot 8 \cdot 4}}$$

$$Q = \frac{1}{4 r^{\frac{4}{3}} w^{\frac{8}{3}} \cdot \sqrt[3]{4 \cdot 2 \cdot 4 \cdot 4 \cdot 2 \cdot 4}}$$

$$Q = \frac{1}{4 r^{\frac{4}{3}} w^{\frac{8}{3}} \cdot 4 \sqrt[3]{2 \cdot 2}}$$

$$= \frac{1}{\sqrt{32} \sqrt[3]{2} r^{\frac{4}{3}} w^{\frac{8}{3}}}$$

d. How does the demand for labor vary with respect to w and r ? Show your result by using partial derivative.

$$\text{from } L = \frac{1}{32rw^3}$$

$$= \frac{1}{32} \cdot r^{-1} \cdot w^{-3}$$

$$\frac{\partial L}{\partial r} = \frac{1}{32} \cdot (-1r^{-2}) \cdot w^{-3}$$

$$\frac{\partial L}{\partial r} = \frac{-1}{32r^2w^3} \quad \#$$

$$\frac{\partial L}{\partial w} = \frac{1}{32} r^{-1} [-3w^{-4}]$$

$$\frac{\partial L}{\partial w} = \frac{-3}{32rw^4} \quad \#$$

e. Confirm your answer with the second-order condition.

S.O.C find f_{KK} , f_{KL} , f_{LK} , f_{LL}

$$f_K = \frac{1}{4} K^{-\frac{3}{4}} L^{\frac{1}{2}} - r$$

$$f_{KK} = \frac{1}{4} \left[\frac{3}{4} K^{-\frac{3}{4}-\frac{4}{4}} \right] L^{\frac{1}{2}} - 0$$

$$f_{KK} = -\frac{3}{16} K^{-\frac{7}{4}} L^{\frac{1}{2}}$$

$$f_{KK} = \frac{-3L^{\frac{1}{2}}}{16K^{\frac{7}{4}}}$$

$$f_{KL} = \frac{1}{4} K^{-\frac{3}{4}} \left[\frac{1}{2} L^{-\frac{1}{2}} \right] - 0$$

$$f_{KL} = \frac{1}{8K^{\frac{3}{4}} L^{\frac{1}{2}}}$$

$$f_L = \frac{1}{2} K^{\frac{1}{4}} L^{-\frac{1}{2}} - W$$

$$f_{LK} = \frac{1}{2} \left[\frac{1}{4} K^{-\frac{3}{4}} L^{-\frac{1}{2}} \right] L^{-\frac{1}{2}} - 0$$

$$f_{LK} = \frac{K^{-\frac{3}{4}} L^{-\frac{1}{2}}}{8}$$

$$f_{LK} = \frac{1}{8K^{\frac{3}{4}} L^{\frac{1}{2}}}$$

$$f_{LL} = \frac{1}{2} K^{\frac{1}{4}} \left[-\frac{1}{2} L^{-\frac{1}{2}-\frac{2}{2}} \right] - 0$$

$$f_{LL} = \frac{-K^{\frac{1}{4}} L^{-\frac{3}{2}}}{4}$$

$$f_{LL} = \frac{-K^{\frac{1}{4}}}{4L^{\frac{3}{2}}}$$

$$H = \begin{bmatrix} f_{KK} & f_{KL} \\ f_{LK} & f_{LL} \end{bmatrix}$$

$$H = \begin{bmatrix} \frac{-3L^{\frac{1}{2}}}{16K^{\frac{3}{4}}} & \frac{1}{8K^{\frac{3}{4}} L^{\frac{1}{2}}} \\ \frac{1}{8K^{\frac{3}{4}} L^{\frac{1}{2}}} & \frac{-K^{\frac{1}{4}}}{4L^{\frac{3}{2}}} \end{bmatrix}$$

$$\text{substitute } K = \frac{1}{64r^2 w^2},$$

$$L = \frac{1}{32rw^3}$$

$$L^{\frac{1}{2}} = \left(\frac{1}{32rw^3} \right)^{\frac{1}{2}}$$

$$= \frac{1}{32^{\frac{1}{2}} r^{\frac{1}{2}} w^{\frac{3}{2}}}$$

$$= \frac{1}{2^{\frac{5}{2}} r^{\frac{1}{2}} w^{\frac{3}{2}}} \quad \#$$

$$K^{\frac{1}{4}} = \left(\frac{1}{64r^2 w^2} \right)^{\frac{1}{4}}$$

$$= \frac{1}{64^{\frac{1}{4}} r^{\frac{1}{2}} w^{\frac{1}{2}}}$$

$$= \frac{1}{2^{\frac{21}{2}} \cdot r^{\frac{1}{2}} \cdot w^{\frac{1}{2}}} \quad \#$$

