**Data Scientist, Economist Take Home Exercise**

**Theoretical Part**

We would like to develop a loyalty scheme for our riders. The general idea is to reward riding for Deliveroo beyond the fees riders earn for delivering individual orders.

1. What incentive schemes seem promising to you? Would you consider monetary or non-monetary awards? Why?

For the decision a rider makes in choosing how many hours to work or deliveries to make, I assume that the utility they are aiming to maximise is largely influenced by monetary gains. So, the more money they make, the more hours they work although this might exhibit diminishing returns where the extra hours worked decreases with the same monetary increase. Given this setup, I would choose to use an incentive scheme based on monetary awards.

From Deliveroo’s perspective, the aim is to maximise profit and this could be achieved with a few inputs. First, they would want to ensure they have an adequate and consistent amount of rider supply for the demand in different zones and times of day. Second, they might want the times between order and delivery to be short whilst ensuring food delivered is warm and not harmed. Third, they might want to minimise our carbon footprint by maximising the number of bicycle riders. A few price and quantity based incentive schemes which may help achieve these aims include:

* Surge pricing to boost supply at high demand periods in certain zones.
* One-off bonus add-ons for using a specific vehicle such as a bicycle.
* Fee increases for consistently high performing riders who have strong feedback, low delivery times and high availability.
* Fee increases for riders accepting and/or delivering a certain number of deliveries in an hour for busy periods. This could improve the speed of rider and customer matches and ensure we have a consistent supply of riders.

1. An incentive scheme could either be based on hours logged in to the rider app or orders delivered. What do you think are the advantages of an hours based one? What about one based on orders delivered?

An hours based incentive scheme could either provide a bonus add-on for completing a certain number of hours logged in or provide a permanent fee raise for deliveries. This scheme could be useful in incentivising drivers to remain available for deliveries. As a result, you may see quicker and more frequent matches to customer orders which may improve customer satisfaction and increase of repeat orders. Both things are key to ensuring a strong and growing revenue stream for Deliveroo to maximise profit.

An orders delivered based scheme may increase fees for consistently completing a certain number of orders or a bonus add-on upon completing a certain number of orders. This scheme is great because it targets Deliveroo’s end goal which is to maximise profit through maximising the revenue generated from riders making deliveries. It also indirectly boosts the supply of riders but compared to an hours based scheme, customer order matching might be slow if riders are not active on the app. On the other hand, this overrides the issue you may get with an hours based scheme where riders may be active but not delivering enough customer orders. They may be slow at delivering which would in turn, reduce the number of available drivers. By incentivising orders delivered, Deliveroo can ensure that drivers complete orders as soon as possible and become available for the next order.

1. Imagine that your team has worked on developing an incentive scheme and you are ready to test it. Often, new product ideas at Deliveroo are tested through experiments. How would you design an experiment for the incentive scheme you developed?

The incentive scheme I will use to answer the following questions is the surge pricing scheme. With this, drivers receive additional fees for each order at certain times and certain zones which experience excess demand.

* 1. What metrics would you test to determine whether the scheme is a success?

First, the supply and productivity of riders should be tracked by capturing the number of riders available and the number of deliveries made per hour. Second, the change in the time between matching and customer orders should be tracked to help assess whether demand is being met quickly. Finally, the change in profit should be assessed. This is to ensure that the increase in supply is not excessive and at the cost of less profit.

* 1. What experimental design would you use to test the scheme?

An A/B testing protocol could be used to test the effectiveness of the scheme.

To identify the control and treatment groups, I would aim to identify zones and hours which are similar in terms of demand, excess demand, supply of riders and average fees generated. By having similar characteristics, we can be reasonably confident that any difference observed will be a result of the incentive scheme rather than other external factors.

I would also try to ensure that the distance between these two groups is reasonably far or exclude riders that usually ride in the control group from riding in the treatment group. This is to ensure that riders from one zone are not able to switch to the treatment zone as a result of the incentive scheme which would skew the results on the effectiveness of the incentive.

