INTERNATIONAL
ECONOMICS
OLYMPIAD

2021

Open Questions

Solve no more than 4 questions out of 5. Indicate your choice of questions.

If you provide solutions for all 5 questions, all of them will be commented on by the Jury, but only 4 will add to your score. In this case, if you do not specify which to grade, the maximum grade of 5 will be excluded.

Every open question is worth 30 raw points.

If not stated otherwise, think of all goods, services and assets as of infinitely divisible. Numbers of firms and people may be only integer.

Convey your ideas clearly. Don't skip important logical transitions in your reasoning.

Good luck!

Question 1. "Dynamic Equilibrium" *(30 raw points)*

Oil (good A) and Gas (good B) are substitutes in consumption; the demand and supply functions are given by:

Good	Demand	Supply
Oil (A)	$D_A = K - 2P_A + P_B$	$S_A = -10 + 2P_A$
Gas (B)	$D_B = 80 - 6P_B + 2P_A$	$S_B = -5 + P_B$

(a) *(5 rp)* Find equilibrium prices $P_A^\star$ and $P_B^\star$ if $K = 210$.

(b) *(10 rp)* Now consider a dynamic version of this model. We consider the demand for Gas constant for simplicity, but the demand for Oil is volatile. In period t, parameter K takes the value of K_t. Suppose that $K_1 = 210$, so in the first period, the equilibrium from part **(a)** realizes.

For producers of both natural resources, it takes some time to change production capacity, so they have to make a production decision one period before the actual sale occurs. In the first period ($t = 1$), they expect the demand for Oil to fall sharply, so the expected K_2 equals 80. How many units of Oil and Gas will be produced for selling in period 2?

(c) *(5 rp)* The prediction of demand decline turned out to be wrong, so K_2 remained at level 210. Still, the goods are produced, and capacity is exhausted. What prices of Oil and Gas will clear the market?

(d) *(10 rp)* Suppose that starting from period 2, firms' expectations are naïve. This means that they always expect the next period's prices to equal the prices in the current period and make decisions about future production based on this prediction. At the same time, the actual value of K always remains 210. What will happen to prices and outputs when $t \longrightarrow \infty$?

Solution

(a) By setting demand equal to supply on both markets, we get a system of two equations:

$$\begin{cases} 210 - 2P_A + P_B = -10 + 2P_A, \\ 80 - 6P_B + 2P_A = -5 + P_B. \end{cases}$$

From that we get $P_A^\star = 62.5$ and $P_B^\star = 30$.

(b) The producers predict future prices thinking that $K = 80$, that is, solving the system:

$$\begin{cases} 80 - 2P_A + P_B = -10 + 2P_A, \\ 80 - 6P_B + 2P_A = -5 + P_B. \end{cases}$$

From that we get $P_A = 27.5$ and $P_B = 20$. Plugging these to the equations, we get the outputs: $Q_A = 45$, $Q_B = 15$. These outputs will actually be produced for sale in period 2.

(c) Given that the outputs are already produced, when $t = 2$ comes, supply is perfectly inelastic: $S_A = 45$, $S_B = 15$. The actual demand function has $K = 210$. The markets are cleared when:

$$\begin{cases} 210 - 2P_A + P_B = 45, \\ 80 - 6P_B + 2P_A = 15. \end{cases}$$

Of course, the prices skyrocketed: $P_A = 105.5$ and $P_B = 46$.

(d) We can continue this process further. At prices $P_A = 105.5$ and $P_B = 46$, the firms will produce $Q_A = 201$, $Q_B = 41$. This, in turn, will lead to market-clearing prices $P_A = 9.3$ and $P_B = 9.6$. At these prices, the firms will produce $Q_A = 8.6$, $Q_B = 4.6$. This will lead to prices at around 128 and 55. It can be seen that the system diverges — prices fluctuate more and more. At some point, prices and/or outputs will reach zero levels, and if the firms' expectations remain naïve, the system will go through a cycle of extremely high and extremely low outputs and prices.

