Effect of the Nominal Value of Foreign Currencies in valuing a good

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Abstract

Research into the effect of using foreign currencies on consumption behaviour suggests that consumers systematically under- or overspend based on the nominal (face) value of the foreign currency. However, previous research is undecided on which direction this effect has, with the two most prominent models leading to different and mutually exclusive outcomes. This paper considers the different models and tests their predictive and explanatory accuracy using a study. It finds that individuals tend to underspend when the foreign currency is less numerous than (a fraction of) the home currency and overspend when the opposite is the case. The paper discusses which model is most accurate at predicting and explaining this effect and considers limitations as well as opportunities for future research.

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Introduction

Experience suggests that we treat foreign currencies differently to our home currency and have difficulty adjusting to them. Previous research, such as the "money illusion" effect (Shafir, Diamond, and Tversky 1997) suggests that individuals are biased towards the nominal (or face value) of prices. This bias has also been explored in the context foreign currencies, with research finding systematic effects that arise based on the numerousity of values in a foreign currency compared to individuals' home currencies. However, previous research is split on how and why this effect occurs.

Raghubir and Srivastava (Raghubir and Srivastava 2002) examined the effect of using foreign currencies on consumption behaviour and argue that there is a systematic difference in spending behaviour based on the exchange rate of the foreign currency to an individuals' home currency. Specifically, they showed that when a foreign currency is a fraction of the home currency (e.g. 1 unit in home currency is 0.2 units in foreign currency) consumers tend to overspend in real terms relative to their home currency. On the other hand, when the foreign currency is a multiple of the home currency (e.g. 1 unit in home currency is 5 units in foreign currency) consumers tend to underspend in real terms.[1] Raghubir and Srivastava argue that this effect arises because individuals are anchored on the face value of the foreign currency which influences the exchange rate calculations from and to their home currencies. Hence, Raghubir and Srivastava term the result of this inadequate adjustment the "face value effect".

Wertenbroch, Soman and Chattopadhyay (Wertenbroch, Soman, and Chattopadhyay 2007) consider the findings by Raghubir and Srivastava and reiterate their conclusion that individuals inadequately calculate the values of goods between differnet currencies, leading to systematic differences in spending behaviour based on the exchange rate between the foreign and home currencies. However, Wertenbroch, Soman and Chattopadhyay argue that the process of adjustment occurs differently, namely that individuals calculate their valuations of goods based on salient reference points, such as budget constraints. Contrary to standard theory, Wertenbroch, Soman and Chattopadhyay argue that consumers care about the difference between a valuation and their budget rather than the ratio of the two. In the context of foreign currencies, the nominal value of this difference will diverge, leading to systematic differences in spending behaviour. However, the direction of this bias is the exact opposite of the one shown by Raghubir and Srivastava. Specifically, Wertenbroch, Soman and Chattopadhyay show that consumers underspend when the foreign currency is a fraction of the home currency and overspend in the opposite case.

Fang (Fang 2019) further builds on top of the research by Raghubir and Srivastava and aims to extend it to the domain of "virtual" currencies, which refers to non-fiat currencies that are digital in nature

[1] For consistency, I will use the terms fraction and multiple currencies throughout this paper as defined here.

and not controlled or issued by a central bank. Examples of virtual currencies include video game (or in-game) currencies, rewards points, airmiles, cryptocurrencies and more to the extent that these are at least somewhat liquid. Investigating in-game currencies specifically, Fang shows that consumer valuations systematically deviate when using these currencies relative to the home currency. Fang's findings correspond with those of Raghubir and Srivastava and the face value effect.

This paper aims to build on the aforementioned research in several important ways. Foremost, previous research is conclusive that there is an effect that using foreign currencies has on individuals' consumption behaviour relative to using their home currencies, but is divided on the direction of this effect. Hence, this paper attempts to evaluate the different models posed and use a study to test which model most adequately predicts the perceived behaviour. Second, previous research has only assigned minor significance to using incentive-compatible mechanisms to elicit true preferences of participants. These mechanisms have been established to elicit more accurate responses from participants that are closer to their true preferences (Burchardi et al. 2021). Hence, this study will use the Becker-DeGroot-Marshak (BDM) mechanism to elicit participants' willingness to pay (WTP).[2] Raghubir and Srivastava (Raghubir and Srivastava 2002) expressed the concern that "despite attempts to make the tasks as realistic as possible, the studies reported were laboratory experiments, and issues of generalizability when real money is on the line do arise. For instance, when people actually exchange foreign currency they may feel richer or poorer depending on the exchange rate, and the differences in perceptions of wealth may affect product valuation". Similarly, Fang (Fang 2019) noted that implementing the BDM mechanism was infeasible for the study he conducted but that future research should focus on using something like it to elicit WTP. Finally, this paper aims to extend the previous literature on the effects of using virtual currencies specifically, due to their increasing rise in importance when transacting or making purchasing decisions online, and determine whether spending behaviour differs when using them.

First, I present the theoretical frameworks that have been outlined by previous research in a standard form that makes it easy to compare and contrast them. These frameworks are the standard model described in consumer choice theory, the model suggested by Raghubir and Srivastava and the model suggested by Wertenbroch, Soman and Chattopadhyay. Then, I consider what each of these frameworks would predict in a concrete case and show that all three models come to different and mutually exclusive conclusions. In order to test which of these frameworks is most accurate in predicting observed behaviour, I conduct a study in which two groups each formulate their WTP for a specific good in an incentive compatible way, with the only difference between the groups being the exchange rate of the currency used to their home currency and, as a result, the numerousity of the values of their budget and bid. Analysing the study, I find that consumers tend to underspend when the foreign currency is a fraction and overspend when the foreign currency is a multiple, which is predicted by the model proposed by Wertenbroch, Soman and Chattopadhyay (Wertenbroch, Soman, and Chattopadhyay 2007). However, due to the limited sample size of the study, this result is not statistically significant and does not have significant statistical power. In the discussion, I evaluate the implications of the findings for the theoretical frameworks outlined, consider alternative explanations for the perceived effect and argue that the model proposed by Wertenbroch, Soman and Chattopadhyay is the most accurate in predicting and describing consumer behaviour when using foreign currencies. Finally, I will consider the limitations of this paper and opportunities for further research.

