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Banking on lottery tickets: A behavioural study of prize-linked savings

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Banking on lottery tickets: A behavioural study of prize-linked savings

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Abstract

Research has identified lower income Canadians who could improve their welfare if availed consumption smoothing through income rationing or savings. Likely, some such individuals struggle to save because their preferences are not well represented by expected utility theory, including those exhibiting hyperbolic discounting. Prize-linked savings (PLS) programs like Britain's Premium Bond offer principal protection with the chance of winning monetary prizes. They have demonstrated success in creating new savers, but Canadian versions are only sparsely available through NGOs. I test individual risk preferences in a portfolio building laboratory experiment, and find individuals primed to perceive their income as low take significantly more risk. Further, these individuals significantly reduce risk when presented a PLS option. I posit this behaviour can be explained by social preferences like the inequity aversion described by Fehr and Schmidt (1999), and find their model significantly outperforms the classical model in predicting behaviour in this experiment.

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List of Symbols, Abbreviations and Nomenclature

Symbol	Definition
i	Indexes the individual decision maker in the experiment
j	Indexes all others in the experiment but individual *i*
k	Indexes a specific individual j, a prize winner
n	Number of participants per experiment group, n = 8
w_i	Individual endowment
s_i	Individual contribution to "safe account"
l_i	Individual contribution to "risky account"
m_i	Individual contribution to "mixed account" (PLS)
r	Net rate of return (interest) on the safe account
R	Gross rate of return on the safe account = (1+*r)*
L	Risky Prize = Total contributions to the risky account
M	Mixed Prize = *r* * Total contributions to the mixed account
π_i	Individual profit after prizes are awarded and interest paid
$u_i(\pi)$	Individual utility over the profit outcomes to all *n* participants
$E(\sum_k^N l_k) \ \forall k \neq i$	Individual belief about the risky contributions of others
$\frac{l_i + r \cdot m_i}{w_i}$	Individual's percentage of endowment at risk
σ_p^2	Variance of the constructed portfolio
η_i^R	Individual estimate of CRRA risk aversion (Holt and Laury, 2002)
α_i	Individual aversion to *less* wealth than others (Fehr and Schmidt, 1999)
β_i	Individual aversion to *greater* wealth than others (Fehr and Schmidt, 1999)

Chapter One: Introduction

1.1 Saving is the right thing to do…

It is well established that there exist individuals for whom increasing their savings "is the right thing to do", but for whom it is exceedingly difficult because of their individual preferences and the lack of meaningful incentives offered by the market. In particular, economists have found evidence of lower-income individuals whose welfare could be improved through consumption smoothing, maintaining a relatively equal balance of spending over a period of time. For example, Shapiro (2006) finds evidence that individuals receiving food stamps reduce their caloric intake 10-15% over the food stamp month. Individuals with even small savings buffers could draw on them to smooth consumption over the month, avoiding the many costs of hunger. Without access to savings or credit, much of the economic behavior by these individuals can appear irrational to an economist, particularly one working under the classical assumptions of Expected Utility Theory. A great deal of research has attempted to "explain" seemingly irrational behavior by individuals at the low end of the income distribution, including their propensity towards gambling and short-run impatience.

One pernicious example of such seemingly irrational behavior is the high prevalence of lottery playing in North America. 67% of American adults (Dubner, 2010) and 72-74% of Canadian adults (Lotto 649 Stats, 2010) play the lottery in a given year. Relative to other games of chance, lotteries offer a gamble of very low expected value, and are played most frequently by the lowest-income individuals. For example, American households earning less than $12,400 spend 5% of their income on lotteries, and average annual lottery spending by this segment in dollars exceeds the national average (Economist, 2011). Likewise, Canadian households earning less than $20,000 spend 3.6% of their income on lotteries, higher than any other segment and well below the national average of 0.8% of income (CBC News, 2009). Following Friedman and Savage (1948), Markowitz (1952), and many economists since, I look for explanations of such behaviour in economic theory of preferences over risk, time, social distributions, and asset portfolios.

In this thesis, I demonstrate that individual lottery playing cannot be predicted under standard assumptions of expected utility theory, and examine whether individual preferences over portfolios of risk can be better explained using Fehr and Schmidt's (1999) model of inequity aversion. Further, I test whether "choice structuring" – framing a decision in such a way to encourage more individuals to make the best decision for themselves as described by Thaler and Sunstein (2008) – can be a meaningful policy tool in encouraging individuals to save. In particular, the aim is to better understand the effectiveness of Prize-Linked Savings (PLS) – such as the U.K.'s Premium Bond – in creating new savers. Through an economic experiment, I aim to better understand the potential effect a Canadian PLS offering could have on individual preferences for risk and savings, as well as identify some key drivers of PLS uptake.

PLS accounts offer individuals both the certainty of savings accounts and the hope of a large payoff offered by lotteries. At their core, they are savings accounts which divert some portion of the individual's interest proceeds to fund a lottery prize for account holders. In the simplest example, imagine a bank offering 5% guaranteed interest on regular savings accounts, and 0% interest on their PLS product. The bank would set aside 5% of the balance of every PLS account holder, and at the end of the year (or month), randomly select one account holder to win the jackpot equal to the sum of all PLS account holder's 5% "interest". Further, the number of chances an account holder has at this interest jackpot is based on their account balance (e.g., one chance for each dollar deposited in the account), incenting savings growth. The U.K.'s Premium Bond is the most successful example, it has been offered continuously since 1958 and is as prevalent in the portfolios of UK households as common equities (Tufano, 2008). Similar PLS accounts are prevalent in Latin America, but noticeably absent in Canadian and U.S. markets.

In this thesis, I conducted an experiment with students from the University of Calgary in the Calgary Behavioural and Experimental Economics Laboratory. In the experiment, participants were asked to allocate an endowed amount of money across a portfolio of assets in two separate decision environments (games). In the first game, participants allocated their endowment between a 'safe' account and a 'risky' account, proxies for traditional savings and lottery tickets.

In the second game, a third ‘mixed’ account was available, with the same expected value as the ‘safe’ account but stochastic interest payments, as offered by a PLS.

My thesis offers two substantial contributions to the literature. First, using participant decisions and survey responses, I estimate parameters for Fehr and Schmidt’s (1999) model of inequity aversion and determine whether such preferences over social distributions offer better predictions of gambling behavior than expected utility theory. In doing so, I find support for the experimental finding of Haisley, Mostafa, and Loewenstein (2008), who demonstrated that lower income individuals choose to gamble more when they are cued to perceive their income as low relative to an implicit standard.

Second, the experiment offers a within-subject test of the effect of a PLS option on the risk preferences of an individual. By equating the expected value of the ‘mixed’ account to the ‘safe’ account, the ‘mixed’ account provides a savings vehicle that is effectively a combined portfolio of ‘safe’ securities and ‘risky’ securities in a fixed proportion. As such, I am able to establish whether individuals prefer more or less risk when their choice is structured with an explicit PLS option. I find that individuals in the experiment significantly reduce their risk when offered a PLS option, with particularly strong effects for those who are primed to perceive their income as low relative to others. Further, individuals who choose to take any level of risk in the first decision between ‘safe’ and ‘risky’ take significantly less risk in the presence of a PLS option. PLS-type prize structures appear to have a marked effect on individual attitudes towards risk.

The results offer hope that PLS can have a meaningful place in Canadian policy discussion, particularly in household savings and welfare distributions. Additional field research would add credibility to the findings, but I see in PLS the promise of an offering that can entice some segment of the non-saving population to begin to develop a savings buffer, availing to them the benefits of consumption smoothing.

1.2 …when it's the right thing to do.

I am not such an ideologue to suggest that the world is beset with profligate spenders, all of whom would be better off by increasing savings. In fact I believe there are individuals with such immediate consumption needs that saving can be detrimental to their welfare. Wooley (2004) identifies one such case as dependent women and children in making her "maternalist" case for paying child benefits to mothers, as fathers in her survey were more inclined to save the benefit and less inclined to spend on their children. Further, asset-testing restrictions can lead to strong disincentives to save for some welfare recipients, discussed further below. However, the papers outlined below by Shapiro (2006) and Tanguay et al (2005) lead us to believe that there are Canadians whose welfare would be improved with the appropriate means and incentives to smooth consumption, such as individual savings or more frequent social security distributions. Further, the natural field experiment conducted with banking customers in the Philippines conducted by Ashraf, Karlan, and Yin (2006) showed that such incentives can be created through simple but innovative banking products, such as commitment mechanisms or randomized interest payments.

Shapiro (2006) empirically tested for the presence of hyperbolic discounting using data on the caloric intake of food stamp recipients. Over the course of a food stamp month, average household caloric intakes declines by 10 to 15%, evidence from the field of individual time preferences demonstrating short-run impatience (hyperbolic discounting). Household survey responses to a number of control measurements allow Shapiro to reject a number of alternative explanations for the decline. For example, the decline is similar among single and multi-member households, suggesting the reduction is not a result of resource competition among members; similarly the decline is consistent across different levels of shopping frequency, eliminating potential explanations from declining household stocks over the month. The data show no evidence of 'learning' to smooth consumption over time, eliminating explanations from over-optimism about how long food stocks will last; finally, suggestions that individuals rely on transfers for calories late in the cycle are questionable given there is no increased incidence of meals in others' homes later in the month.

Shapiro's field observations of hyperbolic discounting lead him to suggest that the timing of government distributions could lead to improved individual welfare ex ante through an induced smoothing of income. There is further support for this hypothesis in Tanguay, Hunt and Marceau's (2005) finding of correlation between grocery prices and the timing of welfare distributions. The authors focus on a Montreal neighbourhood where 15% of residents receive welfare payments, and they record prices of a basket of 31 goods over 26 weeks in seven grocery stores. They find that prices are lowest in the week welfare payments are received, and that prices significantly increase (7 to 12%) over subsequent weeks. The authors suggest this is evidence of firms increasing prices when their customers are most captive, i.e., when household wealth is at its lowest and individuals are least mobile to seek lower prices in other neighbourhoods. Smoother patterns of income would no doubt reduce the mobility limitations and improve the welfare of such individuals, as it would limit the power of local grocers to increase prices when their local customers are most captive. The authors again suggest this as fodder for policy discussions to adjust the timing of welfare payments.

Both of the above papers focus at least tangentially on individuals receiving welfare, many of whom form an important but distinct subset of non-savers, primarily because many provincial governments have explicit asset-testing eligibility criteria. For example, Ontario Works limits non-exempt[1] assets for a single recipient with one dependent to $1,657 (Ontario Ministry of Community and Social Services, 2012a). A similar recipient of the Ontario Disability Support Program is limited to $5,500 (Ontario Ministry of Community and Social Services, 2012b). Individuals with assets above these limits have their benefits clawed back until they can demonstrate more dire circumstances. This context is important for policy discussions relating to welfare recipients, as asset-testing eliminates the incentive for some individuals to save beyond a certain maximum. Asset-testing may even explain some of the prevalence of lottery playing at the low-end of the income distribution, as any recipient nearing the asset limit has a disincentive to save any disposable income.

[1] Exempt assets in Ontario include principal residence, business assets, motor vehicles under $10,000, RESPs, life insurance policies, and pre-paid funerals. Alberta offers a $5,000 exemption for RRSPs and TFSAs.

When considering the recommendations above in light of the context of asset-testing, it may explain why the authors focused on supply-side timing of welfare distributions rather than more individual incentives to smooth consumption through savings. However, it is difficult to argue that increasing the frequency (though not the annual amount) of welfare distributions moves individuals any closer towards self-sufficiency. In a slightly more liberal view, I still see in their results the case for policy solutions that offer new incentives to create savings. Many have previously made the argument that when low-income and asset-poor adults are given incentives that allow them to obtain and retain assets, their time horizon lengthens and they become better able to withstand the ravages of poverty (Stapleton, 2009; Social and Enterprise Development Innovations, 2009). In the cases offered by Shapiro (2006) and Tanguay et al. (2005), it is more likely the single parent with no savings than the one with $1,500 in savings who goes hungry or is gouged by high prices at the end of the month. PLS may offer the right mix of incentives for the parent with no savings to begin to develop that buffer, and the existence of the asset-testing limit on the parent with $1,500 in no way diminishes the welfare benefit of PLS to the parent with no savings.

In this thesis, individuals toward the low end of the income distribution are of particular interest, not least because of their particular preponderance towards gambling and their potential welfare benefits of smoother consumption. It is important to remember that this population is not limited to asset-tested welfare recipients, but also a large number of young people and "working poor"[2]. Further, I am interested in the effect of PLS on the risk and saving attitudes of individuals across the income spectrum. *Table 2* demonstrates the broad appeal of PLS in the U.K.; there are some 23 million PLS accounts in the U.K., 0.37 accounts for each man, woman, and child. Over 20 million of the smallest accounts have an average balance of $320CAD, suggesting the accounts are attractive to many lower-income individuals, the majority of whom would not approach any asset-testing limit through their PLS balances alone. Evidently, for a number of individuals there

[2] Defined by the U.S. Bureau of Labor Statistics as "persons who spent at least 27 weeks in the labor force but whose incomes still fell below the official poverty level". 24% of Americans below the poverty level in 2009 qualified as "working poor" (US Bureau of Labor Statistics, 2009).

is something about the structure of prize-linked savings which enhances the utility of saving beyond that offered by traditional interest bearing accounts.

Previous research has demonstrated that the welfare of individuals can be improved through financial innovations which ought to carry no positive marginal utility in a classical expected utility framework. Ashraf, Karlan, and Yin (2006) invoke the story of Odysseus as an example of such a tool helping hyperbolic discounters. In Homer's *Odyssey*, Sirens sang so beautifully that they would cause sailors to go mad, crashing their ships on the rocks surrounding the Sirens' island. Odysseus ordered his sailors to plug their ears and tie him to the ship's mast, so that he might hear the Sirens, but not be tempted to steer towards them. The authors argue that if individuals with time-inconsistent preferences are sophisticated enough to realize it, we should observe them engaging in similar forms of commitment. The authors survey banking customers in the Philippines to determine which have hyperbolic preferences, and use a natural field experiment (as defined by Harrison and List, 2004) to measure their interaction with a commitment-based savings product. After the survey, individuals had their savings activity and balances monitored over the following year. Individuals were randomly selected to have no further interaction (control treatment), or to receive a home visit from a marketing team offering either a traditional savings account (marketing treatment), or a commitment-based savings account (commitment treatment). The commitment account forced individuals to choose a savings goal in the form of an amount or a date, and funds were not released to the account holder until the goal was met. In classical utility theory there is no place for such a liquidity-limiting account feature for individuals with "time consistent" preferences (exponential discounting), but those with "short run impatience" (hyperbolic discounting) can improve their utility ex ante by participating in such an account. Ashraf et al (2006) demonstrate a greater preference for the commitment product amongst individuals who exhibit hyperbolic utility in the survey. They offer this as evidence that low traditional savings rates in some segments of the population may be driven by hyperbolic discounting, and that such welfare-reducing preferences may be overcome with innovative savings vehicles.

Regardless of whether it is due to opportunistic pricing by businesses (as in Tanguay et al, 2005) or due to individual preferences (as in Shapiro, 2006), it is clear that the welfare of many lower-income individuals could be improved through consumption smoothing. Such smoothing may be achieved through more frequent welfare payment distributions, or through individual savings. Ashraf et al (2006) provides evidence that seemingly innocuous financial products can generate new savings among non-savers by appealing to their preferences beyond those outlined in expected utility theory. I believe that non-traditional savings vehicles have the potential to improve savings for certain segments of the population, and as such should have a greater role in policy discussions. This thesis explores one such type of account – known broadly as Prize-Linked Savings (PLS) – and its effect on preferences in an experimental setting.

1.3 Premium Bond Statistics

In order to introduce unfamiliar readers to Prize-Linked Savings in practice, I provide some facts and statistics on the U.K.'s Premium Bond program. From a policy standpoint, it is worth noting that Premium Bonds are offered only by National Savings & Investment (NS&I), which is an executive agency of the Chancellor of the Exchequer (the U.K.'s treasury). NS&I's "*strategic objective is to provide retail funds for the Government that are cost effective in relation to funds raised on the wholesale market… by issuing and selling savings and investment products to the public*" (Chancellor of the Exchequer, 2009). This is noteworthy as the biggest opponents to prize-linked savings in many countries have been national lottery boards (Tufano, 2008). Housing the accounts within the Government's treasury can alleviate the argument that prize-linked savings reduce Government revenues as a substitute to national lotteries because the benefits of participation still accrue to the taxpayer. This is in direct contrast to PLS in Latin America where products are offered by private banks (Guillen and Tschogel, 2002).

As of June 2013, NS&I paid 1.5% interest on all Premium Bond balances into the prize pool, and all prizes are free from capital gains and income taxation. This compares with rates of 0.75%-2.25% on similar NS&I accounts with no fixed term (Chancellor of the Exchequer, 2013a). Not surprisingly, in practice the prize pools are more complex than the winner-take-all draw described in *Section 1.1*. *Table 1* provides NS&I statistics of the June 2013 prize pool, with additional calculations by the author to estimate the total stock of prizes and payout in £.

Table 1: Premium Bond Prize Distribution

NS&I Data			Author Calculations	
Prize band	Prize value (£)	Number of prizes	Total dispersed (£)	% of Prize Pool
Higher value (6% of prize fund)	1,000,000	1	1,000,000	1.8%
	100,000	5	500,000	0.9%
	50,000	9	450,000	0.8%
	25,000	18	450,000	0.8%
	10,000	48	480,000	0.9%
	5,000	93	465,000	0.8%
Medium value (5% of prize fund)	1,000	1,114	1,114,000	2.0%
	500	3,342	1,671,000	3.0%
Lower value (89% of prize fund)	100	32,769	3,276,900	5.9%
	50	32,769	1,638,450	2.9%
	25	1,788,080	44,702,000	80.2%
Total value for June 2013	**55,747,350**	**1,858,248**	**55,747,350**	**100.0%**

Est. Monthly Interest Rate (1.5% / 12)	0.1250%
Est. June 2013 Balances (£)	44,597,880,000
Odds against any prize for a £1 bond	24,000.0
Skew of Prizes dispersed	3.29
Kurtosis of Prizes dispersed	10.88

The prize distribution is notable for its large frequency of small prizes, and for the magnitude of its largest prizes; it is consistent with prize distributions described in Argentina by (Guillen and Tschogel, 2002). They suggest this distribution evolved to account for individual preferences for portfolio payoffs with skew (from finance) as well as mechanisms to reduce investor fatigue from frequent loss (from psychology).

In order to maintain a modicum of fairness for smaller investors, Premium Bond holdings are limited to £30,000 per person. *Table 2* provides a distribution of account sizes, as well as author calculations estimating the number of accounts. Note that despite the tax-advantaged status of prizes for wealthy individuals, over 90% of accounts hold under £5,000, suggesting this account effectively reaches a large number of lower-income consumers (at least 20 million accounts, by my estimates). That said, it is clearly also a tax-advantaged instrument for those of moderate to high wealth; fully 37.2% of the total value is held by some 550,000 investors whose accounts hold the maximum of £30,000 per person.

