Solutions for the Macro 2 Mock exam 3
With an additional question about growth and convergence

<u>CLIMATE CHANGE</u>

1. Consider that the total global CO2 emissions in 2020 (E) amounted to 12 billion tonnes. Estimate the average annual growth rate of the CO2 emissions per unit of GDP (E^*/Y) between that year and 2050 that is compatible with: (i) total global CO2 emissions of 15 billion tonnes in 2050; (ii) average annual growth of GDP per capita of 3.5% throughout the period; and (iii) average annual growth rate of the global population of 1%. (For purpose of simplification, consider N = L). Explain the rationale for your result.

<u>Solution</u>:

$$\boldsymbol{r\left(\frac{E}{Y}\right) = r(E) - r(L) - r\left(\frac{Y}{L}\right)}$$

[Where E = emissions, L = labour force, N = total population, Y = income or GDP (r stands for "rate of growth of…")]

$$\boldsymbol{t = 30;\ \ r(L) = 0.01;\ \ r\left(\frac{Y}{L}\right) = 0.035;\ \ r(E) =?}$$

$$\boldsymbol{r(E) = \frac{ln\left(\frac{E_{2050}}{E_{2020}}\right)}{t} = \frac{ln\left(\frac{15}{12}\right)}{30} = 0.00744}$$

$$\boldsymbol{r\left(\frac{E}{Y}\right) = 0.00744 - 0.01 - 0.035 = -0,03756 \approx -3.756\%}$$

Given that total income, $\left[\left(r(Y) = r\left(\frac{Y}{L}\right) + r(L)\right)\right]$, is projected to growth faster than global emissions of CO2 are allowed to grow, emissions per unit of GDP must fall (GDP must become greener).

2. Taking the above-mentioned assumptions, if the UN could enforce a reduction of global emissions of CO2 to 10 billion tonnes by 2050 (from 12 billion tonnes in 2020), what would the average annual growth rate of CO2 emissions per unit of GDP be for the period? Explain the rationale for your result.

<u>Solution</u>:

$$\boldsymbol{r(E) = \frac{ln\left(\frac{E_{2050}}{E_{2020}}\right)}{t} = \frac{ln\left(\frac{10}{12}\right)}{30} = -0.0061}$$

$$\boldsymbol{r\left(\frac{E}{Y}\right) = -0.0061 - 0.01 - 0.035 = -0,051 \approx -5.1\%}$$

If global emissions of CO2 are to be reduced by 2050 relative to 2020, while total income, $\left[r(Y) = r\left(\frac{Y}{L}\right) + r(L)\right]$, continues to growth at the same rate, emissions per unit of GDP must fall much faster than GDP grows.

3. If technological innovation allows emissions of CO2 per unit of GDP to reduce by an average of 5% per year for the period 2020-2050, what could the rate of growth of GDP per capita be that is consistent with a 1% annual growth of population and a ceiling of 15 billion tonnes of CO2 emissions by 2050? Explain the rationale of your result.

Solution:

$$\boldsymbol{r\left(\frac{E}{Y}\right) = r(E) - r(L) - r\left(\frac{Y}{L}\right)}$$

$$\boldsymbol{r\left(\frac{E}{Y}\right) = -0.05}$$

$$\boldsymbol{-0.05 = 0.00744 - 0.01 - r\left(\frac{Y}{L}\right)}$$

$$\boldsymbol{r\left(\frac{Y}{L}\right) = 0.00744 - 0.01 + 0.05 = 0.0474 = 4.74\%}$$

Given that science and technology made GDP growth substantially less intensive in CO2 emissions, the global ceiling of 15 billion tonnes of CO2 by 2050 can be met at significantly higher rates of growth of per capita GDP. The greener the economy, the larger the margin for higher rates of GDP growth.

4. If CO2 emissions per unit of GDP could not be reduced, what would the rate of growth of GDP per capita be to meet the maximum target of 15 billion tonnes by 2050? Explain the rationale for your result.