[2]The BDM mechanism will be defined and explained in more detail in the Methodology section below.

Theoretical Framework

Standard Model

Standard consumer choice theory suggests that individuals formulate valuations of goods in relation to reference points, such as their budget (Deaton and Muellbauer 1980). Specifically, standard theory poses that consumers evaluate their valuation for a good as a ratio to their budget in order to determine what proportion of their spending power is required to purchase the good. To formulate valuations of goods in a different currency, consumers would first determine the value of the good in their home currency and subsequently apply the exchange rate to get their valuation in the foreign currency. Hence, the model follows a two step process:

1. Formulate valuation of good as ratio to budget in home currency
2. Convert the valuation into foreign currency

Alternatively, this can be stated using the following syntax:

$$V_n = f(\frac{x}{M_n})$$
$$V = V_n * X = V_r$$

where V is the valuation of the good in the foreign currency, V_n is the valuation of the good in the home currency (nominal), V_r is the valuation of the good in the foreign currency, M_n is the budget in the home currency, X is the exchange rate and $f(x)$ is some function that uses a valuation relative to the budget in order to compute V_n. Note that V_r is simply V_n multiplied by the exchange rate, whereas V need not always be identical to V_r.

One assumption that is implicit in this model is that a consumer will always correctly adjust their valuation ratio based on the exact exchange rate. However, this might not always be the most rational thing to do. For example, when exchange rates fluctuate it might not be worth the effort of a consumer to always use the most up-to-date exchange rate, but rather to use some approximate value. Further, when an individual needs to do these exchange rate calculations in their head, it might not be worth the mental effort to calculate the amount in the foreign currency perfectly, but an approximation might suffice. For example, it would be rational to multiply an amount in home currency by 1.2 if the real exchange rate is 1.2113248 and the effort required is significant, such as when attempting to calculate it in one's hand. By loosening these assumptions, the standard model is able to account for small deviations from a consumer's real valuation of a good in a foreign currency.

Face Value Effect Model

Raghubir and Srivastava (Raghubir and Srivastava 2002) put forth a different model for how consumers formulate their valuation of a good in a foreign currency based on their studies conducted. Specifically, they pose that a consumer will first formulate a valuation of a good in their home currency, before converting that amount into the foreign currency using the exchange rate. However, they argue that this calculation is biased by the nominal value of the good in the home currency (in cases where a consumer does not determine their valuation but observes a price, this calculation would be biased by the nominal value of the good in the foreign currency). This model may be formulated as follows:

1. Formulate valuation of good in home currency
2. Convert the valuation into foreign currency
3. Adjust using the nominal value of good in home currency

Alternatively, this can be stated using the following syntax:

$$V = \alpha(V_n) + (1 - \alpha)V_r$$

where is a weighting parameter such that $\alpha \in [0, 1]$. Importantly, Raghubir and Srivastava (Raghubir and Srivastava 2002) argue that $\alpha > 0$ and that V is hence not equal to V_r but is biased towards V_n.

Perceived Value of Money Model

Wertenbroch, Soman and Chattopadhyay (Wertenbroch, Soman, and Chattopadhyay 2007) build on top of Raghubir and Srivastava, but put forth a different model that they argue is more representative of the behaviour of actual consumers. Specifically, they agree with the standard model that valuations are made in relation to salient reference points, such as a consumers' budget, and argue that the model put forth by Raghubir and Srivastava fails to account for this. However, they disagree with the standard model that valuations use a ratio of price to budget, but instead argue that consumers think in terms of differences. Hence, instead of considering what fraction of their purchasing power is required to buy a good, consumers consider how much of their budget is left over. However, Wertenbroch, Soman and Chattopadhyay argue that consumers inadequately adjust this difference to the exchange rate and are thus biased when considering goods in different currencies since the nominal differences between price and budget will differ when considering different currencies. This model can be formulated as follows:

1. Formulate valuation of good as difference to budget in home currency
2. Convert the valuation into foreign currency
3. Adjust using the difference to budget in the foreign currency

Alternatively, this can be stated using the following syntax:

$$V = \alpha(M_r - V_r) + (1 - \alpha)V_r$$

where M_r is the budget in the foreign currency (real). Importantly, Wertenbroch, Soman and Chattopadhyay (Wertenbroch, Soman, and Chattopadhyay 2007) argue that $\alpha > 0$ and that V is hence not equal to V_r but is biased towards $M_r - V_r$.

Predictions

The three different models laid out above would each generate a different prediction in the following scenario, considering fraction and multiple exchange rates (the latter in brackets): a consumer values a good at £25 and needs to express this valuation in BlueCoin, a fictional currency. The exchange rate of Pounds to BlueCoin is 1 BlueCoin = £5 (1 BlueCoin = £0.2) and their budget is 10 (250) BlueCoin. The models above would make the following predictions:

- Standard model: $V_r = 5(125)BlueCoin$
- Face value effect model: $V_r > 5(< 125)BlueCoin$
- Perceived value of money model: $V_r < 5(> 125)BlueCoin$

As a result:

- Standard model: $V_rf = V_rm$
- Face value effect model: $V_rf > V_rm$
- Perceived value of money model: $V_rf < V_rm$

where V_rf is the valuation of the good in the foreign currency for the fraction group and V_rm is the valuation of the good in the foreign currency for the multiple group.