Table 2: Premium Bond Account Distribution

NS& I Data			
Premium Bond holding value bands	% of customer holdings	% of eligible £1 Bonds	% of prizes won in January 2013 draw
Under £5k	90.60%	9.30%	9.40%
£5,000 - £9,999	2.30%	7.80%	7.90%
£10,000 - £19,999	2.50%	16.90%	16.90%
£20,000 - £29,999	2.20%	28.60%	28.60%
£30,000	2.40%	37.20%	37.30%
Total	100%	100%	100%

Total Holdings (est from Table 1)	44,597,880,000
% in accts w/ exactly 30,000	37.20%
Value of accts w/ exactly 30,000	16,590,411,360
Value per account	30,000
Number of accounts w/ exactly 30,000	553,014
Percentage of all accounts w/ exactly 30,000	2.40%
Est. Total number of accounts	23,042,238
Est. Number of accounts under £5k	20,876,268
Total holdings by small accounts	4,147,602,840
Average holdings by small accounts	199
GBP:CAD 16 August 2013	1.61
Average holdings by small accounts (CAD)	320

1.4 Organization of Topics

The remainder of this thesis is organized as follows. In *Chapter 2*, I review the existing literature specific to PLS, as well as a variety of literature that informed my views of individual preferences over risk, time, and social distributions. This literature was instrumental in helping me form the central research questions, which are covered in *Chapter 3*. *Chapter 4* details the premise and logistics of the experiment, as well as introducing the theoretical notation. *Chapter 4* is complemented by *Appendix A*, the participant instructions, and *Appendix B*, which expands on theoretical predictions over topics such as risk aversion, inequity aversion, and choice architecture. *Chapter 5* covers the experimental treatments in detail, with specific hypotheses to be tested in pursuit of answering the research questions. *Chapter 6* details the experiment results and findings, and *Chapter 7* offers conclusions, next steps, and limitations of the experiment. Finally, *Appendix C* replicates risk preference analyses using portfolio variance, and *Appendix* D offers a test of whether Thaler and Sunstein's (2008) "diversification heuristic" explains observed behaviour.

Chapter Two: Literature Review

2.1 Prize-Linked Savings

Academic studies of prize-linked savings are limited in number and scope, as the majority of research has been conducted over the past 10 years. In this section I review work in the field and how current findings have informed the experimental design. Further, I hope to extend on previous works by examining previously unstudied or unproven hypotheses.

Murphy (2005) documents the first recorded instance of prize-linked savings; the "Million Adventure" launched in England in 1694 to finance the Nine Years War with France. The government issued one hundred thousand £10 tickets, and prizes ranged from £1,000 per year for 16 years to £10 per year for 16 years. Most interestingly, losing "blank" tickets paid £1 per year for 16 years, and a secondary market developed for them just after the prize drawing, with an approximate price of £7. Thus the "Million Adventure" offered the first PLS, with a random chance of a large win and some element of principal protection. Their existence in the centuries to follow has been somewhat sporadic, similarly occurring to meet exigent needs for sovereign debt during times of war.

Guillen and Tschoegl (2002) document the existence of prize-linked savings programs across the world, provide a supply-side case study from two Latin American banks, and review theory on their appeal to investors from both finance and behavioural sciences. Their summary can surprise an average Canadian with the apparent prevalence of these accounts; they present evidence of them in the UK, France, Sweden, Japan, Germany, Turkey, Kenya, Indonesia, Spain, Mexico, Argentina, and Pakistan. It serves also as a warning to those considering introduction of such accounts, as their documented flare-ups with government bodies in Pakistan and Japan portended the successful launch and subsequent shut down of Millionaire-a-Month Accounts (MaMA) occurring in South Africa around the time of publication (Tufano 2008).

The authors review literature to suggest that the prize structures exist in their current form – with large numbers of small prizes and a small number of very large prizes – to account for individual preferences for portfolio payoffs with skew (from finance) as well as mechanisms to reduce fatigue from frequent loss (from psychology). They also offer the argument from Ng (1965) suggesting that large sums are sought because of indivisibilities in consumption of such goods as cars, houses, TVs and so forth which are sold in (expensive) units. Such a view is supported by the prevalence of ROSCAs (rotating savings and credit associations) in countries with poor consumer credit. The authors conduct supplementary interviews and find "the bankers we spoke with believe that (LLS) are especially successful with low-income depositors, and in cases where there are lots of people outside the banking system." Regardless, the demand for such a product is supported as much by their historical appendix (and intuition) as from the theory and interviews presented.

Guillen and Tschoegl's (2002) supply-side case studies the effect of prize-linked savings from the point of view of two private Spanish banks offering prize-linked accounts in Brazil and Argentina. Calculations performed by the authors using publicly available information on prizes and account volumes demonstrate that the prize-linked accounts offered by Banco Rio in Brazil and BBV Banco Frances in Argentina appear to be *over-fair* relative to the interest rate on regular savings accounts from those institutions. The authors point out these calculations omit deposit insurance, and that this result could change as account volumes grew relative to the total prizes. Nevertheless, they demonstrated that even when over-fair, the accounts were attractive to banks that would otherwise pay more for funding in the interbank market or for customer acquisition, particularly among the unbanked. Like the accounts examined by these authors, the experiment in this thesis offers participants a prize-linked account that is only negligibly *over-fair*, both in order to emulate real-life offerings and to test whether people prefer the prize-linked account to a mix of traditional savings and lottery spending with identical expected payoffs.

Tufano (2008) provides an econometric analysis of drivers of the U.K.'s Premium Bond program. He compares net premium bond sales per capita from 1978 through 2006 to two potential substitutes: money in traditional riskless savings such as savings and time deposits, and gambling activity such as general betting and the National Lottery reported through Her Majesty's Revenue and Customs. He compares changes in these accounts over time to suspected drivers of PLS sales, including the top prize, the prize rate spread, the income tax rate, and rates of returns on substitutes such as the interest rate and the return on the FTSE index of equities. He finds positive correlation with the size of the top prize, corroborating previous research on lotteries. He also finds negative correlation with the savings rate and with the prize spread over the interest rate. He uses these findings to suggest that individuals view PLS as a mix of both gambling (as sales are driven by the size of the top prize) and savings (as sales are driven by the interest rate spread relative to other savings accounts). He makes a theoretical case for inequality as a driver of PLS, but is unable to find a statistical result with little variation in the inequality measure (GINI) over the 38 years of data. He laments the lack of household level data to sort out income and substitution effects (for example those driven by changes in the tax rate), and suggests future research consider the effect of PLS on household savings to enlighten policy discussions where governments ban its use. I aspire to re-visit Tufano's hypotheses about the effect of PLS on savings, and the effect of inequality on PLS adoption.

In a survey-based study, Maynard, De Neve, and Tufano (2008) find a majority of 547 individuals would be "interested in a savings account that awarded chances to win prizes based on the amount of money [they] save… The account would also have no fees, no minimum balance and still earn interest". Further, they find that "interest in prize-linked savings is greatest among people who do not have regular saving habits, who have little actual savings, who play lotteries extensively, and who are optimistic about their futures". The authors note that this question did not indicate the precise terms of the account, nor whether individuals would actually execute transactions in the account. This experiment takes the next step by testing the extent to which people execute transactions in PLS with real money when given precise parameters on the account relative to other savings and lottery vehicles.

Similarly, Lobe and Holzl (2007) conduct a longitudinal empirical analysis of sales and redemptions of Premium Bond sales. In doing so, they calculate the threshold levels of risk aversion for rational participation in the British Premium Bond across time. With participation from the U.K.'s National Savings & Investment, the bond's sole distributor, the authors "hand collected" 592 monthly observations of the prize distribution and account size distribution from 1958 through 2006. They compare the decision to participate in the Premium Bond to the similarly marketed and interest-bearing NS&I Income Bond as well as the benchmark interest rate, which limits their comparison set to 1969-2006. They do so while parameterizing each potential purchaser with risk-averse utility of the constant relative risk aversion – CRRA $\left(u(x) = \frac{(x)^{1-\eta}}{1-\eta}\right)$ – and constant absolute risk aversion = CARA $\left(u(x) = \frac{e^{\eta x}}{\eta}\right)$ – forms. The authors iteratively calculate the value of η which equates the expected utility of the Premium Bond (for which the prize distribution is key) with the expected utility of the safer investments. The analysis augments utility to account for the tax-free nature of Premium Bond prizes, and estimates the threshold value of η that equated the marginal utility of the next £1 investment. Interestingly, there are times across the Premium Bond's history where falling interest rates and sticky prize levels created a situation in which it became rational for investors in higher tax brackets who are strictly *risk-averse* to prefer the Premium Bond to more traditional savings.

Lobe and Holzl's (2007) analysis of sales over time finds significant positive correlation in Premium Bond sales with the skew of the prize pool, the size of the largest prize, and the maximum level of investment (£30,000 at the time of writing). The correlation with skew and maximum prize size supports a hypothesis of individuals seeking life-changing amounts, and the correlation with maximum investment supports the earlier calculations demonstrating the considerable patronage the account garners from those in higher tax brackets holding the maximum amount. The authors fail to find correlation between sales and the threshold risk aversion described above, and use this as an argument that "classical risk preferences do not play a major role in this investment decision". I find this to be too strong a conclusion, as it relies on unstated distribution assumptions about the nature of people's income and risk preferences over time. For example, the risk-aversion threshold for participation in Premium Bonds decreased between 1972 and 1973 as a result of falling interest rates and sticky prize pools. This should be associated with an increase in sales if each individual's risk aversion and investable income stayed constant; as the Premium Bond became more lucrative, those who previously found it just marginally too risky begin to find it attractive and dollars flow into the account. However, this fails to account for how a precipitous fall in interest rates could affect the distribution of individuals' incomes and risk preferences around the threshold level. As such, I am not willing to eliminate risk preferences in the analysis as a result of their finding.

I use a similar iterative process to Lobe and Holzl when estimating individual preference parameters. However, I am aided by measuring each individual's decisions over moderate amounts and spared necessary assumptions about the distribution of society's risk and income over time. I estimate a potential range of risk aversion parameters η_i in the CRRA preferences $u_i(\pi_i) = \frac{(\pi_i)^{1-\eta_i}-1}{1-\eta_i}$ for each experiment participant *i* based on their responses to the lottery preference questionnaire from (Holt and Laury, 2002). This range of risk aversion estimates for the participants is maintained throughout the identification of individual parameters, which is outlined in more detail in the sections concerned with theory and results.

Filiz-Ozbay et al (2013) studied the effect of a PLS option on individual willingness to delay consumption and found that participants were more willing to defer payment if they had a PLS option available; the authors interpret this result as an increase in savings. Participants in their laboratory experiment completed 100 binary choices – ten decision problems each with ten questions – in order to estimate individual risk and time preferences, similarly to Holt and Laury (2002) and Andersen (2008). Seven of their decision problems were "PLS decision problems", while the other three were "Standard Holt Laury" problems; in all problems, Option A was paid 2 or 3 weeks later and Option B was paid 5 or 6 weeks later.

As an example of their methodology, provided in *Figure 1* are three of the decision problems in more detail. In each of Problems (a)-(c), Option A paid \$20 in 3 weeks, and Option B paid a varying amount in 5 weeks, always at least \$20. Problem (a) elicited standard time preferences: Option B increased from \$21 to \$30 over the 10 choices, and where an individual first elects to defer payment represents her time preferences. In problem (b), Option B paid \$30 with probability x% and paid \$20 with probability y%; the probability x% increased from 10% to 100% over the 10 choices, maintaining the same expected value as Option B in problem (a). Problem (c) was structured similarly to (b) but with a larger top prize and smaller probability. In problems of this sort, participants typically choose a series of As followed by a series of Bs, and where they cross represents a proxy for their risk and time preferences. By varying only the risk structure and not the expected value or timing of Option B between Problems (a), (b), and (c) the authors look for changes in the cross-over point between problems that could indicate a behavioural response to the structure of the payout.

Figure 1: Decision Problems (a)-(c) from Filiz-Ozbay et al, 2013

(a) Standard Time		(b) Certain Early vs. Later Lottery		(c) Certain Early vs. Later Lottery	
Option A (3 weeks)	Option B (5 weeks)	Option A (3 weeks)	Option B (5 weeks)	Option A (3 weeks)	Option B (5 weeks)
20	21	20	(30, 20); (0.10, 0.90)	20	(120, 20); (0.01, 0.99)
20	22	20	(30, 20); (0.20, 0.80)	20	(120, 20); (0.02, 0.98)
20	23	20	(30, 20); (0.30, 0.70)	20	(120, 20); (0.03, 0.97)
20	24	20	(30, 20); (0.40, 0.60)	20	(120, 20); (0.04, 0.96)
20	25	20	(30, 20); (0.50, 0.50)	20	(120, 20); (0.05, 0.95)
20	26	20	(30, 20); (0.60, 0.40)	20	(120, 20); (0.06, 0.94)
20	27	20	(30, 20); (0.70, 0.30)	20	(120, 20); (0.07, 0.93)
20	28	20	(30, 20); (0.80, 0.20)	20	(120, 20); (0.08, 0.92)
20	29	20	(30, 20); (0.90, 0.10)	20	(120, 20); (0.09, 0.91)
20	30	20	(30, 20); (1.00, 0.00)	20	(120, 20); (0.10, 0.90)

Filiz-Ozbay et al (2013) find that the PLS offered in problem (b) results in a significantly earlier average switch point than the traditional savings offered in problem (a), indicating that PLS increases the likelihood an individual defers payment (interpreted by the authors as delaying consumption or generating savings).

If a PLS option is enough to incent someone to defer consumption, it behooves the policy maker to determine whether the individual has reduced their risk in doing so. The 550,000 Premium Bond investors holding the maximum of £30,000 per person have most likely substituted those funds from other, less tax-advantaged investments. It is the 20 million plus investors with under £5,000 or less whose behaviour is most important to making a case for the welfare benefit of PLS. If these PLS adopters were previously unbanked, their accounts can avail the welfare benefits of consumption smoothing discussed above. Similarly, if PLS balances are created by substitution away from more costly forms of gambling, there could be substantial welfare benefit. If, however, PLS balances are created by substituting from traditional savings – as is likely the case with the max balance investors – the welfare benefit is less clear. The experimental aim is to begin to answer this question, by examining the total amount of risk individuals choose to take in a portfolio building exercise in the presence of a PLS.

2.2 Preferences

While literature specific to prize-linked savings is limited, this experiment has been informed by a great deal of economic literature on preferences; specifically individual preferences over risk, time, asset portfolios, and social preferences such as status and inequality.

2.2.1 Risk Preferences

Standard neo-classical theory of risk preferences was coalesced mathematically by Pratt (1964), who demonstrated the two coefficients of risk that determine an individual's preferences over small gambles – absolute risk aversion $\left(\eta_i^A = -\frac{U''(x)}{U'(x)}\right)$ – and over larger gambles – relative risk aversion $\left(\eta_i^R = -x \cdot \frac{U''(x)}{U'(x)}\right)$ – in an expected utility framework. Pratt demonstrated the importance of how these measures change with wealth, e.g., $\frac{\partial \eta_i^R}{\partial x} > 0$ would imply increasing relative risk aversion (IRRA), meaning the individual becomes incrementally more averse to risk as her wealth increases. The importance of such predictions becomes more clear when considering the possibility of $\frac{\partial \eta_i^A}{\partial x} \geq 0$, increasing or constant absolute risk aversion (IARA or CARA). An absurd consequence of CARA would see someone of moderate wealth who turns down a 50-50 gamble to lose $100 or win $110 also turn down a 50-50 gamble to lose $4,000 or gain $60,000,000 (Rabin, 2000), IARA predictions are even more absurd. Pratt's work allowed economists to make predictions of the optimal level of insurance for an individual with a given level of risk aversion, as well as their willingness to pay a premium to eliminate consumption risk. However, this model was ineffective at explaining gambling behavior evident in the field. In fact, it can be shown that under neo-classical assumptions, an individual exhibiting positive coefficients of risk aversion would never participate in a fair or less-than-fair gamble such as those offered by our casinos and governments. And yet they are pervasive.

Parts of this thesis aspire to explain observed gambling behaviour within the frameworks of known economic models, and this type of work dates back at least as far as Friedman and Savage (1948), who discuss the classical assumption of universally diminishing marginal utility and the inability of expected utility theory to explain observed gambling behaviour under such a construct. They consider the possibility that marginal utility is diminishing not universally, but over the parts of the utility function where the majority of individuals exist, and that a great deal of observed gambling and insurance choices can be explained by utility functions that are convex between these concave sections. They posit the concave sections of the function as distinct social classes, and the sparsely populated convex regions between them as a transitional region between classes. It is on these transitional convex intervals that individuals are most willing to engage in fair gambles, because of the local increasing marginal utility of moving to a higher social class. Such a utility function can explain lower-income individuals engaging in gambles with poor chances of very large payoffs (such as lotteries) as well as the propensity of wealthier individuals to engage in both the purchase of insurance and in gambling. One issue with such a construct is that it requires that each individual faces the same, known social classes with distinct thresholds of wealth to divide them; it also requires that the majority of populations are concentrated on these concave sections. I would prefer to consider a less absolute construct not in which an individual pursues these income thresholds, but in which she considers her position relative to other visible members of society, as suggested by Fehr and Schmidt (1999). I expand the Fehr and Schmidt model to the experiment's multi-player game of choice over savings and gambling decisions in the *Section 4.3 Theory and Notation.*

Markowitz (1952) offered several absurd predictions of the Friedman and Savage (1948) hypothesis, such as an "almost rich" individual whose most preferred bet would be a small chance of a large loss and a large chance of a small gain. Such a person would become a "one-man insurance firm", underwriting the risk of others to maximize his expected utility, with no intent of diversifying away this risk. He offers a slight revision of the Friedman-Savage hypothesis in order to improve its predictive power; Markowitz' proposed utility of wealth is a function with three inflection points, the second of which is located at the person's present or "customary" wealth. One token of evidence offered for such preferences comes from the typical responses to choices of certain gains or certain losses versus gambles of the same expected value. People often prefer to gamble over small potential gains, but always accept $1,000,000 guaranteed over a 10% chance of $10,000,000. The opposite curvature is observed in the loss space; over small amounts certainty is preferred (losing $10 certainly is preferred to a 10% chance of losing $100), while people will gamble when facing large debts (a 10% chance of owing $10,000,000 is preferred to a certain loss of $1,000,000). Such a construct better described the anecdotal gambling behaviour of individuals who have experienced gains or losses away from their "customary wealth", in particular the propensity to take more risk after small gains and large losses, and less risk after small losses and large gains. This work was a clear precursor to the "choice between lotteries" methods used by experimental economists such as Holt and Laury (2002), as well as to Kahneman and Tversky's (1979) work on Prospect Theory, discussed below.

Ng (1965) offered a different rationalization of gambling under expected utility theory by considering indivisibilities in consumption. Using the example of a young person considering the purchase of a university education (which is expensive and indivisible, he assumes you cannot purchase 1/3 of such an education). With this hypothetical subject, who presently has too little income to afford such an education, Ng shows how a risk-averse individual can rationally play the lottery with such problems of indivisibility. The utility trade-off between a near-certain small loss from purchasing a lottery ticket is outweighed by the potential utility gained from a large enough win to afford a university education. The resulting utility curve is similar to the one described by Friedman and Savage (1948), but the area of local convexity on which individuals are more likely to gamble is caused by a discontinuity resulting from indivisibility, not from an area of convexity between social classes.

