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Prospect theory and the potential for lottery-based subsidies

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Abstract: The relevant literature notes a lack of applications relative to the theoretical impact of prospect theory. In this paper, I provide a brief review of this literature aimed at policymakers before developing an idea for lottery-based government subsidy policies. I consider the general conditions under which such policies could be effective in (1) increasing the performance of desired behaviours and (2) saving governments money. I provide two examples of current Canadian subsidies that I argue could be improved with the addition of a lottery option.

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Introduction

In this paper, I will provide policymakers with a review of some of the key ideas of one of the most important advances in behavioural economics: prospect theory. I will trace the development of prospect theory from the seminal Kahneman and Tversky (1979) paper through to applied present-day research and consider the limitations and criticisms of the theory.

After reviewing the literature, which notes a lack of applications relative to the theoretical impact of prospect theory, I develop an idea for lottery-based government subsidy policies. I consider the general conditions under which such policies could be effective in (1) increasing the performance of desired behaviours and (2) saving governments money. For policies likely to be interpreted by recipients as 'gains', I posit that lotteries could be used to replace small subsidies due to the overweighting of small probabilities. For policies likely to be interpreted by recipients as 'losses', lotteries with small chances of recipients losing nothing could be used to replace subsidies due to the

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convexity of the value function in losses. In general, subsidies that involve 'losses' are good candidates for replacement due to loss aversion.

I demonstrate these ideas through two examples of current subsidies that I argue could be improved with the addition of a lottery option.

Government incentives

Broadly speaking, a government has two main financial mechanisms for encouraging certain behaviours: taxation and subsidies. Additional taxation can be used to punish, and thus dis-incentivize, certain behaviours. Subsidies, which represent some form of financial aid given to certain individuals, businesses or institutions, can be used to incentivize the desired behaviour by being offered conditional on the performance of that behaviour. Common forms of subsidies include cash grants, tax breaks, reduced interest-rate loans and rebates. Examples range from reduced interest-rate student loans to tax-deductible donations.

While these diverse policies share a similar goal of encouraging certain behaviours, they are also similar in a less noticeable, seemingly unimportant, way: the subsidy they provide is guaranteed conditional on the behaviour. In particular, government subsidies (and taxes) do not rely at all on probabilistic lotteries. If a government offers a tax credit on contributions to a retirement plan and you contribute to your retirement plan, you will benefit from that tax credit for sure. In this paper, however, I hypothesize that there are situations where, if governments replaced guaranteed subsidies with probabilistic lotteries, they could encourage more people to exhibit desired behaviours and/or save money.

As a simplified example, consider a reduced interest-rate loan that amounts to an individual being responsible for a \$3000 total loan repayment. Now consider an alternative policy in which the individual must pay back \$4000 in total with an 80% chance and \$0 with a 20% chance. Furthermore, consider that in an experiment in a foundational paper of behavioural economics, 92% of participants preferred to lose \$4000 with an 80% chance and \$0 with a 20% chance than to lose \$3000 for sure (Kahneman & Tversky, 1979). If we believe that Kahneman and Tversky's results hold external validity in this hypothetical case, which I will consider in this paper, then not only should we predict that the proposed alternative policy would result in more people taking on the loan (i.e., exhibiting the incentivized behaviour), but also that the government would gain an extra \$200 in revenue per participant, as the expected value of the lottery minus the value of the subsidy is:

$$(0.8 \times \$4000 + 0.2 \times \$0) - \$3000 = \$3200$$

If such a policy is predicted to better incentivize behaviour *and* increase government revenue, why has it not been implemented already? Later in this paper, I will present potential limitations of the theory – known as prospect theory – that motivates the above example. I will also briefly consider some of the logistical and philosophical concerns of my proposed policy alternative. However, I argue that part of the reason that lottery-based subsidies have not been implemented is that the traditional economic theory of choice under risk and uncertainty – expected utility theory – does not predict their success.