In other words, the standard model would expect the valuations to be the same across both exchange rates, the face value effect model would expect the consumer to overspend when presented with the fraction exchange rate (and vice-versa) and the perceived value of money model would expect the consumer to underspend when presented with the fraction exchange rate (and vice-versa).

Method

To test which model is most accurate in predicting and explaining consumption behaviour, I conducted an online study. There were 41 participants in the study, most of them current undergraduate students at the University of Oxford, but some participants were also recent graduates and postgraduate students. The study took place online, using Qualtrics, and students were incentivised to participate by taking part in a lottery, which will be explained in further detail below.

Study

The study itself was a survey split into four parts: consent, introduction, auction and follow-up Questions. The entire experiment instructions can be found in the Experiment Instructions section of the Appendix. The first section asked participants to read through and sign the consent form in order to ensure that they were informed about the study and what data would be collected. In the introductory section, the BDM mechanism was explained to participants and they were asked to complete four question that tested their understanding of the mechanism. The aim of this section was to ensure that participants properly understood how the mechanism worked in order to elicit their true WTP during the main part of the study.

The auction was the main part of the study, with the aim of eliciting the participants' WTP on a specific item and comparing these across different exchange rates used. In this section, participants were randomly split into two groups with almost-identical instructions. The participants were instructed to bid on an item shown below, a tabletop airhockey table, using the virtual currency "BlueCoin". The auction was explained to follow the BDM mechanism and it was also stated that three participants of the experiment would be randomly selected for their auction to be simulated and to receive the outcome (either their budget in Pounds or the item and remaining budget). The only difference between the groups was the exchange rate between BlueCoin and the British Pound (£) and the endowment that the participants received in BlueCoin. The first group received an endowment of 10 BlueCoin where 1 BlueCoin equals £5 and the second group received an endowment of 250 BlueCoin where 1 BlueCoin equals £0.2. To complete the auction, participants were asked to respond with their bid, in BlueCoin.

The final part of the experiment consisted of optional follow-up questions that were used to determine if there are any trends in bidding behaviour based on some characteristics of the participants. The questions asked were about whether they had previously lived in a different country than the UK, how often they tend to travel outside of the UK and what their typical expenditure is in a given month. The intention behind the first two questions is to use them as a proxy for experience dealing with foreign currencies, where presumably people that travel frequently or have lived in multiple countries

are more experienced with currency conversion calculations. The final question was asked to be able to determine whether there were any systematic differences in WTP based on a participants normal expenditure.

Auction Design

Since the aim of the study was to determine whether there were any systematic differences in WTP between consumers when the only differing factor is the numerousity of the currency used, I decided to not include a control group that bid on the item using Pounds, which was the design of some of the experiments run by Raghubir and Srivastava (Raghubir and Srivastava 2002). This allowed for a simpler design and more power given the same sample size. Further, unlike the studies run by Raghubir and Srivastava (Raghubir and Srivastava 2002) and Wertenbroch, Soman and Chattopadhyay (Wertenbroch, Soman, and Chattopadhyay 2007), I did not use a fiat currency or mix of fiat and virtual currencies, but used only one virtual currency for both groups. On the one hand, this simplification was due to a focus of wether the effects described in previous papers also held in similar ways for virtual currencies. On the other hand, it also allowed me to preclude any biases or previous experience that participants might have had towards or with certain currencies. Raghubir and Srivastava (Raghubir and Srivastava 2002) acknowledge that "the face value effect is due to the accessibility and perceptual salience of the face value of the foreign currency … [which] is likely to depend on the extent to which an individual has the opportunity or the time available to process exchange rate information and/or has experience in using a particular foreign currency". Further, Alter and Oppenheimer (Alter and Oppenheimer 2008) show that people use "familiarity and fluency" when valuing goods in different currencies. To bias participants the least, I chose the relatively nondescript name for a fictional, virtual currency: BlueCoin.

Another important decision in the design of the experiment was which item to select that a majority of participants would have a non-zero WTP. This is important since if the majority or even the entirety of participants were to bid zero on the item, then I would only learn that this was the participants' WTP for that good, but not whether there are any systematic differences in the WTP when using different currencies. Hence, I selected a tabletop airhockey table, something that few enough people have so that they would not not want another one, but enough people want with a non-zero WTP, especially among a student population. This turned out to be a good choice, since only six participants of the experiment stated a WTP of 0.

In designing the main part of the experiment, I chose to conduct an auction, specifically using the BDM mechanism, in order to have an incentive-compatible method of eliciting the participants' WTP. The BDM's incentive compatibility in eliciting WTP is a well-established phenomenon that is superior to using participants' stated preferences (Burchardi et al. 2021). The BDM is essentially a sealed-bid, second price auction that is, in its' most common variant, played against a computer drawing a bid from a known distribution. If the players' bid is greater than or equal to the computers' bid, they win and pay the computers' bid, otherwise they lose. As mentioned above, the studies conducted by Raghubir and Srivastava (Raghubir and Srivastava 2002), Wertenbroch, Soman and Chattopadhyay (Wertenbroch, Soman, and Chattopadhyay 2007) (with the exception of one permutation of one of the studies) and Fang (Fang 2019) did not implement incentive-compatible methods of eliciting the participants' preferences, making this experiment an important addition to these previous studies in examining whether the effects described still hold when a more truthful way of eliciting WTP is used. In order to incentivise the participants to participate, I ran a lottery that paid out three randomly-

chosen participants based on their actual choices made in the auction and by simulating the BDM mechanism using a random number generator. Due to budget constraints, I was only able to play this lottery for three people, but given that the sample size of the experiment was relatively small, the potential to receive one's outcome is likely to have helped in eliciting the participants' true WTP.

