Why do people panic-buy presents so late in the run up to Christmas?

The following is a

2,374 word

behavioural economic blogpost written by

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MFWW8, MSCG1, KVXF0.

The run up to Christmas is invariably a stressful one; tidying spare bedrooms for relatives, ordering turkeys almost always too large for consumption and adorning bannisters and doorframes alike with sparkling decorations. For many, however, there exists an event even more frenetic; the last-minute present-purchasing panic. And it is rife, to the extent that over 79% of US shoppers leave their shopping until the 2 weeks before Christmas (Klarna study, 2021).

Neoclassical Economics leads us to believe that such suboptimal behaviour never happens. Agents have the mental command and readiness of perfect information to calculate the utility-maximising gift for each relative, subject to cost/availability constraints. Gifts then arrive in ample time and *homo economicus* lives happily ever after in her utility-maximised world.

So why do we see so much last-minute delay and vacillation? Simply put, because people do not fit the impossible mould postulated by Neoclassicists; there is no room at the inn for non-standard preferences, beliefs or decision-making. Although many people plan to improve their behaviours in the future, when the time comes, excuses are plenty. Milkman *et al.* (2008) describe this as a tug of war between the immediate gratification-seeking *'want' self*, and the *'should' self*, which pursues longer-term interests.

Behavioural Economics seeks to add realism and flexibility to enhance the explanatory power of traditional models. In the first section of this blog, we will draw on relevant behavioural concepts of Outcome-based Models to suggest why we feel the need to buy presents, Time Inconsistency and Bounded Rationality to explain purchasing delays, and Demand for Commitment to offer a solution. In the second section we use a model to quantitatively analyse the impact of these behavioural concepts on a sample of agents. We study when they decide to purchase their Christmas presents, and the impact their decision has on utility.

Section I

Outcome-based Models

In the context of Christmas shopping, the utility of an individual is dictated by the assumption that they receive presents. Human nature of valuing reciprocity imposes a cost if they do not buy a present for someone who bought a present for them. The fear of incurring this cost is one source of the stress of Christmas shopping. Moreover, a simple outcome-based model can be used to show how buying a present is the optimal decision since the largest cost occurs when a non-buyer receives a present. We use a simple 2x2 game to show that rational individuals should buy a present, as ***(Buy, Buy)*** is the unique pure strategy Nash Equilibrium.

	Buy	$No\,Buy$
Buy	$(10, 10)$	$(5,\ -10)$
$No\,Buy$	$(-10,\ 5)$	$(0, 0)$

Time Inconsistency

Dynamic preference reversals offer insight into the occurrence of this phenomenon. Traditionally, models of choosing *when* the optimal time to complete a task is, or *how* to trade short-term benefits with long-term costs fall under those of intertemporal choice. A widely accepted model is the Exponential Discounted Utility (EDU) model, an extension of DU (Samuelson, 1937). It incorporates all motivates affecting intertemporal choice into one parameter, the discount rate δ^t. In discrete time,

$$U(C) = \sum_{t=0}^{T} \delta^t u(c_t),\ where\, \delta^t = \left(\frac{1}{1+\rho}\right)^t$$

However, a limiting property of EDU is the constant discount rate between any two given periods. Assuming in the utility function $u(c_t)$ there is an increasing cost of stress as the time becomes closer to Christmas, the constant discount rate means an individual will calculate on which day that cost will be lowest and will shop then, since the difference in stress between the 3rd and 4th is the same as between the 23rd and 24th. Yet this is inconsistent with Klarna data above, as gift purchases bunch near month-end. To substantiate, there are ample studies also showing that empirically this rate is not constant and declines across time horizons (Benzion *et al.*, 1989), (Thaler & Shefrin, 1981). Given no change in the opportunity set, this represents *time inconsistent behaviour*. Relating this phenomenon to

Christmas presents, empirical data suggests individuals will re-estimate the cost of shopping every day, and if the cost today is not the lowest, they will not go; individuals regularly postpone. This is a result of *present bias* (an individual's tendency to overvalue an immediate reward), which manifests itself in self-control problems. This concept is empirically widespread and further contradicts exponential discounting models (Benhabib *et al.*, 2008). Therefore, empirical existence of present bias and the overestimation of future-selves' self-restraint help to explain the phenomenon.

Bounded Rationality

Bounded rationality offers another cause for delaying purchases. It dictates that people are rational, however their ability to make rational decisions is bounded by cognitive ability, time constraints and imperfect information. In this context, this is represented by an individual's inability to effectively manage all the factors pertaining to Christmas shopping.

Neoclassically, a fully rational (*unbounded*) individual would be perfectly aware of each product's availability, required shipping time and time remaining until Christmas. However, shoppers focus more on factors most obvious to them. We posit that consumers' 'limited attention' makes them ignorant to less-salient costs such as items selling out. This suggests individuals lack the cognitive endurance to consider all important factors, leading to purchase delay.

Commitment Devices

What do we suggest as a solution? Commitment devices - methods to impose voluntary restrictions or penalties on oneself in order to achieve a goal. Dolan *et al.* (2010) highlight that a successful commitment device introduces a greater cost of failure and reciprocity. For gym commitment, scheduling sessions with a partner to impose a cost of disappointment among friends (Rogers *et al.*, 2014) helps to increase the cost of failure. Moreover, with a natural experiment using optional lecture attendance sign-ups, average commitment increases by over 50% if choices are made public (Exley & Naecker, 2016). This suggests greater observability also translates into a more binding device.

Commitment devices only work with certain agents. We can characterise those who exhibit present bias as either *sophisticated* or *naïve*. While sophisticates recognise their self-control problem, naïves do not. Although both tend to favour the immediate reward of postponing, a sophisticate could impose commitment devices to ensure she shops. Naïves not only favour this immediate reward more, but mis-predict future behaviour too; they do not believe they will need commitment devices, and so the usefulness fails to hold. This suggests the majority of last-minute buyers are naïve.

Organising a designated Christmas shopping trip with a group of friends is an effective solution to incorporate a *more observable* cost of failure and reciprocity. Electing not to go levies the costs of disappointing and damaging friendship relations, and one could even impose further costs by offering to drive – who would let their friends down in that case!