Expected utility theory and the lack of probabilistic policy

Throughout the seventeenth century, the dominant understanding of decision-making under risk was given by the expected value criterion, which posited that individuals consider only the raw outcomes involved and their probabilities of occurrence (Golik, 2016). To illustrate, consider a coin-flip bet where, if the coin lands on heads, you win \$1, and if it lands on tails, you lose \$1. The expected value of this bet is $0.5 \times 1 + 0.5 \times (-1) = 0$, so the expected value hypothesis posits that an individual should be indifferent between playing this game and not playing it.

However, Swiss mathematician Daniel Bernoulli's early eighteenth-century work regarding the 'St Petersburg paradox' called the legitimacy of the expected value hypothesis into question (Halevy, 2019). As a result, Bernoulli developed the expected utility hypothesis, which introduced utility functions that allowed for diminishing marginal utility. A person's expected utility from discrete outcomes x_i with probabilities p_i where $i \varepsilon N$ is given by $E(u(x)) = p_1 u(x_1) + p_2 u(x_2) + \ldots$. The assumption of diminishing marginal utility implies that $u"(x_i) < 0$ for all i, and thus that people are risk averse, as opposed to being risk neutral under the expected value criterion (Halevy, 2019).[1]

Expected utility theory is still the core decision-under-uncertainty model taught in undergraduate-level economics courses and has been widely and often implicitly applied in many fields outside of academia, despite the fact that researchers began to criticize the theory in the latter half of the twentieth century (e.g., Allais, 1953; Lichtenstein & Slovic, 1973; Kahneman & Tversky,

1 Generally speaking, an individual is risk averse if they prefer a more predictable but lower payoff to a less predictable but potentially higher payoff. If we consider losses instead of gains, an individual is risk averse if they prefer a more predictable loss to a less predictable but potentially more substantial loss.

1979; Pope, 1986).[2] It is difficult to determine what economic theory of decision under uncertainty (or decision under risk), if any, has historically motivated subsidization policies. It seems likely that governments simply never considered lottery-based subsidies. Yet it should be acknowledged that traditional expected utility theory does predict that guaranteed subsidies would be preferable to lottery-based subsidies. If a government sees citizens as risk-averse expected utility maximizers who weigh all probabilities equally, the government would have to offer a lottery with an expected value above the guaranteed subsidy's value for people to maintain the same level of the desired behaviour. This is clearly not in the government's best interests.

But what if citizens are not actually risk-averse expected utility maximizers who weigh all probabilities equally? This is a central question posed by Kahneman and Tversky (1979) in their seminal paper on prospect theory. They find that, in many ways, people do indeed behave differently from what expected utility theory predicts. Thus, one may be able to build the case that there are some situations in which current subsidization policies are not optimal.

Prospect theory

In order to think about policy alternatives based on prospect theory, it is important to develop a good understanding of the model's key results and its limitations. In this section, I will focus on Kahneman and Tversky's 1979 paper, while also providing some discussion of later work that aimed to estimate the key mathematical functions and parameters of prospect theory. I comment briefly on some limitations and criticisms of prospect theory. I omit discussion of more recent and complex advances in the field, as they are beyond the scope of this paper.

The development of prospect theory: Kahneman and Tversky (1979)

Critique of expected utility theory

Kahneman and Tversky (1979) begin by showing the responses of students and university faculty to various hypothetical choice problems. These responses contradict expected utility theory and motivate the authors' development of prospect theory.

First, the authors demonstrate the 'certainty effect' using a variation of Allais' paradox. In Problem 1, respondents are asked to choose between Option A, which gives 2500 with probability 0.33, 2400 with probability

2 Twenty-first-century academics have built on these critiques of expected utility theory and the alternative models they inspired. See, for example, Koszegi and Rabin (2006), Bruhin *et al.* (2010) and Barberis (2013).

0.66 and 0 with probability 0.01, and Option B, which gives 2400 with certainty. A total of 82% of respondents choose Option B. Then, according to expected utility theory, most participants had utility functions such that

$$u(2400) > 0.33u(2500) + 0.66u(2400)$$

or

$$0.34u(2400) > 0.33u(2500)$$

In Problem 2, respondents are asked to choose between Option C, which offers 2500 with probability 0.33 and 0 with probability 0.67, and Option D, which offers 2400 with probability 0.34 and 0 with probability 0.66. A total of 83% of respondents choose Option C. Then, according to expected utility theory, most participants had utility functions such that

$$0.33u(2500) > 0.34u(2400)$$

Thus, the results of the two problems are contradictory. The authors run several other experiments that indicate similar results. They conclude that their participants value certain events proportionately higher than merely probable events. They use this insight, which they call the 'certainty effect', to infer that people are risk averse in choices involving sure gains and risk seeking in choices involving sure losses.