$$K^{\frac{3}{4}} = \left(\frac{1}{64r^2 w^2} \right)^{\frac{3}{4}}$$

$$= \frac{1}{64^{\frac{3}{4}} \cdot r^{\frac{3}{2}} \cdot w^{\frac{3}{2}}}$$

$$= \frac{1}{2^{\frac{9}{2}} r^{\frac{3}{2}} \cdot w^{\frac{3}{2}}} \quad \#$$

Q3. In a duopoly market, suppose that firms 1 and 2 face market demand, $p = 100 - (q_1 + q_2)$. Firm costs are $c_1 = 10q_1$ and $c_2 = q_2^2$.

(a) Calculate market price under the Cournot environment. How much is the profit that each firm yields in the equilibrium?

a Cournot Environment

$$\begin{aligned} \text{Profit}_1 (\pi_1) &= p \cdot q_1 - c_1 \\ &= (100 - (q_1 + q_2)) q_1 - 10q_1 \end{aligned}$$

$$\pi_1 = 90q_1 - q_1^2 - q_1q_2$$

$$\max \pi_1 \quad \pi_1 = 2513.8$$

$$\frac{d\pi_1}{dq_1} = 90 - 2q_1 - q_2 = 0$$

$$q_1 = 45 - 0.5q_2$$

$$\text{Profit}_2 (\pi_2) = p \cdot q_2 - c_2$$

$$= (100 - (q_1 + q_2)) q_2 - q_2^2$$

$$\pi_2 = 100q_2 - q_1q_2 - 2q_2^2$$

$$\max \pi_2 \quad \pi_2 = 492.98$$

$$\frac{d\pi_2}{dq_2} = 100 - q_1 - 4q_2 = 0$$

$$q_2 = 100 - q_1$$

$$\therefore 100 - 4q_2 = 45 - 0.5q_2$$

$$55 = 3.5q_2$$

$$q_2 = 15.714$$

$$q_1 = 37.143$$

$$Q = q_1 + q_2 = 15.714 + 37.143 = 52.857$$

$$P = 100 - 52.857 = 47.143 \#$$

(b) Calculate the market price under the joint production decision, i.e. collusive equilibrium. How much is the profit that each firm yields in the equilibrium?

$$\text{Total } \Pi = \pi_1 + \pi_2$$

$$= p \cdot q - c_1 - c_2$$

$$= (100 - q_1 - q_2)(q_1 + q_2) - 10q_1 - q_2^2$$

$$= 100q_1 - q_1^2 - q_1q_2 + 100q_2 - q_1q_2 - q_2^2 - 10q_1 - q_2^2$$

$$= 90q_1 - 2q_1q_2 - 2q_2^2 - q_1^2 + 100q_2$$

$$\frac{d\Pi}{dq_1} = 90 - 2q_2 - 2q_1 = 0$$

$$q_1 = 45 - q_2 \rightarrow 1$$

$$q_1 = 50 - 2q_2 \rightarrow 2$$

$$\frac{d\Pi}{dq_2} = -2q_1 - 4q_2 + 100 = 0$$

Substitute 1 into 2:

$$45 - q_2 = 50 - 2q_2$$

$$q_2 = 5, \quad q_1 = 40$$

$$Q = 40 + 5 = 45$$

$$P = 100 - 45 = 55$$

$$\pi_1 = p \cdot q_1 - c_1 = 55(40) - 10(40) = 1800$$

$$\pi_2 = p \cdot q_2 - c_2 = 55(5) - 5^2 = 250$$

(c) Do you think that the collusive equilibrium will sustain? What would be the profit of firm 1 if firm 1 chooses to deviate from the collusive allocation?

$$\left. \begin{array}{l} \pi_1 = 2513.8 \\ \pi_2 = 492.98 \end{array} \right\} \text{Cournot}$$

$$\left. \begin{array}{l} \pi_1 = 1800 \\ \pi_2 = 250 \end{array} \right\} \text{collusion}$$

$$\therefore \pi_1 \text{ collusion} < \pi_1 \text{ Cournot}$$

firm 1 is not collusion

$$\pi_2 \text{ collusion} < \pi_2 \text{ Cournot}$$

firm 2 is not collusion

So, collusion is not stable.