Solution:

$$r\left(\frac{Y}{L}\right) = r(E) - r(L) - r\left(\frac{E}{Y}\right) = 0.00744 - 0.01 - 0 = -0.00256 = -0.256\%$$

If CO2 emissions per unit of GDP could not be reduced, the rate of growth of GDP per capita must be negative (GDP per capita must fall), such that the ceiling of global emissions could be met despite the pressure of population growth.

INDUSTRIALIZATION AND INDUSTRIAL POLICY

1. Why does the growth of the manufacturing sector accelerate GDP growth more than proportionally, according to some authors?

Solution:

Structuralist economists pay critical attention to how different economic sectors affect economic trajectories differently. Earlier authors on development emphasised the specific role of industrialization in development because of its impacts on the other sectors of the economy. First, productivity gains in manufacturing are reflected in the lowering of the cost of industrial goods (including machinery and other investment related goods), thus lowering the costs of investment for the whole economy. Second, technological progress reflected in the quality of industrial goods (including investment goods) is reflected in higher productivity of the whole economy. Third, industrialisation increases incomes, and this is reflected in higher levels of savings and of consumption, resulting in higher investment. Fourth, as manufacturing goods are tradable, the balance of payments may benefit from expansion of manufacturing (this is reflected in higher import capacity, ability to sustain higher levels of debt and investment), the resilience to macroeconomic shocks may increase and the ability to absorb new technologies from abroad improves. Fifth, as manufacturing expands and the labour productivity of the whole economy increases, labour shifts from lower to higher productivity sectors, thus further accelerating the rate of growth of productivity. Hence, manufacturing contributes to economic growth by more than its sectoral rate of growth and its sectoral share of GDP.

2. Explain the rationale of using the business or product cycle as a reference point for the designing of specific industrial policies.

Solution:

Authors like Ha-Joon Chang and other proponents of selective, non-market conforming industrial policy consider that, typically, industries follow cycles of infancy (sunrise), maturity

(noon) and senility (sunset), which are linked with different challenges and different policy needs. In their *sunrise stage,* industries are intensive in innovation, adaptation, and experimentation, are not competitive yet and need to build scale economies fast. Policies are required to lower costs and risks of innovation, adaptation and experimentation (such as R&D subsidies); to accelerate adoption of technologies while protecting those that produce innovation (such as subsidies to adopt and adapt innovations, and rents – maybe patents – for those that generate innovation); guarantee scale of production by coordinating competitive investment and limiting entry in new industries; guarantee complementary investment (in new technologies and R&D, and/or in horizontal and vertical linkages); and guarantee some level of market protection while the competitive capacities of sunrise industries are developed at accelerated pace. In their *stage of maturity*, industries require consolidation of institutions, static coordination of competitive (scale) and complementary (linkages) investment, coordination of adjustments to short term fluctuations in demand, reduction of transaction costs. In their *sunset stage,* production shrinks and sunk costs of highly specific assets and labour increase, thus preventing adjustments and relocation of assets. At this stage, three related sets of policies are the most required: coordination of asset scrapping, coordination and subsidisation of retraining of labour and relocation of flexible assets, and preparation of a new *sunrise stage,* either by significantly modernising the industry or shifting to a different one.

ADDITIONAL EXERCISE ON GROWTH AND CONVERGENCE

Consider the following data:

GDP per capita in US$

	1987	1997	2007	2017
USA	34,017	40,916	50,017	53,083
Germany	32,561	41,881	45,688	48,472
Japan	29,038	35,573	41,963	46,578
Russia	8,461	8,726	10,246	10,904
Brazil	9,986	5,804	10,517	11,586
India	457	671	1,130	1,965
China	636	1,444	3,488	7,331
South Africa	6,000	5,659	7,180	7,491

1. Estimate the annual average continuous rate of growth of GDP per capita for each country for the entire period of 1987-2017.