Next, the authors demonstrate the 'reflection effect'. They use the exact same experiments here as the ones run to demonstrate the certainty effect, except that they change the outcome values from positive gains to negative losses. Table 1 illustrates their results, with the choice percentages in square parentheses.

We see that individuals flip their preferences when they are forced to consider losses instead of gains. In other words, their preferences 'reflect' around 0. The reflection effect then implies that people will be risk averse when considering gains and risk seeking when considering losses (Kahneman & Tversky, 1979). For example, whereas a clear majority of people prefer to gain $3000 for sure rather than gain $4000 with an 80% chance, many of those same people also prefer to lose $4000 with an 80% chance than to lose $3000 for sure. Note that these experiments are also inconsistent with expected utility theory. For example, Problem 3' demonstrates that outcomes that are obtained with certainty are over-weighted relative to uncertain outcomes. This invokes the certainty effect, which was already shown to be inconsistent with expected utility theory.

Development of prospect theory

With the experimental evidence contradicting expected utility theory in mind, the authors develop a new theory of decision under risk that aims to better

Table 1. Preferences between positive and negative prospects.

	Positive prospects		Negative prospects
Problem 3 ($n = 95$)	(4000, 0.80) [20] < (3000) [80][a]	Problem 3' ($n = 95$)	(–4000, 0.80) [92][a] > (–3000) [8]
Problem 4 ($n = 95$)	(4000, 0.20) [65][a] > (3000, 0.25) [35]	Problem 4' ($n = 95$)	(–4000, 0.20) [42] < (–3000, 0.25) [58][a]
Problem 7 ($n = 66$)	(3000, 0.90) [86][a] > (6000, 0.45) [14]	Problem 7' ($n = 66$)	(–3000, 0.90) [8] < (–6000, 0.45) [92][a]
Problem 8 ($n = 66$)	(3000, 0.002) [27] < (6000, 0.001) [73][a]	Problem 8' ($n = 66$)	(–3000, 0.002) [70][a] > (–6000, 0.001) [30]

[a]Favoured prospect.

explain their observed results. In their model, the overall value of a prospect is determined by a decision weight $w(p)$, which reflects the impact of the relevant probabilities on the overall value of the prospect, and a value function $v(x)$, which reflects the subjective value of outcome x. Utility over a range of possible probabilistic outcomes is given simply by $\sum_{i \epsilon N} w(p_i)v(x_i)$.

The value function has two important characteristics. First, based on the understanding that the psychological response to many perceptual processes can be modelled as a concave function of the magnitude of change, the authors posit that the value function should be concave in gains and convex in losses. To motivate concavity in gains, they give the example that “the difference in value between a gain of 100 and a gain of 200 appears to be greater than the difference between a gain of 1100 and a gain of 1200” (Kahneman & Tversky, 1979). They later refer to this phenomenon as diminishing sensitivity (Tversky & Kahneman, 1992). Second, they acknowledge that, for most people, losses loom larger than gains. They give the example that “most people find symmetric bets of the form (x, 0.50; –x, 0.50) distinctly unattractive” (Kahneman & Tversky, 1979). They then posit that the value function should capture this ‘loss aversion’ by being steeper for losses than for gains. A graph of a value function with the above characteristics is shown in Figure 1.