Section II

Preference Modelling

Laibson (1997) offers a model of Quasi-Hyperbolic Discounting (QHD) consistent with Thaler & Shefrin (1981), Benzion *et al.* (1989) and Benhabib *et al.* (2008). For $\beta,\ \delta\ \leq 1$,

$$D(\tau) = \begin{cases} 1 & if\,\tau = 0 \\ \beta\delta^t & if\,\tau > 0 \end{cases} \quad \ldots(*) D(\tau) = \begin{cases} 1 & if\,\tau = 0 \\ \beta\delta^t & if\,\tau > 0 \end{cases}$$

QHD individuals view a cost, x, that they would prospectively experience *today* as:

$$PV\,of\,Cost_{t=1} = Cost_{t=1} = x$$

Whereas at a future point in time τ, they would calculate the present value of the same cost, x, as:

$$PV\ of\ Cost_{t+\tau} = \beta\delta^{\tau}x \leq x,\ \tau > 1$$

Each day, agents consider the present value of all future costs. If their cost today is lowest, they shop. Present bias ($\beta < 1$) is normally distributed within the sample. Delta is constant.

Cost Modelling:

We identify three inputs to the cost that each agent considers for every $\boldsymbol{t+\tau}$ at $\boldsymbol{t}$.

1. Inconvenience/opportunity cost of actually purchasing presents, $\boldsymbol{\alpha}$

This doesn't vary over time. We assume that it is the same for everyone, and that the mode of 'shop' doesn't affect it- ordering online and going to the shop are the same. $\boldsymbol{\alpha}$= 15 for all agents.

2. Stress that occurs when one hasn't bought presents, $\boldsymbol{\gamma}$

Agents experience stress every time period that they haven't purchased their presents, and increases exponentially as you get closer to Christmas as displayed in figure 1. The stress of person *i* at time *t*:

$$Stress_i = \frac{\gamma_i}{25-t}$$

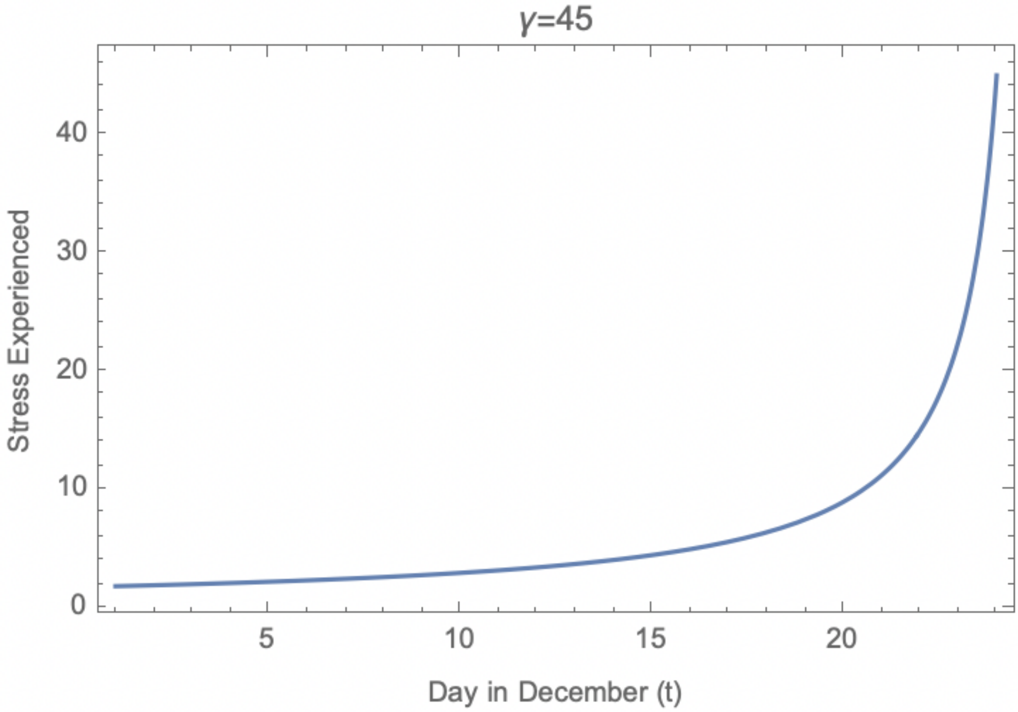

Fig. 1: Graph of stress against day of December.

To add some variation, we distribute gamma $\boldsymbol{\gamma \sim \mathcal{N}(45, 15)}$. 45 is chosen such that stress on Christmas eve $\left(\frac{45}{25-24} = 45\right)$ is 3x worse than the prospect of actually doing the shopping **(15)**.

3. Choice set reducing when items sell out, $\boldsymbol{\Omega}$

This is a cost experienced by consumers as the available choice of goods reduces. As such, *this cost isn't considered by agents when deciding to go to the shops or not on a given day*. We will measure the utility the agent expects to experience versus the utility the agent actually experiences as a means to quantitatively examine the cost of bounded rationality.

At time $\boldsymbol{\tau}$, and across $i = 1, 2, \ldots, n$ individuals in the sample:

$$Cost\,of\,reduced\,choice_\tau = \Omega \frac{\sum_{t=1}^{t=\tau-1} \sum_{i=1}^{n} Purchases}{n}$$

$\boldsymbol{\Omega}$ is constant, as the choice set impact is for each agent, and the cost increases linearly as agents in the sample purchase their presents. Figure 2 shows this.

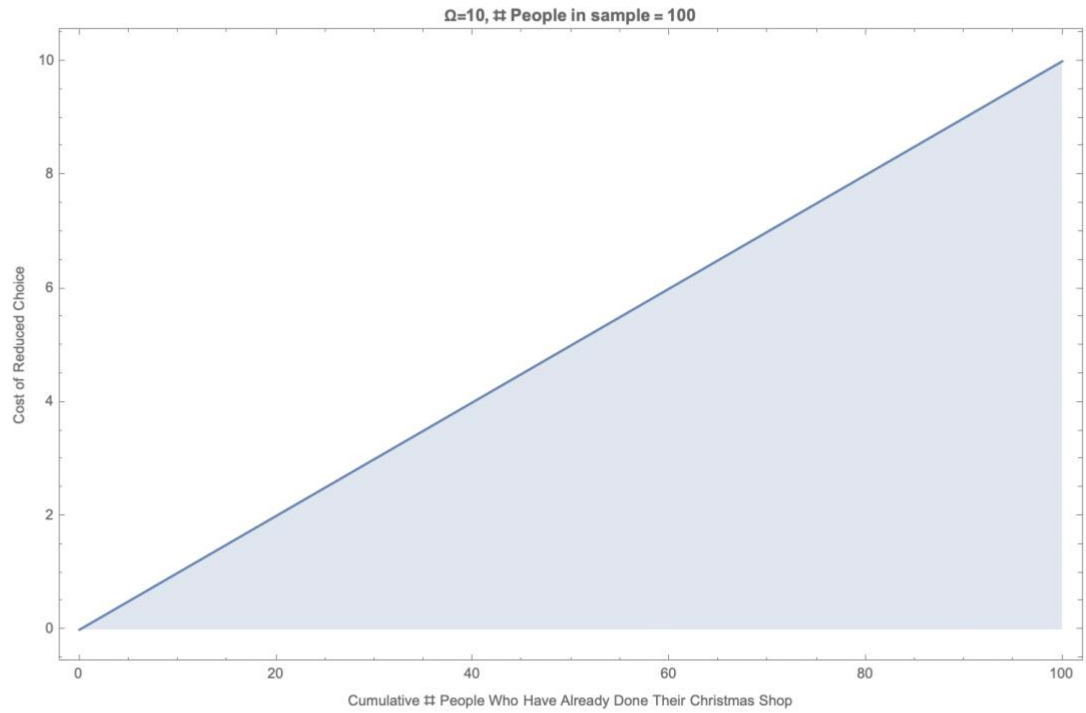

Fig. 2: Graph of cost of reduced choice set against number of people who have shopped.