Finally, given the budget, I was able to give participants an endowment of £50 each, which was around double of what the item costs to buy. Assuming that the item is priced roughly around the average WTP (which turned out to be correct), this endowment was chosen to leave enough room for people with higher WTP to make their bid and to capture this in the data. This is important for the goals of the experiment, since if I had, for example, chosen an endowment of £20, the majority of participants might have bid their maximum amount, hindering my ability to meaningfully compare WTP across the two groups. I chose relatively simple exchange rates of 5 and 1/5 so that the exchange rate calculations would be relatively easy to make, allowing me to be more confident that differences between groups were not due to the mental effort required to do calculations but due to something else. Raghubir and Srivastava (Raghubir and Srivastava 2002) acknowledge that "the reliance on face value may be a function of the ease with which the foreign money can be converted. … Future research should examine the asymmetric and nonlinear nature of this effect". Since the goal of this study is to investigate that an effect exists that is not solely based on a high difficulty or large mental effort required when doing specific, difficult calculations, I aimed to make the calculations as easy as possible in order to isolate the effect of the exchange rate and nominal value of the foreign currency. Further, since the study was conducted online, participants were easily able to and allowed to use calculators for any part.

Limitations

In setting up the experiment, I incorrectly used the BDM mechanism. Instead of explaining it as a sealed-bid second-price auction, the experiment instructions explained it as a sealed-bid first-price auction. Unlike in a second-price auction, the participants of a first price auction do not have a (weakly) dominant strategy to bid their true valuations, in fact there generally is no dominant strategy in such an auction (Noussair, Robin, and Ruffieux 2004). This is true even in this auction in which participants knew that they were bidding against a computer agent who would randomly draw a bid from a uniform distribution from 0-50, with an expected bid of 25. Indeed, the optimal strategy by participants was to choose their bid b by maximising their payoff p:

$$\frac{b}{50} * u(x = 1, 50 - b) + (1 - \frac{b}{50}) * u(x = 0, 50)$$

where u(x, m) is their utility function, x is a binary variable where x = 1 signifies owning the good (and vice-versa) and m = 50 is their budget (in Pounds). As is obvious, the value of b depends on the participants' utility function. Hence, while players in this auction need not necessarily have the optimal strategy of telling their true valuation, sufficient randomisation should ensure that the utility functions of agents in each group should be evenly distributed. This would entail that we can nonetheless compare bids across both groups.

Another limitation of the study is the low sample size of 41 participants, which entails lower statistical power and thus a lower likelihood of detecting a true positive when an effect actually exists. I will examine this in further detail in the next section, conducting a power analysis and estimating how big the sample size should have been to achieve an adequate level of power.

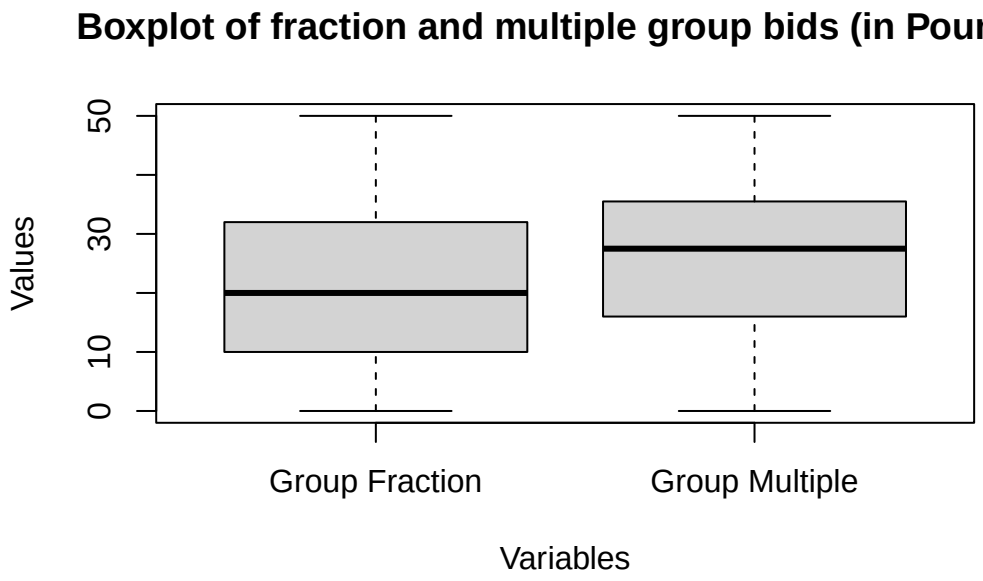
Results

There were 41 participants, 21 in the first group and 20 in the second. To conduct the data analysis, I have normalised the bids across both groups by converting them into pounds and computed the following summary statistics:

```
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.    NA's
   0.00   10.00   20.00   19.74   32.00   50.00      20
```

```
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.    NA's
   0.00   16.50   27.50   25.57   35.25   50.00      21
```

Further, I plotted the following boxplot, in order to visually see the difference between the groups:



As is obvious from the summary statistics and the boxplot, there is a difference between both groups, namely that the bids in the multiple group seem to be higher on average than those in the fraction

group. To investigate this hypothesis, I conducted a t-test of a difference in means between the groups, specifically a Welch Two Sample t-test. The null hypothesis is that the difference in means is equal to 0 (or, alternatively, that the means are the same) and the alternative hypothesis is that this difference is not equal to 0 (or, alternatively, that the means are not the same):

$$h_0 : {}_1 = {}_2$$
$$h_1 : {}_1 \neq {}_2$$

Hence, I conducted the t-test:

```
t = -1.23227791692727
```

```
p-value = 0.225223137738591
```

```
95 percent confidence interval:
```

```
-15.4019012943159 3.74009177050641
```

The t-value of -1.2323 suggests that there is a difference in the means between the groups and, since it is negative, that the mean of the fraction group is lower. However, the p-value is 0.2252, which is quite high. If we take the typical significance level of $\alpha = 0.05$ we find that the p-value is higher than this value, and thus fail to reject the null hypothesis at the 5% significance level. Further, the 95% confidence interval is $[-15.401901, 3.740092]$ which includes 0, providing further evidence that the difference in means between the groups is not statistically significant. Thus, we must conclude that while there seems to be a difference in means based on the sample data, this difference is not statistically significant for this sample size.