* 1. How would you determine the number of riders and the duration of the experiment?

Both factors should be large enough to provide a strong enough sample size of observations which will allow us to test for statistically significant results.

The duration should be long enough for the riders to become fully aware of the incentive scheme and help us achieve a representative sample of rider behaviour.

The number of riders might be influenced by the shortfall of riders in a zone of excess demand. We might want to target a number larger than this shortfall is the shortfall is number of riders we want to influence. We might also want to stop the scheme once we have met demand as we will then run into excess supply. If we have excess supply of riders, then we will be over estimating the impact of the treatment.

A final constraint will of course be the budget. We don’t want to run an experiment for too long for which we don’t have the budget to pay for.

A common rule of thumb used in A/B testing is the where σ is the sample variance and δ is the difference between treatment and control groups. Our variance σ could be the number of riders during the periods we want to analyse and our δ could be the desired number of riders we want to influence.

* 1. How would you analyse the experiment?

I would first carry out some sanity checks to ensure our treatment and control groups are still comparable and our experiment was conducted properly. This could be checking the number of customer orders across both groups to see that demand was similar.

Then, I would compare the difference in number of riders for the experiment duration and the number of deliveries per half hour for the experiment. This should then be checked for statistical significance by comparing with the confidence interval. If the change is larger than the confidence interval, we can be sure that our experiment has made a strong enough difference in rider supply.

We could carry out the same analysis for the number rider and customer order matches and profit to assess statistically significant impact for both metrics. Our results can then inform whether surge pricing has led to the desired increase in rider supply and the corresponding desired effect on profit.

**Empirical Part**

The attached data set contains (simulated) information on different riders (rider\_id), the areas in which they worked (zone\_id), the hour-date (start\_time), the fraction of the hour that they worked (hours\_worked), the number of orders they delivered during that hour (orders\_delivered), and the earnings they received (earnings).

1. Using the data, characterize the distribution of rider activity in terms of hours worked, orders delivered, and earnings per hour. What patterns do you see? Do they seem sensible?

As you can see from Table 1, 33% of riders earn less than £1 an hour, 76% of riders make less than 2 deliveries an hour but 59% of riders work more than 48 minutes every hour.

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| Figure 1: Relative frequencies for earnings, hours worked and deliveries | | |
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This relationship between hours worked and earnings/deliveries is further explored in Figure 2 where a small positive relationship can be observed. This suggests that an increase in hours worked will likely lead to more earnings and deliveries but this relationship is weak, possibly because riders may work hours where they may receive or carry out few deliveries. As demand might vary throughout the day and if there is an excess supply situation, you might expect riders to receive few deliveries.

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| Figure 2: Relationship between hours worked and earnings (left) and between hours worked and number of deliveries (right) | |
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1. If you were to choose an incentive scheme based on hours worked, using the data at hand, how would you set the different tiers (i.e., where would you choose the cutoffs)?

An incentive scheme based on hours worked could target the proportion of an hour worked or the number of hours worked in day. The former might be used if we want to increase the supply of riders during certain hours and the latter might be used if we want more riders available throughout the day. Either way, I would target riders in the bottom 25th percent of the distribution which, as seen in Table 1, includes riders who work less than 36 minutes in an hour or 6.2 hours a day. The incentive scheme could be either 1) Riders who work more than 36 minutes in an hour, receive a slight increase in fee for orders past that mark or 2) Riders who work more than 6.2 hours in a day earn a slight increase in fee for orders after that point.

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| **Table 1: Distribution of orders delivered** | | |
| **Distribution statistic** | **Hours worked in a day** | **Fraction of an hour worked** |
| **count** | 26,567 | 288,322 |
| **mean** | 8.3 | 0.8 |
| **standard dev** | 3.2 | 0.3 |
| **min** | 0 | 0 |
| **25%** | 6.2 | 0.6 |
| **50%** | 8.4 | 0.9 |
| **75%** | 10.6 | 1.0 |
| **max** | 18.7 | 1.0 |

1. If you were to choose an incentive scheme based on orders delivered, using the data at hand, how would you set the different tiers (i.e., where would you choose the cutoffs)?