Thus, for agent *i*:

Perceived cost of doing Christmas shopping today at time $\boldsymbol{t}$

$$c_{i,t} = \underbrace{\frac{\gamma_i}{25-t}}_{\text{stress}} + \underbrace{\alpha}_{\text{inconvenience}}$$

Today's perceived present value cost of doing the Christmas shopping at future time period $\boldsymbol{t+\tau}$:

$$c_{i,t+\tau} = \underbrace{\beta}_{\substack{\text{Present bias-}\\ \text{present in all PV}\\ \text{considerations}\\ \text{for future costs}}} \underbrace{\delta^{\tau}}_{\substack{\text{Future}\\ \text{discounting}\\ \text{parameter from}\\ \text{standard EDU}\\ \text{preferences}}} \left(\underbrace{\frac{\gamma_i}{25-(t+\tau)}}_{\substack{\text{Stress that will}\\ \text{be experienced}\\ \text{at time } t+\tau \text{ in}\\ \text{the future}}} + \alpha \right)$$

Actual **total** cost over the month once Christmas shopping has been done at date T :

$$C_{i,T} = \alpha + \underbrace{\sum\nolimits_{t=1}^{T} \left(\frac{\gamma_i}{25-t} \right)} + \underbrace{\Omega \left(\frac{\sum_{j=1}^{n} p_j}{n} \right)}$$

Stress experienced from not having bought presents experienced every day, up to, and including the day the agent chooses to go shopping

The proportion of agents in the sample who have already bought presents by time T ($p_j = 1$ if agent j has bought their presents prior to time T) multiplied by a constant Ω to give a desirable magnitude

Results

We look first at how different distributions of beta impact agents' choice of when to shopping, assuming all agents optimise their QHD schedule. This is then compared to when each agent would choose to go if they instead optimised a standard EDU schedule. $N = 2000$.

Our first distribution is as follows, with a beta distribution where the population in aggregate only little afflicted with present bias:

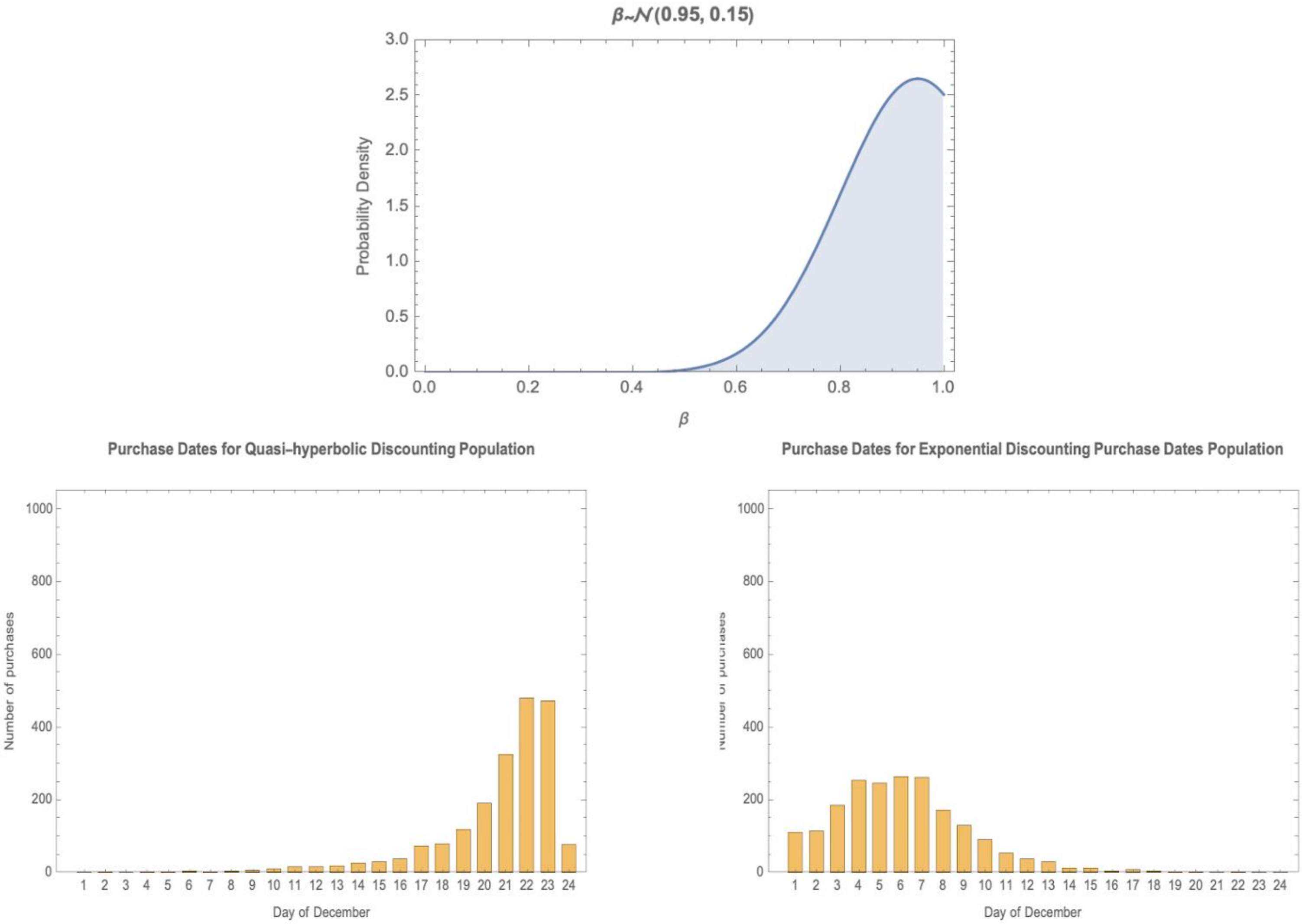

Fig. 3: Purchase dates for EDU/ QHD with $\beta \sim \mathcal{N}(0.95, 0.15)$

Despite the population's seeming ability to resist significant present bias, we still see bunching towards the latter end with QHD (figure 3). However, by Christmas eve, most have done their shopping.

