

# An Experimental Investigation of Health Insurance Policy and Behavior

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## Abstract

We introduce a new experimental approach to measuring the effects of health insurance policy alternatives on behavior and health outcomes over the life course. Cash-motivated subjects are placed in a virtual environment where they earn income and allocate it across multi-period lives. We compare behavior across age, income and insurance plans—one priced according to an individual’s expected cost and the other uniformly priced through employer-implemented cost sharing. We find that 1) subject behavior approximated optimal responses; 2) in all treatments, subjects under-invested in health early in life and over-invested in health late in life; 3) subjects in the employer-implemented plan purchased insurance at higher rates; 4) the employer-based plan reduced differences due to income and age; 5) subjects in the actuarial plan engaged in more health-promoting behaviors, but still below optimal levels, and did save at the level required, so did realize the full benefits of the plan. Contrary, to model predictions, the actuarial priced insurance plan did not increase utility relative to the employer-based plan. Subjects had more difficulty optimizing choices in the Actuarial treatment’s more dynamic and more complicated decision space.

**Keywords:** Health insurance, Moral hazard, Inter-generational, Subsidies, Actuarially fair, Employer-based

**JEL-Codes:** I11, I12, I13, I14

## 1 Introduction

US health care costs consume 17.5% of GDP (CDC, 2018), or nearly 10,000 per person, close to twice that of other developed nations (OECD, 2017, CMS, 2019a). At the household level, these costs can result in bankruptcies and other financial hardships (CFPB, 2014). Yet, even with this vast spending, there are still unmet medical needs. 64% of Americans say that have avoided or delayed

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medical care in the last year due to expected costs (20—20 Research, 2018). This combination of high costs and unmet need have led to on-going debate about healthcare and insurance reform.

Much of the debate regarding health insurance policy concerns individual freedom and responsibility versus universal coverage and reducing health disparities (Moffit et al., 2019). Proponents of universal coverage argue that it improves the average health of the population, decreases disparities in health outcomes within the population, and generates efficiencies by eliminating the transactions costs associated with private insurance billing systems. Proponents of systems emphasizing individual responsibility argue two points: first, that such plans allow people to exert their own priorities in health decisions regarding how much and what kind of coverage to purchase; and second, if insurance premiums and co-pays depend on health behavior, such as smoking, exercise and diet, people will have incentives to improve their health, reducing the total costs of health care.

There is a growing body of research designed to measure the effects of policy alternatives with respect to individual responsibility and social cost sharing. One approach is to take advantage of cross-national data to measure the impacts of health insurance alternatives on patient behavior, population health and health disparities (NRC, 2010, IOM, 2013). That research shows that health outcomes in the U.S. have been decreasing in recent decades relative to other developed countries, who all practice universal cost sharing. However, given that many other nation-level variables covary with insurance policy (NRC, 2010, IOM, 2013), it has been difficult to determine whether differences in health insurance policies are responsible for the trend and to pinpoint the causes of the decreasing relative status of the US.

Another approach is to take advantage of ‘natural experiments’ associated with policy changes, such the Oregon Medicaid Expansion, the SSDI Accelerated Benefits Demonstration Project, RomneyCare and ObamaCare (Weathers and Stegman, 2012, Courtemanche and Zapata, 2014, Finkelstein et al., 2015, Lipton and Decker, 2015, Courtemanche et al., 2018, Ghosh et al., 2019). Those studies confirm that health care usage increases in response to more generous insurance benefits. They have been less conclusive, however, about the health benefits from the additional spending and services. There is evidence that self-reported health increases with increased health insurance coverage in Oregon (Baicker and Finkelstein, 2011) and with ‘RomneyCare’ in Massachusetts (Courtemanche and Zapata, 2014), but effects on objective measures of health were not detected (see also Weathers and Stegman (2012)) with respect to mortality following the Affordable Care

Act. The assessment of long term impacts is limited by the fact that all are relatively recent reforms, in comparison to the decades over which chronic diseases develop.

There is also a rich literature of field experiments offering financial incentives for health promoting behavior. [Giné et al. \(2010\)](#) show that financial incentives can promote smoking cessation. [Volpp et al. \(2008\)](#) show that incentives can induce subjects to lose weight in the short term, but in the long-term, post-incentive period the weight is regained. Incentives can also be used to increase gym attendance and exercise. The latter are more effective at inducing changes in health indicators. Again, it is not clear that healthy behaviors are sustained in the post-incentive period. See [Mitchell et al. \(2013\)](#) and [Barte and Wendel-Vos \(2017\)](#) for systematic reviews. In general, this research shows financial incentives influence people to adapt healthier behaviors. However, given their short time frames, such experiments are limited in their ability to measure the effects of interventions on chronic disease outcomes.