Marking Scheme

(a) 0 rp – at least one equilibrium price value is incorrect
5 rp – both equilibrium price values are correct

(b) 0 rp – at least one equilibrium price is incorrect
5 rp – both equilibrium prices are correct, but at least one quantity is incorrect
10 rp – both quantities correct (with correct prices or without mentioning prices)

(c) 0 rp – at least one equilibrium price is incorrect
5 rp – both equilibrium price values are correct

(d) 0 rp – no answer or very little explanation with no clear idea
5 rp - explanation of the idea that fluctuations continue (no matter if covergence or divergence); argument needs to stick to model framework
10 rp - explanation of idea of increasing flucttutations with either some kind of (numeric) proof or with a reference to the problem that K is open

Question 2. "Effective Lower Bound" *(30 raw points)*

By the assumption made by many standard textbooks and models, zero is the lower bound of an interest rate, limiting the central bank's capacity to stimulate the economy through monetary policy loosening. This assumption has been disputed recently, as central banks of several countries have set interest rates at negative levels.

Some economists tried to identify (at least theoretically) the interest rate which is, indeed, a lower bound for expansionary monetary policy. They have found that for an interest rate below some (probably negative) level, the further decrease may surprisingly be contractionary. This task will walk you through their reasoning.

(a) *(5 rp)* Explain why zero is sometimes considered the lower bound of an interest rate.

(b) *(5 rp)* Decreased interest rates lead to capital gains on securities owned by banks, improving their capital position. Explain this phenomenon.

(c) *(10 rp)* On the other hand, there is some evidence that when the interest rates go down because of the central bank's decision, commercial banks' net interest margins narrow, causing profitability decline. Explain why this might be the case.

(d) *(10 rp)* If the decline of today's value of future profits outweighs the capital gains, the bank's overall capital position deteriorates. Explain how this may lead to less lending by a bank, making the "stimulus" contractionary.

Solution

(a) Keeping paper currency can always bring 0 interest rate. That's why, if nominal interest rates are negative, people will hold cash instead of keeping money in banks, so lowering the interest rate further would not stimulate spending.

(b) The prices (and present values) of assets are inversely related to interest rates. So, if the rate goes down, the securities owned by a bank increase in prices.

(c) Banks net interest margins equal the difference between the lending and the borrowing rate. The pass-through of the policy rate to market rates is imperfect because of the stickiness of deposit rates. Banks are competing with one another, so they will be reluctant to decrease deposit rates in fear of losing their customers. Thus, the credit rates decline to a greater extent than deposit rates, causing the margins to shrink.

(d) If capital position deteriorates, banks need more high quality liquid assets (government bonds, cash) and less loan portfolio because it is not a high quality liquid asset. It is regulated by capital requirements regulation (Basel III). This may cause a decrease in lending.

Comment. The idea of 'reversal interest rate' was first expressed by Markus K. Brunnermeier & Yann Koby in 2018[1]. They present a theoretical model of how the effect of interest rate decreasing may reverse, but convincing empirical evidence of such phenomenon is still missing. For popular (ant critical) discussion of the matter, see https://www.ft.com/content/3dbca034-df7f-11e9-9743-db5a370481bc
and https://voxeu.org/article/reversal-interest-rate-critical-review.

[1]Brunnermeier, M and Y Koby (2018), "The Reversal Interest Rate," NBER Working Paper No. 25406.

Marking Scheme

(a) 5 points: answer clearly states holding cash (earning 0 interest) as alternative to bank deposit;

3 points: correct logics without stating cash (earning 0 interest) as alternative to bank deposit;

1 point: answer has some economic rationale;

0 points: other.

(b) 5 points: answer clearly states that prices of securities are inversely related to the interest rates. Therefore, lower interest rate increases prices of securities hold by bank. Alternatively, answer mentions net present value.

3 points: correct logics without explicitly mentioning the negative link between interest rates and securities;

1 point: answer has some economic rationale;

0 points: other.

(c) 10 points: lending rates adjust more than deposit rates (lending rates are linked to money market rates, but deposit rates are fixed). Banks' borrowing (deposit) market is more competitive. Lending market is more segmented, regional, less competitive.

8 points: lending rates adjust more than deposit rates (lending rates are linked to money market rates, but term deposit rates are fixed at the beginning). Deposit rates already are close to 0 and negative deposit rates can lead to withdrawal of deposits.

5 points: all rates are decreasing; thus net interest margins narrow. Low rates equal less profit.

2 points: people withdraw money from banks. Trust issues.

1 point: answer has some economic rationale.

(d) 10 points: full explanation;

8 points: banks switch to bonds;

4 points: less money means less loans; bank loses money; lower demand for loans;

1 point: answer has some economic rationale.