Kahneman and Tversky (1979) took issue with some game theorists and economic experiments of their time, which often ignored the curvature of the utility function (risk aversion) by assuming participants to be risk-neutral or that a game's payoffs were measured in utilities. The authors coined Prospect Theory, a new theory of choice under uncertainty, which suggested that individuals consider the utility of each potential risk from a point of reference – their current level of wealth – and that potential gains offered diminishing marginal utility (concave in the gains space), while potential losses in wealth offered diminishing marginal disutility (convex in the losses space). Such a utility function was able to explain their observation that individuals faced with a certain loss are typically willing to face a gamble of equal expected loss, while conversely preferring a certain gain to a gamble of equal expected gain.

de Meza and Dickinson (1984) undertook a critique of the assumptions of Prospect Theory, which was among the most prevalent frameworks of decision making under uncertainty in their time. They point out that Prospect Theory can only explain gambling behaviour in fair or under-fair bets if the individual first experiences a loss, so as to re-locate to the convex portion of the utility function in the losses space. Kahneman and Tversky alleviate this concern with a "weighting function". Rather than individuals considering probabilities objectively, they "over-emphasize" small probabilities, resulting in fair odds potentially being considered over-fair, allowing for the rationality of some gambling and insurance purchasing behaviour. Further, de Meza and Dickinson criticize the unexplained process by which people re-calibrate their reference point, a necessary process to explain why someone would stop gambling before going bankrupt, for example. They offer a less radical revision of expected utility theory, which borrows aspects of the curvature of the utility function from Prospect Theory and Markowitz (1952), but does away with reference point recalibration and the probability weighting function through the introduction of durables and transaction costs.

de Meza and Dickinson (1984) propose a function for utility over losses with diminishing marginal disutility for relatively small losses and increasing marginal disutility over larger losses, including two inflection points; this is a similar S-shaped curve as proposed by Friedman and Savage (1948) for utility over gains. When they introduce transaction costs and durables to the expected utility framework, they demonstrate that an unexpected loss can lead to greater than anticipated losses of utility if consumption cannot be scaled back continuously (e.g., large durables consumed in units). Under such a construct, it can be entirely rational for individuals to take unfair insurance against losses that would force them to incur transaction costs, e.g., liquidating a durable at a loss or going without one completely. From a policy perspective, I am more like Friedman and Savage (1948) in being interested in how perceived social differences and individual tastes for risk affect an individual's consideration of PLS in its context as a substitute to savings and gambling, than I am interested in explaining how this decision is augmented by durables and transaction costs. In order to rule out such valid explanations as offered by de Meza and Dickinson for the gambling observed experimentally, the experimental design is effectively continuous in consumption (in units of $0.10 CAD) and omits any such transaction costs and durables from the individual's consideration.

Beyond the largely theoretical works discussed above, much empirical and experimental work was completed to estimate the curvature of the utility function, i.e., to determine whether they were best modeled with increasing, decreasing, or constant relative risk aversion (IRRA, DRRA, and CRRA, respectively). Binswanger (1980) was an early pioneer in using disparities in purchasing power to elicit preferences over larger payoffs in an affordable manner. In his study of farmers in Bangladesh, he demonstrated significant increases in relative risk aversion as payoffs are increased. This was suggested as support for IRRA preferences, a finding that was subsequently bolstered by Bosch-Domenech and Silvestre (1999), who demonstrated willingness to purchase actuarially fair insurance increased in the scale of the potential loss. The empirical support for IRRA preferences was not concerning *per se*, but it did open the door mathematically to the existence of the absurd IARA preferences over absolute risk discussed above.

Holt and Laury (2002) addressed this concern in their seminal experimental treatments of risk aversion. They used a "choice between lotteries" framework, in which an individual chooses to face either lottery A (which has two potential payoffs of moderate value) or lottery B (with one very large payoff and one very small potential payoff). They make the choice 10 times, with the probability of good and bad outcomes systematically changing across each choice. The lottery payoffs and probability variations were chosen in such a way that a rational individual would only "cross-over" from preferring low-risk lottery A to high risk lottery B once, and that cross-over point represented a distinct band of potential values for η_i^R in the CRRA utility function:

$$u_i(\pi_i) = \frac{(\pi_i)^{1-\eta_i-1}}{1-\eta_i}$$

Participants were randomly selected to complete this choice between lotteries with the payoffs multiplied by (1x, 20x, 50x, and 90x). Any changes in the cross-over point across different incentive levels would represent a change in the level of relative risk aversion as income changed. They found sufficient evidence to reject the null hypothesis of CRRA preferences over risk in favour of the IRRA preferences observed by previous authors: $\left(\frac{\partial \eta_i^R}{\partial x} > 0\right)$. They also demonstrated support for the intuitive DARA preferences, and demonstrate that both first order conditions can be accommodated by so-called "Power-Expo" utility functions of the form: $(x) = \frac{1- e^{(-ax^{(1-r)})}}{a}$; with relative risk aversion: $-\frac{\frac{\partial 2\, u(x)}{\partial x2}}{\frac{\partial\, u(x)}{\partial x}} \cdot x \ = r + a(1-r)x^{(1-r)}$

$If\ r,\ a > 0\ \rightarrow IRRA\ and\ DARA$

$If\ r = 0\ \rightarrow CARA$

$If\ a = 0\ \rightarrow CRRA$

I feel Kahneman and Tversky's (1979) critiques of omitted risk aversion are valid in the context of this experiment, and so I mimic Holt and Laury's (2002) design to estimate CRRA risk aversion coefficients for each of the participants. This allows us to proxy and control for each individual's level of risk aversion when examining between-subject treatment effects. Because all subjects receive the same endowment across games, I do not feel it is necessary to estimate the Power-Expo function for each to control for incentive size effects. However, I will be able to indirectly test for IRRA preferences in a between-subject design, as random assignment allows us to compare the observed value of η_i^R for three different levels of income.

2.2.2 Time Preferences

Almost all individuals demonstrate some form of positive time discounting, behaving as if "a dollar today is worth more than a dollar tomorrow" because in most circumstances, it is. This difference in the utility of a dollar over time can be driven by inflation, as purchasing power is eroded, but it is also driven by the opportunity cost of forgoing investment of the dollar. In order to incent individuals to lend in the market, they must be compensated for this loss of utility on the principal, and this is typically achieved with positive (real) rates of interest.

Many previous experiments have had individuals choose between smaller amounts of payment today versus a larger amount at some point in the future in order to estimate their individual discount rate (see Thaler, 1981; Loewenstein, 1988). Often, these studies have found double-digit discount rates that are significantly higher than prevailing market interest rates, these results have been cited as "anomalies" which reject the classical model of time preferences from Fisher (1930). Explanations for the anomaly include individuals demonstrating present-biased hyperbolic or "power-expo" utility as in Holt and Laury (2002), as well as the immediacy of the "sooner" option, which can be overcome with a front-end delay.

Coller and Williams (1999) first posited uncontrolled field opportunities as a potential explanation for the previously reported anomalies in individual discount rates. In particular, an individual may make "sooner" choices in the laboratory that represent a very high discount rate if his investment opportunities outside the lab are more lucrative than the rate offered on the "later" amount. Similarly, an individual may appear extraordinarily patient in the laboratory if they believe they can arbitrage by borrowing the "sooner" amount in the market and paying a lower rate of interest than they earn by deferring in the lab. To determine whether such field opportunities were affecting individual choices, the authors conducted an experiment where individuals completed a series of binary choices where discount rates could be inferred. Before the participants made their choices, groups received information on prevailing market interest rates, the effective annual rate on the deferred payout, or information on both, while a control group received no additional information. The experiment recognized that two conditions must be met for individuals to engage in the arbitrage described above. First, the subject must know the rate of interest offered in the lab, and second, the subject must know comparable rates of return on field opportunities. If the subject either does not know or cannot calculate either of these rates, she may reveal an erroneous discount rate with her choices in the lab; further, individuals looking to arbitrage are likely to make (random) errors in calculation. The authors suggest that such individuals will make decisions that better align with theoretical predictions in the presence of information.

The authors find that the median discount rate implied by subject choices across all sessions is in the interval of 17.5%-20% annually. When participants are provided with the information treatment, the median discount rate is significantly reduced to 15-17.5% annually, which better aligns with market borrowing rates for their subject pool. Further, the unexplained variance of subject responses is reduced in the presence of information. The authors take this as evidence that field opportunities can impact revealed preferences, and that human errors in estimating arbitrage opportunities are reduced in the presence of comparable rate information.

Coller and Williams (1999) also included two additional treatments that added evidence to the discussion on the effect of hypothetical payments and front-end delays on payment. They find that participants receiving hypothetical payments displayed higher discount rates and greater unexplained variance. They also find that instituting a front-end delay reduces discount rates, though their findings are on the threshold of significance (p-value 0.168).

Coller and Williams (1999) informs this experiment by clearly laying out how experimental measures can be augmented by hypothetical payments and, more importantly, by field opportunities. Their experiments provide evidence of subjects miscalculating field opportunities in their quest for arbitrage, however, they do not provide a methodology to identify and control for each individual's opportunities. In order to avoid confounding such effects on time preference with the desired measures of risk preference, the experiment design excluded any lapse in time between the date of the decision-making session in the lab and the date of payment.

McLeish and Oxoby (2007) explore intertemporal decision making in a within-subject design, where participants participated in four time preference experiments over eight weeks. Every two weeks, participants made choices in two games designed to elicit individual discount rates. In the first game, participants were asked to choose between an amount 2 weeks from the decision and a larger amount 5 weeks from the decision. By comparing variations in an individual's response to the first game over the four sessions, the authors were able to conclude that individual discount rates are consistent across time, i.e., one's discount rate on amounts 5 weeks from now versus 2 weeks from now does not change from week to week. The second game was designed to test for hyperbolic discounting, in it, participants were asked to choose between a "sooner" amount and a "later" amount. In all cases, the later amount was to be paid 5 weeks later than the sooner amount. In the first session the sooner amount was 6 weeks into the future, and the later amount was to be paid in 11 weeks. Each respective session elicited discount rates from the same people, for the same payment date, but with the payment date two weeks closer, i.e., in the second session payments were 4 and 9 weeks into the future, then 2 and 7 weeks into the future, and in the fourth session the decision was between an immediate payment versus 5 weeks into the future.

This experimental design improved on previous results by collecting decisions over four periods rather than two, allowing for more robust timing of the inflection point in hyperbolic preferences. In doing so, the authors found that men with hyperbolic utility display their present bias earlier than women by several weeks (when making decisions in the fourth session where immediate payment was available, men demonstrated significantly more present bias). Further, the consistency of the framework in eliciting discount rates allowed the authors to test the effect of a mood-inducing treatment, in this case a bargaining game that preceded the decisions over discount rates. The authors created a “negative” indicator to measure if someone received less than $5 of the $10 available, and a “positive” indicator to measure if someone received more than $5. They find that women who are primed with a “negative” emotion by receiving the worse end of a bargaining game are significantly more impatient; there is no similar result for men.

McLeish and Oxoby (2007) inform the experiment in two ways. First, I use a similar economic outcome at the beginning of the experiment to test whether the outcome has an effect on decision making. In the experiment, individuals are randomly allocated the equivalent of either $10, $20 or $30 CAD, and are told the distribution of endowments so that they are effectively cued to perceive their income as being either higher, lower, or the same as others in the group. I test whether this impacts and individual’s preference for risk, as previous field experiments by Haisley, Mostafa, and Loewenstein (2008) have found that being cued to perceive oneself as lower income increases the number of lottery tickets one purchases. Second, their demonstration that such a treatment can impact one’s subsequent time preferences, and that these preferences differ significantly by gender demonstrated the many intricacies of time preferences that ought to be controlled for in a lab. As mentioned earlier with respect to field opportunities impacting lab decisions, I have omitted any time lag in payment decisions in order to eliminate potential compounding effects of the treatment on time preferences, as this could manifest as risk preferences when examining lab behavior. Specifically, in the experiment, the interest payment on the ‘safe’ account is paid with the same timing as any prizes won from ‘risky’ or ‘mixed’ accounts (at the end of the session). While this is a simplification, I feel it is necessary to isolate effects on risk preferences and is not drastically different from the situation in the UK, where interest payments and Premium Bond prizes are both paid monthly.

To illustrate how time preferences can be confounded with risk preferences in the lab, consider a participant in a discount rate experiment similar to Coller and Williams (1999). If they are choosing between a series of two guaranteed payments, one “sooner” and one “later”, the experimenter would infer from their cross-over point a range of potential discount rates. The experimenter is naïve, however, to any risk the participant places on the “later” payment, such as the risk of forgetting to pick it up after six weeks have passed. The experimenter might therefore interpret the individual as having a very high discount rate, when in reality he is observing unmeasured memory risk or payment risk on the later payment. One of the earliest successful attempts to disentangle individual risk preferences from time preferences comes from Andersen et al (2008). They use a two stage method to estimate the curvature of the utility function; first the discount rate is estimated using a framework from Coller and Williams (1999), then risk aversion is estimated independently using the methodology from Holt and Laury (2002). Using the individual’s risk aversion estimate to proxy for the curvature of the utility function, they are able to infer each participant’s true time preferences, independent from risk. Like Coller and Williams (1999), they find discount rates that are more in line with market interest rates than earlier studies.

Recently, Laury et al (2012) proposed a novel solution to elicit time preferences in the laboratory in a way that is invariant to the individual’s risk preferences (i.e., the curvature of the utility function). The authors use a “choice between lotteries” framework, in which lottery A is a lottery to be drawn in 3 weeks, and Lottery B is a lottery to be drawn in 12 weeks, both with the same prize amount. The authors ask participants to choose which lottery they prefer to participate in over 20 decisions, and increase the probability of winning Lottery B incrementally over each decision. As in other similar experiments, the cross-over point between Lottery A and Lottery B represents a potential band of discount rates, but by using lotteries rather than guaranteed payments they are able to estimate the discount rate independent of risk aversion. As a control, they also have the same participants complete the independent rounds of risk and time preferences measured in Andersen et al (2008). In a within-subject comparison, the authors find consistent, "plausibly low" discount rates using either the Andersen et al (2008) method or the authors' new single-stage method.

Future experiments to determine preferences for PLS experimentally should include elements of both time preferences as in Filiz-Ozbay et al (2013), and risk preferences, as in this experiment. While it is important to understand the effect PLS has on risk and time preferences independently, the two should be tested together in field experiments with timing and rates similar to the Premium Bond to lend greater credibility to current findings on the potential welfare benefits of PLS. Laury et al's (2012) methodology will allow this to be done in a single stage without parametric assumptions about the utility function, freeing time for the experimenter to focus on treatments while controlling for the necessary curvatures of the utility function.

2.2.3 Portfolio Preferences

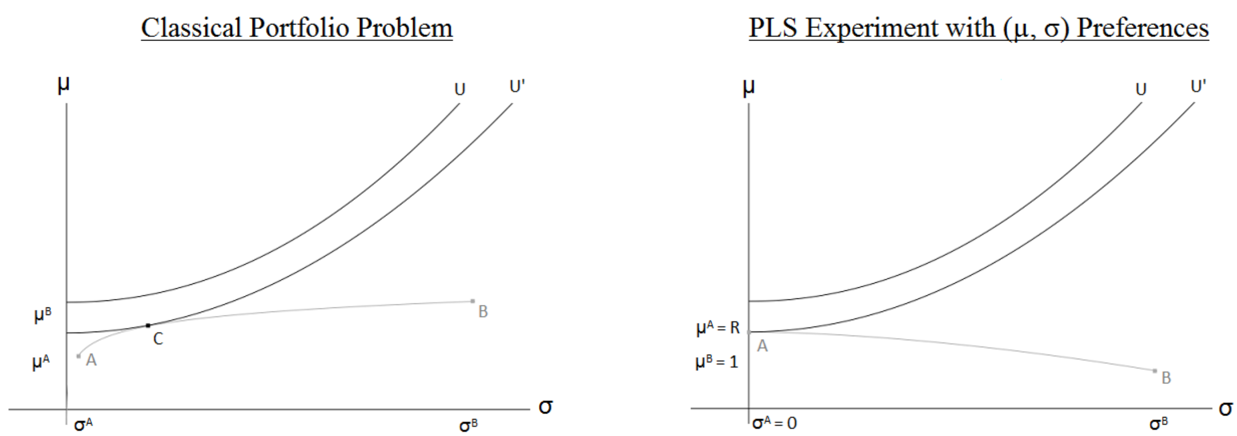
Much of expected utility theory is based on "state-contingent claims", an individual's claim to wealth or consumption for all potential future states of the world. An individual's expected utility is the sum of all these potential claims, weighted by their (subjective) probability of occurring. Discussion of individual preferences over such claims led to theories of risk aversion, e.g., many people are not equally satisfied with a claim for $100 with 50% probability as they are with a claim for $50 with 100% probability. In fact, anyone who is not risk-neutral or risk-loving strictly prefers the guaranteed $50.

Hirshleifer and Riley (1992) describe a portfolio of assets as an alternative view of state-contingent claims. Each asset consists of a set of claims over a number of potential states of the world, e.g., a corporate bond can be described as a claim to its monetary face value if "no bankruptcy" occurs, as well as a claim to a smaller fraction of its value if "bankruptcy" occurs. Any number of assets can be combined to create a portfolio of claims. If the form of the individual's utility over wealth is concave (risk averse) and quadratic, and the asset returns can be described as a normal distribution, then the individual's preferences over portfolios can be described using only two measures, the mean μ and standard deviation σ of the income generated by a portfolio. All else equal, individuals prefer portfolios with higher μ and lower σ. The authors call preferences of this form $\mu, \sigma\ preferences$ or mean-variance preferences.

The experiment offers a test of mean-variance preferences in a laboratory setting. If individuals strictly have preferences over (μ, σ) they would prefer a portfolio consisting of only the safe account, which provides both the highest μ (1.1) and lowest σ (0) relative to the risky account and 'mixed asset' (each has $\mu \leq 1.1\ and\ \ \sigma > 0$).

In *Figure 1*, I demonstrate graphically the portfolio problem for an individual with (μ, σ) preferences. In the classical portfolio problem, an individual chooses a mix of low risk, low return asset A and higher risk, higher return asset B. Without borrowing or short selling, the individual chooses some mix on the lighter-shaded portfolio set, and optimally chooses the tangency point C. The portfolio choices in the PLS experiment have less interesting predictions under (μ, σ) preferences. On the right side of *Figure 1*, the safe account is represented with A and the risky or mixed account with B, the individual always chooses the corner solution with 100% of the portfolio in safe asset A.

