Although the benefits of vaccination for a society are obvious, a non-negligible percentage of people are refusing this protection against COVID-19. In game theory, the 'prisoner's dilemma' provides individual decision-makers with a similar problem: choosing an optimising strategy for individual players does not result in an optimal outcome for the whole of society. Game theory can also explain the current refusal of individuals to get vaccinated, and show the impact of incentives.

THE VACCINE *dilemma*

Servaas Houben looks at the prisoner's dilemma and how it can be applied to COVID-19 vaccination

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The prisoner's dilemma

The prisoner's dilemma is one of the most famous examples of game theory. In this game, two prisoners (Abi and Ben) are suspected of committing a crime. The prisoners can either remain silent or betray the other prisoner. The police do not have sufficient evidence to prosecute either of them on the principal charge without a betrayal from either prisoner, but there is sufficient evidence to convict them on a lesser charge. The prisoners are therefore offered an incentive in the form of a reduction in their sentence if they betray their partner. The two prisoners are not allowed to communicate.

Let's suppose the payouts for the prisoners are as follows.

- When neither betrays the other, there is a small penalty of -1 for the lesser charge
- When there is sufficient proof (one betrays the other), there is a large penalty of -10 for the principal charge for the betrayed party, and the other is set free
- If both of the prisoners confess, then each of them is penalised -9, because there is a small +1 reduction in the penalty for a confession.

TABLE 1: The original prisoner's dilemma.

		BEN	
		Silence	Betrayal
ABI	Silence	(-1, -1)	(-10, 0)
	Betrayal	(0, -10)	(-9, -9)

Looking at the payoff matrix in *Table 1*, we can see that the best option for both prisoners is to remain silent (top left). In this case, each of them receives a small penalty of -1 and the total negative benefit for the pair of them is -2. However, when looking at the optimising choice for each individual, it is always beneficial to choose betrayal:

- **Case 1: The other person stays silent** – Choosing silence receives a penalty of -1, while choosing betrayal receives no penalty, so betrayal is the better option
- **Case 2: The other prisoner betrays** – Silence leads to a penalty of -10, while betrayal receives only a penalty of -9, so betrayal is the better option.

Rational players will therefore choose their optimising strategy to betray, and the result will be the right bottom option, with a total negative benefit of -18 – worse than the total of -2 if they had both chosen to co-operate and stay silent.

COVID-19: The individual versus society

The example in the two-person game above can also be used for the choice of vaccination (V) or refusal (R). Instead of a game between two prisoners, it could be formulated as a game between an individual and wider society.

We assume the following payouts:

- There is a small cost for receiving the vaccine of -1 (because some people suffer vaccination side effects and a small amount of pain)
- Lockdown costs are severe at -10, and these occur when a large part of society refuses the vaccine
- The choice of a single individual cannot result in lockdown.

The game outcomes are summarised in *Table 2*.

TABLE 2: COVID-19 dilemma – individual vs. society.

		SOCIETY	
		Vaccination	Refusal
INDIVIDUAL	Vaccination	(-1, -1)	(-11, -10)
	Refusal	(0, -1)	(-10, -10)

The game is still the same from the individual perspective in the original prisoner's dilemma: the better option for the individual is to refuse the vaccine, as this has the higher payout in each of the scenarios. In addition, the choice of a single individual does not have a material effect on society as a whole: no lockdown, evening curfew or school closure occurs because just one person decides not to take the vaccine. Therefore, the payouts to society will not be impacted by the choice of an individual; option V is best for society independently of the choice of the individual considered in this set-up.

This shows that a single individual deciding not to get the vaccine does not negatively affect the payout to society, as the impact of the individual's choice on the outcome of the game is immaterial.

COVID-19: The group versus society

Now suppose that, instead of a single person, an entire substantial group – say, 50% of the population – refuses the vaccine. This alters the game, as a bigger group will have a material effect on the outcome for the rest of society. The game is now as in *Table 3*.

TABLE 3: COVID-19 dilemma – group versus society.

		SOCIETY	
		Vaccination	Refusal
GROUP	Vaccination	(-1, -1)	(-6, -5)
	Refusal	(-5, -6)	(-10, -10)

The group now has a material impact on society; if it decides to refuse the vaccine, this will affect the whole of society, implying there is a higher chance (50%) of lockdown.

This example agrees with the intuition that when a significant group decides not to get the vaccine, this does negatively affect the payout to society, as the impact of the groups' choice on the outcome of the game is material.

The individual versus group paradox

This discussion shows that society can end up with a worse equilibrium (no one taking the vaccine) if the individual perception is that there is a penalty in receiving the vaccine and little cost while wider society is vaccinated. Clearly, one individual on their own does not impact the whole of society, so the optimising strategy for an individual person in *Table 2* is not to take the vaccine. The individual on their own will not impact the possibility of lockdown, and by not taking the vaccine, they avoid the drawbacks of taking the vaccine, avoiding the small penalty of -1.

However, when a substantial part of society decides to play this strategy, the outcome of society as a whole worsens: as we can see in *Table 3*, when all of the individuals in a group decide not to receive the vaccine (based on their individual preference in *Table 2*), the best possible response from society is to vaccinate the remaining portion in order to limit the impact, resulting in an overall loss of -11 (left bottom). However, this is a worse outcome than the one in the left top corner of -2.

Using incentives to achieve optimal equilibrium

In a free society, there is little option for compulsory vaccination and it is up to the individual to make the decision; incentives should therefore be provided to make vaccination more attractive. Assume this creates an additional benefit of +2, as shown in *Table 4*.

TABLE 4: COVID-19 dilemma – Individual vs. society with incentives.

		SOCIETY	
		Vaccination	Refusal
INDIVIDUAL	Vaccination	(+1, +1)	(-9, -10)
	Refusal	(0, +1)	(-10, -10)

As a result, the optimising strategy for the individual has changed from Refuse to Vaccination. This leads to a better overall outcome in *Table 3*, as the top left is now the new equilibrium.

This shows that current policies for providing positive incentives (such as easier overseas travel and access to certain events) for vaccinated individuals will result in a better outcome for society as a whole. The incentives should be strong enough to limit the size of the group refusing the vaccine to the extent that this group's choice does not impact the outcome of society as a whole.

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"Current policies for providing positive incentives to vaccinated individuals will result in a better outcome for society as a whole"