To investigate this further, I have conducted a power analysis in order to determine the power of the t-test, which refers to the likelihood of the test detecting a true positive when an effect actually exists. High power would indicate that this likelihood is high and vice versa. To conduct the analysis, we first need to find the effect size, or Cohen's D, and then implement the power analysis. Further, I will also conduct an analysis that investigates how big the sample size should have been to get a power of 80%, which is a generally accepted threshold for significant power.

```
     t test power calculation

             n1 = 21
             n2 = 20
              d = 0.3845806
      sig.level = 0.05
          power = 0.2246363
    alternative = two.sided


     Two-sample t test power calculation

              n = 107.1047
              d = 0.3845806
```

```
      sig.level = 0.05
          power = 0.8
    alternative = two.sided

NOTE: n is number in *each* group
```

Based on the first test with the same significance level of 0.05, we can see that the power is 0.2246363 or 22%, which means that there is only a 22% likelihood of detecting a true positive if an effect actually exists. In other words, the likelihood of detecting a true difference in means between the two groups, when this difference exists, is only 22%, which is far below the usual value of 80%. The second test takes in this power of 80% and calculates the required sample size at the observed effect size. The result is $n = 107$ where the sample size is $2n$ or 214. Hence, using a sample size of 214 and observing the same effect, this t-test would yield a power of 80% at the 5% significance level.

Finally, I conducted a regression of the demographic values collected in the fourth part of the experiment on the bids of each group. This is done in order to determine whether there is any correlation between the demographic variables and the bid amount, which would suggest that randomisation did not occur correctly, which could have been exacerbated by the small sample size.[3] Based on this regression, there are no statistically significant correlations at the 5% significance level or lower. However, there is one correlation that is significant at the 10% significance level, namely of `expenditure£551-£700` on the multiple group. The coefficient of -43.487 suggests that people whose usual expenditure is between £551 and £700 per month bid lower than the group overall. However, given that this is only significant at the 10% level and not at any lower ones, it is likely that this correlation is due to the low sample size rather than it representing a true correlation between these variables.

[3] For brevity, the regression output has been moved into the appendix.

Discussion

The study conducted found that the fraction group bid less on average than the multiple group. The difference in the means across the two groups is around £6, or over 10% of the budget, signifying that this difference occurs due to a systematic difference in how each group calculated their value in the foreign currency BlueCoin rather than random chance. The only difference between the groups was the exchange rate of BlueCoin to the Pound and, as a result, the numerousity of the nominal values of the budget and the bids. This would suggest that this difference in bids occurs based on whether the foreign currency is a fraction or multiple of the home currency.

Above, I outlined the three models for how consumers value goods in a foreign currency that have been suggested by previous research. The standard model would have predicted that both groups would on average bid the same, the model proposed by Raghubir and Srivastava (Raghubir and Srivastava 2002) would have predicted that the fraction group would on average bid more than the multiple group and the model proposed by Wertenbroch, Soman and Chattopadhyay (Wertenbroch, Soman, and Chattopadhyay 2007) would have predicted the opposite, namely that the fraction group would on average bid less than the multiple group. Hence, the third model would have made the most accurate prediction for the study conducted.

Wertenbroch, Soman and Chattopadhyay (Wertenbroch, Soman, and Chattopadhyay 2007) argue that this systematic difference in valuations and spending behaviour occurs because consumers are biased by the nominal difference between their budget and the product valuation in the foreign currency and thus anchor on this value when converting amounts between their home currency and foreign currency. In the context of the study, this would entail that the fraction group calculated the difference between their budget and their bid in BlueCoin and adjusted their bid downwards based on it, since this difference will be small (< 10) in nominal terms. The multiple group, on the other hand, would have calculated this difference and received a larger amount of surplus for the same product valuation in real terms (25 times as large as the fraction group). Hence, the multiple group would have adjusted their bid upwards, leading to a higher average bid in real (and nominal) terms.

However, there might be alternative explanations that would be consistent with one or more of the other models outlined above. One explanation would be that consumers are biased by only the nominal value of their budget in the foreign currency and not by the difference between their budget and their valuation of a product in the foreign currency. While this alternative hypothesis would be hard to prove, it would not change the prediction for how the difference in product valuations across groups that use either a fraction or multiple currency. Indeed, it would predict the exact same result and is thus consistent with the model proposed by Wertenbroch, Soman and Chattopadhyay, even though it differs in explaining the internal work that individuals would do to come to that conclusion.

Another explanation might be that people are simply worse at dividing than multiplying (or the reverse), which could explain the perceived differences between the groups. On this explanation, even when consumers have the same valuation in real terms, one group will systematically fail to accurately convert this value into the foreign currency. However, this explanation is unlikely for several reasons. First, it assumes that a significant amount of people are significantly worse at performing one of the operations across all numbers. From experience, it seems that when considering most numbers, one of these operations is more difficult to do but it is not always the same one. Secondly, this assumes that people are unaware enough of their difficulties (even when they are very significant) that they do not use a calculator even when one is easily accessible, such as when completing the survey for this study online. For these reasons, this explanation seems unlikely to be accurate.

A third contending explanation could be that individuals simply prefer to use whole numbers over fractions or decimals, leading consumers to make less granular valuation choices when considering a currency with a low face value. Because of this, there can be differences in groups of individuals if, for example, many participants in the same group choose to round down. For example, it could have been the case that the average valuation of the good in the fraction group was £24 but if a significant amount of participants rounded this down to the nearest whole number in BlueCoin (4), then this average valuation would now be 20. This explanation can be supported empirically, given that only 3 bids out of 41 were decimal numbers. One might also claim that this behaviour of preferring whole numbers is rational, given that it requires less mental effort, especially when multiplying and dividing these numbers. Further research is required to determine whether this hypothesis could explain the observed behaviour, either entirely or in conjunction with one of the models proposed above.