Figure 2: Mean-Variance Preferences in Classical Portfolio Problems vs. PLS Experiment



I view mean-variance utility functions as a useful tool, but find two of the assumptions to be too limiting to accurately describe preferences. First, the assumption that utility is quadratic restricts the individual to preferences over only the first and second derivatives of the portfolio, as its third derivative is necessarily zero. This eliminates the possibility of preferences over the skew and kurtosis of a portfolio's outcomes, i.e., non-centered outcomes and "fat tails". It is this assumption that allows the preferences to be simplified to just the two measures, but I believe that individuals do have preferences over these omitted measures. The prevalence of stocks and stock options with limited liability (skinny left tail) and unlimited upside (fat right tail) suggest preferences over kurtosis, such as the "minimax" strategies extolled by the likes of Warren Buffet. This nature of equity-linked assets hints at the second limiting assumption, that of normally distributed outcomes. It is clear that many limited liability assets like stocks do not have the infinite left tail of the normal distribution, as their loss is limited to the value invested.

For these reasons, I do not perform this experiment under the assumption that individuals preferences can be represented by (μ, σ) preferences; rather, I look to confirm to what extent these preferences are observed in a portfolio choice exercise in a laboratory. The wide divergence from "all safe" portfolios observed suggests individuals in our experiment are not driven by these two measures alone.

2.2.4 Social Preferences

A number of potential explanations for gambling behaviour stem from the theory of other-regarding preferences, the notion that one derives utility not only from consumption but from social factors such as relative income (Fehr and Schmidt, 1999), class status (Friedman and Savage, 1948), and the intentions of others (Charness and Rabin, 2002). Such preferences can predict the gambling behaviour empirically observed in segments of the population by including the social benefits of gambling; for example a rich person may participate in a national or charitable lottery because they feel good about contributing to public goods, a lower-income person may gamble because they would obtain disproportionate benefit by moving up a social class. The cases by Shapiro (2006) and Tanguay et al (2005) offer evidence of lower-income Canadians who suffer from a lack of ability to smooth consumption. PLS offers hope of alleviating both needs, one's social preferences driving a need for a chance at a life-changing sum, as well as the classical need for a savings buffer to smooth consumption.

Haisley, Mostafa, and Loewenstein (2008) demonstrated in a field experiment that the demand for lotteries among lower-income individuals is increasing in perceived income inequality. Their participant pool was recruited from the Greyhound Bus Station in Pittsburgh, PA and had median annual income of $19,944. Their treatment was a survey conducted for a $5 payment, which included one of two questions on income distribution. The control test had bins for incomes in increments of $10,000-$20,000 beginning at "$0-$10,000" and ending at "More than $60,000". The "low relative income" treatment had "Less than $100,000" as the first bin, ending at "More than $1 million". Afterwards, participants were allowed to use their $5 to purchase $1 Pennsylvania Lottery scratch tickets. They demonstrated that participants purchased more lottery tickets when they were cued to find themselves with "low relative income". The authors posited that this could be explained by a model similar to that offered by Freidman and Savage (1948), in which low-income individuals derive disproportionate utility from lottery prizes because of the associated move to the middle or upper class. With the primary population consisting of undergraduate students, I do not believe I can test for such effects on perceived relative annual income, as many students have zero income or may answer based on a belief about their parents' income. Rather, I intend to test if such an effect is observed when individuals are cued to see themselves as having significantly less disposable income to be used in a savings versus gambling decision.

Fehr and Schmidt (1999) developed a model that can accommodate such preferences as those observed by Haisley, Mostafa, and Loewenstein above. They offer a model of inequity aversion, in which an individual obtains not only utility from wealth, but from his relative wealth to those within the realm of comparison. The model takes the form:

$$U_i(\pi_i, \pi_j) = \pi_i - \alpha_i \frac{1}{n-1} \sum_{j \neq i}^{n} \max[\pi_j - \pi_i, 0] - \beta_i \frac{1}{n-1} \sum_{j \neq i}^{n} \max[\pi_i - \pi_j, 0] \; ; \; \forall j \neq i \qquad (6)$$

Note α represents the individual's degree of aversion to having *less* income than others, and β represents the individual's degree of aversion to having *more* income than others. The term π_i above becomes $u_i(\pi_i)$ when moving from a risk-neutral to a risk-averse framework. In such a model, the individual considers how he will feel about being ahead or behind of others at the outcome of the game, and chooses to minimize the associated α and β losses. For example, an individual at the low end of the income spectrum with very high α and low or negative β may choose to take a lot of risk despite their risk aversion if they are desperate to avoid the large α-related utility losses associated with coming out on the low end of the income spectrum. I expand the model above in considerably greater depth for the experiment parameters in *Section 4.4 Income Inequality.*

Charness and Rabin (2002) developed a similar model of inequality aversion of the form:

$$U_b(\pi_a, \pi_b) = (\rho \cdot r + \sigma \cdot s)\pi_a + (1 - \rho \cdot r + \sigma \cdot s)\pi_b$$
$$r = 1\ if \pi_b \geq \pi_a, 0\ otherwise$$
$$s = 1\ if \pi_b < \pi_a, 0\ otherwise$$

These preferences are similar to those in Fehr and Schmidt (1999), but rather than an individual caring specifically about being behind or ahead as measured respectively by α_i and β_i, Charness and Rabin's (2002) model is one of "conditional caring". An individual cares about other's payoffs with magnitude ρ when ahead, and cares about them with magnitude σ when behind. Modelling preferences in this way is very useful in determining the importance of intentions (e.g., by comparing choices in a dictator game versus those in an ultimatum game), but does not add much to the discussion of an individual's preferences over inequality. This model also allows to test for an individual's preferences between efficiency (Pareto improvement) and distributional equality. Because the experiment excludes any role for intentions or reciprocity between participants, I focus on the (Fehr and Schmidt 1999) model.

2.3 The Importance of Context

Harrison and List (2004) provide a categorization of field experiments; their six factors are the subject pool, the information subjects bring to the task, the commodity within the task, the nature of the task or trading rules applied, the stakes, and the environment the subject operates within.

Their paper provides a review of a number of previous field experiments of various forms, and does an excellent job of highlighting the ways in which specific context, experience, or subject pools in the field may result in different findings than a similar experiment conducted with students in a lab. The authors state that

"…if one wants to draw conclusions about the validity of theory in the field, then one must pay attention to the myriad of ways in which field context can affect behavior. We believe that conventional lab experiments, in which roles are exogenously assigned and defined in an abstract manner, cannot ubiquitously provide reliable insights into field behavior."

Eckel and Grossman (1996) tested such laboratory context in between-subject comparison of contributions in a public goods game. They noted large differences between contributions depending on whether they were giving "to another person" versus "to a charity". This led them to conclude:

"Experimental procedures should be as context-free as possible*, and the interaction among subjects should be carefully limited by the rules of the experiment to ensure that they are playing the game we intend them to play.* ***For tests of economic theory, these procedural restrictions are critical****. As experimenters, we aspire to instructions that most closely mimic the environments implicit in the theory, which is inevitably a mathematic abstraction of an economic situation. We are careful not to contaminate our tests by unnecessary context.* ***But it is also possible to use experimental methodology to explore the importance and consequence of context****. Economists are becoming increasingly aware that social and psychological factors can only be introduced by abandoning, at least to some extent, abstraction.* ***This may be particularly true for the investigation of other-regarding behavior in the economic arena.****" [Emphasis added]*

In the experiment, I hope to determine the importance of "inequality" as an other-regarding contextual variable in a portfolio construction exercise; as such I introduce the context of income allocation prior to the decision task as in McLeish and Oxoby (2007). In order to have a clean test of the impact of income inequality, I abstract away from other context, such as explicitly naming the account types "lottery tickets" or "prize linked savings", which might allow participants to draw on more dominant heuristics or beliefs they have about lotteries. Such abstraction from context allows us to test the theory of other-regarding preferences offered by Fehr and Schmidt (1999), namely whether risk-taking behaviour is better predicted when incorporating relative income into the expected utility framework.

Benartzi and Thaler (2001) empirically examined behavior in retirement savings plans of 170 companies. They found that the more stock funds the plan offered, the greater the percentage of participants' money invested in stocks. In the same paper, the authors survey university employees on how much of their retirement money they would invest in each of two funds. Regardless of the assets in respective funds offered (whether all equities, all bonds, or a blended fund), individuals most frequently chose a 50/50 split, resulting in very different mixes of equities and bonds depending on what was offered. Thaler and Sunstein (2008) refer to this as the diversification heuristic, where individuals typically invest a share of their wealth (1/n) equally over the n available options. "This result implies that the set of funds offered in a particular [retirement] plan can greatly influence the choices participants make". Further, Thaler and Sunstein find this heuristic is robust to children, who demonstrate similar behaviour when choosing a 'portfolio' of candies while trick-or-treating. In order to test this heuristic, I use a within-subject design, comparing the portfolios constructed by individuals both with and without the availability of a PLS option. I aim to test the effect a PLS option has on risk-taking, the specific mixes of portfolios selected offer clues of whether the heuristic itself or some other factor resulted in a change in risk preference. As a point of interest, I find subjects' behaviour cannot be explained by the diversification heuristic, with supporting analyses in *Appendix D.*

Chapter Three: Research Questions

Based on the empirical evidence of lottery spending, I conjecture a link between the level of income inequality the person perceives, and their utility of prize money. This link is shown by Haisley, Mostafa, and Loewenstein (2008) who established that experiment participants were more likely to purchase lottery tickets when they were primed to perceive that their own income was low relative to an implicit standard.

Further, I suggest that choice architecture plays an important role in the risks taken with income, whether disposable or for retirement, as found by Benartzi and Sunstein (2001). The mere existence of PLS around the world suggests that there are individuals for whom it is preferable to save more when that savings creates a chance – however small – of large payoffs. Prior to the existence of PLS in these individuals' respective countries they could have replicated the payoffs of PLS very closely by saving an identical amount to their PLS contribution and spending all accrued interest on lottery tickets. I do not believe this behaviour can be accounted for by transaction costs, particularly as the majority of individuals who participate in PLS were lottery players prior to entering PLS.

I hope through the experiment, to begin to answer the following questions:

1) **How does the perception of income inequality affect an individual's choices over portfolios of risk (e.g., willingness to gamble)?**
    a. How do predictions from Fehr and Schmidt's (1999) model of preferences over inequality compare to predictions from classical expected utility theory in the choice of portfolios of risk?
    b. This question will be addressed through a between-subject design. Subjects are randomly assigned into "no inequality" treatments in which all are endowed with $20, or "inequality" treatments, in which half are randomly assigned $10 and half are randomly assigned $30. I look for significant differences in risk taking (e.g., portfolio variance, percentage of wealth at risk) across the three income treatments.

2) **How, if at all, can the structure or context surrounding a decision affect an individual's observed preferences over portfolios of risk?**
    a. Given that PLS can be thought of as a hybrid of saving and playing the lottery with interest earned, will subjects choose similar portfolios of risk when they are offered a PLS option explicitly?
    b. This question will be addressed through a within-subject design. Subjects undergo the same portfolio building exercise twice, in one game they are offered "safe" and "risky" accounts, and in the other there is a third "mixed" account which is effectively a mix of "safe" and "risky". I look for significant differences in risk taking across the two games, in particular, I test if individuals will take less risk in the presence of the PLS option.

3) **What drivers of PLS adoption can I identify in a laboratory setting?**
    a. Will laboratory evidence support previous hypotheses of drivers of PLS uptake?
        i. (Maynard, De Neve, and Tufano 2008) report "interest in prize-linked savings is greatest among people… who play lotteries extensively".
        ii. (Guillen and Tschogel 2002) quote bankers who "believe that (LLS) are especially successful with low-income depositors"
    b. Much of this question will be addressed using standard binary (logit) tests of experiment conditions on PLS adoption. For example, I test if there is a significant difference in the likelihood of PLS adoption between men and women; I also test for differences in PLS adoption between those who shun risk altogether versus those who take risk in the control decision *(see Section 4.1 Experiment Premise for additional details)*. Finally, I test if risk aversion as estimated by Holt and Laury (2002) is a driver of PLS adoption, either positively or negatively.

In the following section, I discuss the experimental design that will help us address the above questions, then model the individual choices faced by participants under expected utility theory and Fehr and Schmidt's (1999) model of inequity aversion. I develop the conditions for lottery participation to be rational and preferred to savings under each model. Following this, I fit parameters of Fehr and Schmidt's model to each participant making a decision on the interior of the portfolio selection set. I then test the predictive power of the model using these parameters and compare the distribution of these values to those observed in the lab.

Chapter Four: Experiment Design

4.1 Experiment Premise

The experiment consists of groups of individuals making allocation decisions with their wealth over two independent games. Participants were randomly assigned to groups of N=8 individuals, who remain grouped together over both games. The decisions made by individuals within a group affect the probabilities and prizes faced by other participants in the group, but each group of 8 is independent of other groups. Each individual's wealth w_i is randomly assigned within a known distribution and remains constant across both games.

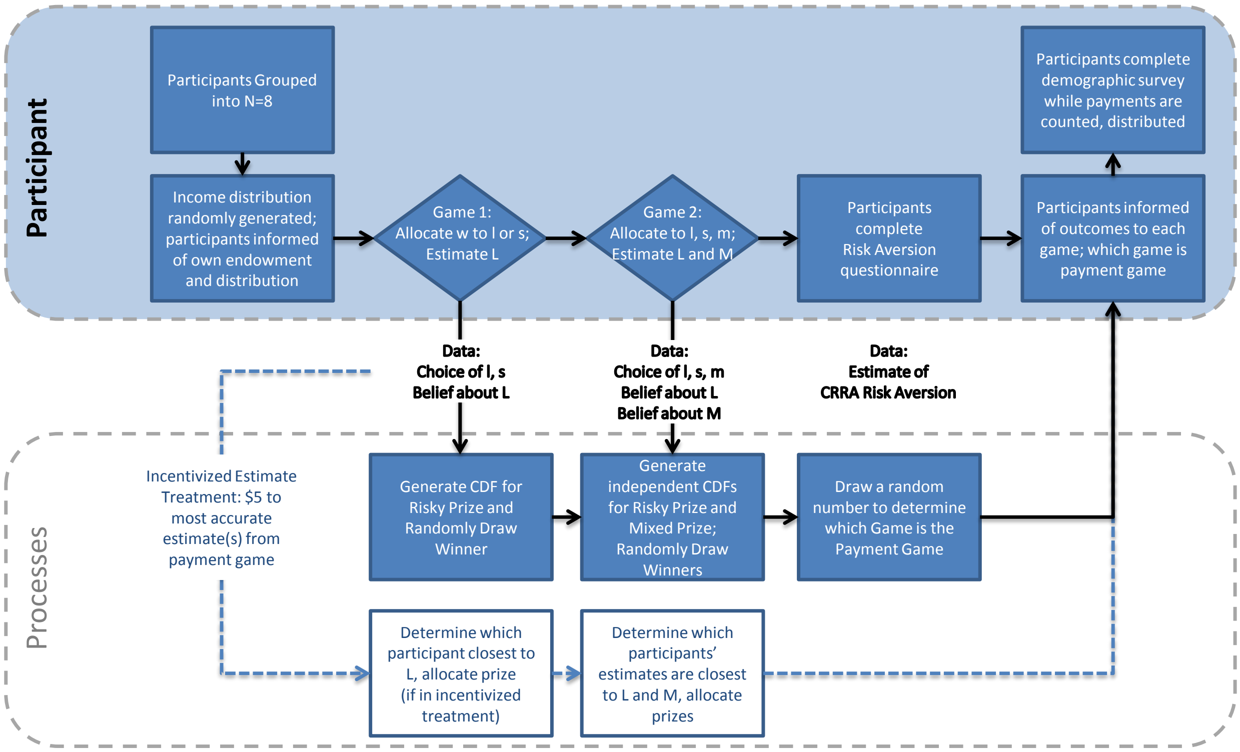
In each game, participants allocated a given endowment across accounts. Participants were not aware of the allocations made by the other members of their group. In Game 1, participants allocate their wealth between a 'safe account' and 'risky account'. In Game 2, a third, 'mixed account' representing a PLS option was available. The individual profit functions are as described in the next section. As they made their decisions, participants were asked to record what they believe the contributions of the group were in order to estimate their perceived probabilities and variances.

Following each participant's allocation decision, a computer calculated a wealth outcome for each participant in the group subject to the probabilities and prizes their decisions have generated. This outcome included any savings interest accrued as well as any risky account prizes and mixed account prizes won in that game. These outcomes were not revealed to participants until after the completion of all games.

After the completion of both games, one game was chosen at random and participants are paid their wealth outcome generated for that game. This random-lottery incentive system removes the possibility of generating wealth effects over a number of games (Wakker, 2007).

Figure 3 demonstrates the experiment flow, with the participant path highlighted. Key data collected include participant portfolio choices, their beliefs about the group's decisions, and estimates of their risk aversion derived from Holt and Laury (2002).

Figure 3: Experiment Flow Diagram – Participant Focus



4.2 Experiment Logistics

CBEEL research assistants and professors periodically recruit individuals from University of Calgary lectures who are interested in paid economic experiments to register through the online recruitment system for economic experiments (ORSEE). All of our 64 participants are registered with ORSEE, and registered to participate in scheduled sessions when invited by e-mail. The experiment was conducted at the CBEEL laboratory at the University of Calgary using zTree and zLeaf software (Fischbacher, 2007). Participants were seated at personal computer terminals and given a copy of the instructions in *Appendix A* before they were read aloud by an experimenter. Participants had an opportunity to ask questions before beginning.

zTree randomly assigned individuals in the lab into groups of n=8, participants were not aware of who specifically was in their group. zTree then randomly assigned a number to each participant in each group, and that was used to generate the distribution of endowments to group members. Before the games began, participants were informed of their endowment, and the distribution of endowments to others in their group, without specific information of any one person's endowment. All participants then entered the first game, where they allocated their entire endowment in increments of 1 Lab Dollar ($0.10 CAD) to either the safe or risky account using a keyboard and mouse in zLeaf software. They also entered an estimate of their entire group's total allocation to the risky account. Following Game 1, the third page of instructions from *Appendix A* was distributed to participants to introduce the mixed account, and participants worked through the sample problems on a whiteboard with the experimenter to ensure understanding. Game 2 then began, with individual allocations and estimates entered into zLeaf. Their individual decisions and estimates are included as part of *Table 9*.

After completing both games, participants completed the Holt and Laury (2002) CRRA risk aversion table and a short demographic questionnaire. After all participants completed the questionnaire, they were informed privately on the computer screen of their wealth outcome from both games, including whether they had won any prizes. They were also informed of which game was randomly selected for participant payment. Experimenters paid each participant in cash, in private. Participants received a minimum show-up payment of $5.00 CAD. Though not disclosed to participants before the experiment, payment amounts were typically rounded up to the nearest $0.25 CAD for experimenter convenience.

4.3 Theory and Notation

In this section I review the expected profit functions for individuals participating in Game 1. This theory is developed in considerably more detail in *Appendix B,* including incorporation of risk aversion, social preferences, and choice structuring.