Question 3. "Pandemic Possibility Frontier" *(30 raw points)*

Last year, IEO contestants were asked to solve a problem about an optimal lockdown. Unfortunately, in 2021 this topic is no less relevant. So suppose society is facing a severe viral pandemic and contemplates introducing a lockdown. How strong should the lockdown be? The answer to this question apparently depends on the preferences of the society between the lives/health of people and GDP. Or does it really?

Let $d \in [0, 1]$ be the level (strength) of a lockdown ($d = 0$ is no lockdown while $d = 1$ is complete lockdown) and v be some measure of the total amount of virus in circulation. The relation between the two is given by $v = 2(1 - d)$. Aggregate demand in the economy is given by the function $Y = 10 - 2d - P$ while aggregate supply is governed by the equation $Y = 2 + P - d - \alpha \cdot v$ where $\alpha \geqslant 0$ is a parameter; Y is real GDP and P is price level, as usual. Finally, let H be the aggregate health of people; it depends on the amount of virus in circulation as follows: $H = 3 - v/2$.

Define the *Pandemic Possibility Frontier* (PPF, for short) as the set of all pairs (Y, H) that can be achieved by a policy-maker by choosing various levels of lockdown $d \in [0, 1]$.

(a) *(7 rp)* Give a reason for why α may be positive.

(b) *(16 rp)* Sketch the PPF and show the coordinates of its extreme points if $\alpha = 1$ and $\alpha = 2$ (on **two different** diagrams).

(c) *(7 rp)* Suppose the preferences of the society over GDP-Health combinations (Y, H) are given by some family of indifference curves. In practice, no one knows a society's indifference curves exactly; this generates heated debate about the optimal level of lockdown. For which values of α a policy-maker does *not* have to know the society's indifference curves over (Y, H) in order to find the optimal level of lockdown? (The policy-maker still knows all the data in the task and assumes correctly that the society values each of Y and H.)

Solution

(a) A positive α means that the amount of virus has a direct negative effect on aggregate supply. This may be due to an adverse effect of the virus on labor supply: people who are sick or have died cannot work. Also, when the amount of virus grows, some people may choose voluntarily to work from home rather than from office and, at least in some occupations, this lowers labor productivity and thus GDP supplied.

(b) It is convenient to derive the PPF equation for all α at once. First, equate aggregate demand and aggregate supply:

$$10 - 2d - P = 2 + P - d - \alpha v,$$

so equilibrium price level is $P = (8 - d + \alpha v)/2 = 4 - d/2 + \alpha v/2$ and thus, equilibrium GDP is $Y = 2 + P - d - \alpha v = 6 - 3d/2 - \alpha v/2$. Plugging $v = 2(1 - d)$ in the last equation, we get

$$Y = 6 - 3d/2 - \alpha(1 - d) = 6 - \alpha - (3/2 - \alpha)d.$$

Health, in its turn, depends on the level lockdown as follows:

$$H = 3 - v/2 = 3 - (1 - d) = 2 + d.$$

Note that since $d \in [0,1]$ H ranges from 2 to 3.

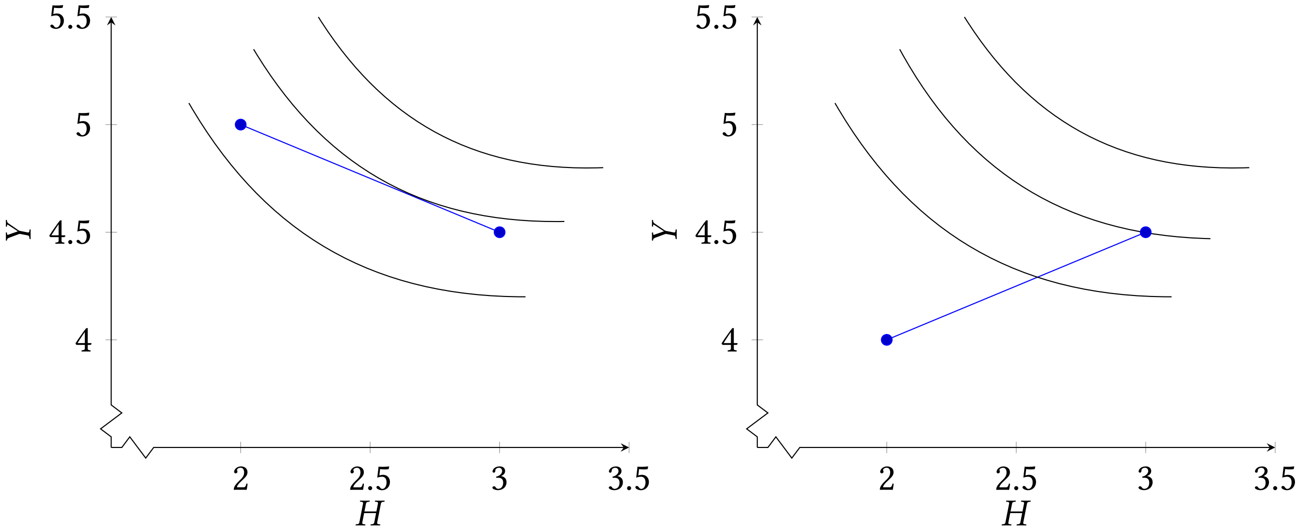
To derive the PPF, we eliminate d from the last two equations by expressing it, say, in terms of H and plugging the result into the equation for Y. Namely, $d = H - 2$, so finally