Q4. Consider a simple two-market model where demand and supply for each market is given below. (Notationally, let's name the two markets as A and B, respectively.)

Market A:

Demand: $p_A = 10 - 2Q_A$

Supply: $p_A = 1 + Q_A$

Market B:

Demand: $p_B = 20 - Q_B$

Supply: $p_B = 2 + 2Q_B$

- Derive the market equilibrium
- Suppose the government imposes unit tax on both markets at the rate of t_A and t_B . Solve for the after-tax equilibrium as the function of t_A and t_B .
- How much revenue can the government collect from the taxation?
- Determine the level of t_A and t_B that maximizes government's revenue.

c) tax revenue = $t_A + t_B$

tax R = $t_A Q_A + t_B Q_B$

tax R = $t_A \left(\frac{9 - t_A}{3} \right) + t_B \left(\frac{18 - t_B}{3} \right)$

d) Max

find tax R

tax R = $3t_A - \frac{t_A^2}{3} + 6t_B - \frac{t_B^2}{3}$

$\frac{\partial \text{tax R}}{\partial t_A} = 3 - \frac{2}{3}t_A = 0$ $t_A = 4.5$

$\frac{\partial \text{tax R}}{\partial t_B} = 6 - \frac{2}{3}t_B = 0$ $t_B = 9$

Mkt:

A: Demand = Supply

$10 - 2Q_A = 1 + Q_A$

$9 = 3Q_A$

$Q_A^* = 3 \rightarrow P_A^* = 4$

B: D = S

$20 - Q_B = 2 + 2Q_B$

$Q_B = 6$

$P_B = 14$

b) $t = P^D - P^S$

Mkt A

$t_A = [10 - 2Q_A] - [1 + Q_A]$

$t_A = 9 - 3Q_A$

$Q_A = \frac{9 - t_A}{3}$ $P_A = \frac{1 + 9 - t_A}{3}$

tax A = 4.5

tax B = 9

Mkt B

$t_B = [20 - Q_B] - (2 + 2Q_B)$

$t_B = 18 - 3Q_B$

$Q_B = \frac{18 - t_B}{3}$ $P_B = 2 + 2 \left(\frac{18 - t_B}{3} \right)$

Q5. (Monopolist and the Optimal advertising)

Consider a linear demand equation faced by a monopolist.

$$Q = 2000 + 4\sqrt{A} - 20P,$$

where A is the dollar amount of the expenditure on advertisement, P is the unit price, and Q is the amount of quantity demanded by consumers. Both θ and β are strictly positive.

The demand equation is an extended version of the traditional one. The proposed function captures an idea that advertising can boost the total demand in the market as potential customers get more information about the product.

Suppose that the monopolist cost function is given by $C(Q, A) = c(Q) + A$ where $c(Q) = 2Q + 1000$

a) Construct the profit function.

$$\begin{aligned}\pi &= P \cdot Q - C(Q) - A \\ &= P(2,000 + 4\sqrt{A} - 20P) - 2Q - 1,000 - A \\ &= 2,040P + 4PA^{1/2} - 20P^2 - 5,000 - 8A^{1/2} - A\end{aligned}$$

b) Determine the optimal pricing (P^*) and optimal advertisement (A^*) that maximize the profit of the monopolist.

$$\begin{aligned}\text{optimal pricing } (P^*) &\rightarrow 2,040 + 4A^{1/2} - 40P = 0 \\ &40P - 4A^{1/2} = 2,040 \\ &P^* = \frac{2,040 + 4A^{1/2}}{40}\end{aligned}$$

$$\begin{aligned}\text{optimal advertisement } (A^*) &\rightarrow 2PA^{-1/2} - 4A^{-1/2} - 1 = 0 \\ &2P - 4 = A^{1/2} \\ &4P^2 - 16 = A^*\end{aligned}$$

c) Confirm the result with the second-order differential test, i.e. hessian-matrix method.

$$H = \begin{bmatrix} \pi_{PP} & \pi_{PA} \\ \pi_{AP} & \pi_{AA} \end{bmatrix} = \begin{bmatrix} -40 & 2A^{-1/2} \\ 2A^{-1/2} & A^{-3/2}(2-P) \end{bmatrix} \rightarrow \text{negative definite}$$

$$|H_1| = -40 < 0 \rightarrow \forall (P, A)$$

$$|H_2| = -40(A^{-3/2}(2-P) - (2A^{-1/2})^2) < 0 \rightarrow \forall (P, A)$$

$\therefore P^*, A^*$ are global solution.