The former two of these alternative explanations seem unlikely, but the latter seems like it could be accurate at least to some extent. Without further research, however, it seems like the model proposed by Wertenbroch, Soman and Chattopadhyay is the most accurate in predicting and explaining the perceived behaviour when formulating valuations of goods in different foreign currencies.

Limitations, Theoretical Implications and Future Research

The main limitation of the study conducted is that due to small sample size, the results are not statistically significant at the 5% level and the power of the t-test for a difference in means is only 22%. Hence, even though the observations line up with the model proposed by Wertenbroch, Soman and Chattopadhyay, it could be the case that this result is due to random chance. In repeating this study, it would be useful to get a sample size of at least 200 participants to roughly achieve a power of 80% and likely also statistical significance in conducting the t-test. The second major limitation is that the BDM mechanism was implemented incorrectly, entailing that there was no dominant strategy for participants to reveal their true valuations on the good. In a redo, this mistake could be fixed relatively easily by adjusting the experiment instructions.

Apart from the limitations, the major theoretical implication of this paper is the finding that the model proposed by Wertenbroch, Soman and Chattopadhyay (Wertenbroch, Soman, and Chattopadhyay 2007) seems to be most accurate in predicting and explaining consumer behaviour when eliciting a WTP on a good in a foreign currncy. In line with these authors, this conclusion contradicts the findings of the "face value effect" by Raghubir and Srivastava (Raghubir and Srivastava 2002) and subsequently by Fang (Fang 2019). Further, this conclusion also implies that, contrary to traditional consumption theory, individuals formulate their WTP in relation to the difference between their budget and the

valuation of a good rather than its' ratio.

Future research could build on this study and its' findings in several important ways: first, it would make sense to conduct a similar or identical study with the BDM mechanism implemented correctly and a greater sample size. This would allow for greater certainty that the effect observed is statistically significant and reproducible. Further, it would be interesting to investigate the third alternative hypothesis formulated above in order to gain a better understanding into the exact process that leads individuals to systematically under- or overspend when using foreign currencies. It might, however, be difficult to conduct an adequate study to accurately test that claim.

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Appendix

Regression output

```
Call:
lm(formula = group_fraction_bid_in_pounds ~ lived_abroad + travel_frequency +
    expenditure, data = experiment_data)

Residuals:
    Min      1Q  Median      3Q     Max
-20.744 -10.085   0.000   7.481  33.333

Coefficients: (2 not defined because of singularities)
                                          Estimate Std. Error t value Pr(>|t|)
(Intercept)                                 16.667     11.144   1.496    0.169
lived_abroadNo                              16.883     34.290   0.492    0.634
lived_abroadYes                              4.651     28.453   0.163    0.874
travel_frequencyLess than once per 5 years  12.768     31.087   0.411    0.691
travel_frequencyOnce per 1-2 years          -4.952     27.679  -0.179    0.862
travel_frequencyOnce per 2-5 months          5.085     23.987   0.212    0.837
travel_frequencyOnce per 3-5 years         -18.005     42.079  -0.428    0.679
travel_frequencyOnce per 6-11 months        -6.488     24.395  -0.266    0.796
travel_frequencyOnce per month or more          NA         NA      NA       NA
expenditure£251-£400                        -6.317     17.686  -0.357    0.729
expenditure£401-£550                        -5.544     19.548  -0.284    0.783
expenditure£551-£700                        -8.884     20.685  -0.429    0.678
expenditureAbove £1000                      -13.549     37.738  -0.359    0.728
expenditureBelow £250                           NA         NA      NA       NA

Residual standard error: 19.3 on 9 degrees of freedom
  (20 observations deleted due to missingness)
Multiple R-squared:  0.3013,    Adjusted R-squared:  -0.5528
F-statistic: 0.3527 on 11 and 9 DF,  p-value: 0.9466
```

```
Call:
lm(formula = group_multiple_bid_in_pounds ~ lived_abroad + travel_frequency +
    expenditure, data = experiment_data)

Residuals:
    Min      1Q  Median      3Q     Max
-15.667  -4.550   0.000   5.383  17.200

Coefficients: (2 not defined because of singularities)
                                     Estimate Std. Error t value Pr(>|t|)
(Intercept)                            20.000     13.715   1.458   0.1788
lived_abroadNo                         -0.600     17.250  -0.035   0.9730
lived_abroadYes                        17.600     17.250   1.020   0.3342
travel_frequencyOnce per 1-2 years      4.600     21.843   0.211   0.8379
travel_frequencyOnce per 2-5 months    12.400     17.250   0.719   0.4905
travel_frequencyOnce per 6-11 months    7.267     19.717   0.369   0.7210
travel_frequencyOnce per month or more     NA         NA      NA       NA
expenditure£251-£400                   -5.000     18.025  -0.277   0.7877
expenditure£401-£550                  -17.200     15.801  -1.089   0.3046
expenditure£551-£700                  -43.487     21.461  -2.026   0.0734 .
expenditure£701-£850                   -8.400     17.250  -0.487   0.6379
expenditureAbove £1000                 -25.000     19.396  -1.289   0.2296
expenditureBelow £250                      NA         NA      NA       NA
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 13.72 on 9 degrees of freedom
  (21 observations deleted due to missingness)
Multiple R-squared:  0.5937,    Adjusted R-squared:  0.1422
F-statistic: 1.315 on 10 and 9 DF,  p-value: 0.3456
```