These bodies of research illustrate the methodological challenges in assessing the effects of policy alternatives with respect to population health and total health care costs. The central challenge derives from the fact the vast majority of healthcare costs and disease burdens are due to chronic illnesses, such as heart disease, stroke, diabetes, cancer and dementia. The most important risk factors for those diseases are directly or indirectly behavioral, such as an obesogenic diet, lack of physical activity, smoking and drug use. In addition, the effects of behavior accumulate over many decades, suggesting that full policy impacts may accumulate slowly over time. Another challenge is that people can prepare for, and prevent, disease events along several different fronts. Examples are saving money, purchasing health insurance, changing habitual behavior, and engaging in preventative surveillance and treatment. Since different policies may affect the value of investing in those fronts, assessing total impacts will require an understanding of potential substitutions and complements between policies and individual behavior. Because of these challenges, there is very little causal evidence regarding the impacts of healthcare policy alternatives, despite the very precise statistics on costs and morbidity and the vigor of the policy debate.

This paper introduces a new, complementary experimental economic approach to address those challenges in examining the effects of health insurance policy alternatives on behavior and health outcomes over the life course. This experiment compares two types of premium systems for health insurance, one based on individual responsibility and the other on cost sharing.

This paper addresses the following questions with this experimental design. Do differences in individual responsibility and social cost sharing in health insurance premiums affect: 1) people's decisions about whether to purchase insurance; 2) personal investments in health; 3) behaviors that prevent or increase the risk of adverse health events; 4) savings to buffer the costs of treating adverse health events; and 5) long-term health outcomes. We also investigate how those effects vary with income and age to impact disparities in health and behavior.

The paper proceeds as follows. The next section presents detailed descriptions of the theoretical model motivating the experiment, the experimental environment, and the research design. The following sections presents the theoretical and empirical results, respectively. The theoretical results show how the optimal time paths of consumption and investments in health vary as a function of the insurance and income treatments. The empirical section analyzes the treatment effects on subject behavior and compares their behavior to the theoretically predicted time paths of investments. The discussion section presents a summary of our main findings and their theoretical implications. Additionally, it discusses some of the weaknesses in the current design, and appropriate directions for future research. The conclusion addresses how our approach complements existing approaches.

## **2 Methods**

### **2.1 Environment and Treatments**

Our test environment, based on the [Grossman \(1972\)](#) lifecycle model of health investment, is designed to model the multiple health-related decisions people make in their daily lives and the different ways people can prepare for and ameliorate disease events. Subjects live multi-period lives and have a stock of health that naturally deteriorates each period, and declines further if the subject suffers a stochastic illness event ([Khwaja, 2002](#)), which we call a 'shock.' Each period, subjects receive an income (an allocation of virtual currency) that depends positively on their individual health ([Viscusi and Evans, 1990](#)); this is to capture the idea that health affects the earnings from work. Subjects must then decide on how to allocate their income to current consumption versus savings and health-related investments. Health-related investments include the purchase of health insurance, health recovery from deterioration and shocks, and expenditures on physical fitness, which we call resilience, that lowers the size of potential future shocks. The ability to invest in

resilience is designed to capture preventative behaviors such as exercise, diet and abstention from smoking, drugs, etc. whereas health investment is meant to model services from medical providers, pharmaceuticals, etc. Shock probability increases in the second half of life to capture the effects of aging. Insurance pays for recovery from shocks.

The first treatment is actuarially based insurance, in which the cost of each individual subject's premium depends on that subject's expected health care costs to the insurer, which, in turn, depend on that subject's age, health state, and health-related behavior. The actuarial plan embodies the concept of individual responsibility in a competitive insurance marketplace. Each subject chooses whether or not to purchase insurance given her personal premium. To alleviate the costs of premiums and continuing health degradation, subjects can invest in resilience, save to buffer against adverse health events, and directly invest in improving current health. The actuarial plan smooths the lumpy costs of health shocks and provides incentives for individuals to improve their health. However, it may generate significant inequality in health outcomes, due to variable premium costs associated with individual conditions.

The second treatment is employer-based insurance, resembling the plans most American have. Premiums are largely subsidized by the employer (funded through a reduction in wages), and there is social cost sharing. The premium the employer must pay the insurer is determined by the average expected costs of all employees who choose the plan. The proportion of the premium paid directly by the employee is fixed, regardless of age, health state or behavior. The employer treatment and its incentives differ significantly from the actuarial plan. First, since premiums do not depend on resilience, there is less incentive to invest in prevention (often referred to as, 'moral hazard'). Second, people with greater risk (the 'old') would have a greater incentive to purchase the insurance since their expected health costs would be greater (often referred to as, 'adverse selection'). However, this plan is expected to generate less inequality in health outcomes due to social cost sharing.