The weighting function $w(p)$, meanwhile, is an increasing function of p with $w(0) = 0$ and $w(1) = 1$. One important characteristic is the over-weighting of low probabilities (i.e., $w(p) > p$ for small p). The intuition here is supported by the popularity of both gambling and insurance. The authors mimic both phenomena with two experiments. In the first, 72% of participants prefer a 0.1% chance at 5000 compared to getting the expected value 5 for sure. In the second, 83% of people prefer to lose 5 for sure than to risk losing 5000 with a 0.1% chance. Both results support the over-weighting of low probabilities, as in the first case, people seem to be risk seeking in gains, and in the second, people seem to be risk averse in losses. That these results seem to contradict all earlier findings can only be explained by the hypothesis that people over-weight small probabilities. That is, if participants did not over-weight small probabilities, then the fact that the majority preferred a 0.1% chance at 5000 compared to getting the expected value 5 for sure could only be explained if their value functions were such that they preferred a lottery in gains to the expected value of that lottery (i.e., if they were risk seeking in gains). This goes against Kahneman and Tversky’s specified value function, which reflects the assumption that people are risk averse in gains. All else being equal, a person who is risk averse in gains would prefer to receive the expected value of a lottery for sure rather than to play that lottery game. Then the only way the prospect theory

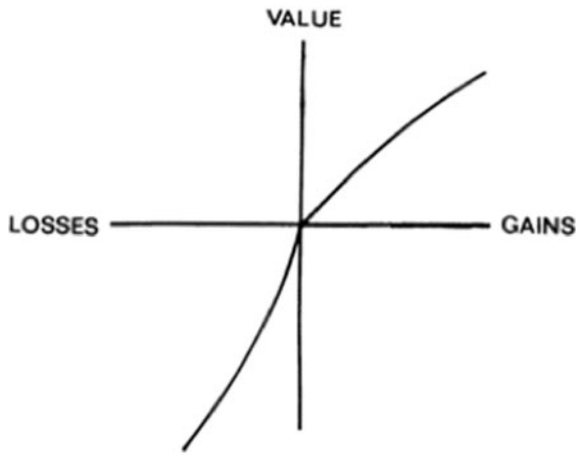

Figure 1. General prospect theory value function.

model, which is based on observed behaviour, can be internally consistent is if it allows for the over-weighting of small probabilities.

Estimating functions and parameters

Tversky and Kahneman (1992) provide an updated version of prospect theory, considering important developments in the field in the decade since their first prospect theory paper. I omit discussion of the theoretical developments and focus on their development of mathematical estimates for the value and weighting functions.

Tversky and Kahneman (1992) proceed to run several experiments in order to better specify the value and weighting functions. In line with their initial views of prospect theory, their results indicate that the value and weighting functions should generally imply risk-averse preferences for gains of moderate or high probability or losses of low probability, and risk-seeking preferences for gains of small probability and losses of moderate or high probability (Tversky & Kahneman, 1992). Based on their results, they specify the following functional form for the value function:

$$v(x) = \begin{cases} x^{\alpha} \; if \; x \geq 0 \\ -\lambda(-x)^{\beta} \; if \; x < 0 \end{cases}$$

where x is an outcome and the other variables are parameters. Furthermore, they specify the weighting functions for gains and losses, respectively, as:

$$w^{+}(p) = \frac{p^{\gamma}}{(p^{\gamma} + (1-p)^{\gamma})^{\frac{1}{\gamma}}} \; and \; w^{-}(p) = \frac{p^{\delta}}{(p^{\delta} + (1-p)^{\delta})^{\frac{1}{\delta}}}$$

Based on experimental data, they estimate $\alpha = \beta = 0.88$, $\lambda = 2.25$, $\gamma = 0.61$, $\delta = 0.69$.

Several studies after Tversky and Kahneman (1992) constructed different value and weighting functions using either different functional forms or different parameters based on other experimental data. For example, Prelec (1998) specifies the weighting function as:

$$w(p) = e^{-(-lnp)^{\gamma}}$$

Camerer and Ho (1994) use similar functional forms as Tversky and Kahneman (1992), but they use data from other experiments and estimate $\alpha = 0.32$ and $\gamma = 0.56$. Wu and Gonzalez (1996) estimate $\alpha = 0.52$ and $\gamma = 0.74$ with Kahneman and Tversky's functional form, and $\alpha = 0.48$ and $\gamma = 0.74$ using Prelec's. In his 2008 textbook, Wakker adds the neo-additive weighting function $w(p) = b + ap$, where $w(0) = 0$, $w(1) = 1$ and $a + b \leq 1$ (Wakker, 2008). Barberis (2013) notes that later estimates of the value and weighting functions, which also confirm the general properties of the functions posited by Tversky and Kahneman (1992), are constructed by Gonzalez and Wu (1999), Abdellaoui (2000) and Bruhin *et al.* (2010).