The expected profits π_i for individual i, from a basic lottery-savings decision with a single lottery prize over N individuals can be expressed as a function of the individual's wealth w_i, her choice of lottery spending (or allocation to the risky account) l_i , the gross return on saving $R=1+r$, the lottery prize L, and their beliefs about the lottery playing decisions of other individuals $E(\sum_k^N l_k)\ \forall k \neq i$:

$$E(\pi_i) = (w_i - l_i)R + \left(\frac{l_i}{\sum_i^N l_i}\right) \quad (1)$$

$$E(\pi_i) = (w_i - l_i)R + \left(\frac{l_i}{l_i + E(\sum_k^N l_k)}\right)L \quad \forall k \neq i$$

Note: In order to keep the lottery actuarially fair, $L = \sum_i^N l_i$ *so that* $E(l_i) = l_i$*. Participants are informed of the actuarial fairness by explicit statement in the instructions that the lottery prize L is the sum of all contributions.*

If one expects the participants to be risk-averse or risk neutral profit maximizers, one would expect at a minimum that they would only participate in the lottery when $\frac{\partial E(\pi_i)}{\partial l_i} > 0$, that is, the marginal expected profit from lottery participation is positive. In the treatment above,

$$\frac{\partial E(\pi_i)}{\partial l_i} = -R + 1,$$

$$\therefore \frac{\partial E(\pi_i)}{\partial l_i} < 0$$

The marginal expected profit from lottery participation is negative for any non-negative interest rate (R > 1). In this case, expected utility theory predicts zero lottery participation, i.e., no contributions to the risky account.

In *Appendix B* I verify this result under CRRA risk-averse preferences. I then extend our analysis to the Fehr and Schmidt (1999) model of inequity aversion, with terms α and β to represent the individual's degree of aversion to having less income than others, and more income than others, respectively. I examine the mathematical decision criteria in the Fehr and Schmidt model, which opens up the possibility of rational lottery participation under some conditions of inequality and beliefs about the allocations of others. The derivations in this section also enabled fitted estimates of α_i and β_i for each experiment participant i, which are further discussed in *Chapter 6: Results.*

Chapter Five: Hypotheses and Treatments

With the experiment and decision models laid out above, I generate explicit hypotheses about the outcomes to be observed. I then review the experimental treatments and related incentives that allow us to test these hypotheses.

5.1 Hypotheses

The counterfactual experimental hypotheses are categorized by their respective research questions below.

1) **How does the perception of income inequality affect an individual's choices over portfolios of risk (e.g., willingness to gamble)?**

H_{1a}) There is no difference in risk taking (as measured by perceived and actual portfolio variance σ_p^2; or percentage of wealth at risk $\frac{l_i+r\cdot m_i}{w_i}$) between those experiencing income inequality ($w_i = 10\ or\ 30$) and those in homogenous income games($w_i = 20$).

H_{1b}) Individuals are purely self-interested, and demonstrate no utility from relative income as proposed by Fehr and Schmidt (1999). Specifically, a restricted model where the inequity aversion parameters $\alpha = \beta = 0$ performs as well as the F-S model in explaining individual behavior in the laboratory experiment.

2) **How, if at all, can the structure or context surrounding a decision affect an individual's observed preferences over portfolios of risk?**

H_2) Individuals demonstrate no difference in risk taking (as measured by σ_p^2 and $\frac{l_i+r\cdot m_i}{w_i}$) between Game 1 and Game 2; that is, they construct portfolios with similar risk, expected value, or percentage at risk in both games.

3) **What drivers of PLS adoption can I identify in a laboratory setting?**

H_{3a}) There is no correlation between individual risk aversion (η_i^R, a range estimated using methodology from Holt and Laury, 2002) and PLS adoption.

H_{3b}) There is no difference between genders in PLS adoption

H_{3c}) There is no difference in PLS adoption based on relative income ($w_i = 10, 20,$ or 30)

H_{3d}) Individuals observed taking risk in Game 1 ($l_i > 0$) are no more likely to adopt the PLS in Game 2 than those who shun risk altogether in Game 1.

5.2 Constant Parameters

The following parameters remain constant across all games:

R = 1.1;

N = 8;

w_i constant $\forall i$ as described below.

5.3 Income Inequality

In order to generate income inequality and test **H_{1a}, H_{1b},** and **H_{3c}**, each group will be randomly selected into one of two income distributions described below:

No Inequality: $w_i = \$20\ \forall i \in I\ (1,2,..,8)$

Inequality: $w_i = 10\ if\ 1 \leq i \leq 4;\ w_i = 30\ if\ 5 \leq i \leq 8\ ;\ i \in I$

These hypotheses are tested with a between-subject design, I test whether there is a significant difference in the risk preferences of individuals when they are primed to perceive themselves as experiencing inequality. I am particularly interested in the behaviour of those primed to perceive their income as low relative to peers, both as a means of replicating previous findings and for its potential policy implications.

5.4 Choice Architecture

In order to test **H_2**, options available to participants are varied by game:

Game 1: Participants can allocate between a safe account s_i and risky account l_i

Lottery prize L is *endogenous* and *actuarially fair, i.e.*, $L = \sum_i^N l_i$

Before Game 2, participants receive an introduction to PLS, the "mixed account".

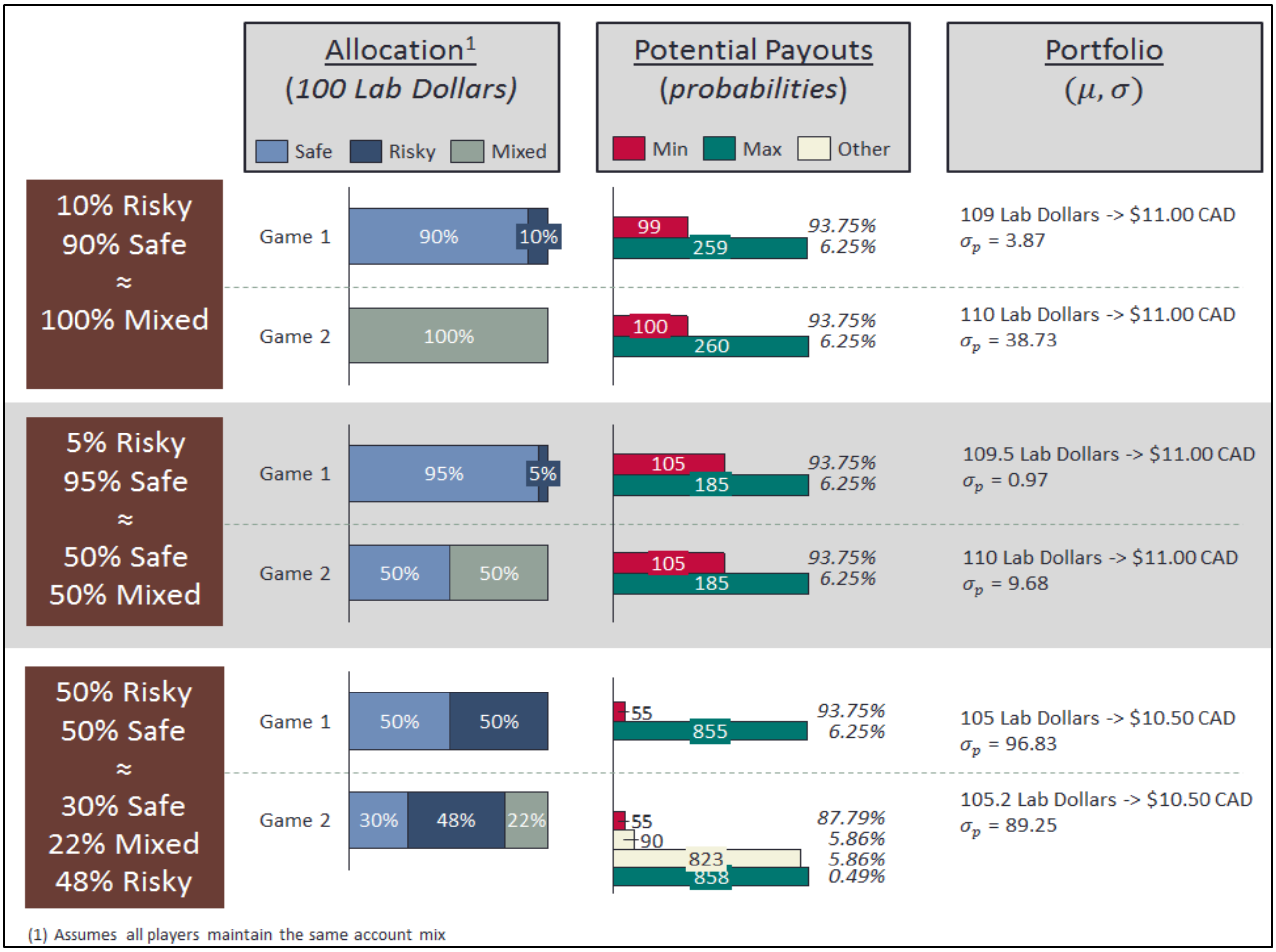
Game 2: Participants can allocate between $s_{i,}$ $l_{i,}$ and mixed account m_i

Lottery prize L is *endogenous* and *actuarially fair, i.e.*, $L = \sum_i^N l_i$

M is *endogenous* and *actuarially fair, i.e.*, $M = (R - 1) \cdot \sum_i^N m_i$

$\mathbf{H_2}$ is tested with a within-subject design; I test whether there is a significant difference in the risk preferences of an individual when they are given a PLS option which is, theoretically, just a hybrid of the safe and risky accounts. I conjecture that any risk/payoff combinations that can be created under Game 2 can be very closely replicated in Game 1, i.e., I have not fundamentally altered the selection set by introducing the mixed account. This is demonstrated through three examples in *Figure 4.* The top example demonstrates that a mix of 90% safe and 10% risky in Game 1 can be replicated with a portfolio of 100% mixed. The potential outcomes have equivalent probabilities, and equivalent payouts when rounding to outcomes in CAD. The second and third examples again demonstrate an equivalent portfolio that includes the mixed account for one relatively safe and one relatively risky portfolio, respectively. The very slight differences in expected value are driven by the fact that I use a round 10% interest rate on the mixed account. A rate closer to 9.1% would have resulted in even closer expected values but the differences were not large enough to warrant complicating the experiment with such an unusual rate. The effective equivalence of the selection set across the two games is critical to the analysis of $H_{2.}$ If the games offered fundamentally different portfolio options, I would not be able to draw any conclusions from the within-subject design. *Figure 4* provides evidence that any significant reduction in risk-taking observed in Game 2 can be attributed to the payoff structure of the mixed account, as opposed to subjects reacting to a fundamentally different problem than Game 1.

Figure 4: Effective Equivalence of Options in Game 1 vs. Game 2 – three examples



5.5 Participant Estimates

In order to generate an implicit perceived variance, participants were asked to estimate the total amount their group of 8 allocated to each account in each game while they made their allocation decisions. I believe participants have implicit incentive to estimate this amount when making their allocation decisions, as these amounts directly affect the risk/reward profile of any portfolio option. However, this incentive may not be clear to all participants, or they may simply not have sufficient incentive to enter their estimate accurately. T these estimates were elicited both with and without explicit monetary incentives, without significant differences in accuracy.

Chapter Six: Experiment Results

6.1 Discussion of Experiment Context and Interpretation of Results

As discussed in *Section 2.3*, one cannot ignore the importance of the context of the experiment. In particular, this thesis hopes to explore how the explicit context of a PLS-structured payoff compares to a context in which the same returns can be constructed without explicitly offering PLS (see *Figure 4* above). Other specific attention in this experiment ought to be paid to the account names, the rates of return, and the income inequality treatment.

With respect to the naming of accounts, I abstract away from other context, such as explicitly naming the account types “lottery tickets” or “prize linked savings”, which might allow participants to draw on more dominant heuristics or beliefs they have about lotteries. Without question the names chosen still impacted observed behaviour, but they were chosen in order to emphasize the salient characteristics of the payoff structure of each account.

With respect to the rates of return on our accounts, it is clear that the expected value of each of the three accounts is greater than their proxies in the field. Interest rates of 10% do not exist on risk-free securities, and most lotteries have an expected value closer to 0.5 than to the 1.0 offered in this experiment. It is well-established that results from this experiment could not be used to infer behaviour from the field, so rather than focusing on replicating payoffs exactly, I focused instead on making the payoff structures of “safe”, “risky”, and “mixed” both salient and representative of the underlying structure of savings, lotteries, and PLS, respectively. I focus on how PLS-type payoffs impact risk preferences relative to safe and risky payoffs, without any specific interpretation of the effect of the interest rate.

Interpretation of the income inequality treatment is most critical. As discussed in *Chapter One*, One of the segments of the population I believe could benefit the most from a Canadian PLS offering are those towards the low end of the income distribution. However, because subjects were University of Calgary students – most of whom do not work full time and obtain substantial financial support from the government or their parents – individual effects based on annual income are difficult to ascertain. Instead, it is important to focus on the relative income treatment. Participants were primed to perceive themselves among either a homogenous group of eight (each with \$20 to invest), or as part of a heterogeneous group, where they were one of four with \$10 or one of four with \$30. Results based on the income inequality treatment should not be interpreted as generalizable to the field. A difference in risk taking behaviour based on the income inequality treatment should not be viewed as evidence of greater risk taking by those of lower income, but rather by those who view their income as low relative to their comparison set, which in the field could be true of both the impoverished as well as those who view themselves as the least wealthy of their peers.

6.2 General Results

In analyzing individual risk preferences, I focus more on the risk measure $\left(\%_{at\ risk} = \frac{l_i + r \cdot m_i}{w_i}\right)$ than on portfolio variance for two reasons. First, the variance of an individual's portfolio cannot be known without knowing the total contributions to each account by each of the other group members, as this impacts the probability of winning and size of each prize. An individual's perceived variance calculated based on their estimate of prize sizes may be very different from the actual variance resulting from collective behaviour. Second, $\%_{at\ risk}$ is a more likely heuristic for decision making in the laboratory. Intuitively, individuals are more likely to consider their maximum loss or minimum wealth outcome than they are to perform complex calculations to estimate their portfolio variance. Analyses performed in this section with $\%_{at\ risk}$ are replicated using actual variance in *Appendix C*, with similar observed effects.

The first hypothesis tested is **H$_2$:** *Individuals demonstrate no difference in risk taking (as measured by* $\frac{l_i + r \cdot m_i}{w_i}$*) between Game 1 and Game 2; that is, they construct portfolios with similar risk, expected value, or percentage at risk in both games.* To test this hypothesis, I use a Wilcoxon matched-pairs signed-rank test. The null hypothesis under this test is that the observed values of *% at risk* in Game 1 come from the same distribution as the observed values of *% at risk* in Game 2. The probability of the null being true for each sub-population can be found in the bottom row of *Table 3.* Results which reject the null can be interpreted as the two distributions having significantly different medians. *Table 3* demonstrates that there is sufficient support to reject the null under $\mathbf{H_2}$ for the entire population. The Wilcoxon sign-rank test demonstrates one can reject the null that the percentage of wealth at risk chosen in Games 1 and 2 come from the same distribution. This result also holds for our "low-relative income" at a 1% significance level, and for our "high relative income" treatment at a 10% significance level. The null cannot be rejected for our subjects with homogenous relative income. Overall, there is evidence to indicate that the existence of PLS reduces risk taking, and the effect is strongest among those primed to perceive their income as low relative to an implicit standard.

Table 3: Portfolio Choices by Income Treatment

		Endowment	200	100	300	All
		Participants	24	20	20	64
		Avg. Risk Aversion	5.3	5.4	5.4	5.3
Game 1	Participation	Lottery Participants	19	16	12	47
		Lottery Penetration	79%	80%	60%	73%
	Avg. Allocation	Safe	72%	56%	77%	69%
		Risky / % at risk	28%	44%	23%	31%
		Exp. Value	214.3	105.6	323.1	214.4
		Portfolio st.dev.	58	34	35	49
Game 2	Participation	Lottery Participants	13	8	10	31
		Lottery Penetration	54%	40%	50%	48%
		Mixed Participants	19	14	14	47
		Mixed Penetration	79%	70%	70%	73%
	Avg. Allocation	Safe	44%	43%	48%	45%
		Risky	18%	16%	14%	16%
		Mixed	38%	42%	38%	39%
		% at risk	22%	20%	18%	20%
		Exp. Value	216.4	108.5	325.9	217
Delta (Game 2 v Game 1)		Change in % at risk	-6%	-24%	-5%	-9%
		% of sample reducing risk	30%	50%	55%	45%
		1-Tail Wilcoxon Signed-Rank p(Median Risk Game 2 >= Median Risk Game 1)	0.3158	0.0056	0.0933	0.0291

Table 4: Tests of Differences in Risk-Taking by Income Treatment

	Game 1			Game 2		
Endowment	Mean % at Risk	Median % at Risk	M-W U (one-tail) p(Median wi = Median wj)	Mean % at Risk	Median % at Risk	M-W U (one-tail) p(Median wi = Median wj)
100	44%	48%	0.0336	22%	15%	0.0823
300	23%	17%		20%	10%	
100	44%	48%	0.0869	22%	15%	0.0475
200	28%	8%		18%	10%	
200	28%	8%	0.2709	18%	10%	0.4562
300	23%	17%		20%	10%	

The next hypothesis tested is $\mathbf{H_{1a}}$: *There is no difference in risk taking (as measured by percentage of wealth at risk* $\frac{l_i + r \cdot m_i}{w_i}$*) between those experiencing income inequality* $(w_i = 10 \ or \ 30)$ *and those in homogenous income games*$(w_i = 20)$. To test this hypothesis, I use a Mann-Whitney U test of independent samples. The null hypothesis under this test is that the observed values of *% at risk* for a given income treatment and game are the same as those observed for a different income treatment under the same game. Results of these tests for each income treatment and game are found in *Table 4*. *Table 4* demonstrates that the amount of risk taken by those with low relative income is significantly greater than those in the homogenous or high relative income treatments, with results holding at a 10% significance level in both Games 1 and Game 2. This is in line with the empirically established prevalence of lottery playing among those of lower relative income (Haisley et al., 2008). However, there are not sufficient differences between the high relative income and homogenous income treatment to suggest they are drawn from different distributions.

When controlling for those who completely shun risk in the control game (choosing the corner solution of "all savings"), one finds further significant support for $\mathbf{H_2}$ in *Table 5*. *Table 5* compares the distribution of variances before and after a PLS option, with separation between those who were lottery players before the introduction of the PLS. A Mann-Whitney U test of the two distributions delivers a significant result, indicating that the median variance chosen when a

PLS is available is significantly lower for lottery players. This indicates substitution to a less-risky portfolio as a result of being presented a different set of choices. There is also a significant result in the opposite direction for non-lottery participants, though this is to be expected as this sample includes only participants with Game 1 variance equal to 0.