Subjects were assigned to one of four experimental treatments groups in a 2x2 experimental design. One treatment dimension was the actuarial versus employer insurance plan, and the other was high versus low subject income. In addition, all subjects face a young and an old period during each life with the latter characterized by higher health risks, so our statistical analysis is necessarily 2x2x2. Payments to subjects were a linear transform of their total lifetime utility, based on their

health and consumption choices in each period. The challenge subjects faced was to optimize the allocation of income and previous savings in each period among current consumption, health repair, investment in resilience, purchase of insurance, and future savings, so as to maximize the payment they received at the end of the experiment. This framework was chosen to represent the problem of maximizing the total lifetime utility, subject to income constraints and random shocks to health.

## 2.2 Model

This subsection presents the general model employed in our experimental design. We build upon Grossman (1972) where resources are limited and can be allocated between enjoying life and ensuring that it continues. Players live for a maximum of  $T$  periods. There are two state variables: health  $H_t$  and savings  $S_t$ . Each period, health degrades by a fixed amount  $\delta$ , and is improved through an investment of  $I_t^H$  into health. Increasing health allows an individual to be more productive, earn greater income and spend less time attending to ailments; thus, income available to be spent by the player during each period of the experiment is dependent on health. Any income not invested on health or current consumption is deposited into a savings account available for future consumption or investments in health. Players derive utility (which we refer to as ‘joy’ in the subject interface) from investments in joy  $I_t^J$  summed across all periods in life. Joy is a concave function of dollars invested in consumption, moderated by health, as being healthy allows one to enjoy life more. Joy is our primary outcome and joy earned determines subjects payouts.

In addition to the standard elements of the Grossman model, we add the prospect of stochastic negative health shocks, and two additional investments, resilience  $I_t^R$  and insurance  $I_t^I$ . Should a shock occur that period, resilience investment reduces the magnitude of the shock, and if purchased, insurance will recover any health lost to the shock.

Listed below is the event timeline faced by players in our model. Each period,  $t$ , is subdivided into the following four stages:

1. Investments  $\vec{I}_t = \{I_t^H, I_t^J, I_t^R, I_t^I\}$  are set.
2. Intermediate health  $H_{t'}$  is determined for the current period considering health at the end of last period, health improvement  $R(H_t, I_t^H)$ , health degradation  $\delta$ , and whether the stochastic

health shock  $\Delta_t(I_t^R)$  is realized.

3. Joy  $J_t(I_t^J, H_{t'})$  and income  $M(H_{t'})$  are computed based on investments and intermediate health.
4.  $\Delta_t(I_t^R)$  health is recovered if insurance was purchased and a health shock occurred, yielding a final health  $H_{t+1}$ .

Figure 1 shows the events each period and when health is a level  $H_t$  versus  $H_{t'}$ . We included the health experienced  $H_{t'}$  so that players incurred a penalty from a shock even if insurance was purchased, capturing the real-life costs of health shocks outside of medical bills. Additionally, placing insurance recovery at the end of the period is equivalent to a cash payout that is earmarked towards next period's health,  $I_{t+1}^H$ . This allows for direct comparisons between insurance purchase and self-insurance through savings.<sup>1</sup>

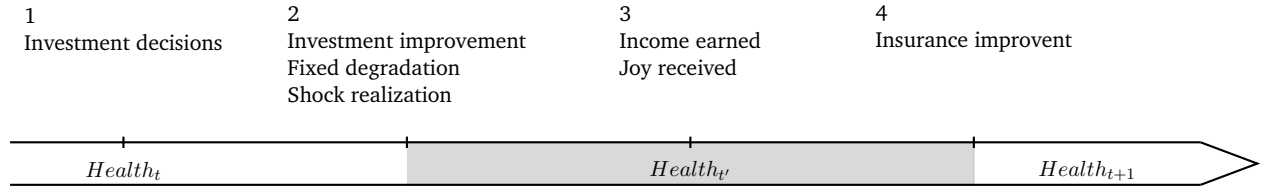


Figure 1: Sequence of Events within a Period

The equations that govern the individual's welfare maximization problem are:

Maximize:

$$\sum_{t=1, T} J(I_t^J, H_{t'}) \quad (\text{Lifetime Joy})$$

Subject to:

$$H_{t'} = H_t - \delta + R(H_t, I_t^H) - x_t \Delta(I_t^R) \quad (\text{Health Experienced})$$

$$H_{t+1} = H_{t'} + D_t^I x_t \Delta(I_t^R) \quad (\text{Health at start of next period})$$

$$S_t + \sum_k I_t^k = S_{t-1} + M(H_{(t-1)'}) \quad (\text{Budget constraint})$$

Where:

<sup>1</sup>An additional constraint is that the health improvement function must be additive with investments so that if  $I$  is the cash equivalent insurance payout, then  $R(H_{t'}, I) + R(H_{t+1}, I_{t+1}^H) = R(H_{t'}, I + I_{t+1}^H)$

$J(I_t^J, H_{t'})$  is the joy realized in period  $t$ .

