HE1002 Macroeconomics I

Problem Sheet 4 – Problems & Solutions

Academic Year 2025/2026, Semester 1

Quantitative Research Society @NTU

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Problem 4-1

Fill in the blanks in Table 10P-1.

Table 10P-1

Country	Nominal GDP growth (%)	Population growth (%)	Inflation (%)	Real GDP growth per capita (%)
Svea	4	3		-1
Bonifay	3	1	0	2
Chaires		2	6	4
Drifton	5	1	-2	
Estiffanulga	7		2	4

Solution:

We use the relationship:

$$\text{Real GDP growth per capita} = \text{Nominal GDP growth} - \text{Inflation} - \text{Population growth}$$

or equivalently

$$\text{Nominal GDP growth} = \text{Real GDP growth per capita} + \text{Inflation} + \text{Population growth}$$

Country	Nominal GDP growth (%)	Population growth (%)	Inflation (%)	Real GDP growth per capita (%)
Svea	4	3	2	-1
Bonifay	3	1	0	2
Chaires	12	2	6	4
Drifton	5	1	-2	6
Estiffanulga	7	1	2	4

Problem 4-2

Equation 10-1 states that the Real GDP per capita growth rate = Nominal GDP per capita growth rate − Inflation rate − Population growth rate. This equation is an approximation of the exact rate of growth of GDP per capita, and so it results in some errors when calculating this rate. However, the simplified equation is both easy to use and results in small error terms when inflation, nominal GDP growth, and population growth are low, and so it is a useful approximation. Table 10P-2 lists a fictional country's nominal GDP, real GDP, GDP deflator, and population over two years.

Table 10P-2

Year	Nominal GDP ($)	GDP deflator	Real GDP ($)	Population
2023	1,000,000	1.00	1,000,000	1,000
2024	1,050,000	1.03	1,019,417	1,005

(a) **Use your knowledge from Chapter 8, "The Cost of Living," to verify that the real GDP figures in Table 10P-2 are accurate.**

Solution:

Real GDP is calculated by dividing Nominal GDP by the GDP deflator:

$$\text{Real GDP} = \frac{\text{Nominal GDP}}{\text{GDP deflator}}$$

For 2023:

$$\text{Real GDP}_{2023} = \frac{1,000,000}{1.00} = 1,000,000$$

For 2024:

$$\text{Real GDP}_{2024} = \frac{1,050,000}{1.03} \approx 1,019,417$$

Thus, the real GDP values shown in the table are accurate.

(b) **Calculate this country's real GDP per capita for both 2023 and 2024.**

Solution:

$$\text{Real GDP per capita}_{2023} = \frac{1,000,000}{1,000} = 1,000$$

$$\text{Real GDP per capita}_{2024} = \frac{1,019,417}{1,005} \approx 1,014$$

(c) **Calculate the growth rate in this country's real GDP per capita between 2023 and 2024.**

Solution:

$$\text{Growth Rate} = \frac{\text{Real GDP per capita}_{2024} - \text{Real GDP per capita}_{2023}}{\text{Real GDP per capita}_{2023}} \times 100\%$$

$$= \frac{1,014 - 1,000}{1,000} \times 100\% = 1.4\%$$

(d) **Calculate the growth rates in the nominal GDP, GDP deflator, and the population.**

Solution:

Nominal GDP growth rate:

$$\frac{1,050,000 - 1,000,000}{1,000,000} \times 100\% = 5.0\%$$

GDP deflator (inflation) rate:

$$\frac{1.03 - 1.00}{1.00} \times 100\% = 3.0\%$$

Population growth rate:

$$\frac{1,005 - 1,000}{1,000} \times 100\% = 0.5\%$$

Problem 4-3

For each growth rate below, use the rule of 70 to calculate how long it will take incomes to double.

Formula: Time to double (in years) $= \frac{70}{\text{growth rate (\%)}}$

(a) 4 percent.

Solution:

$$\text{Time to double} = \frac{70}{4} = \textbf{17.5 years}$$

(b) 7 percent.

Solution:

$$\text{Time to double} = \frac{70}{7} = \textbf{10 years}$$

(c) 2.5 percent.

Solution:

$$\text{Time to double} = \frac{70}{2.5} = \textbf{28 years}$$

(d) 10 percent.

Solution:

$$\text{Time to double} = \frac{70}{10} = \textbf{7 years}$$

(e) 3 percent.