More recent developments in prospect theory

Kahneman and Tversky's 1979 and 1992 papers drew significant attention within the field of behavioural economics and among economists in general. Their ideas, which would eventually result in a Nobel Prize for Kahneman, were subsequently tested empirically and experimentally by numerous researchers. Much of this subsequent work found further support for the key tenets of prospect theory. (Birnbaum (2008) constructs a detailed list of such research.[3]) In a more recent review of prospect theory over its first three decades, Barberis (2013) notes that there has been significant support in particular for loss aversion and diminishing sensitivity being incorporated into the value function, for the inverse-S shape of the weighting function and for probability weighting in general.

The most significant conceptual development in recent years was made by Koszegi and Rabin (2006). They argue that a person's reference point is determined by the "probabilistic beliefs she held in the recent past about outcomes." They are particularly interested in what happens when the status quo is not maintained and expectations differ from the status quo. In this case, they

3 Other studies of particular relevance to the application of the ideas developed later in this paper include Kachelmeier and Shehata (1992), Chark *et al.* (2016) and Lewandowski (2017).

argue that the reference point should be determined by the individual's expectations.

Finally, a small subset of the literature has begun to observe and consider real-world applications of prospect theory. Barberis (2013) provides a comprehensive review of prospect theory-influenced work in fields ranging from finance to industrial organization. Cole *et al.* (2018) provide an even more recent example in which the authors find that prize-linked savings accounts in South Africa were successful in promoting household saving.

Limitations and criticisms of prospect theory

Prospect theory is not without its limitations and criticisms. Perhaps one of the most significant limitations of Kahneman and Tversky's cumulative prospect theory is the fact that it does not consider dynamic or long-term effects. In particular, Ebert and Strack (2015) point out that since a prospect theory agent will always want to take a lottery-like risk, even if it has a negative expectation, the agent will keep gambling until he or she goes bankrupt. This behaviour is quite extreme and likely only accurately describes the behaviour of a small portion of the population. Thus, it is questionable how well prospect theory predicts behaviour in a dynamic context.

Some critics argue that the application of prospect theory outside of the lab may be limited by the nature of the experiments used to inform the theory (Barberis, 2013). Notably, the foundational experiments and results are based on study participants making hypothetical choices. In their 1979 paper, Kahneman and Tversky themselves acknowledge that the use of hypothetical choices in their experiments relies on the contentious assumption that people know how they would truly behave if such situations were real. While some researchers (e.g., Kachelmeier & Shehata, 1992) have found results that align with prospect theory in scenarios that more closely approximate the real world, the aforementioned relative lack of applications of prospect theory does flag some warranted concern about prospect theory's external validity.

Lastly, a particular concern for policymakers looking to apply prospect theory should be critiques about the mathematical specifications of the probability weighting and value functions. For example, Neilson and Stowe (2002) argue that commonly used functions developed by Tversky and Kahneman (1992), Camerer and Ho (1994) and Wu and Gonzalez (1996) struggle to simultaneously satisfy the strongest choice patterns from Battalio *et al.* (1990), the Allais paradox and the popularity of lottery tickets and insurance. However, such critiques have often been followed by tweaked models that seek to address the noted concerns. (Pfiffelmann (2010) provides such a response to Neilson and Stowe (2002).) A policymaker interested in using prospect theory functions to develop policy should thus consult the most recent literature and select the model that best suits their situation.

Designing lottery-based subsidies

The evidence above suggests that, at the very least, there are some cases where prospect theory models choices under risk and uncertainty more accurately than traditional expected utility theory. I also argued above that current subsidy programmes implicitly align with a view that citizens behave according to expected utility theory. Given these claims, and the importance of designing subsidy programmes that are both successful in motivating citizens to alter behaviour and cost-effective, it seems reasonable to propose alternative subsidy programmes that use key findings from prospect theory.