Table 5: Portfolio Choices – Risk Takers vs. Risk Shunners

		Lottery Participants	Yes	No	All
		Avg. Endowment	191.5	223.5	200
		Participants	47	17	64.0
		Avg. Risk Aversion	5.2	5.8	5.3
Game 1	Participation	Lottery Participants	47	0	73%
		Lottery Penetration	100%	0%	73%
	Avg. Allocation	Safe	60%	100%	27%
		Risky / % at risk	40%	0%	7398
		Exp. Value	203.0	245.9	49
Game 2	Participation	Lottery Participants	30	1	31
		Lottery Penetration	64%	6%	48%
		Mixed Participants	40	7	47
		Mixed Penetration	85%	41%	73%
	Avg. Allocation	Safe	38%	63%	46%
		Risky	22%	1%	16%
		Mixed	40%	36%	39%
		% at risk	26%	5%	20%
		Exp. Value	206.5	245.6	216.9
Delta (Game 2 v Game 1)		Change in % at risk	-14%	5%	-9%
		% of sample reducing risk	62%	0%	45%
		1-Tail Wilcoxon Signed-Rank p(Median Risk Game 2 >= Median Risk Game 1)	0.0009	0.0086	0.0291

The next hypothesis tested is $\mathbf{H_3}$, under which I test for significant demographic or behavioural predictors of PLS adoption. The null hypothesis under $\mathbf{H_3}$ is that there is no correlation between *(factor being examined)* and PLS adoption. For example, under $\mathbf{H_{3a}}$ the null hypothesis is there is no correlation between individual risk aversion (η_i^R) and PLS adoption. Binary logit tests were used to determine whether one can reject the null hypotheses under $\mathbf{H_3}$, and identify significant drivers of PLS adoption. *Table 6* displays the significance levels of a variety of potential drivers of PLS adoption under a logit model. There is not sufficient evidence to reject the null hypotheses under $\mathbf{H_{3a}}$, $\mathbf{H_{3b}}$, or $\mathbf{H_{3c}}$. That is, risk aversion, gender, and relative income are not significant drivers of PLS adoption. However, there is sufficient evidence to reject the null under $\mathbf{H_{3d}}$. Those who shun risk altogether in Game 1 are significantly less likely to adopt the mixed account in Game 2. In other words, the PLS option is adopted more frequently by those who choose to take some risk (play the lottery) in the portfolio building exercise. This result lends further support for the hypothesis that choice structuring matters in a portfolio building exercise.

I expand on this PLS adoption analysis using a linear probability model in *Table 7*. Selection of continuous predictive variables was limited to individual risk taking and risk aversion, complemented by dummy variables for endowment, gender, and whether or not the individual shunned risk altogether in Game 1. I focus on the results of Model 2, which has omitted insignificant variables. The significant negative coefficients on MaleRiskShun and FemaleRiskShun suggest that those who chose the maximum expected value portfolio of “all safe” were 68% and 54% less likely to adopt PLS in Game 2. This suggests that individuals are not substituting away from riskless saving behaviour towards PLS. The coefficient on “% at Risk” is significant at -0.439, suggesting for every additional 1% an individual risks in Game 1, they become 0.44% less likely to adopt PLS. Because the “RiskShun” dummies were included, there is reason to believe the predictive effect of “% at Risk” is significant for those taking some risk. Together, these coefficients suggest that PLS is most likely to be adopted by individuals who prefer taking small (non-zero) risks in Game 1. This linear probability model suggests a PLS-type payoff (or minimax strategy) with a large guaranteed amount and a small chance of a prize is more attractive to those who take small risks than to those who shun risk altogether or those who are very risk-loving.

Table 6: Logit Tests of PLS Adoption

Logit Tests of Drivers of PLS Adoption, Significance levels in italics

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
Constant	0.999	1.366	1.3	1.099	0.847	1.099	1.017	1.743	1.846
	0.009	*0.001*	*0.005*	*0.002*	*0.014*	*0.002*	*0.187*	*0.000*	*0.003*
% at Risk	0.057								
	0.945								
CRRA Risk Aversion		-0.722							
		0.225							
MaleDummy			-0.478						
			0.414						
Wealth = 100				-0.251					
				0.675					
Wealth = 200					0.488				
					0.424				
Wealth = 300						-0.251			
						0.675			
Endowment							0.0		
							1.0		
RiskShun (li =0)								-2.100	
								0.001	
MaleRiskShun									-2.405
									0.006
FemaleRiskShun									-1.846
									0.072
MaleRiskTaker									-0.188
									0.821
FemaleRiskTaker									*Omitted Dummy*
Measures of Fit									
LR Chi^2	0	1.49	0.68	0.17	0.66	0.17	0.00	11.5	11.85
Prob > Chi^2	0.9453	0.2227	0.4091	0.6767	0.4161	0.6767	1.00	0.0007	0.0079
Pseudo R^2	0.0001	0.0201	0.0092	0.0023	0.0089	0.0023	0.00	0.1552	0.1599

Table 7: Linear Probability Models of PLS Adoption

Linear Probability Models of PLS Adoption, Significance levels in italics

Robust standard errors used throughout

	Model 1	Omit insignificant - >	Model 2
Constant	**1.004**		**1.039**
	0.000		*0.000*
% at Risk	**-0.471**		**-0.439**
	0.035		*0.029*
CRRA Risk Aversion	-0.007		
	0.959		
Dummy Wealth = 100	-0.002		
	0.985		
Dummy Wealth = 300	0.04		
	0.766		
Dummy Wealth = 200	*Omitted dummy*		
MaleRiskShun	**-0.657**		**-0.675**
	0.001		*0.000*
FemaleRiskShun	**-0.513**		**-0.539**
	0.04		*0.02*
MaleRiskTaker	0.078		
	0.389		
FemaleRiskTaker	*Omitted dummy*		
Measures of Fit			
F-statistic	**3.53**		**6.4**
Prob > F	*0.0033*		0.0008
R^2	0.2842		0.2785
Root Mean Squared Error	**0.39947**		**0.38746**

6.3 Analysis of Fehr-Schmidt Model of Inequity Aversion

In order to test the effectiveness of the Fehr-Schmidt model in predicting gambling behaviour relative to the classical CRRA model, I generated estimates of α_i and β_i for each individual, given their risk aversion estimate, belief about prize sizes, and individual endowment. This was done by iteratively calculating the values of α_i and β_i for each individual that resulted in $\frac{\partial E[u_i(\pi_i)]}{\partial l_i} = \frac{\partial E[u_i(\pi_i)]}{\partial s_i}$. Results for the mean, median, and difference from zero for the fitted α and β values are provided in *Table 8*. The estimates of $\hat{\alpha}$ and $\hat{\beta}$ for each income level were derived only from those in the sample choosing a mix of both safe and risky, as corner solutions can result in any number of possible values for α_i and β_i. Note that values for α are significantly greater than zero for all subsamples, suggesting that individuals experience utility loss from experiencing lower relative income than others. Interestingly, β values are significantly less than zero for all but those with the greatest income, suggesting individuals derive positive utility from having greater relative income than others. The values of $\hat{\alpha}$ and $\hat{\beta}$ used in generating a Fehr-Schmidt prediction can be found in the bottom right corner of *Table 8.* It is worth noting that the coefficients are larger for those in the homogenous income treatment, which is to be expected given the smaller differences in wealth in this group.

Table 9 shows the resulting predictions of the individual choice of risk under both the Fehr-Schmidt model and Classical CRRA model. Interestingly, the Fehr-Schmidt model is dependent not only on the individual's level of risk aversion and inequity aversion, but also on their beliefs about the prize size. In contrast, the classical model offers an all-or-nothing prediction of risk taking, with the threshold at CRRA coefficient $\eta_i^R = -0.0475$, which demonstrates that an individual must be strictly risk-loving in order to overcome the dominant expected value of the safe account and still prefer to take risk. In the sample of 64 individuals, the Fehr-Schmidt model offers a better prediction for 31 individuals (48.4%) and the same prediction for 22 individuals (34.4%), while the classical model is a superior predictor for the remaining 11 individuals (17.2%).

These predictions allow us to test $\mathbf{H_{1b:}}$ *Individuals are purely self-interested, and demonstrate no utility from relative income as proposed by Fehr and Schmidt (1999).* The null hypothesis is that a restricted model where the inequity aversion parameters $\alpha = \beta = 0$ performs as well as the F-S model in explaining individual behavior in the laboratory experiment. An F-test was used to generate a test of predictive value between the Fehr-Schmidt model (unrestricted) and the classical CRRA model (restricted model with linear restrictions $\alpha = \beta = 0$ for all individuals). Values at the bottom of *Table 9* suggest there is sufficient evidence to reject the null under $\mathbf{H_{1b}}$ at a 1% significance level; The F-statistic generated suggests that the Fehr-Schmidt model offers significantly better predictions.

Figure 5 provides an illustration contrasting subjects' actual risk-taking behaviour with the predicted relationship under both the classical CRRA model and the Fehr-Schmidt model. Observed individual portfolio selections and risk aversion estimates are depicted with small red dots. Generally, the expected relationship is negative; as risk aversion increases, the expected level of risk-taking should decrease. As mentioned above, the CRRA model offers an all-or-nothing prediction of risk-taking (illustrated by the dotted line), with a threshold at individual relative risk aversion $\eta_i^R = -0.0475$. Fehr-Schmidt predictions are more nuanced, and rely on both individual estimates of prize sizes (represented through the size of the bubble) as well as the inequity aversion through the $\hat{\alpha}$ and $\hat{\beta}$ terms. For example, the grey dots - which represent Fehr-Schmidt predictions of risk-taking for our \$10 subjects – demonstrate a negative relationship, but one can see that larger prize sizes can result in greater predicted risk taking, as illustrated by the large grey bubble near $\left(\eta_i^R = 0.68,\ \%_{at\ risk} = 87\%\right)$. In such an instance, two factors mitigate the individual's relatively high risk aversion. First, a large prize size can result in large positive prize utility for individuals with $\hat{\beta} < 0$, such as our \$10 subjects. Secondary effects are even more impactful, for example a very large prize necessitates others in the group taking relatively large risks. As a result, there is very little risk of experiencing utility loss from $\hat{\alpha}$-based inequity for moderate risk taking, because there is little chance of falling behind the six individuals other than the winner.

Table 8: Fitted Values of α and β for Fehr-Schmidt Model

Tests of Fehr-Schmidt paramater difference from zero, probability null is true displayed in italics below

		Full Sample	wi=100	wi=200	wi=300	Excluding "Inconsistent"	Excluding Corner Solutions	Interior, Consistent Only: All Endowments	Interior, Consistent Only: wi=100	Interior, Consistent Only: wi=200	Interior, Consistent Only: wi=300
	N	64	20	24	20	56	39	33	9	14	10
β	Mean	-0.0854	0.0445	-0.3387	0.0887	-0.0892	-0.0877	-0.1037	**-0.0283**	**-0.2380**	**0.0165**
	Median	-0.0066	-0.0030	-0.4236	-0.0016	-0.0066	-0.0119	-0.0150	-0.0210	-0.2799	-0.0048
	t test of mean: Ho: β = 0 ; Ha: β < 0	*0.0338*	*0.2019*	*0.0001*	*0.0791*	*0.0096*	*0.0882*	*0.0110*	***0.0320***	***0.0103***	***0.1067***
	wilcoxon sign rank test of median: Ho: β = 0 ; Ha: β ≠ 0	*0.0230*	*0.8959*	*0.0008*	*0.8373*	*0.0229*	*0.0369*	*0.0179*	*0.1097*	*0.0303*	*0.5754*
α	Mean	0.5181	0.0852	1.1885	0.1464	0.4153	0.5458	0.3420	**0.0379**	**0.7229**	**0.0825**
	Median	0.0137	0.0137	0.1024	0.0070	0.0137	0.0120	0.0118	0.0135	0.0000	0.0119
	t test of mean: Ho: α = 0 ; Ha: α > 0	*0.0003*	*0.0507*	*0.0010*	*0.0118*	*0.0018*	*0.0037*	*0.0237*	***0.0683***	***0.0374***	***0.0221***
	wilcoxon sign rank test of median: Ho: α = 0 ; Ha: α≠ 0	*0.0000*	*0.0006*	*0.0003*	*0.0025*	*0.0000*	*0.0000*	*0.0000*	*0.0178*	*0.0154*	*0.0110*

I use only the interior, consistent estimates of alpha and beta as values for prediction because corner choices of 0% or 100% risky have multiple possible solutions.
"Inconsistent" solutions are those that cannot under any values of alpha and Beta reconcile the level of risk taken with the level of risk aversion; i.e., an estimate cannot be generated.

Resulting Estimates for FS Model>>

	wi=100	wi=200	wi=300
Beta Hat i	**-0.0283**	**-0.2380**	**0**
Alpha Hat i	**0.0379**	**0.7229**	**0.0825**

I am not concerned about the coefficients being larger for wi=200 because wealth differences in their group are necessarily smaller, larger coefficients are needed to impact expected utility meaningfully

Table 9: Predictions of Fehr-Schmidt Model vs. Classical CRRA Preferences

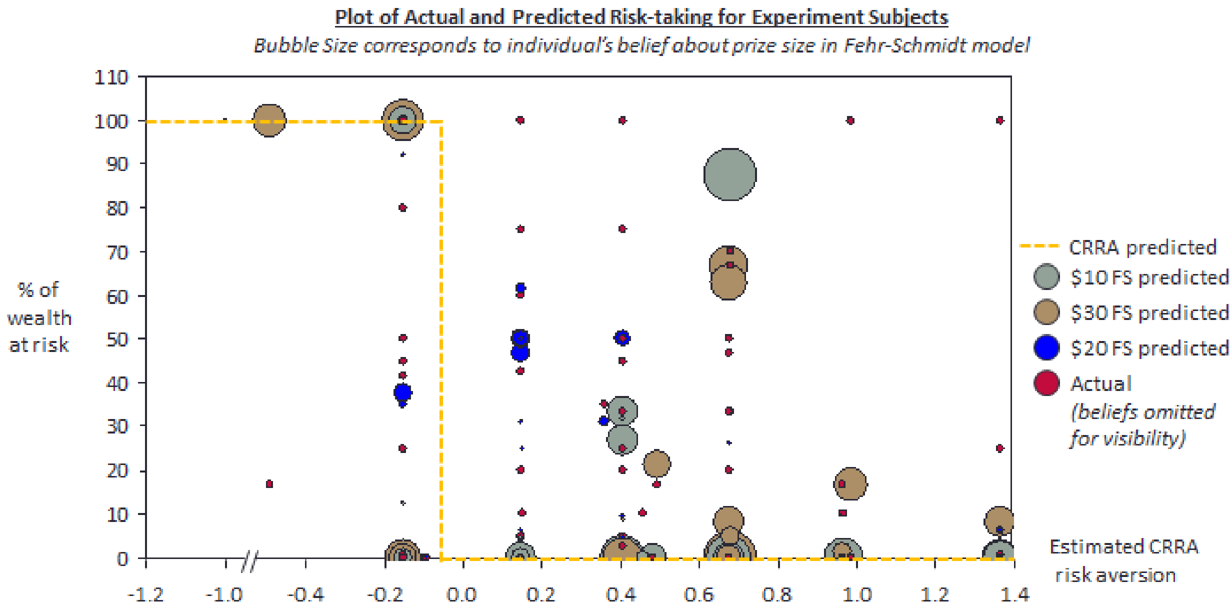
Evaluation of predictions from Fehr-Schmidt Model versus Classical CRRA preferences

	Parameters				Behaviour / Beliefs		Prediction		Evaluation		
Participant	Endowment	CRRA Risk Aversion (eta1)	Alpha Hat	Beta Hat	Actual Choice of Risky %	Belief Sum Risky	FS Prediction Risky %	Classical Predict Risky %	FS Squared Residual	Classical Squared Residual	Difference in Squared Residuals
G6P1	100	-0.15	0.038	-0.028	0%	250	0%	100%	0.00	1.00	1.0000
G6P2	300	-0.09	0.082	0.000	0%	51	0%	100%	0.00	1.00	1.0000
G6P5	100	0.99	0.038	-0.028	100%	1	100%	0%	0.00	1.00	1.0000
G8P2	300	-0.15	0.082	0.000	0%	400	0%	100%	0.00	1.00	1.0000
G5P19	200	-0.09	0.723	-0.238	0%	0	0%	100%	0.00	1.00	1.0000
G3P18	200	0.15	0.723	-0.238	100%	200	50%	0%	0.25	1.00	0.7500
G3P7	200	0.15	0.723	-0.238	100%	200	47%	0%	0.28	1.00	0.7178
'G4P23 NS'	200	-0.15	0.723	-0.238	25%	50	35%	100%	0.01	0.56	0.5525
G5P10	200	0.41	0.723	-0.238	75%	150	50%	0%	0.06	0.56	0.5000
G4P5	200	0.15	0.723	-0.238	75%	150	50%	0%	0.06	0.56	0.5000
G2P15	100	0.68	0.038	-0.028	70%	1500	87%	0%	0.03	0.49	0.4594
G1P12	300	0.68	0.082	0.000	67%	1500	100%	0%	0.11	0.44	0.3333
G7P2	100	0.41	0.038	-0.028	50%	0	32%	0%	0.03	0.25	0.2172
G7P1	300	0.68	0.082	0.000	47%	760	63%	0%	0.03	0.22	0.1911
G2P7	100	0.41	0.038	-0.028	45%	550	27%	0%	0.03	0.20	0.1690
G7P5	300	-0.15	0.082	0.000	42%	750	0%	100%	0.17	0.34	0.1667
'G5P6 NS'	200	-0.15	0.723	-0.238	1%	1	92%	100%	0.84	0.99	0.1520
G4P12	200	0.15	0.723	-0.238	43%	85	62%	0%	0.04	0.18	0.1443
G3P16	200	0.36	0.723	-0.238	35%	70	31%	0%	0.00	0.12	0.1211
G7P8	100	0.15	0.038	-0.028	60%	0	5%	0%	0.31	0.36	0.0522
G2P4	300	0.41	0.082	0.000	33%	4	9%	0%	0.06	0.11	0.0507
G2P3	300	0.68	0.082	0.000	33%	240	5%	0%	0.08	0.11	0.0305
G5P22	200	1.37	0.723	-0.238	25%	50	6%	0%	0.04	0.06	0.0273
G6P4	300	0.68	0.082	0.000	20%	500	8%	0%	0.01	0.04	0.0264
G7P7	300	0.50	0.082	0.000	17%	400	21%	0%	0.00	0.03	0.0257
G2P6	100	0.41	0.038	-0.028	20%	500	33%	0%	0.02	0.04	0.0224
G8P7	300	0.97	0.082	0.000	17%	250	1%	0%	0.02	0.03	0.0037
G4P9	200	0.15	0.723	-0.238	5%	10	6%	0%	0.00	0.00	0.0023
G5P3	200	0.15	0.723	-0.238	5%	10	6%	0%	0.00	0.00	0.0023
G5P14	200	0.41	0.723	-0.238	5%	10	9%	0%	0.00	0.00	0.0006
G3P15	200	0.41	0.723	-0.238	3%	5	5%	0%	0.00	0.00	0.0001
G6P7	300	0.68	0.082	0.000	33%	800	67%	0%	0.11	0.11	0.0000
G1P11	100	0.15	0.038	-0.028	20%	200	0%	0%	0.04	0.04	0.0000
G1P5 NS'	100	0.97	0.038	-0.028	10%	4	0%	0%	0.01	0.01	0.0000
G1P9	100	0.97	0.038	-0.028	10%	800	0%	0%	0.01	0.01	0.0000
G1P8	300	0.41	0.082	0.000	33%	800	0%	0%	0.11	0.11	0.0000
'G2P1 NS'	100	-0.15	0.038	-0.028	50%	400	100%	100%	0.25	0.25	0.0000
G5P17	200	-0.15	0.723	-0.238	45%	90	100%	100%	0.30	0.30	0.0000
G3P24	200	1.37	0.723	-0.238	0%	0	0%	0%	0.00	0.00	0.0000
'G4P8 NS'	200	0.97	0.723	-0.238	0%	0	0%	0%	0.00	0.00	0.0000
G6P3 NS'	300	-0.15	0.082	0.000	100%	950	100%	100%	0.00	0.00	0.0000
G6P6	100	0.68	0.038	-0.028	50%	490	0%	0%	0.25	0.25	0.0000
G6P8	100	0.41	0.038	-0.028	100%	1100	0%	0%	1.00	1.00	0.0000
G7P3	100	0.68	0.038	-0.028	0%	1100	0%	0%	0.00	0.00	0.0000
G7P6	300	1.37	0.082	0.000	0%	4	0%	0%	0.00	0.00	0.0000
G8P1	100	0.15	0.038	-0.028	100%	500	0%	0%	1.00	1.00	0.0000
G8P3 NS'	300	-0.49	0.082	0.000	17%	650	100%	100%	0.69	0.69	0.0000
G8P4	100	1.37	0.038	-0.028	100%	655	0%	0%	1.00	1.00	0.0000
G8P5	100	1.37	0.038	-0.028	0%	750	0%	0%	0.00	0.00	0.0000
G8P6	100	0.49	0.038	-0.028	0%	400	0%	0%	0.00	0.00	0.0000
G8P8	300	0.15	0.082	0.000	0%	0	0%	0%	0.00	0.00	0.0000
G2P10	300	0.68	0.082	0.000	0%	350	0%	0%	0.00	0.00	0.0000
G4P2	200	0.41	0.723	-0.238	25%	50	50%	0%	0.06	0.06	0.0000
G3P1	200	1.37	0.723	-0.238	1%	1	6%	0%	0.00	0.00	-0.0033
G2P2	300	1.37	0.082	0.000	0%	500	8%	0%	0.01	0.00	-0.0069
G1P13	300	0.68	0.082	0.000	0%	500	8%	0%	0.01	0.00	-0.0069
G4P21	200	0.15	0.723	-0.238	10%	20	25%	0%	0.02	0.01	-0.0125
G1P14	300	0.99	0.082	0.000	0%	600	17%	0%	0.03	0.00	-0.0278
G3P20	200	0.68	0.723	-0.238	0%	0	26%	0%	0.07	0.00	-0.0689
G5P11	200	0.15	0.723	-0.238	0%	0	31%	0%	0.10	0.00	-0.0977
G3P4	200	0.15	0.723	-0.238	5%	9	50%	0%	0.21	0.00	-0.2050
G4P13	200	-0.15	0.723	-0.238	100%	200	38%	100%	0.39	0.00	-0.3906
G7P4 NS'	100	-0.15	0.038	-0.028	80%	8	13%	100%	0.46	0.04	-0.4154
G1P16	100	0.46	0.038	-0.028	10%	120	87%	0%	0.60	0.01	-0.5886