Solution:

$$\text{Time to double} = \frac{70}{3} = \textbf{23.3 years}$$

Problem 4-4

For each part below, determine whether the following actions will increase or decrease productivity, and name the component of productivity that each affects.

(a) The local government builds a new school.

Solution:

Increase – Physical capital (L)

(b) Teachers in the new school hold classes for young students.

Solution:

Increase – Human capital (L)

(c) A manufacturer installs robots on its assembly line.

Solution:

Increase – Physical capital (K)

(d) A research team designs a more efficient system of irrigation.

Solution:

Increase – Technology/Knowledge (A)

(e) A soda company discovers a new source of underground water that can be used to make its products.

Solution:

Increase – Natural resources (N)

(f) A professor writes a new and improved economics textbook.

Solution:

Increase – Human capital (L)

(g) A large number of people have less access to health care.

Solution:

Decrease – Human capital (L)

(h) A worker receives on-the-job training to be a mechanic.

Solution:

Increase – Human capital (L)

Problem 4-5

Which of the countries shown in Table 10P-3 had the highest level of per capita income in 2024? Which had the highest rate of income growth from 2019 to 2024? Do incomes in these countries appear to be converging?

Table 10P-3

Solution:

1. **Artinia** has the highest level of per capita income in 2024.
2. **Chi** has the highest rate of income growth from 2019 to 2024:

$$\begin{aligned} \text{Bolivia growth} &= 25.3\% \\ \text{Chi growth} &= 83.3\% \\ \text{Ghala growth} &= 30.3\% \\ \text{Artinia growth} &= 46.0\% \\ \text{Plazi growth} &= 30.6\% \end{aligned}$$

3. **No, incomes do not appear to be converging.** Ghala has the lowest GDP per capita but does not have the highest income growth rate, so it is unlikely to catch up with the GDP of other countries that started with higher GDP per capita. Additionally, the richest country Artinia still grew at a strong rate of 46%.

Problem 4-6

In 2021 the median household income in Louisiana was approximately $52,087 per year, while the income per household in Massachusetts was about $89,645. However, suppose the growth rate of per capita real GDP in Louisiana is higher than in Massachusetts (3 percent versus 2 percent).

(a) From the perspective of trying to maximize your income per capita, which state will have a higher increase in income in the first year?

Solution:

$$\text{Louisiana increase} = \$52{,}087 \times 0.03 = \$1{,}562.61$$
$$\text{Massachusetts increase} = \$89{,}645 \times 0.02 = \$1{,}792.90$$

Massachusetts has the higher increase in income in the first year at \$1,792.90.

(b) From the perspective of trying to maximize your income per capita, which state will have a higher increase in 60 years?

Solution:

$$\text{Louisiana income in 60 years} = \$52{,}087 \times (1.03)^{60} = \$324{,}550.70$$
$$\text{Massachusetts income in 60 years} = \$89{,}645 \times (1.02)^{60} = \$294{,}128.00$$

Louisiana will have a higher increase in 60 years despite starting with lower income, due to the higher growth rate compounded over time.

Problem 4-7

Will the three countries in Table 10P-4 converge to the same level of economic development given enough time? **Table 10P-4**

Country	Income per capita ($)	Real per capita GDP growth rate (%)
Ansonia	5,000	7.0
Trumbull	7,500	4.5
Shelton	10,000	2.0

Solution:

Yes, the three countries will converge. Shelton's growth is slowing down to 2% while having the highest income value, while Ansonia has the lowest income but the highest growth of 7%. Trumbull has income and growth in the middle range between both countries. Thus, with enough time, the slower-growing but richer Shelton and the faster-growing but poorer Ansonia will be able to converge to similar levels of economic development.

Problem 4-8

Indicate whether each of the following statements is true or false and explain your answer.

(a) Country A's labor share is 60 percent, Country B's labor share is 70 percent, and labor is growing at a rate of 3 percent in both countries. All else the same, Country B has a higher growth rate of output.

Solution:

True. Using the growth accounting equation: $g_Y = g_A + \alpha g_K + (1-\alpha)g_L$

Since country B has a higher labor share (70% vs. 60%), and labor is growing at the same rate in both countries, country B will have a higher contribution from labor growth to output growth.

(b) Country A's labor share is 40 percent, Country B's labor share is 70 percent, and labor is growing at a rate of 10 percent in country A and 6 percent in country B. All else the same, Country A has a higher growth rate of output.