Experiment Instructions

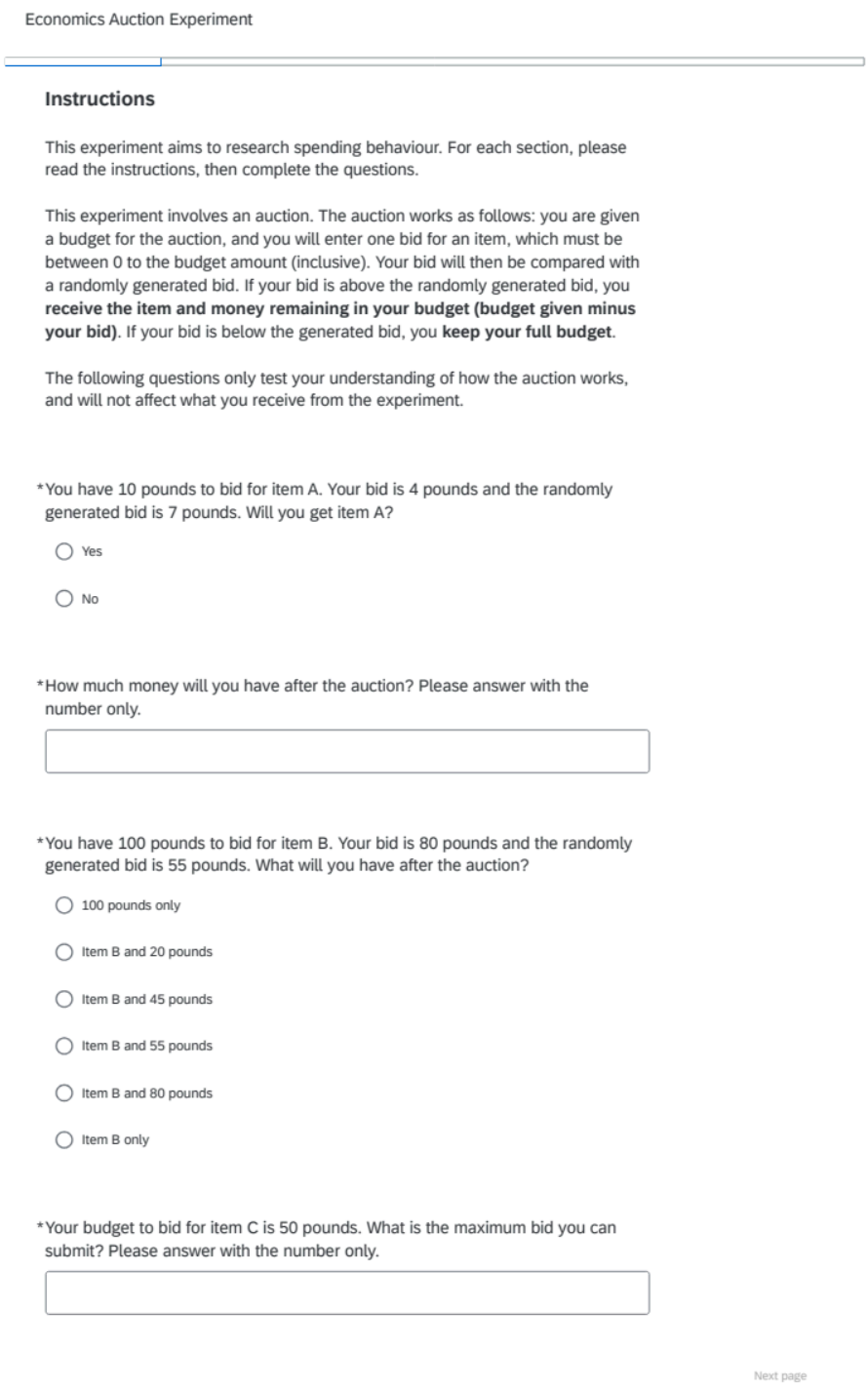

Figure 1: Instructions

Economics Auction Experiment

Instructions

This is the auction for the experiment.

'BlueCoin' is a virtual currency. The exchange rate between BlueCoin and the British Pound is: **1 BlueCoin = 5 Pounds.**

You participate in an auction to purchase a tabletop air hockey game. Your budget is **10 BlueCoins**, and you will enter one bid for the item. You are to bid in BlueCoin and you may bid any amount between 0 and your budget 10 (inclusive, you may bid amounts with decimals if you would like). Like before, your bid will be compared with a randomly generated bid. If your bid is above the randomly generated bid, you **receive the tabletop air hockey set and money remaining in your budget (budget given minus your bid)**. If your bid is below the generated bid, you **keep your full budget**.

This is an image of the tabletop air hockey game:

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We will randomly select 3 participants after the study to actually receive the results from the auction, with what is to be received as detailed above. Any money you receive will be converted into Pounds.

*How much will you bid for this tabletop air hockey game, **in BlueCoin**?

Next page

Figure 2: Auction: Fraction Group

Economics Auction Experiment

Instructions

This is the auction for the experiment.

'BlueCoin' is a virtual currency. The exchange rate between BlueCoin and the British Pound is: **1 BlueCoin = 0.2 Pounds**.

You participate in an auction to purchase a tabletop air hockey game. Your budget is 250 BlueCoins, and you will enter one bid for the item. You are to bid in BlueCoin and you may bid any amount between 0 and your budget 250 (inclusive, you may bid amounts with decimals if you would like). Like before, your bid will be compared with a randomly generated bid. If your bid is above the randomly generated bid, you **receive the tabletop air hockey set and money remaining in your budget (budget given minus your bid)**. If your bid is below the generated bid, you **keep your full budget**.

This is an image of the tabletop air hockey game:

Copyright Funtime Gifts Ltd 2021

We will randomly select 3 participants after the study to actually receive the results from the auction, with what is to be received as detailed above. Any money you receive will be converted into Pounds.

*How much will you bid for this tabletop air hockey game, **in BlueCoin**?