Sum of Squared Residuals (FS Model)	9.2229	
Sum of Squared Residuals (Restricted/Classical Model)		17.6178
Restrictions	2	
Regressors	4	
Observations	64	
F-test Numerator	4.1974	
F-test Denominator	0.1563	
F-statistic	**26.85**	
F-statistic threshold, 0.99 confidence, 2df1, 59df2	**4.984**	<- FS is a significantly bet

	N	Share	Mean Belief L	Median Risk Aversion	Mean Endowment
Observations where FS predicts better	31	48.4%	279	0.41	210
Observations with equal prediction	22	34.4%	459	0.58	182
Observations where Classical predicts better	11	17.2%	178	0.46	209
TOTAL	64	100.0%	323	0.41	200

Figure 5: Actual and Predicted Risk-taking under Classical and Fehr-Schmidt Models



Chapter Seven: Conclusion

7.1 Concluding Remarks

This study was designed to inform a Canadian policy discussion about the potential effects of prize-linked savings on risk preferences, particularly those who perceive their income as low. I find the lack of prize-linked savings options in North America both notable and surprising, and hope this study can provide evidence to those looking to champion the launch of such accounts in Canada.

The study is provided external validity by the previous findings of other researchers. Notably, the experiment produced greater levels of gambling among the participants with low relative income, replicating empirical evidence of greater lottery playing at the lowest levels of the income distribution and evidence from field experiments conducted by Haisley et al (2008). Further, the estimates of α and β parameters for the Fehr-Schmidt model are in line with previous findings (Fehr and Schmidt 1999, Charness and Rabin 2002), particularly for the no-inequality treatment (with α near 0.7 and β near zero); coefficients for the inequality treatment are necessarily smaller due to the magnified differences in wealth. The models of inequity aversion do a significantly better job of describing risk preferences of individuals than the classical model, providing yet another piece of evidence to the literature looking to explain gambling in an expected utility framework that began with Friedman (1948).

The within-subject test of risk-taking with and without a prize-linked savings option supports the notion that choice structuring plays an important role in portfolio selection, as previously suggested by Thaler and Sunstein (2008). In particular, the result of participants taking significantly less risk in the presence of a prize-linked savings option supports the policy case for PLS as a tool for enabling greater consumption smoothing among lower-income individuals. The risk-reduction result is strongest for those with low relative income, suggesting potential for meaningful policy impact for individuals who view their income as low relative to their comparison set.

I believe these three pieces of evidence – greater risk-taking among those who perceive their income as low, risk-reduction in the presence of prize-linked savings options, and the explanatory power of other-regarding preferences – provide a sufficient case to invest in the development of a field study of prize-linked savings in Canada. Such a field study should include a more representative sample of Canadian society than my convenience sample of university students, and should be of sufficient scale to create prize sizes that more closely replicate real life lotteries and Premium Bond prizes. Further, the study should include a period of pre and post-treatment observation of savings and gambling behaviour in order to tease out long-term effects on behaviour (such as substitution away from traditional savings or traditional gambling) versus those created by novelty.

In addition to field study, there is a policy case to be made for *how* to effectively implement a PLS program in Canada. The major private banks in Canada would no doubt appreciate the opportunity to offer PLS and obtain the clear first-mover advantage (more accounts create larger prizes, drawing more accounts in a positive-feedback loop), and would invest substantially in a product launch. However, the success and subsequent shutdown of South Africa's MaMA account lead us to believe that politically, housing the accounts within the treasury or central bank is much more tenable. My initial view is that private banks could be used for distribution, while the balance sheet belongs to the government, as is the case with Ontario Savings Bonds. Such a policy case would also need to carefully lay out the welfare benefits of PLS versus the potential loss of government revenues through the provincial lottery boards (due to substitution effects from gambling to PLS). Finally, the tax status of prizes should be considered; there is no doubt that the tax-free status has boosted the balances and prize sizes of the U.K.'s Premium Bond by appealing to wealthier investors, making the accounts more marketable to those with lower incomes.

Generally, I hope studies such as this can begin to sway Canadian financial regulators such as the Ontario Superintendent of Financial Institutions (OSFI) to take a more open-minded and evidence-based approach to financial innovation in the retail banking environment. As Ashraf, Karlan and Yin (2006) demonstrated in the Philippines, there exists the potential for "second best” financial products that trade off classical utility benefits (such as liquidity or guaranteed interest) for behavioural benefits (such as greater savings rates and less gambling). These products are not necessarily designed to swindle non-sophisticated investors or induce them to take too much risk; they may be designed to make investing appeal to those with non-classical preferences, such as the distributional and short-term biases often measured among individuals with lower incomes.

7.2 Study Limitations

Several limitations of the experiment ought to be acknowledged, especially the sample population and untested effects.

With respect to the sample, I concede that the convenience sample of University of Calgary students available to the Calgary Behavioural and Experimental Economics Laboratory (CBEEL) is not representative of the broader Canadian population. Further, the majority of the recruiting done by CBEEL research assistants such as me occurs in economics courses, biasing the sample further. The sample size of 64 is sufficiently large to perform several non-parametric tests, but larger numbers would allow for more robust analyses and greater confidence and power of existing tests.

With respect to untested effects, I acknowledge that both inexperience and limited budget led me to omit potentially important factors in designing the experiment. First, all experimental sessions were conducted in the same order, with the “safe versus risky” game followed by the game with the mixed account as a third option creating the potential for so-called order effects. However, arguments that subjects may have reduced risk in the second game from learning or regretting an outcome from the first are mitigated by two factors: that the outcome of both games was not revealed until all decisions were made, nor was the decision of which game was to be paid. These points were made clear to subjects in the instructions, so there is reason to believe they made their best decisions in both games independently. Due to budgetary constraints, I was not able to test for the effects of payout magnitude, for example by conducting treatments in which prize distributions more closely resembled real-life lotteries and Premium Bonds. Finally, it is clear that including questions about the gambling behaviours of participants in the demographic survey would have been wise, an omission that leaves an important question unanswered.

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APPENDIX A: PARTICIPANT INSTRUCTIONS – INEQUALITY TREATMENT

You will be participating in an experiment during which you will be asked to make a series of decisions. Based on these decisions and those of others, you will receive a monetary payoff. Your decisions and those of others will be tracked using software in the laboratory. All your decisions is confidential and entered on the computers. Personal information cannot be identified

We ask that you refrain from talking to one another; if you have questions raise your hand and the experimenter will help. If your question cannot be answered before completion of the experiment (e.g., questions about the design of the experiment) there will be opportunity for debrief following the experiment. The experiment will last approximately 30 minutes.

<u>Experiment Structure:</u>

You will be placed in a group of eight (8) individuals who will play of two (2) one-shot games, followed by a short individual questionnaire. At the end of the experiment, the computer will randomly select your payoff for one of the games and you will receive that amount for your participation in today's experiment. As either game may be chosen, you should make the best decisions you can in each game.

<u>Money Allocation</u>

Before the games begin, the experimenter will randomly assign money to the eight (8) people in your group. Four (4) people will be given 300 Lab Dollars, and four (4) people will be 100 Lab Dollars (where 10 Lab Dollars = $1.00 CAD). You will be told which group you are in, but will not be told which group any other participant is in. You will have the same amount of money for both games.

<u>Instructions</u>

In Game 1, you must decide an amount to allocate to one of two accounts: the 'safe' account and the 'risky' account. The amount of money you are provided must be allocated between the on screen boxed marked "safe account" and "risky account". You can choose to allocate any amount from zero to all of your money in each account, and amounts are divisible to one Lab Dollar (no fractions or decimals). After every participant has submitted their decision, a winner is chosen to receive the Risky prize for that game (details below).
Game 2 is constructed in a similar fashion to fame 1, and additional instructions will be provided upon the completion of Game 1.

<u>The Risky Account:</u>

In each game, there will be one winner of the "Risky Account Prize". For each Lab Dollar you put in the Risky Account, you have one draw for the Risky Account Prize. For example, if you allocate 100 Lab Dollars to the Risky Account, and the sum total of everyone else's allocation to the Risky Account is 900 Lab Dollars, you have a 1 in 10 (100/1,000 total = 1 in 10 or 10%)

chance of winning the Risky Account Prize. Each group of 8 participants create the Risky Account Prize based on their decisions; the Prize is equal to the sum of all allocations to the Risky Account. All prize draws will be performed randomly by the software.

Interest on the Safe Account:

Safe account deposits pay 10% guaranteed interest per game. For example, if you choose to allocate 50 Lab Dollars to the safe account, that money will grow to 55 Lab Dollars by the end of the Risky Account Prize draw.

Estimate Prize

You will be asked to estimate the total Risky contributions of your entire group. The member of your group with the closest estimate to the actual total Risky contributions will win an Estimate Prize of 50 Lab Dollars. Any ties will split the prize.

Outcomes and Payment:

Your "outcome" for each game is the total money you have after the Risky Account Prize winner is drawn. This is equal to your total Lab Dollars in the Safe Account plus 10% interest, plus any Risky Account prize you may have won. Lab Dollars allocated to the Risky Account that do not win the prize have no value. Games are independent of each other; e.g., Game 1 savings do not accumulate to Game 2.

The outcome of each game will be revealed to participants after all 8 participants in the group have made a choice and random outcomes are determined.
Payment will be calculated based on the outcome of one of the games, which will be randomly selected after all games are completed. For example, imagine you began Game 1 with 200 Lab Dollars, and chose to allocate 100 to the Safe Account, and 100 to the Risky Account. Further, imagine you were not the Risky Account Prize winner in Game 1. If Game 1 is selected as the payment game, your payment for the experiment is the 100 Lab Dollars in the Safe Account, plus 10 Lab Dollars of interest. This will be converted to CAD before payment, ((100+10)/10 = $11.00). In this example, the outcome of Game 2 is irrelevant to your payment. Any game can be selected for payment, with equal probability.

Survey and Payment Calculation:

Following Game 2, you will be asked to complete a short survey, and then called up to receive your payment. Upon completion of the survey, an experimenter will stay in the room to debrief or answer any questions.

Mixed Accounts:

For Game 2 we will introduce a third option for your money; a “Mixed Account”. As before, you must divide all of your money between the boxes labeled “Safe Account”, “Risky Account” and “Mixed Account”. Mixed Accounts work like Safe Accounts where the value of the money you put in is guaranteed, however the interest payment is different. Rather than being paid a guaranteed 10% interest, all contributions to the mixed account are pooled and the 10% interest on that amount , the “Mixed Account Prize,” is randomly allocated to only one contributor.
For example, imagine all 8 participants invest 100 Lab Dollars each in a Mixed Account. Each participant’s deposit earns 110 Lab Dollars of interest, and all of this interest is pooled together for a total of (10 * 8 = 80 Lab Dollar Mixed Account Prize pool). Each participant will keep their 100 Lab Dollar deposit, and one participant will be randomly chosen to win the additional 80 Lab Dollars in the Mixed Account Prize pool.

Mixed Account Prize odds:

Your odds to win the Mixed Account Prize work in the same way as Risky Account Prize odds; for each Lab Dollar in the Mixed account, you have one draw for the Mixed Account Prize. For example, if you allocate 100 Lab Dollars in a Mixed Account, and the total of everyone else’s Mixed Account deposits is 900, you have a 1 in 10 (100/1,000 total = 1 in 10 or 10%) chance of winning the Mixed Account prize. In this case, the Mixed Account prize would be 100 Lab Dollars (1,000 of total Mixed Account deposits *10% Mixed Account interest).

Estimate Prizes

In Game 2, there are two Estimate prizes like that in Game 1. 50 Lab Dollars goes to the closest estimate for each of total Risky and total Mixed contributions. Any ties will split the prize.
Please answer the questions below to be sure all participants understand the Mixed Account

In each question, assume you do not win the estimate prize.

1. Say you begin a game with 200 Lab Dollars, and allocate 100 to the Safe Account and 100 to the Mixed Account. If you do not win the Mixed Account prize, how large is your outcome for the game?

2. Say you begin a game with 150 Lab Dollars, and allocate 100 to the Safe Account and 50 to the Mixed Account. If total Mixed Account deposits across all participants equal 400 Lab Dollars, and you win the Mixed Account Prize, how large is your outcome?

3. Say you begin a game with 100 Lab Dollars, allocate 50 to the Risky Account and 50 to the Mixed Account. If you do not win either of the Risky Account prize or the Mixed Account Prize, how large is your outcome?

APPENDIX B: DECISION CRITERIA AND METRICS UNDER RISK AVERSION, FEHR AND SCHMIDT INEQUITY AVERSION, AND CHOICE ARCHITECTURE

B.1. Risk Aversion

Incorporating risk-averse preferences, such as the constant relative risk aversion (CRRA) utility function, where $\eta_i \geq 0$ represents individual i's constant of relative risk aversion:

$$u_i(\pi_i) = \frac{(\pi_i)^{1-\eta_i} - 1}{1 - \eta_i}$$

Individuals make an allocation decision to maximize expected utility of wealth (2), subject to their beliefs about other's contributions to the lottery prize $E(\sum_k^N l_k)\ \ \forall k\ \neq i$:

$$\max_{l_i} E[u_i(\pi_i)] = \left(\frac{l_i}{l_i + E(\sum_k^N l_k)}\right) \frac{\left((w_i - l_i)R + l_i + E(\sum_k^N l_k)\right)^{1-\eta_i} - 1}{1-\eta_i} + \left(\frac{E(\sum_k^N l_k)}{l_i + E(\sum_k^N l_k)}\right) \frac{\left((w_i - l_i)R\right)^{1-\eta_i} - 1}{1-\eta_i} \qquad (2)$$

The first two terms of (2) are the probability and utility of winning the lottery prize, respectively, and the third and fourth terms are the probability and utility of losing the lottery prize. Again it is required at a minimum that $\frac{\partial E[u_i(\pi_i)]}{\partial l_i} > 0$ for lottery participation to be individually rational. Examining the first order condition (FOC):

$$\frac{\partial E[u_i(\pi_i)]}{\partial l_i}$$

$$= \left(\frac{E(\sum_k^N l_k)}{[l_i + E(\sum_k^N l_k)]^2}\right)\left[\frac{\left((w_i - l_i)R + l_i + E(\sum_k^N l_k)\right)^{1-\eta_i} - \left((w_i - l_i)R\right)^{1-\eta_i}}{1 - \eta_i}\right] \qquad (3)$$

$$+ \left(\frac{l_i}{l_i + E(\sum_k^N l_k)}\right) \frac{(1 - R)}{\left((w_i - l_i)R + l_i + E(\sum_k^N l_k)\right)^{\eta_i}} + \left(\frac{E(\sum_k^N l_k)}{l_i + E(\sum_k^N l_k)}\right) \frac{-R}{\left((w_i - l_i)R\right)^{\eta_i}}$$

The terms on the bottom line of (3) are necessarily non-positive because R >1, while the top row is necessarily non-negative. Note that this can be re-written in a more intuitive form, and signed:

$$\frac{\partial E[u_i(\pi_i)]}{\partial l_i} = \frac{\partial p(win)}{\partial l_i}\left[u_i\left(\pi_i^{win}\right) - u_i\left(\pi_i^{lose}\right)\right] + p(win)\frac{(1-R)}{\left(\pi_i^{win}\right)^{\eta_i}} + p(lose)\frac{-R}{\left(\pi_i^{lose}\right)^{\eta_i}} \quad (4)$$

$$\frac{\partial E[u_i(\pi_i)]}{\partial l_i} = (>0) \qquad [\geq 0] \qquad + (\geq 0)\frac{(<0)}{(>0)} \quad + \quad (\geq 0)\frac{(<0)}{(\geq 0)} \quad (5)$$

Equation (4) shows that the marginal expected utility of lottery participation is directly related to how your next dollar improves your odds, the marginal utility of winning over losing, the (subjective) winning probabilities, individual risk aversion levels, and the interest rate.

Note the signs in equation (5). It is only when $l_i = 0$ that $\left[u_i\left(\pi_i^{win}\right) - u_i\left(\pi_i^{lose}\right)\right] = 0$and $p(win) = 0$, otherwise the inequalities hold strictly. It is easily verified that

$$\left.\frac{\partial E[u_i(\pi_i)]}{\partial l_i}\right|_{l_i=0} < 0$$

Given the global concavity of the expected utility function, the result above implies that the optimal decision is all savings for any level of wealth, i.e., $l_i^* = 0\ \forall w_i$.

As such, it can be shown for any positive relative risk aversion that the rationality condition for lottery participation is not met, which does not explain the years of evidence of lottery playing around the world. In the next section I suggest potential explanations for lottery playing within these expected utility frameworks.