In particular, I propose that there are certain forms of subsidies that could be redesigned as lotteries. Kahneman and Tversky (1979) showed that people like having a small chance to win a big prize more than getting a very small prize for sure (recall the aforementioned 0.1% chance of \$5000 versus \$5 for sure experiment). They also showed that people are risk seeking in losses. Both findings motivate the use of lottery-based subsidies. I will demonstrate using existing subsidies as examples of candidates for replacement.

Improving the effectiveness of the Northern and Rural Recruitment and Retention Initiative

Ontario's Ministry of Health (MOH) currently offers physicians roughly \$25,000 a year for four years to relocate to rural and remote regions in the hope that this financial incentive will encourage physicians to move to these underserved areas. This programme is known as the Northern and Rural Recruitment and Retention Initiative (NRRRI).

As I have previously stated, under the traditional assumption that individuals are risk-averse expected utility maximizers, a government can do no better than to offer subsidies as guaranteed amounts. However, I posit that if we instead assume that physicians behave according to prospect theory, and, in particular, if we use the key tenet of prospect theory that people overweight small probabilities, we can develop a simple lottery option that physicians prefer, despite it having the same expected value as the current option.

As a somewhat trivial example, consider an alternative policy whereby the MOH offers physicians a choice between two options: (A) receive \$25,000 for sure; or (B) receive \$24,999.50 for sure and a 0.00005% chance of winning \$1 million. It seems likely, given Kahneman and Tversky's experimental findings, that most people would prefer Option B, which essentially amounts to a cheap lottery ticket with relatively good odds compared to other lotteries (though a smaller prize). Indeed, plugging these numbers into Tversky and Kahneman's (1992) value and weighting function specifications[4] shows that prospect theory predicts that people will prefer Option B to Option A, despite the two options having the same expected value and Option B representing a risk-seeking decision in gains. This holds both if the individual views the two options as two separate gains or if the individual frames the choice by asking themselves, "Should I pay \$0.50 for a 0.00005% chance to win \$1 million?"[5] Changing the NRRRI to offer physicians this alternative option could thus increase interest in participating in the programme at no added cost to the MOH on average.

To go further, we can mathematically derive the lottery design that will maximize participant utility and should thus maximize programme participation.[6] I will assume, to be conservative, that individuals frame the choice as, "Should I pay l in order to have a p chance to win a big prize g?" rather than viewing the two choices independently.[7] The problem is then:

$$max_{l,p,g}\, v(l) + w(p)v(g)$$

$$where\ l \leq 0,\ \ 0 \leq p \leq 1,\ \ g \geq 0$$

$$such\ that\ pg \leq -l$$

The inequality constraint here represents the fact that the 'price' of the lottery must be greater than the expected value of the lottery for the government not to pay out more to physicians than they were doing under the current \$25,000-guaranteed policy.

We can solve this problem numerically using Tversky and Kahneman's (1992) weighting and value functions and parameters (though other functions and parameters will work similarly) and non-linear programming.[8] The results show, roughly, that the optimal lottery for participants would be to pay \$750 for a 0.75% chance at winning \$100,000. That is, physicians would be offered

4 I use Tversky and Kahneman's (1992) mathematical specifications for illustrative simplicity. The nature of the results of the calculation is similar using other parameters and functional forms recommended in the literature.

5 See calculations in Appendix A.

6 Note that I am only concerned with the financial incentive aspect of the programme here. Also note that increasing utility for the participants in the programme does not necessarily mean that programme participation will increase, as there are many factors beyond financial motivations that will influence a physician's participation.

7 This is conservative, as the latter way of framing the problem yields better results from the government's perspective.

8 I performed this analysis using the *solnp* command within the *Rsolnp* package in *R*.

a choice between: (A) \$25,000 for sure; and (B) \$24,250 for sure with a 0.75% chance of winning \$100,000. These are the lottery conditions that maximize participant utility subject to the constraint that the government does not lose money implementing this option relative to the prior policy.