We compare this to a more widely distributed beta with lower mean, (implying more present bias).

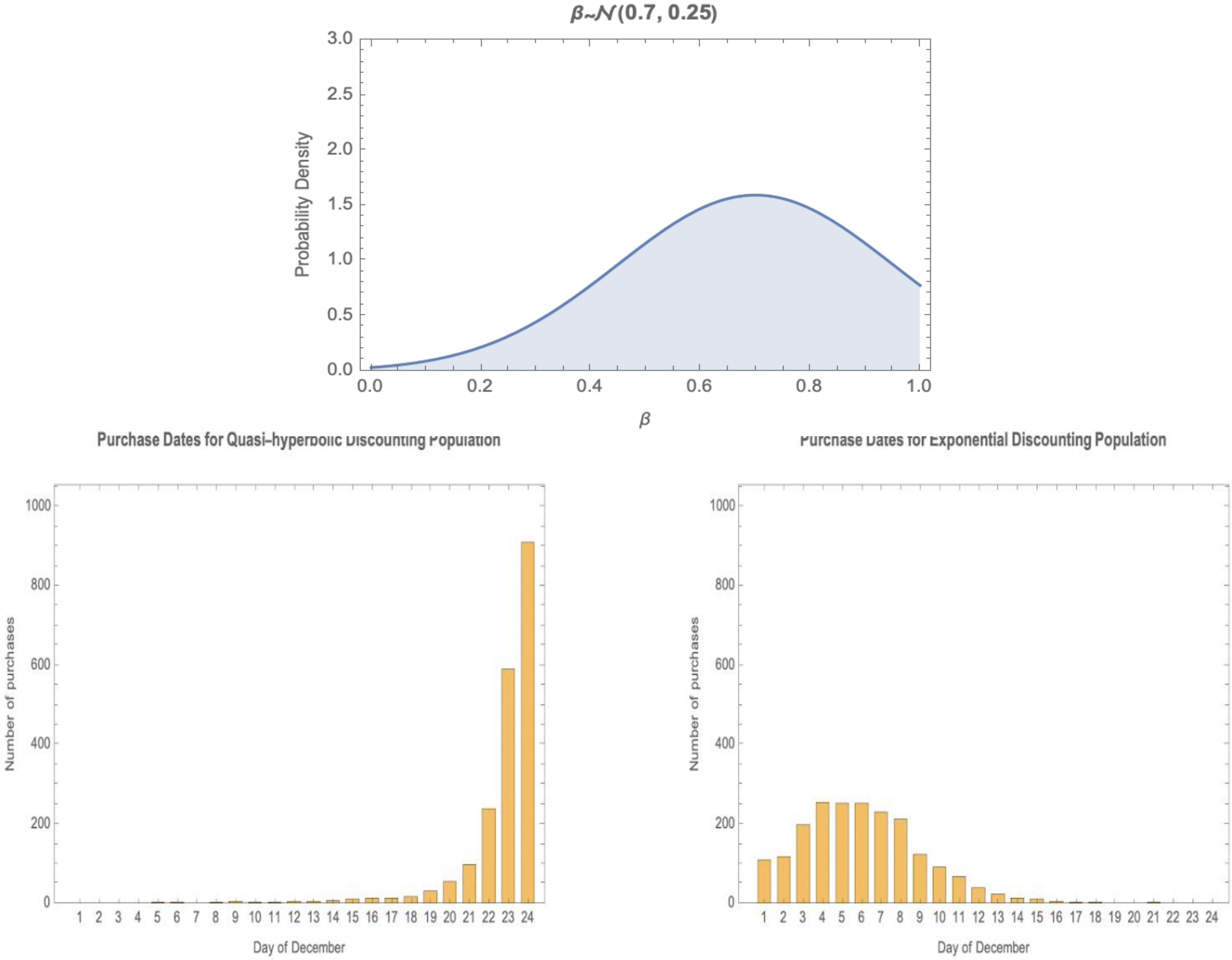

Fig. 4: Purchase dates for EDU/ QHD with $\beta \sim \mathcal{N}(0.7, 0.25)$

Clearly (per figure 4), a more present biased population significantly alters collective behaviour, with significantly more bunching towards Christmas eve, and far less earlier buying. As people buy later, they incur a larger cost through greater stress across a longer period of time.

We can quantify the impact of present bias by comparing total cost incurred by a given agent under QHD compared with EDU as in figure 5. Looking at a subset of 20 agents, individuals are *significantly* worse off when they exhibit present bias in QHDU preferences vs. EDU preferences, in places up to a magnitude of 10.

Ollie's QHDU/EDU *("relative")* cost of 9.91 corresponds to a low beta (0.765) and high gamma (68.3). This combination of large present bias and high stress leads to late shopping (23rd December); the point at which stress exceeds present bias. Compare this to a case where he isn't present biased (EDU). He understands how stressed he will get and consequently shops on the 2nd.

Contrastingly, Katie, with a relative cost of only 1.12, has negligible present bias (β = 0.998), meaning she shops on the 8th, preventing her higher-than-average stress from building.

Interestingly, Niamh, who shops on the 24th, isn't the worst off in the group, with relative cost equal to a mere 2.12. Despite her relatively low beta (=0.69), her stress level is so low (gamma=17.2) that she isn't worried nearly as much as others by the prospect of leaving gift buying so late. If you're reading this and know you're present biased, be more like Niamh.