Next page

Figure 3: Auction: Multiple Group

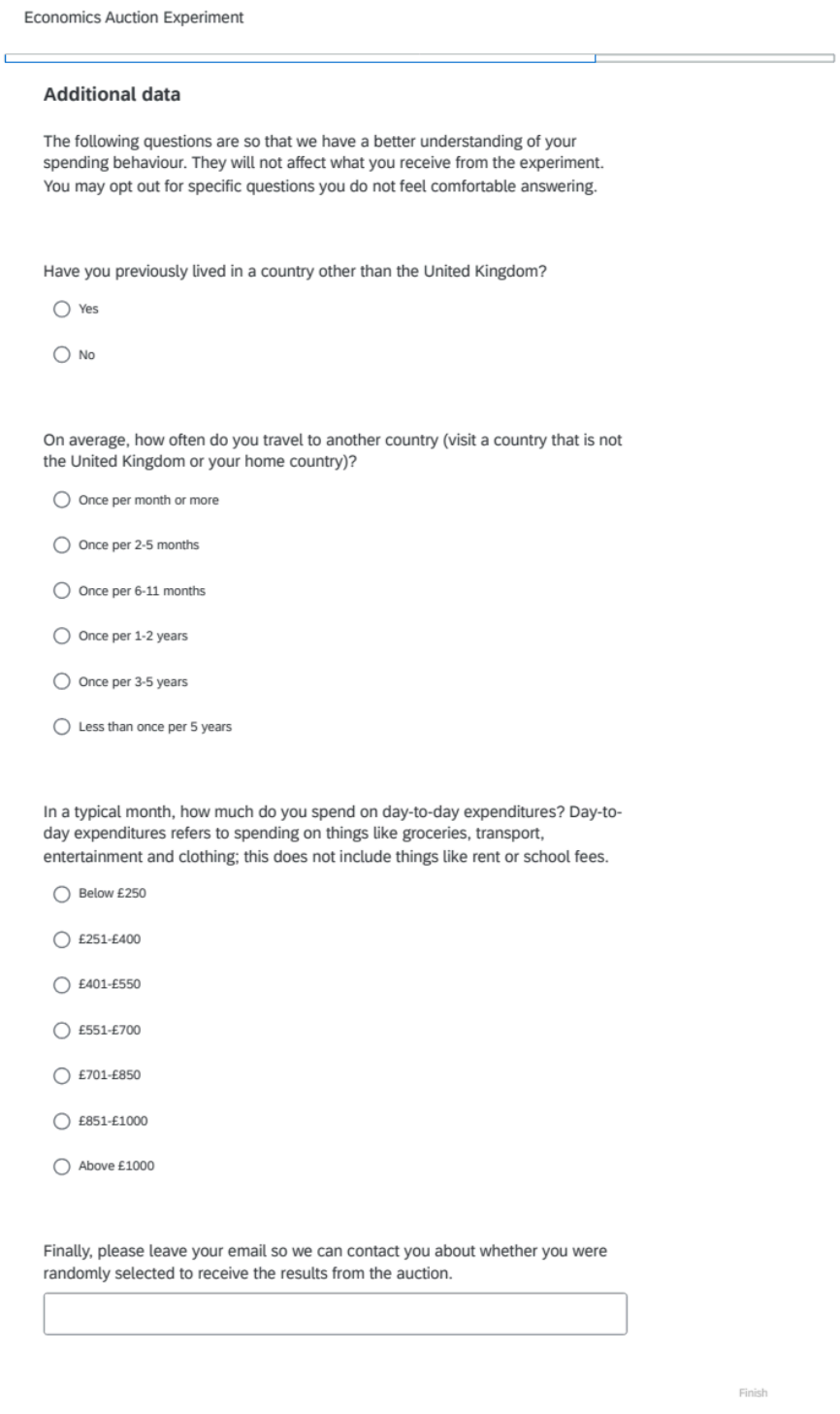

Figure 4: Follow up

Source Code

The full source code of the data analysis is follows:

```
# Load the required libraries
library(pwr)
library(lsr)

# Load the experiment data
experiment_data <-
  read.csv("virtual-currencies-paper/data/experiment_data_formatted.csv")

# Summary statistics for the bid columns
summary(experiment_data$group_fraction_bid_in_pounds)
sd(experiment_data$group_fraction_bid_in_pounds, na.rm = TRUE)

summary(experiment_data$group_multiple_bid_in_pounds)
sd(experiment_data$group_multiple_bid_in_pounds, na.rm = TRUE)

# Plot a boxplot for the bid columns
boxplot(
  experiment_data$group_fraction_bid_in_pounds,
  experiment_data$group_multiple_bid_in_pounds,
  main = "Boxplot of fraction and multiple group bids (in Pounds)",
  names = c("Group Fraction", "Group Multiple"),
  xlab = "Variables",
  ylab = "Values"
)

# Perform a t-test to compare the means of the two groups
t.test(
  experiment_data$group_fraction_bid_in_pounds,
  experiment_data$group_multiple_bid_in_pounds
)

# Conduct a regression analysis to examine the relationship between
# the bid amounts and the demographic variables
model_group_fraction <-
  lm(
    group_fraction_bid_in_pounds ~ lived_abroad +
      travel_frequency + expenditure,
    data = experiment_data
  )
summary(model_group_fraction)

model_group_multiple <-
  lm(
```

```
    group_multiple_bid_in_pounds ~ lived_abroad +
      travel_frequency + expenditure,
    data = experiment_data
  )
summary(model_group_multiple)

# Calculate the effect size (Cohens D)
effect_size <- cohensD(
  experiment_data$group_fraction_bid_in_pounds,
  experiment_data$group_multiple_bid_in_pounds
)

# Find the power of the t test conducted above
pwr.t2n.test(n1 = 21, n2 = 20, d = effect_size, sig.level = 0.05)

# Find the sample size required to achieve a power of 0.8 (80%)
pwr.t.test(power = 0.8, d = effect_size, sig.level = 0.05)
```