B.2. Income Inequality

Fehr and Schmidt (1999) make the case for individuals having preferences over equity. They use a simple model of the form:

$$U_i(\pi_i, \pi_j) = \pi_i - \alpha_i \frac{1}{n-1} \sum_{j \neq i}^{n} \max[\pi_j - \pi_i, 0] - \beta_i \frac{1}{n-1} \sum_{j \neq i}^{n} \max[\pi_i - \pi_j, 0]\ ;\ \forall j \neq i \quad (6)$$

Note α represents the individual's degree of aversion to having *less* income than others, and β represents the individual's degree of aversion to having *more* income than others. The authors suggest the parameters $\beta_i \leq \alpha_i$ and $0 \leq \beta_i \leq 1$, meaning individuals are more averse to disadvantageous inequality than advantageous inequality. Fehr and Schmidt note the possibility and previous evidence suggesting β_i can be negative, i.e., some individuals can derive utility from having more income than others. I therefore use the less restrictive assumption: $-1 \leq \beta_i \leq 1$ and maintain the authors' assumptions: $0 \leq \alpha_i \leq 4$ and $\beta_i \leq \alpha_i$.

When considering the case where $w_i < w_j$, there may be instances where the expected disutility from disadvantageous inequality (through the α term) is sufficiently large to drive individuals at the lower end of the initial wealth spectrum to gamble, in order to minimize the expected disutility from inequality. Maintaining Fehr and Schmidt's assumption that $\beta_i \leq \alpha_i \; \forall i$, one would expect to see individuals in the experiment who are endowed with less wealth to be more inclined to gamble, because the lower income individuals will suffer more disutility from α-type inequality than higher income individuals suffer from β-type inequality. This case is most simply illustrated where the individual is risk-neutral, i.e., $\eta_i = 0$. Substituting expected utility into (6):

$$E[U_i(\pi_i, \pi_j)] = E(\pi_i) - \frac{\alpha_i}{n-1} \sum_{j \neq i}^{n} \max[\pi_j - \pi_i, 0] - \frac{\beta_i}{n-1} \sum_{j \neq i}^{n} \max[\pi_j - \pi_i, 0]\ ;\ \forall j \neq i \quad (7)$$

In the experiment, $\pi_j - \pi_i$ is conditional on the (random) lottery outcome; in particular, different types of inequity will be experienced by player *i* based on which player wins the lottery prize *L*. Note the conditional profit functions:

$$(\pi_j - \pi_i | \ i \ win \ L) = (w_j - l_j)R - \left[(w_i - l_i)R + l_i + \sum_{k \neq i}^{N} l_k\right] = R(s_j - s_i) - L \quad \forall j \neq i$$

$$(\pi_k - \pi_i | \ j = k \ win \ L) = (w_j - l_j)R + l_i + \sum_{k \neq i}^{N} l_k - R(w_i - l_i) = R(s_j - s_i) + L \quad for \ j = k$$

$$(\pi_j - \pi_i | \ j = k \ win \ L) = R(s_j - s_i) \quad \forall j \neq k \neq i$$

Decomposing equation (7) based on conditional winning, wealth, and beliefs about the choices of others allows us to eliminate the maximand and obtain differentiable utility functions:

$$E[U_i(\pi_i, \pi_j)|\ i\ win\ L] = E(\pi_i|\ i\ win\ L)$$
$$-\frac{\alpha_i}{n-1}\sum_{j\neq i}^{n}(\pi_j - \pi_i|\ i\ win\ L) \quad where \quad R\,s_j > Rs_i + L \quad \forall j \neq i$$
$$-\frac{\beta_i}{n-1}\sum_{j\neq i}^{n}(\pi_i - \pi_j|\ i\ win\ L) \quad where \quad R\,s_j < Rs_i + L \quad \forall j \neq i$$

$$E[U_i(\pi_i, \pi_j)|\ j = k\ win\ L] = E(\pi_i|\ k\ win\ L)$$
$$-\frac{\alpha_i}{n-1}(\pi_k - \pi_i|\ j = k\ win\ L) \quad if \quad Rs_k + L > Rs_i \ \ for\ j = k$$
$$-\frac{\beta_i}{n-1}(\pi_i - \pi_k|\ j = k\ win\ L) \quad if \quad Rs_k + L < Rs_i \ \ for\ j = k$$
$$-\frac{\alpha_i}{n-1}\sum_{j\neq i\neq k}^{n}(\pi_j - \pi_i|\ k\ win\ L) \quad where \quad R\,s_j > Rs_i \ \ \forall j \neq i \neq k$$
$$-\frac{\beta_i}{n-1}\sum_{j\neq i\neq k}^{n}(\pi_i - \pi_j|\ k\ win\ L) \quad where \quad R\,s_j < Rs_i \quad \forall j \neq i \neq k$$

These two equations can be combined using the expected winning probabilities:

$$E[U_i(\pi_i, \pi_j)] = \left(\frac{l_i}{l_i + E(\sum_k^N l_k)}\right) E[U_i(\pi_i, \pi_j)|\ i\ win\ L] + \left(\frac{E(\sum_k^N l_k)}{l_i + E(\sum_k^N l_k)}\right) E[U_i(\pi_i, \pi_j)|\ k\ win\ L] \qquad (8)$$

Equation (8) represents a hypothesized thought process or heuristic used by participants in such a decision making process. In words, people consider how well off they will be in each state of the world through the $E[U_i(\pi_i, \pi_j)]$ terms, and consider a trade-off between a desire for higher probability of winning $\left(\frac{l_i}{l_i + E(\sum_k^N l_k)}\right)$ and higher wealth in the losing state $E[U_i(\pi_i, \pi_j)|\ k\ win\ L]$. Taking π as the vector of profits for all participants, this can be simplified to the equation below without loss of generality:

$$E[U_i(\pi)] = p(i\ win\ L)(E[U_i(\pi)|\ i\ win\ L] - E[U_i(\pi)|\ k\ win\ L]) + E[U_i(\pi)|\ k\ win\ L] \qquad (9)$$

Following expected utility theory, one can examine the first order conditions of expected utility with respect to the choice of l_i or s_i:

$$\frac{\partial E[U_i(\pi)]}{\partial l_i} = \frac{\partial p(i\ win\ L)}{\partial l_i}(E[U_i(\pi)|\ i\ win\ L] - E[U_i(\pi)|\ k\ win\ L]) \tag{10}$$

$$+p(i\ win\ L)\left(\frac{\partial E[U_i(\pi|\ i\ win\ L)]}{\partial l_i} - \frac{\partial E[U_i(\pi|k\ win\ L)]}{\partial l_i}\right) + \frac{\partial E[U_i(\pi|k\ win\ L)]}{\partial l_i} = 0$$

The partial terms in equation (9) are expanded below:

$$\frac{\partial p(i\ win\ L)}{\partial l_i} = \frac{E(\sum_k^N l_k)}{[l_i + E(\sum_k^N l_k)]^2}$$

$$\frac{\partial E[U_i(\pi|\ i\ win\ L)]}{\partial l_i} = (1-R)(\pi_i|\ i\ win\ L)^{-\eta_i}$$

$$-\frac{\alpha_i}{n-1}\sum_{j\neq i}^n(R-1)\ where\ (\pi_j - \pi_i|\ i\ win\ L)\ > 0\ \forall j \neq i$$

$$-\frac{\beta_i}{n-1}\sum_{j\neq i}^n(1-R)\ where\ (\pi_j - \pi_i|\ i\ win\ L)\ < 0\ \forall j \neq i$$

$$\frac{\partial E[U_i(\pi|\ k\ win\ L)]}{\partial l_i} = (-R)(\pi_i|\ k\ win\ L)^{-\eta_i}$$

$$-\frac{\alpha_i}{n-1}\sum_{j\neq i}^n(-R)\ where\ (\pi_j - \pi_i|\ k\ win\ L)\ > 0\ \forall j \neq i$$

$$-\frac{\beta_i}{n-1}\sum_{j\neq i}^n(R)\ where\ (\pi_j - \pi_i|\ k\ win\ L)\ < 0\ \forall j \neq i$$

At an optimal (interior) solution, it is required that $\frac{\partial E[U_i(\pi)]}{\partial l_i} = \frac{\partial E[U_i(\pi)]}{\partial s_i}$. Note that $l_i = w_i - s_i$:

$$\therefore \frac{\partial E[U_i(\pi)]}{\partial s_i} = -\frac{\partial p(i\ win\ L)}{\partial l_i}(E[U_i(\pi)|\ i\ win\ L] - E[U_i(\pi)|\ k\ win\ L]) \tag{11}$$

$$+p(i\ win\ L)\left(-\frac{\partial E[U_i(\pi|\ i\ win\ L)]}{\partial l_i} + \frac{\partial E[U_i(\pi|k\ win\ L)]}{\partial l_i}\right) - \frac{\partial E[U_i(\pi|k\ win\ L)]}{\partial l_i} = 0$$

In order to test the effectiveness of the model proposed by Fehr and Schmidt (1999), I estimate each individual's co-efficient for $\alpha_i, \beta_i\ , and\ \eta_i$ such that $\frac{\partial E[U_i(\pi)]}{\partial l_i} = \frac{\partial E[U_i(\pi)]}{\partial s_i}$. I use these estimates from individuals choosing non-corner solutions (any mix of safe and risky) as parameter values for all individuals in order to test the predictive power of the Fehr-Schmidt model versus the classical risk-averse model. I find values for α and β that are significantly different from zero for most income treatments, and these parameters significantly improve on the predictive power of the classical model. Analyses of these estimates are covered in *Chapter 6: Results.*

B.3. Choice Architecture

The research questions outlined in *Chapter 3* demonstrate the desire to test how PLS introduction can affect an individual's behaviour and preferences over portfolios of risk. Benartzi and Thaler (2001), and Thaler and Sunstein (2008) both provide evidence that the structure of choices affects the asset mixture selected by individuals for their retirement portfolio. In order to test for similar effects, I complete treatments of the experiment under which the individual is no longer restricted to allocate money between savings and a lottery; in these treatments there will be a PLS account available as a third allocation option, with individual i's allocation to that account denoted by m_i. The PLS is structured such that the principal (m_i) is returned with certainty, and the 'interest rate' on the PLS which accrues to the PLS prize matches the savings account ($r = R-1$). The PLS pays one account holder a prize M, with probability $= \frac{m_i}{\sum_i^N m_i}$. In order to keep the PLS account actuarially fair, $M = (\mathrm{R}-1) \cdot \sum_{\mathrm{i}}^{\mathrm{N}} \mathrm{m_i}$, so that $\mathrm{E}(\mathrm{m_i}) = \mathrm{m_i}$. Participants were informed of the actuarial fairness by explicit statement in the instructions that the lottery prize L is the sum of the interest on all mixed contributions. Note that now expected utility is conditional on both the winner of L and the winner of M, expanding equation (8):

$$
\begin{aligned}
E[U_i(\pi)] = {} & p(i\ win\ L) \cdot p(i\ win\ M) \cdot E[U_i(\pi) |\ i\ win\ L, i\ win\ M] \\
& + p(i\ win\ L) \cdot p(k\ win\ M) \cdot E[U_i(\pi) |\ i\ win\ L, k\ win\ M] \\
& + p(k\ win\ L) \cdot p(i\ win\ M) \cdot E[U_i(\pi) |\ k\ win\ L, i\ win\ M] \\
& + p(k\ win\ L) \cdot p(k\ win\ M) \cdot E[U_i(\pi) |\ k\ win\ L, k\ win\ M]
\end{aligned} \tag{12}
$$

Expansion of each term is tedious, but for completeness I expand $E[U_i(\pi)] |\ i\ win\ L, k\ win\ M]$ below including Fehr and Schmidt (1999) terms for inequity aversion:

$$E[U_i(\pi)]|\, i\ win\ L, k\ win\ M] = \ E[U_i(\pi_i)\ |\ i\ win\ L, k\ win\ M] \quad (13)$$

$$-\frac{\alpha_i}{n-1}(\pi_k - \ \pi_i | i\ win\ L, k\ win\ M)\ \ if\ \ Rs_k + M > Rs_i + L\ \ for\ j = k$$

$$-\frac{\beta_i}{n-1}(\pi_i - \ \pi_k | i\ win\ L, k\ win\ M)\ if\ \ Rs_k + M < Rs_i + L\ \ for\ j = k$$

$$-\frac{\alpha_i}{n-1}\sum_{j\neq i\neq k}^{n}(\pi_j - \ \pi_i |\ i\ win\ L, k\ win\ M)\ \ where\ \ R\ s_j\ > Rs_i + L\ \ \forall j \neq i \neq k$$

$$-\frac{\beta_i}{n-1}\sum_{j\neq i\neq k}^{n}(\pi_i - \ \pi_j |\ i\ win\ L, k\ win\ M)\ \ where\ \ R\ s_j < Rs_i + L\ \ \forall j \neq i \neq k$$

Similar first order conditions to equation (10) result, with additional expansion around each of the four conditional outcomes outline in equation (12) now that two prizes are awarded.

In this section it also becomes useful to define two statistics to measure risk. Consider an individual's allocations to each of the three account types to constitute that individual's portfolio of assets. The first measure of risk used is an individual's *percentage of money at risk* $\left(\%_{at\ risk} = \frac{l_i + r\cdot m_i}{w_i}\right)$ which is equal to the proportion of wealth allocated to lottery purchases plus the value of the interest from the PLS contributed to the mixed prize. This is the maximum amount of money an individual stands to lose prior to any prize draws.

The second measure of risk requires a short diversion into modern portfolio theory. I calculate an individual's *portfolio variance:*

$$\sigma_p^2 = \left(\frac{s_i}{w_i}\right)^2 \sigma_s^2 + \left(\frac{l_i}{w_i}\right)^2 \sigma_l^2 + \left(\frac{m_i}{w_i}\right)^2 \sigma_m^2 + \sum_{j\neq k} 2\left(\frac{j_i}{w_i}\right)\left(\frac{k_i}{w_i}\right)\sigma_j\sigma_k\rho_{jk}\ \ where\ j,k = s,m,l$$

Because the outcomes across accounts are independent, $\rho_{jk} = 0\ \forall j,k$ simplifying the above to:

$$\sigma_p^2 = \left(\frac{s_i}{w_i}\right)^2 \sigma_s^2 + \left(\frac{l_i}{w_i}\right)^2 \sigma_l^2 + \left(\frac{m_i}{w_i}\right)^2 \sigma_m^2$$

$$where\ \sigma_j^2 = \sum_h p_h \left(X_h - E(j)\right)^2$$

The variance of an asset type j is a function of its potential outcomes X_h over h potential states, the respective probabilities of the states p_h, and the expected return on the asset E(j). Intuitively, savings has only one potential outcome and thus variance of $\sigma_s^2 = (1)(\mathrm{R} - R)^2 = 0$.

The variance of the PLS and lottery accounts vary depending on the actions of others in the economy, as the amount others contribute to an account type affects the probability and expected return of a given outcome h. For this reason, an individual's $\%_{at\ risk}$ is a measure of the individual's risk that is known *a priori*, while there may be a gap between an individual's *ex ante* perception of σ_p^2 and its *ex post* value incorporating the decisions of others in the group. This potential gap in σ_p^2 is driven by the individual's perception of behaviour of other individuals in the group.

When considering my research questions, I conjecture that an individual's percentage of wealth at risk (as well as perceived or actual portfolio variance) will decrease when the individual is presented with the choice that includes a PLS option. I find support for this hypothesis among individuals in the low income treatment, further details of this analysis are provided in *Chapter 6: Results.*

APPENDIX C: REPLICATING RISK PREFERENCE TESTS USING ACTUAL VARIANCE

Table 10: Replicating Tests from Table 3 using Actual Portfolio Variance

	Median Game 1 Actual Var.	Median Game 2 Actual Var.	Wilcoxon Signed-Rank p(Median wi = Median wj)
Total	479.0	247.5	0.0284
100	3622.4	133.2	0.0045
200	50.2	599.1	0.2408
300	479.0	266.1	0.0356

Table 11: Replicating Table 4 using Actual Portfolio Variance

Endowment	Game 1			Game 2		
	Mean Perc Var	Median Perc Var	M-W U (one-tail) p(Median wi = Median wj)	Mean Perc Var	Median Perc Var	M-W U (one-tail) p(Median wi = Median wj)
100	13,218	550	0.0409	(343)	1	0.1685
300	42,891	12,000		763	139	
100	13,218	550	0.117	(343)	1	0.1446
200	29,211	3,950		3,882	212	
200	29,211	3,950	0.3897	3,882	212	0.281
300	42,891	12,000		763	139	

APPENDIX D: TESTING THE DIVERSIFICATION HEURISTIC

Figure 6: Test and Discussion of Diversification Heuristic

		Full Sample	wi=100	wi=200	wi=300
	N	64	20	24	20
%Risky Game 1	Mean	0.315	0.438	0.284	0.229
	Median	0.200	0.475	0.075	0.167
	t test of mean: Ho: %Risky1 = 0.5 ; Ha: %Risky1 ≠ 0.5	***0.0001***	*0.4694*	***0.0067***	***0.0002***
	wilcoxon sign rank test of median: Ho: %Risky1 = 0.5 ; Ha: %Risky1 ≠ 0.5	***0.0004***	*0.5462*	***0.0280***	***0.0012***
%Safe Game 2	Mean	0.448	0.425	0.441	0.480
	Median	0.500	0.450	0.500	0.500
	t test of mean: Ho: %Safe2 = 1/3 ; Ha: %Safe2 ≠ 1/3	***0.0230***	*0.3333*	*0.1975*	*0.1082*
	wilcoxon sign rank test of median: Ho: %Safe2 = 1/3 ; Ha: %Safe2 ≠ 1/3	***0.0436***	*0.4744*	*0.2389*	*0.1071*
%Risky Game 2	Mean	0.160	0.155	0.183	0.138
	Median	0.000	0.200	0.028	0.417
	t test of mean: Ho: %Risky2 = 1/3 ; Ha: %Risky2 ≠ 1/3	***0.0000***	***0.0107***	***0.0133***	***0.0014***
	wilcoxon sign rank test of median: Ho: %Risky2 = 1/3 ; Ha: %Risky2 ≠ 1/3	***0.0000***	***0.0215***	***0.0110***	***0.0090***
%Mix Game 2	Mean	0.392	0.420	0.377	0.383
	Median	0.200	0.300	0.250	0.283
	t test of mean: Ho: %Mix2 = 1/3 ; Ha: %Mix2 ≠ 1/3	*0.2185*	*0.3472*	*0.5734*	*0.5676*
	wilcoxon sign rank test of median: Ho: %Mix2 = 1/3 ; Ha: %Mix2 ≠ 1/3	*0.4853*	*0.4993*	*0.9315*	*0.6801*

Diversification Heuristic

"Individuals typically invest a share of their wealth (1/n) over the n available options."

Benartzi and Thaler (2001) report individuals most frequently chose a 50/50 split of two retirement funds, regardless of whether they were all stocks, all bonds, or pre-mixed.

In Game 1, we can reject the diversification heuristic for the full sample and all subsamples except for the $10 treatment

In Game 2, all samples reject the diversification heuristic because the risky account is significantly different from 1/3 share.