Name	Parameters		Date of Purchase		Total Cost Incurred		*QHDU Cost / EDU Cost*	*Actual Cost / Expected Cost*
	β	γ	*QHDU*	*EDU*	*QHDU*	*EDU*		
Amy	.971	64.6	16th	2nd	84.9	21.0	4.04	1.018
Ben	.961	41.1	19th	7th	78.3	35.3	2.22	1.026
Clara	.985	67.1	13th	2nd	66.8	21.2	3.15	1.015
Dan	.881	47.8	21st	5th	111	30.4	3.67	1.037
Emma	.793	19.3	23rd	12th	75.0	37.5	2.00	1.095
Frank	.946	55.1	19th	4th	99.2	27.8	3.57	1.021
Georgie	.936	27.7	21st	10th	72.8	38.5	1.89	1.058
Harry	.992	58.8	11th	3rd	50.5	24.7	2.05	1.010
India	.874	56.1	21st	4th	128	28.0	4.57	1.032
James	.597	30.7	24th	9th	140	37.1	3.78	1.069
Katie	.998	50.0	8th	5th	34.7	30.9	1.12	1
Leo	.856	40.8	22nd	7th	113	35.2	3.22	1.051
Martin	.814	52.2	22nd	4th	139	27.3	5.10	1.041
Niamh	.690	17.2	24th	13th	88.9	37.5	2.37	1.112
Ollie	.765	68.3	23rd	2nd	211	21.3	9.91	1.032
Poppy	.777	60.1	23rd	3rd	188	24.8	7.58	1.036
Quentin	.947	43.9	19th	6th	82.6	32.8	2.51	1.025
Rosie	.692	31.7	23rd	9th	110	37.5	2.92	1.063
Sam	.747	40.2	23rd	7th	133	35.0	3.80	1.051
Tilly	.931	72.9	19th	1st	126	18.0	6.97	1.016

Fig. 5: Results of analysis

We can also see that bounded rationality, in its ability to cause a higher cost than expected, affects to the greatest extent those who shop latest.

Figure 6 plots relative cost against beta for our sample of 2000 agents to assess the relationship between present bias and impact upon utility:

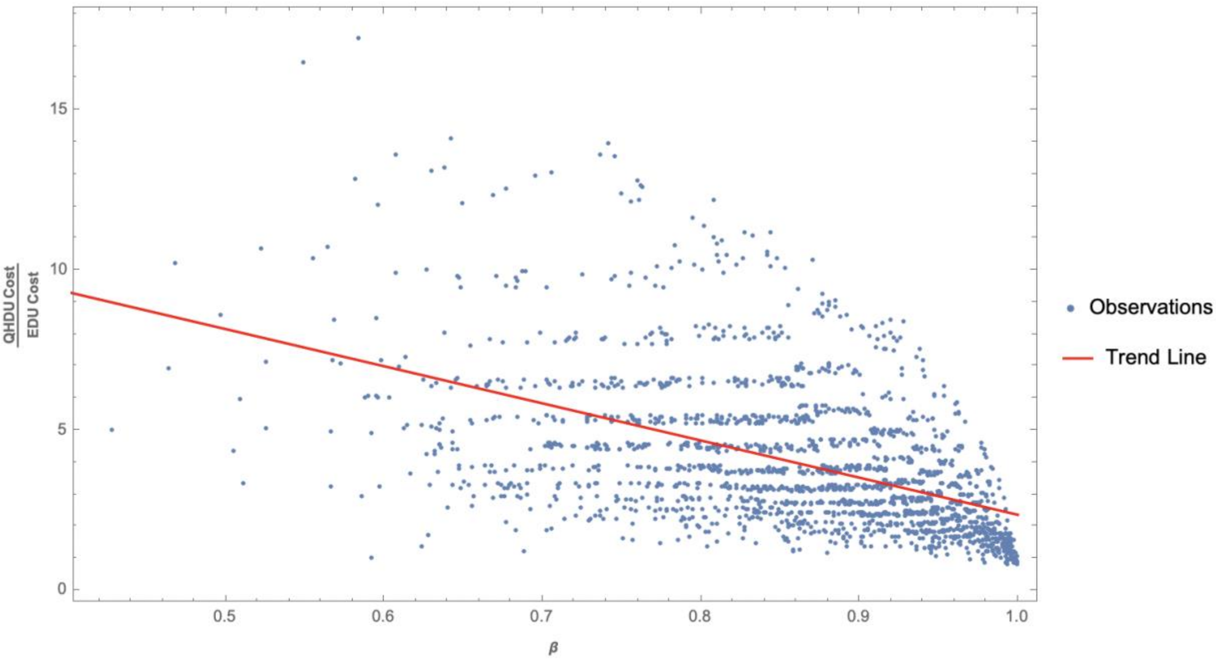

Fig. 6: Graph of relative cost against beta

The clear negative trend line provides clear evidence that the impact of present bias on one's utility is unquestionably related to the magnitude of one's present bias, and that those worse afflicted by present bias are worse off. The clear striations in the observations correspond to the different shopping days. However, this is of little practice use as beta is unobservable.

What is easily observable, however, is when one tends to do their Christmas shopping. Figure 7 plots relative cost against purchase date:

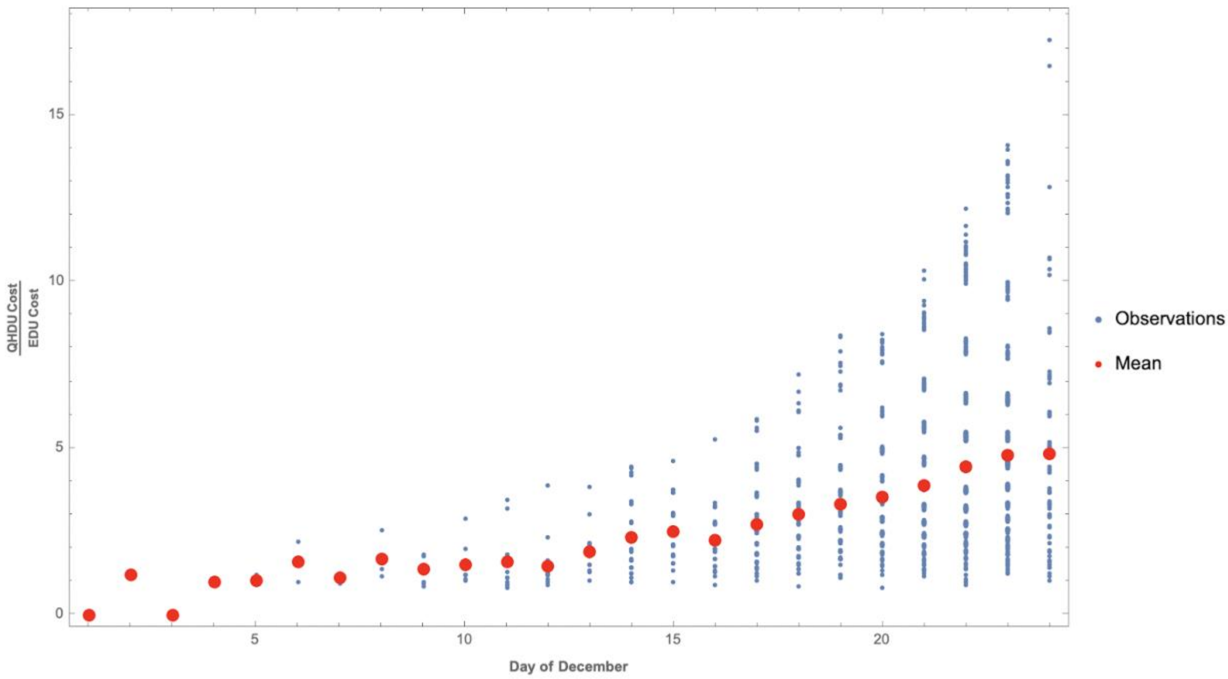

Fig. 7: Graph of relative cost against purchase date

The higher relative cost as the purchase date moves closer to Christmas suggests that people who shop later are generally being worse off; this confirms our intuition again. It also provides large-sample validation for our anecdotal example of Niamh, with the linearly increasing mean cost flattening upon getting to day 24 of December. Clearly, in order to reach Christmas eve, one needs to be so tranquil with the impending obligation of buying presents that their present bias isn't exceeded until the very last moment. Therefore, if you find yourself buying presents on the on the 22nd or later, we recommend you think long and hard about utilising a commitment device and organising to go present shopping with others.

Finally, we aim to understand the relationship between the cost of bounded rationality and present bias. For this, we create a ratio of actual cost incurred to expected cost. Actual cost includes the impact of a reduced choice set, whereas expected cost determines the agent's decisions, and ignores the reducing choice set. Plotting this ratio against beta visualises this relationship in figure 8:

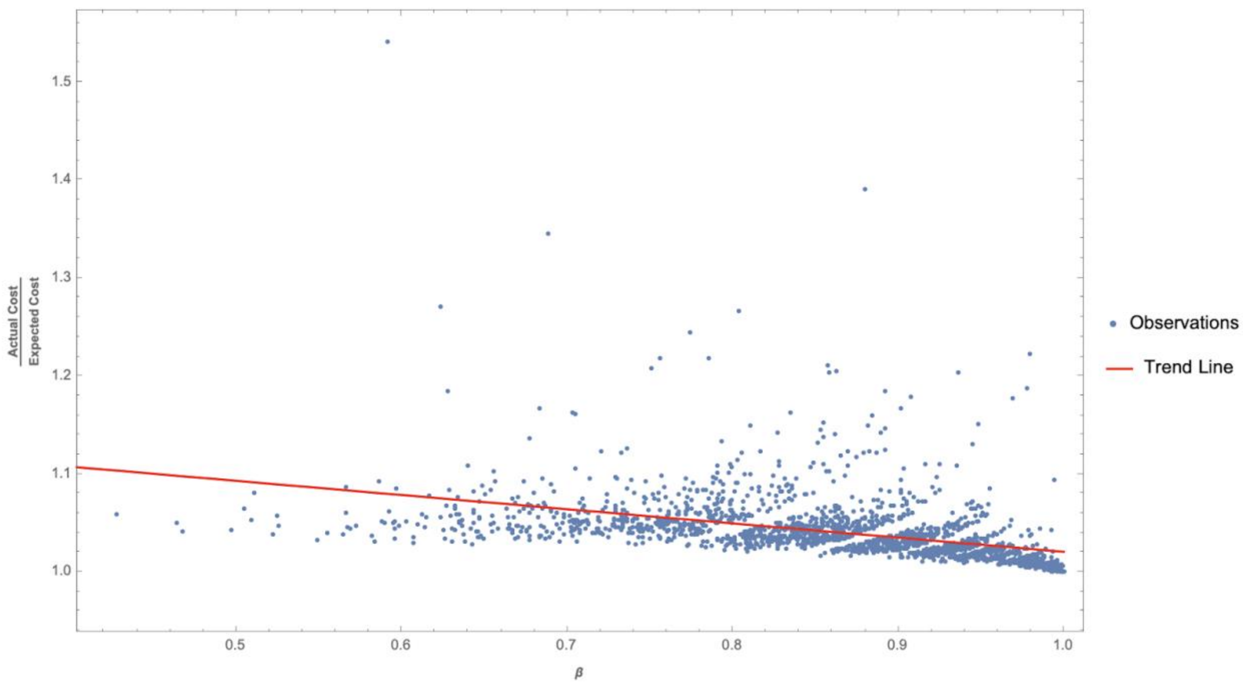

Fig. 8: Graph of actual-to-expected cost against beta. Used to quantify the relationship between cost of bounded rationality and present bias

As per figure 8, being more present biased is correlated with being worse affected by bounded rationality. We maintain however that this claim is of correlation, not causation. There is nothing intrinsic about present bias that makes someone more likely to be affected by bounded rationality, it is simply the fact that in our case, bounded rationality causes agents to not realise their choice set is reducing, which when combined with present bias, means those agents with larger present bias will be worse affected by their bounded rationality.

Conclusion

The stress of delaying buying presents all-to-often mars what is supposed to be a joyous holiday. As a family member's mood darkens as Christmas draws near, pause to ponder: *but why?* We would identify this family member as an 'Ollie'. Their combination of high present bias and a strong preference for reciprocity induces an ever-increasing stress from not having bought presents, but lack the self-control to follow through undermines their quotidian claim of 'I'll do it tomorrow'. Instead of waiting until they act by conscious volition, take the reins and propose a joint shopping trip that afternoon!

While this might seem obvious, we hope our short walkthrough of the relevant behavioural tendencies might contextualise a family member's sub-optimal behaviour, validate your suggestion to go shopping with them, and potentially make the difference in saving your Christmas.

<u>Bibliography and code</u>

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```
In[771]:= Plot[γ/(25 - x) /. γ → 45, {x, 1, 24}, PlotLabel → "γ=45", Frame → True,
  PlotRange → Full, FrameLabel → {"Day in December (t)", "Stress Experienced"}]

TrueUtility[Ω0_, δ0_, c0_, n0_, μβ0_, σβ0_, μγ0_, σγ0_] :=
 Module[{ Ω = Ω0, δ = δ0, c = c0, n = n0, μβ = μβ0, σβ = σβ0, μγ = μγ0, σγ = σγ0},
  BetaList = Table[RandomVariate[
     TruncatedDistribution[{0, 1}, NormalDistribution[μβ, σβ]]], {i, 1, n}];
  GammaList = Table[RandomVariate[TruncatedDistribution[
      {0, ∞}, NormalDistribution[μγ, σγ]]], {i, 1, n}];
  PurchaseList1 = ConstantArray[0, {24, n}];
  PurchaseListEDU = ConstantArray[0, {24, n}];
  TrueUtilityMat = ConstantArray[0, {24, n}];
  TrueUtilityMatEDU = ConstantArray[0, {24, n}];
  TotalPurchases1 = 0;
  TotalPurchasesEDU = 0;
  PBUtilityEvolution =
   Table[utilitylist = ConstantArray[0, {(25 - (t - 1)), n}];
    For[j = 1, j ≤ n, j++,
     utilitylist[[1, j]] = GammaList[[j]]/(25 - t) + c;
     utilitylist[[25 - (t - 1), j]] = ∞;
     TrueUtilityMat[[t, j]] = GammaList[[j]]/(25 - t) + c + (TotalPurchases1/n) Ω;
    ];
    For[i = 2, i ≤ 25 - t, i++,
     For[j = 1, j ≤ n, j++,
       utilitylist[[i, j]] = BetaList[[j]] δ^i (GammaList[[j]]/(25 - (t + (i - 1))) + c);