Conversely, we could determine the lottery options that should keep programme participation the same while minimizing program costs. Here, the problem is:

$$min_{l,p,g}\ 25,000 + l + pg$$

$$where\ l \leq 0,\ \ 0 \leq p \leq 1,\ \ g \geq 0$$

$$such\ that\ v(l) + w(p)v(g) \geq 0$$

Solving numerically, we find, roughly, that a lottery where people ‘pay’ \$1340 in order to obtain a 0.85% chance of winning \$100,000 would be the lottery that minimizes government expenditure while keeping participant utility (and thus, in theory, programme participation) constant. That is, the lottery option here would be to give physicians \$23,660 for sure with a 0.85% chance of winning \$100,000. The expected value of this option is roughly \$24,500, which indicates that switching to this lottery option from the \$25,000-guaranteed policy would yield the MOH \$500 in savings per participating physician.

Improving the effectiveness of the SaskEnergy residential furnace replacement programme

The previous example relies on one fundamental idea of prospect theory: people over-weight small probabilities. We can imagine that other lottery-based subsidies could be developed that rely on other prospect theory ideas. In this short example, I will use the notion that people are risk seeking in losses to design a lottery that would aim to increase use of high-efficiency natural gas furnaces.

SaskEnergy is a natural gas company in Saskatchewan.[9] It currently offers Saskatchewan residents a \$650 rebate when they replace an existing natural gas furnace with a high-efficiency natural gas furnace.[10] A typical high-

9 Obviously, this paper is primarily interested in public-sector applications, but the spirit of this example could be replicated in the public sector.

10 saskenergy.com/saving_energy/specialoffers.asp.

efficiency natural gas furnace costs at least $3000.[11] Thus, with the rebate, programme participants buying the cheapest possible high-efficiency furnace pay $2350.

Consider an alternative option whereby participants could choose to enter a lottery where they could end up paying $3000 with a 78.3% chance, but have a 21.7% chance of getting the new furnace for free. The expected value of this lottery is equivalent to the current $650 rebate, but, plugging these numbers into Tversky and Kahneman's (1992) model, we see that people should prefer this lottery option.[12]

This is consistent with a fundamental idea of prospect theory: whereas people are risk averse in gains, *they are risk seeking in losses*. In particular, notice that this choice problem is quite similar to Problem 3' in Kahneman and Tversky (1979), in which most participants preferred to have an 80% chance of losing $4000 (and a 20% chance of losing nothing) rather than losing $3000 for sure. In the SaskEnergy example, it thus seems reasonable to posit that most people will prefer to risk losing a greater sum of money to gain the chance of losing nothing.

Assorted considerations for effective lottery-based subsidies

Philosophical concerns

There are some important philosophical and logistical concerns for policymakers to consider before offering lottery-based subsidy options. One philosophical concern is that switching to lotteries to better appeal to citizens' psychological biases could be considered exploitative. The government, by virtue of its organization and resources, has a much greater ability to process information 'rationally' (in this case, using expected utility theory). Is it right for a government to use this advantage in policymaking? While according to prospect theory the situations above imply that citizens will be better off under certain lottery policies than the prior subsidies, they will also, on average, have less money if the government sets prizes below the value required for them to break even. For some, this situation might not sit well, and it would likely be aggravated if governments were to target the populations who have been found to deviate the most from expected utility theory, and who are also among the most marginalized in society.

A second philosophical concern is fairness. Suppose a government replaces a certain subsidy with a big-prize lottery and, by sheer chance, wealthy individuals get lucky and win a few of the first draws. Is this acceptable to a society? What would the political reaction be? Would a lottery be politically

11 www.furnaceprices.ca/furnaces/furnace-prices.

12 See Appendix B for calculations.

sustainable in this case? Furthermore, note that there is somewhat of a theoretical issue within prospect theory here, as Kahneman and Tversky's papers do not explicitly consider other-regarding preferences.

Logistically, there would likely be immediate fixed costs associated with switching to a lottery-based subsidy and some human capital would be required to figure out how such a system could operate in an effective and transparent manner.