Solution:

$$g_c = \frac{ln\left(\frac{X_i}{X_0}\right)}{n} = \frac{ln(X_i) - ln(X_0)}{n}$$

[Where g_c = continuous growth rate, ln = natural log, X = is the variable being analysed (in this case, is the GDP per capita of any of the countries in the sample), and the subscripts 0 and i refer to the periods that are being compared (in this case, X_0 stands for per capita GDP in 1987, and X_i stands for per capita GDP in 2017)]

Average annual GDP per capita continuous growth rates for 1987-2017

USA	**1.48**
Germany	**1.33**
Japan	**1.58**
Russia	**0.85**
Brazil	**0.50**
India	**4.86**
China	**8.15**
South Africa	**0.74**

2. Which economies are converging to or diverging from the level of the USA GDP per capita? Explain your answer.

Solution:

China, India and Japan are converging, because their annual average GDP per capita growth rates are higher and their levels of GDP per capita at the starting point are smaller than that of the USA. The remaining countries (Germany, South Africa, Russia and Brazil) are diverging because their GDP per capita growth rates are lower and their levels of GDP per capita at the starting point are smaller than that of the USA.

3. At its average growth rates of GDP per capita for the period 1987-2017, when will China reach the 2017 GDP per capita of the USA?

Solution:

$$t = \frac{ln\left(\frac{X_{USA}}{X_{China}}\right)}{ln(1+r)_{China}} = \frac{ln(X_{USA}) - ln(X_{China})}{ln(1+r)_{China}} = \frac{ln(53,083) - ln(7,491)}{ln(1.0815)} \approx 25\ years$$

[Where r, in the denominator, stands for the rate of growth of GDP for the economy that is catching up. The logic of this equation is that the numerator estimates the distance between the two economies, which is covered at the speed of the rate of growth of the economy that is catching up (n the denominator). The time it takes a moving object to reach a target is given by the distance divided by the speed of movement.]

At its average annual growth rates for 1987-2017, the GDP per capita of China will reach the level of the 2017 GDP per capita in the USA by 2042 (2017 + 25 years = 2042).

[Notice that the question is "…<u>when</u> will China reach" NOT, "…<u>how long</u> will it take for China to reach…". Had we asked for "how long", the answer would be "approximately 25 years". Because we asked for "when", which implies a specific time, the answer is given by the sum of the year when the "race" started, in this case it is 2017, the last year of the sample, PLUS the time it takes, 25 years, this is 2017 + 25 = 2042]

4. At the average growth rates of GDP per capita for the period 1987-2017, when will China and the USA have the same level of GDP per capita?

<u>Solution</u>:

$$\boldsymbol{t = \frac{ln\left(\frac{X_r}{X_p}\right)}{ln\left(\frac{(1+r)_p}{(1+r)_r}\right)} = \frac{ln(X)_r - ln(X)_p}{ln(1+r)_p - ln(1+r)_r} = \frac{ln(53,083) - ln(7,491)}{ln(1.0815) - ln(1.0148)} \approx 31\ years}$$

At their average annual growth rates for 1987-2017, the GDP per capita of the USA and of China will be equal in 2048 (2017 + 31 years = 2048).

[This equation is trying to measure the time it gets for two economies, starting from different positions and growing at different speeds, take to me the same. The target economy is also moving, but the distance between the two reduces over time as the smaller economy is growing at a higher speed than the larger, thus is catching up. The numerator measures the distance between the two at the starting point, whereas the denominator measures how much faster is the catching up economy growing relative to the economy being caught up. Again, the time it takes for the two economies to meet depends on the distance between the to (numerator) and the relative speed between the two (denominator). If the richer economy is growing faster, they will never meet; if the poorer economy is growing faster, they will meet at some time in the future, depending on how far away they are from each other at the beginning and how much faster than the richer is the poorer economy growing.]

[Notice, again, that the question is "…<u>when</u> will the China and the USA have the same level of GDP per capita", NOT, "…<u>how long</u> will it take for China and the USA…". Had we asked for "how long", the answer would be "approximately 31 years". Because we asked for "when", which implies a specific time, the answer is given by the sum of the year when the "race" started, in this case it is 2017, the last year of the sample, PLUS the time it takes, 31 years, this is 2017 + 31 = 2048]