Solution:

False. Although country A's labor is growing faster (10% vs. 6%), country A has a lower labor share (40% vs. 70%). The contribution to output growth is: labor share $\times$ labor growth rate. Country B's contribution from labor is $0.70 \times 6\% = 4.2\%$, while country A's is $0.40 \times 10\% = 4\%$. Country B has the higher growth rate of output.

(c) Labor is growing at a negative rate in country A and a positive rate in country B, so country B must have a higher growth rate of output.

Solution:

False. While labor is growing faster in country B, we also need to consider capital and technology growth. If country A has sufficiently higher capital growth or technology growth, it could still have higher output growth despite negative labor growth.

(d) Labor and capital are both growing more quickly in Country A than in Country B, so Country A must have a higher growth rate of output.

Solution:

False. We also need to consider technology growth. If technology is declining in country A but growing significantly in country B, country B could have higher overall output growth.

Problem 4-9

Calculate the implied growth rate of technology in each scenario in Table 10P-5. Assume labor's share of output is 60 percent and capital's share of output is 40 percent.

Table 10P-5

Scenario	Growth rate of output (%)	Growth rate of labor (%)	Growth rate of capital (%)	Implied growth rate of technology (%)
A	3.0	2	2	1.0
B	4.2	3	3	1.2
C	3.0	1	5	0.4
D	4.2	1	4	2.0

Solution:

Use the formula:

$$g_Y = g_A + \alpha g_K + (1-\alpha) g_L$$

where $\alpha = 0.4$ (capital's share), $(1-\alpha) = 0.6$ (labor's share).

Calculate g_A for each scenario:

$$g_A = g_Y - [\alpha g_K + (1-\alpha) g_L]$$

A:

$$\begin{aligned} g_A &= 3.0 - [2 \times 0.4 + 2 \times 0.6] \\ &= 3.0 - [0.8 + 1.2] = 3.0 - 2.0 = \boxed{1.0} \end{aligned}$$

B:

$$\begin{aligned} g_A &= 4.2 - [3 \times 0.4 + 3 \times 0.6] \\ &= 4.2 - [1.2 + 1.8] = 4.2 - 3.0 = \boxed{1.2} \end{aligned}$$

C:

$$\begin{aligned} g_A &= 3.0 - [5 \times 0.4 + 1 \times 0.6] \\ &= 3.0 - [2.0 + 0.6] = 3.0 - 2.6 = \boxed{0.4} \end{aligned}$$

D:

$$\begin{aligned} g_A &= 4.2 - [4 \times 0.4 + 1 \times 0.6] \\ &= 4.2 - [1.6 + 0.6] = 4.2 - 2.2 = \boxed{2.0} \end{aligned}$$

Problem 4-10

For each of the following examples, state whether this activity would likely hinder or promote economic growth, and name a component of productivity each produces or reduces.

(a) Not requiring students to attend school.

Solution:

Hinder economic growth – Reduces human capital (L)

(b) Granting patents on new inventions.

Solution:

Promote economic growth – Increases technology (A)

(c) Building a solid infrastructure system.

Solution:

Promote economic growth – Increases physical capital (K)

(d) Allowing local rivers and streams to become polluted.

Solution:

Hinder economic growth – Reduces natural resources (N)

Problem 4-11

Policy-makers in the U.S. government have long tried to write laws that encourage growth in per capita real GDP. These laws typically do one of three things, as listed below. For each of the three points, name a law or government program with that intention.

(a) They encourage firms to invest more in research and development in order to boost technology.

Solution:

Example: Small Business Innovation Research (SBIR) program encourages firms to invest in R&D by providing grants and contracts.

(b) They encourage individuals to save more in order to boost the physical capital stock.

Solution:

Example: Tax incentives provided through retirement accounts like 401(k)s and IRAs [USA], or Central Provident Fund [Singapore]. These policies encourage households to save more by offering tax benefits.

(c) They encourage individuals to invest more in education in order to boost the stock of human capital.

Solution:

Examples: Pell Grants provide financial assistance for higher education [USA]. The G.I. Bill supports education and job training for veterans. Public education funding also invests in human capital development.

Problem 4-12

Name the type of institution that is responsible for promoting a stable environment for the economy regarding each of the following situations.

(a) Someone steals your car but is caught.

Solution:

Police force (Law enforcement / Criminal justice system)

(b) You claim that your employer violated the terms of your employment contract.

Solution:

Trade union and Ministry of Manpower (MOM) [Singapore context], or labor board / labor court (General context). These institutions enforce labor contracts and protect workers' rights.