Other notes

It is important to note some other key considerations for the effective design and implementation of lottery-based incentive programmes. First, an aforementioned limitation of prospect theory is its difficulty in predicting behaviour over repetitions as people learn about the consequences of their choices (Ebert & Strack, 2015). Thus, subsidies that people access infrequently may be better candidates for replacement with lottery-based alternatives than ones that people access frequently.

Highlighting lottery winners through various media may be a powerful way to multiply the attractiveness of a lottery. Volpp *et al.* (2008) write that "research on decision making has found that the desire to avoid regret is a potent force in decision making under risk." In their study on lottery incentives for weight loss, they give participants who do not lose weight feedback about what their prizes could have been if they had. Meanwhile, Guryan and Kearney (2008) show that stores selling winning lottery tickets experience greater subsequent demand for lottery tickets, and Cole *et al.* (2018) find that the award of large prizes from prize-linked savings accounts are correlated with a greater demand for prize-linked savings in the area.

Additionally, lotteries may be particularly effective in adding an entertainment factor to 'boring' or small initiatives. Haisley (2008) hypothesizes that people may be more willing to accept risk when there is an entertainment factor involved.

Finally, note that the lotteries I consider, like many of the choice experiments that Kahneman and Tversky (1979) study, are all-or-nothing lotteries between two prospects. Cumulative prospect theory allows the incorporation of more outcomes (Tversky & Kahneman, 1992), and this could be an additional avenue to explore. Furthermore, Haisley (2008) posits that 'combination' lotteries, which combine a large prize with a small probability and a small prize with a moderate probability, may be more effective than simple lotteries of equivalent expected values, though more research is required in this regard. Governments and future researchers could also consider whether compound lotteries would be effective in this context, perhaps by exploiting the isolation effect discussed in Kahneman and Tversky (1979), or they could experiment with using uncertain rather than risky lotteries, which Tversky and Kahneman (1992) also provide background for. A final lottery type to be further considered in this context is a 'punishment' lottery whereby governments replace bad-behaviour taxes or fines with lotteries that have a small potential of a significant loss, exploiting the idea of loss aversion. Note, however, that such a policy would likely be quite unpopular and, if it was successful in deterring bad behaviour, may result in decreased government revenues.

Conclusions

This paper makes a first attempt at applying prospect theory to government subsidies that incentivize certain behaviours or actions. My primary conclusions are that, under the right circumstances, lottery-based subsidies could: (1) increase the performance of desired behaviours; and (2) save governments money. I presented two examples of current subsidy programmes that could potentially be improved with the addition of a lottery option, and I hope that these examples can help policymakers come up with their own ideas for applications within their fields. Before applying such ideas, policymakers should carefully consider the philosophical and logistical concerns, give thought to how individuals will frame lottery options and test the mathematical model with several alternative functions and parameters (i.e., not just those used by Tversky & Kahneman (1992)).

Disclaimer

The views and ideas expressed in this paper are my own, and do not necessarily reflect those of the Competition Bureau of Canada, the Canadian Commissioner of Competition, nor the Government of Canada.

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Appendix A

Consider the case where individuals view the two options separately. Then, the utility from the \$25,000-guaranteed option is:

$$v(25,000) = 7416.29860\ldots$$

whereas the utility from gaining \$24,999.50 for sure with a 0.00005% chance of winning \$1,000,000 is:

$$v(24,999.5) + w^{+}(0.0000005)v(1,000,000) = 7443.47494\ldots$$

So the individual would prefer the lottery option.

Now consider the case where the individuals view the lottery option as losing \$0.50 for a 0.00005% chance of gaining \$1,000,000. Then the utility of the lottery option is:

$$v(-0.50) + w^{+}(0.0000005)v(1,000,000) = 26.08428\ldots$$

Since this amount is greater than 0, the individual prefers the lottery option.

Appendix B

The question here is whether an individual would prefer to lose \$2350 for sure or to lose \$3000 with a 78.3% chance and nothing with a 21.7% chance. The utility of losing \$2350 for sure is:

$$v(-2350) = -2083.15812\ldots$$

The utility of the lottery option is:

$$w^{-}(0.783)v(-3000) + w(0.217)v(0) = -1688.85578$$

Thus, the individual would prefer the lottery option.