$$Y = 6 - \alpha - (3/2 - \alpha)d = 6 - \alpha - (3/2 - \alpha)(H - 2) = 9 - 3\alpha - (3/2 - \alpha)H.$$

Now it is easy to answer parts **(b)** and **(c)**.

For $\alpha = 1$ the PPF equation is $Y = 6 - H/2$. It is a downward-sloping line with extreme points $(2, 5)$ and $(3, 4.5)$ (recall that H takes values from 2 to 3). The first point corresponds to $d = 0$ and the second to $d = 1$.

For $\alpha = 2$ the PPF equation is $Y = 3 + H/2$. It is a upward-sloping line with extreme points $(2, 4)$ and $(3, 4.5)$. The first point corresponds to $d = 0$ and the second to $d = 1$.



$\alpha = 1$ $\alpha = 2$

(c) If the PPF is downward-sloping, the optimal lockdown depends nontrivially on the society's preferences as different families of indifference curves will give rise to different points of tangency with the PPF. There is a nontrivial trade-off between lives and GDP that can be resolved only with the knowledge of society's preferences.

On the other hand, if the PPF is upward-sloping (or flat), the society should choose the rightmost point on the PPF regardless of its preferences since this point generates the highest possible levels of GDP and Health simultaneously. There's no trade-off. Thus, the optimal lockdown will be unambiguously $d^\star = 1$; one won't have to know the society's preferences in order to make this conclusion.

So it remains to find for which α the PPF is upward-sloping or flat. From our general derivation above, we see that this will happen if and only if $\alpha \geq 3/2$.

Note that our conclusion is intuitive: a strong lockdown becomes good for *both* Health and GDP and there is no trade-off exactly when the negative effect of the virus on labor supply is strong enough.

Comment. Modern economic modeling and statistical techniques allow to estimate a Pandemic Possibility Frontier on real data. For example, economists Greg Kaplan, Benjamin Moll and Giovanni L. Violante have estimated (https://www.nber.org/papers/w27794) the Pandemic Possibility Frontier for the US in the context of COVID-19 pandemic. The PPF turns out to be downward-sloping and highly nonlinear. The authors estimated the effect of various non-lockdown policies on the location and shape of the frontier. Beside that, the authors coined the very term Pandemic Possibility Frontier for which we credit them.

Marking Scheme

(a) 7 points for at least one valid explanation is given for the negative direct effect of the virus on aggregate supply.

If a contestant just states something along the lines of "if α is negative then we get a positive effect of virus on GDP which is illogical" she gets 0 points. The problem asks for a reason why α may be positive, not why it is not negative. So a contestant was expected to provide an economic mechanism explaining the negative effect of the virus on aggregate supply.

If a contestant writes about the effect of v on aggregate demand, she gets 0 points.

Moreover, if a contestant states that α reflects the effect of v on GDP supplied *via lockdown* (as in "if v grows, there will be a stronger lockdown which will slow down aggregate supply"), she also gets no credit, as it is clear from the equation that α reflects only the *direct* effects of v on aggregate supply, i.e. the effect when d is fixed.