      ];
    ];

    For[i = 1, i ≤ n, i++,
     If[Total[PurchaseList1][[i]] == 0, If[
        utilitylist[[1, i]] == TakeSmallest[Transpose[utilitylist][[i]], 1][[1]],
        PurchaseList1[[t, i]] = 1, PurchaseList1[[t, i]] = 0],
       PurchaseList1[[t, i]] = 0];
    ];
    TotalPurchases1 = Total[Flatten[PurchaseList1]];
    N[utilitylist]
    , {t, 1, 24}];
  EDUUtilityEvolution = Table[EDU = ConstantArray[0, {(25 - (t - 1)), n}];
    For[j = 1, j ≤ n, j++,
     EDU[[1, j]] = GammaList[[j]]/(25 - t) + c;
     EDU[[25 - (t - 1), j]] = ∞;
     TrueUtilityMatEDU[[t, j]] = GammaList[[j]]/(25 - t) + c + (TotalPurchasesEDU/n) Ω;
```

```
    ];
    For[i = 2, i ≤ 25 - t, i++,
     For[j = 1, j ≤ n, j++,
       EDU[[i, j]] = δ^i (GammaList[[j]] / (25 - (t + (i - 1))) + c);
      ];
    ];
    For[i = 1, i ≤ n, i++,
     If[Total[PurchaseListEDU][[i]] == 0, If[EDU[[1, i]] ==
          TakeSmallest[Transpose[EDU][[i]], 1][[1]], PurchaseListEDU[[t, i]] = 1,
        PurchaseListEDU[[t, i]] = 0], PurchaseListEDU[[t, i]] = 0];
    ];
    TotalPurchasesEDU = Total[Flatten[PurchaseListEDU]];
    N[EDU]
    , {t, 1, 24}];
  {PBUtilityEvolution, EDUUtilityEvolution,
   TrueUtilityMat, TrueUtilityMatEDU, GammaList , BetaList}
  ]
```

In[793]:=
```
DatePurchasedFull[Ω0_, δ0_, c0_, n0_, μβ0_, σβ0_, μγ0_, σγ0_] :=
  Module[{Ω = Ω0, δ = δ0, c = c0, n = n0, μβ = μβ0, σβ = σβ0, μγ = μγ0, σγ = σγ0},
   data = TrueUtility[Ω, δ, c, n, μβ, σβ, μγ, σγ];
   PB = data[[1]];
   EDU = data[[2]];
   TruePB = data[[3]];
   TrueEDU = data[[4]];
   gamma = data[[5]];
   beta = data[[6]];
   PmatPB = ConstantArray[0, {24, n}];
   PmatEDU = ConstantArray[0, {24, n}];
   CountListPB = ConstantArray[0, n];
   CountListEDU = ConstantArray[0, n];
   UtilityListPB = ConstantArray[0, n];
   UtilityListEDU = ConstantArray[0, n];
   PercievedUtilityListPB = ConstantArray[0, n];
   PercievedUtilityListEDU = ConstantArray[0, n];
   For[t = 1, t ≤ 24, t++,
    For[i = 1, i ≤ n, i++,
      If[Total[PmatPB][[i]] == 0,
        If[PB[[t]][[1, i]] == TakeSmallest[Transpose[PB[[t]]][[i]], 1][[1]],
         PmatPB[[t, i]] = 1, PmatPB[[t, i]] = 0], 0];
     ];
   ];
   For[t = 1, t ≤ 24, t++,
    For[i = 1, i ≤ n, i++,
      If[Total[PmatEDU][[i]] == 0,
        If[EDU[[t]][[1, i]] == TakeSmallest[Transpose[EDU[[t]]][[i]], 1][[1]],
```

```
      PmatEDU[[t, i]] = 1, PmatEDU[[t, i]] = 0], 0];
  ];
];
For[j = 1, j ≤ n, j++,
 For[i = 1, i ≤ 24, i++, If[PmatPB[[i, j]] == 1, CountListPB[[j]] = i;
   Break[] ]]];
For[j = 1, j ≤ n, j++,
 For[i = 1, i ≤ 24, i++, If[PmatEDU[[i, j]] == 1, CountListEDU[[j]] = i;
   Break[] ]]];
For[i = 1, i ≤ n, i++,
 UtilityListPB[[i]] =
  TruePB[[CountListPB[[i]], i]] + Sum[gamma[[i]]/(25 - t), {t, 1, CountListPB[[i]]-1}];
 UtilityListEDU[[i]] = TrueEDU[[CountListEDU[[i]], i]] +
   Sum[gamma[[i]]/(25 - t), {t, 1, CountListEDU[[i]]-1}];
 PercievedUtilityListPB[[i]] = c + Sum[gamma[[i]]/(25 - t), {t, 1, CountListPB[[i]]}];
];
AgentTable = ConstantArray[0, {(n + 1), 12}];
AgentTable[[1, 1]] = " Agent Name ";
AgentTable[[1, 2]] = " Beta ";
AgentTable[[1, 3]] = " Gamma ";
AgentTable[[1, 4]] = " Q-HDU Date ";
AgentTable[[1, 5]] = " EDU Date ";
AgentTable[[1, 6]] = " Rational Date ";
AgentTable[[1, 7]] = " Q-HDU Total Cost ";
AgentTable[[1, 8]] = " EDU Total Cost ";
AgentTable[[1, 9]] = " Rational Total Cost ";
AgentTable[[1, 10]] = " Q -HDU Cost / EDU Cost ";
AgentTable[[1, 11]] = " Q -HDU Cost / Rational Cost ";
AgentTable[[1, 12]] = " Actual Cost / Expected Cost ";
For[i = 1, i ≤ n, i++,
 AgentTable[[i + 1, 1]] = i;
 AgentTable[[i + 1, 2]] = beta[[i]];
 AgentTable[[i + 1, 3]] = gamma[[i]];
 AgentTable[[i + 1, 4]] = CountListPB[[i]];
 AgentTable[[i + 1, 5]] = CountListEDU[[i]];
 AgentTable[[i + 1, 6]] = 1;
 AgentTable[[i + 1, 7]] = UtilityListPB[[i]];
 AgentTable[[i + 1, 8]] = UtilityListEDU[[i]];
 AgentTable[[i + 1, 9]] = TruePB[[1, i]];
 AgentTable[[i + 1, 10]] = (AgentTable[[i + 1, 7]] / AgentTable[[i + 1, 8]]) ;
```