An incentive scheme based on orders delivered will target an improvement in the productivity of riders for the same number of riders. This can designed by targeting orders delivered in an hour or delivered in a day. The former might be preferred in cases of excess demand during certain hours whilst the latter might be preferred if there is excess demand throughout the day. For orders delivered in an hour, I would target riders in the bottom half of the distribution as the 25th percentile deliver 0 orders as seen in Table 2. For orders delivered in a day, I would target riders in the bottom 25th percent of the distribution. The incentive scheme could be either 1) Riders receive an extra fee for the first delivery they make in the hour 2) Riders receive an extra fee for the first 9 deliveries they make in the day.

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| **Table 2: Distribution of orders delivered** | | |
| **Distribution statistic** | **Orders delivered in a day** | **Orders delivered in hour** |
| **count** | 26,567 | 288,322 |
| **mean** | 16.0 | 1.5 |
| **standard dev** | 9.3 | 1.4 |
| **min** | 0 | 0 |
| **25%** | 9.0 | 0 |
| **50%** | 15.0 | 1.0 |
| **75%** | 22.0 | 2.0 |

1. This question tries to develop a back-of-the-envelope estimate of the supply impact of the incentive scheme you developed:
   1. Could you use the data set provided to estimate the supply elasticity of riders? Why or why not?

We cannot accurately estimate supply elasticity of riders using this data. Estimating supply elasticity requires data on demand for riders (customer orders) as well as factors which solely affect demand. This will ensure our elasticity estimate does not capture factors which permanently shift supply of riders. For example, a shock in the economy might increase unemployment in other sectors and drive people to take up rider roles in Deliveroo which creates higher supply for similar levels of demand.

* 1. Ignoring the concerns you may have had in your answer to the above question, how would you estimate the labour elasticity? What is the value you estimate?

I will evaluate the labour elasticity for an incentive scheme based on the orders delivered per hour variable discussed in part c).

If we assume supply does not change due to factors discussed above, we could estimate labour elasticity by specification (1) and (2). ‘i’ represents a rider at a specific hour and day. Controls include the zone id of the delivery, the hour of the day and the day of the week. Including these controls helps to ensure we are not capturing the effect of possible unobserved demand and supply fluctuations throughout the day and week or across zones.

* 1. Taking your estimated supply elasticity, what is the estimated total supply impact of your incentive scheme?

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| **Table 3: Regression outputs** | | |
| **Coefficient** | **Specification 1 (Hours worked)** | **Specification 2 (Orders delivered)** |
| Fee per order | 0.0066\*\*\* | - 0.0361\*\*\* |
| Cutoff dummy | -0.1898\*\*\* | - 3.7246\*\*\* |
| Cutoff dummy \* Fee per order | 0.0009\*\*\* | 0.0626\*\*\* |
| Constant | 0.4874\*\*\* | 3.1737\*\*\* |
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| N | 288,322 | 288,322 |

\*\*\* denotes statistical significance at the 1% level

Suppose we implement the incentive scheme with a £1 increase in fees for the first order delivered in the hour. This will lead to an increase of 0.0265 orders delivered in an hour or to increase the average orders delivered by 1, riders must earn an extra £37.7 per order. The current average orders delivered by the target group is 0.4 per hour. If we wish to bring this average up to 1 per hour, then riders must earn an extra £22.6.

In terms of hours worked, this will increase by 27 seconds in response to a £1 increase in fees for the first order delivered in the hour. The current average of hours worked by the target group is 0.63. If we wish to bring this up to 1, riders must earn an extra £56 per order.

As evident, the incentive program will have a small but statistically significant impact on hours worked and order delivered. However, to estimate a more accurate impact of our incentive scheme, we must utilise data on customer demand.