(b) A contestant gets:

1 point for giving a sketch of a downward-sloping PPF if $\alpha = 1$;

2 points for giving a sketch of an upward-sloping PPF if $\alpha = 2$;

2 points for deriving the H-coordinates of the PPF extreme points (that do not depend on α):

1 point for getting an expression of H in terms of d, 1 point for plugging $d = 0, 1$;

11 points for deriving the Y-coordinates of the PPF extreme points:

3 points for the idea that demand should equal supply;

$1 \cdot 2 = 2$ points for correctly solving for P in terms of v, d for each of $\alpha = 1, 2$;

$1 \cdot 2 = 2$ points for correctly solving for Y in terms of v, d for each of $\alpha = 1, 2$;

$1 \cdot 2 = 2$ points for correctly solving for Y in terms of d only for each of $\alpha = 1, 2$;

$1 \cdot 2 = 2$ points for correctly finding the Y-coordinates of the extreme points for each of $\alpha = 1, 2$.

(c) 4 points for correctly finding the condition $\alpha \geqslant 3/2$

3 points for the explanation

If a contestant states the answer $\alpha = 3/2$ rather than $\alpha \geqslant 3/2$, she gets 3 points overall for this part.

If a contestant mentions the idea of tangency without making further progress, she gets 1 point.

Question 4. "Pay as You Earn" *(30 raw points)*

Different college graduates earn different salaries, even after graduating from the same institution. Some are less successful or lucky (and thus have lower salaries); others don't pursue maximization of their earnings, leaning towards socially-oriented not-for-profit jobs. Even if student loans are available, students may abstain from entering prestigious and expensive colleges, uncertain that they will be able to repay. This may create an inefficient allocation when most risk-loving and not most talented young people get the best education. (And then some of them fail to pay off the loans.)

Consider the following alternative to a traditional student loan which intends to solve this inefficiency problem. A student enters college tuition-free, and after graduation, they pay the college a certain percentage of their salary for a fixed number of years. So, a student never has to pay for their education more than they earn after receiving it. The income percentage to be paid is calculated based on an average graduate's salary, so the program should finance itself.

(a) *(20 rp)* Despite its apparent advantages, this type of education financing is uncommon. Skills training programs (such as coding academies and bootcamps) are more likely to offer it than prominent universities. Explain why the program designed as described above may fail economically in a large university but is more likely to be feasible in a bootcamp.

(b) *(10 rp)* Suggest a tweak to the program conditions, which might help solve the problem mentioned in **(a)**.

Comment. This scheme of payment for education is often referred to as Income Sharing Agreement (ISA). One of the most famous examples of an institution using it is Lambda School (https://lambdaschool.com, coding school and bootcamp).

Solution

(a) In large colleges and universities, the students are very diverse in terms of future incomes — much more diverse than in specific skills training programs. If you come to such a program to learn to code on Python, the set of skills you acquire and the salary you'll earn with these skills are more predictable for the education institution than if you enter a long-term program. Notably, a student has more information about himself/herself than the institution or a bank. Those students who enter undergraduate studies and aspire to make a career as a high-paid professional are unlikely to go for ISA. On the other hand, students who think about jobs in the non-commercial sector will go for it because, for them, it's just cheaper than conventional credit. So, only low-paying individuals will go for ISA, and the program will fail economically. This problem is known as *adverse selection*.

(b) One of the ways to change the design of the program (that is used sometimes in ISA) is not to calculate an income percentage to be paid based on the average graduate's salary, but *cap* the absolute amount. This will stimulate high earners to participate because they won't be penalized for earning more. In this case, the problem of adverse selection will be (at least partially) eliminated, although the percentage to be paid will likely increase.

Marking Scheme

(a) Difference: bootcamps are more focused on specific skills that can be evaluated (in terms of future earnings) in advance — **5 rp**

Colleges have more diverse students, and information is asymmetric: students know better whether they aspire to be high earners — **5 rp**

This prevents colleges to set different rates for different students, and this causes adverse selection: high-earners won't go for this option. That's why the way the rate is calculated (simple average) will lead to losses. — **10 rp**

Partial grades:

Graduates may hide their salaries (hard to verify) — **5 rp** total. (Not a full mark, because this evasion can be accounted for in calculating the average, so the failure is not explained.)

(b) Cap on earnings or some other explanation which includes regressive rate – **10 rp**

If the correct idea is mentioned but the explanation is missing or insufficient — **5 rp**

Question 5. "Vaccination Dilemmas" *(30 raw points)*

The city of Vaccineville has a lot of residents. During the coronavirus pandemic, the city authorities are not imposing a lockdown but are urging all residents to get vaccinated. A vaccine is available in the city and can be administered to any resident who wants to get it.