```
      AgentTable[[i + 1, 11]] = (AgentTable[[i + 1, 7]] / AgentTable[[i + 1, 9]]) ;
      AgentTable[[i + 1, 12]] = (AgentTable[[i + 1, 7]] / PercievedUtilityListPB[[i]]) ;
     ];
    BetaExpectedCostRatioRegressionData =
     Table[{AgentTable[[i + 1, 2]], AgentTable[[i + 1, 12]]}, {i, 1, n}];
    BetaActualCostRatioRegressionData =
     Table[{AgentTable[[i + 1, 2]], AgentTable[[i + 1, 10]]}, {i, 1, n}];
    DateRegressionData = Table[{AgentTable[[i + 1, 4]],
       AgentTable[[i + 1, 10]]}, {i, 1, n}];
    {AgentTable, BetaActualCostRatioRegressionData, DateRegressionData,
     BetaExpectedCostRatioRegressionData,
     Total[Transpose[PmatPB]], Total[Transpose[PmatEDU]]}
   ];
```

```
In[727]:= data = DatePurchasedFull[10, 0.9965, 15, 2000, 0.95, 0.15, 45, 15];
agentTable = data[[1]];
BetaPBcostVsEDUdata = data[[2]];
DatePBcostVsEDUdata = data[[3]];
BetaActualVsExpectedData = data[[4]];
PBDatePlot = data[[5]];
EDUDatePlot = data[[6]];
```

```
In[759]:= Plot[PDF[NormalDistribution[0.95, 0.15], x] // Evaluate, {x, 0, 1},
 PlotRange → {Automatic, {0, 3}}, Filling → Axis, Frame → True,
 FrameLabel → {"β", "Probability Density"}, PlotLabel → "β~𝒩(0.95, 0.15)"]
GraphicsGrid[{{BarChart[PBDatePlot, BarSpacing → Large,
     ChartLabels → Range[24], PlotRange → {Automatic, {0, 1000}},
     Frame -> True, FrameLabel → {"Day of December", "Number of purchases"},
     PlotLabel → "Purchase Dates for Quasi-hyperbolic Discounting Population"],
    BarChart[EDUDatePlot, BarSpacing → Large, ChartLabels → Range[24],
     PlotRange → {Automatic, {0, 1000}}, Frame -> True,
     FrameLabel → {"Day of December", "Number of purchases"},
     PlotLabel → "Purchase Dates for Exponential
        Discounting Purchase Dates Population"]}}]
```

```
In[736]:= data1 = DatePurchasedFull[10, 0.9965, 15, 2000, 0.7, 0.25, 45, 15];
PBDatePlot1 = data1[[5]];
EDUDatePlot1 = data1[[6]];
```

```
In[761]:= Plot[PDF[NormalDistribution[0.7, 0.25], x] // Evaluate, {x, 0, 1},
   PlotRange → {Automatic, {0, 3}}, Filling → Axis, Frame → True,
   FrameLabel → {"β", "Probability Density"}, PlotLabel → "β~𝒩(0.7, 0.25)"]
  GraphicsGrid[{{BarChart[PBDatePlot1, BarSpacing → Large,
      ChartLabels → Range[24], PlotRange → {Automatic, {0, 1000}},
      Frame -> True, FrameLabel → {"Day of December", "Number of purchases"},
      PlotLabel → "Purchase Dates for Quasi-hyperbolic Discounting Population"],
     BarChart[EDUDatePlot1, BarSpacing → Large, ChartLabels → Range[24],
      PlotRange → {Automatic, {0, 1000}}, Frame -> True,
      FrameLabel → {"Day of December", "Number of purchases"},
      PlotLabel → "Purchase Dates for Exponential Discounting Population"]}}]

In[811]:= AgentSample = DatePurchasedFull[10, 0.9965, 15, 20, 0.95, 0.15, 45, 15];
  AgentSample[[1]] // MatrixForm

In[743]:= RegressionLine = Fit[BetaPBcostVsEDUdata, {1, x}, x];
  Show[ListPlot[BetaPBcostVsEDUdata,
     Frame → True, FrameLabel → {"β", "QHDU Cost / EDU Cost"},
     PlotRange → Full, PlotLegends → {"Observations"}],
   Plot[RegressionLine, {x, 0, 1}, PlotStyle → Red, PlotLegends → {"Trend Line"}]]

In[776]:= CostList = ConstantArray[0, {2000, 24}];
  For[j = 1, j ≤ 2000, j++,
    For[i = 1, i ≤ 24, i++,
     If[ DatePBcostVsEDUdata[[j, 1]] == i,
      CostList[[j, i]] = DatePBcostVsEDUdata[[j, 2]], CostList[[j, i]] = 0]
    ]
   ];
  MeanData = Table[{i, If[Total[CostList][[i]] == 0,
       0, Total[CostList][[i]] / (2000 - Count[Transpose[CostList][[i]], 0])]}, {i, 1, 24}];
  Show[ListPlot[DatePBcostVsEDUdata, Frame → True,
     FrameLabel → {"Day of December", "QHDU Cost / EDU Cost"},
     PlotRange → Full, PlotLegends → {"Observations"}],
   ListPlot[MeanData, PlotStyle → Red, PlotRange → Full, PlotLegends → {"Mean"}],
   PlotRange → Full, PlotRange → {1, 1, 24}]

In[•]:= RegressionLine1 = Fit[BetaActualVsExpectedData, {1, x}, x];
  Show[ListPlot[BetaActualVsExpectedData,
     Frame → True, FrameLabel → {"β", "Actual Cost / Expected Cost"},
     PlotRange → Full, PlotLegends → {"Observations"}],
   Plot[RegressionLine1, {x, 0, 1}, PlotStyle → Red, PlotLegends → {"Trend Line"}]]
```

In[792]:=
```
Plot[x/10 // Evaluate, {x, 0, 100}, Filling → Axis, Frame → True, FrameLabel →
  {"Cumulative # People Who Have Already Done Their Christmas Shop",
   "Cost of Reduced Choice"}, PlotLabel → "Ω=10, # People in sample = 100"]
```