The likelihood for a person P to contract the coronavirus depends on whether he or she is vaccinated, as well as what proportion of other residents are vaccinated. For simplicity, assume that every day all residents meet in random pairs, so the probability of meeting a vaccinated person equals the proportion α of residents that are vaccinated (assume that the population is very large, so whether one person is vaccinated does not affect α to any significant extent). The risk for person P to contract the coronavirus in different matches are given by their probability of being infected that are included in the following table:

Person P...	...and meets smb. vaccinated	...and meets smb. non-vaccinated
...is vaccinated...	0	0.05
...is not vaccinated...	0.15	0.4

All residents consider vaccination a costly procedure. Even though the vaccine is offered free of charge, the cost may come in the form of the time needed to be spent visiting a doctor, lack of trust in the effectiveness and safety of the vaccine, side effects, etc. A person's utility equals the probability of *not* being infected when she meets someone. For those vaccinated, the cost of vaccination that is equal to 0.3 is subtracted from utility.

(a) *(10 rp)* Suppose people decide individually whether to get vaccinated; each of them maximizes their utility. We say that people's decisions form a *Nash equilibrium* if no one can benefit by changing their decision with others' decisions fixed. What fraction of Vaccineville residents will get vaccinated in the Nash equilibrium?

(b) *(10 rp)* Vaccinetown is just like Vaccineville in all aspects, except that its authorities force some of its citizens to get vaccinated. In particular, vaccination is mandatory for doctors and teachers, which together constitute 20% of the town's population. All other residents decide individually whether to get vaccinated or not. What fraction of Vaccinetown residents will get vaccinated in the Nash equilibrium?

(c) *(10 rp)* Now suppose that cost of vaccination is different across the population. It is not 0.3 for everyone, but instead, it ranges from zero for some people to very high for others. The authorities want to shift the equilibrium so that more people get vaccinated by making vaccination mandatory for some of them. They know what groups of people have low, medium, and high vaccination costs and can choose for whom to make vaccination mandatory. Knowing that it is politically infeasible to make vaccination mandatory to *everyone*, what is your recommendation regarding this matter? Explain using the concept of Nash Equilibrium.

Solution

(a) The probability of being infected for a vaccinated person is $0 \cdot \alpha + 0.05 \cdot (1 - \alpha) = 0.05 - 0.05\alpha$. The probability of being infected for a non-vaccinated person is $0.15\alpha + 0.4 \cdot (1 - \alpha) = 0.4 - 0.25\alpha$. In equilibrium, utilities must be equal, otherwise a few non-vaccinated people would regret and get the vaccination or vise versa.

$$1 - (0.05 - 0.05\alpha) - 0.3 = 1 - (0.4 - 0.25\alpha).$$

In equilibrium, $\alpha^\star = 0.25$.

(b) Residents who are forced to be vaccinated are included in α, so marginally, the utilities remain the same. So, 25%.

(c) People with low costs of vaccination are likely to do it voluntarily. So, medium and high-cost population groups remain. Reasoning in terms of the Nash Equilibrium, forcing high-cost people into vaccination can make vaccination less attractive for some medium-cost residents (not to mention it would require more effort), so the total number of immunized people will not increase. For each of them, the probability of meeting a non-vaccinated person decreases (see part **(b)** with a similar effect). So, authorities should force into vaccination those with middle cost of vaccination.

Marking Scheme

(a) 0 rp – no correct results are reached

3 rp – probabilities are correct

6 rp – Utilities are correct too

10 rp – Nash equilibrium, correct result

only correct number: 2rp

(b) If model is repeated, same as (a)

Otherwise:

0 rp – no correct results are reached

4 rp – mentioning that 20% < 25%

10 rp – answer is correct

only correct number: 2rp

(c) 0 rp – no answer or no correct results are reached

+ 2 rp – very little explanation, understanding the "crowding out" effect of forced vaccinations on non-forced people.

+ 5 rp - explanation of the idea using the concept of Nash Equilibrium without a correct recommendation (+7 if understood that the low-cost residents might vaccinate on their own)

10 rp - explanation of the idea using the concept of Nash Equilibrium with a correct recommendation

only correct recommendation: 2rp