$x_t$  is the realization of the shock degradation random variable  $X_t \sim \text{Ber}(\mu_t)$ , where  $\mu_t$  is a fixed probability of a shock depending only on age.

$I_t^I = D_t^I \rho_t(I_t^R, H_{t'})$ , with  $D_t^I \in \{0, 1\}$  being the binary decision whether to purchase insurance, and  $\rho_t(I_t^R, H_{t'})$  being the insurance premium that may depend on health, shock size and shock probability.

### 2.2.1 Optimization

Health investment  $I_t^H$  increases future income and joy potential. Joy investment  $I_t^J$  increases utility in the current period. Resilience investment  $I_t^R$  reduces any health loss from a shock this period, resulting in higher expected income and joy, as well as the potential of a lower insurance premium depending on how the premium is calculated. Purchasing insurance  $D_t^I$  pays for the significant cost of health recovery should a shock occur, both freeing up future budget and reducing health uncertainty. Balancing these investments across time comprises a difficult dynamic optimization problem.

From the first order conditions of the optimization, we find that: 1) investments in health will decrease as the number of remaining periods decrease; 2) investment in resilience will increase as risk of shock,  $\mu$  increases; 3) optimal saving will increase if  $\mu$  is higher in future periods, and decreases as the number of future periods decreases; 4) purchase of insurance will increase as risk of shock,  $\mu$ , increases or as price,  $\rho$ , decreases.

Additionally, the investment in resilience and insurance purchase are heavily dependent on one another.<sup>2</sup> Purchasing insurance negates the benefits of resilience in future periods since any shock is recovered from. Meanwhile, investing in resilience reduces the value of the insurance. However, they can also act as complements. When insurance premiums are calculated to be actuarially fair, conditional on purchasing insurance, the marginal cost of resilience is reduced as it also results in lower insurance premiums.

In the Results Section, we analyze data generated by a computerized dynamic program (DP) that maximized total expected joy received in a life. The DP calculated maximum expected joy for

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<sup>2</sup>While health level influences insurance price and hence health investment does as well, in practice, the effect is minor within a period.



each possible combination of the two state variables (health and savings) for every period and every shock sequence. Then, working from the last period back, the DP found the optimal decision path given any possible shock sequence experienced by a subject. Results will detail how the optimality conditions discussed above map into an optimal decision path given the parameters we describe below.

### 2.2.2 Functional Forms and Parameters

This subsection presents the specific functional forms we employed in the experiment, in order to implement the general theoretical model discussed in the above two subsections. We begin with the functional forms of the joy, health regeneration, resilience and income functions.

$$J_t(I_t^J, H_{t'}) = \frac{I_t^J}{(\gamma + I_t^J)} H_{t'} \quad (1)$$

$$R(I_t^H, H_t) = \frac{e^{\alpha I_t^H}}{e^{\alpha I_t^H} + (1 - H_t)/H_t} - H_t \quad (2)$$

$$\Delta(I_t^R) = \Phi e^{-r I_t^R} \quad (3)$$

$$M(H_{t'}) = H_{t'} \Omega^c \quad (4)$$

The joy function, Equation 1, has diminishing marginal returns to consumption,  $I^J$  and moderated joy realized by health experienced. The consumption term is asymptotic so that like the health term it has an upper bound. The health regeneration function, Equation 2, is logistic. Improving health is least expensive at the middle of its range, and progressively more expensive toward either end of the range. It is more expensive when health was high to model diminishing marginal returns, and more expensive when health was low to model the complication of treating co-morbid health issues. The specification also ensures that increasing health had the same cost no matter how many periods the subject to make the increase over. The shock moderation function, Equation 3, imposed diminishing returns to investments in resilience,  $I^R$ , the ability to moderate shocks. The income function, Equation 4, was linear and increasing in health experienced. Additionally, income depended on income type, (SEC).

In the experimental environment that is used to implement this model, health is restricted

to values from 100 (perfect health) to 0 (death). Life starts with health at 70 ( $H_0 = 70$ ) and depreciates by 8 ( $\delta = 8$ ) each period with certainty. In addition, health declines further if there is a shock in a given period. The shock probability is 3/12 in the first half of life ( $\mu_t = .25$  for  $t \leq 16$ ), and 5/12 in the second half ( $\mu_t = .4167$  for  $t > 16$ ). The unmitigated shock was set to 25 health points ( $\Phi = 25$ ), but could be reduced to as low as 12 through the purchase of resilience  $I^R$ . We use Equation 3, but impose a maximum investment per period and limit it to take on integer values. The shocks are pseudo-random. We use pre-generated sequences that rule out low probability sequences and reduce variation.

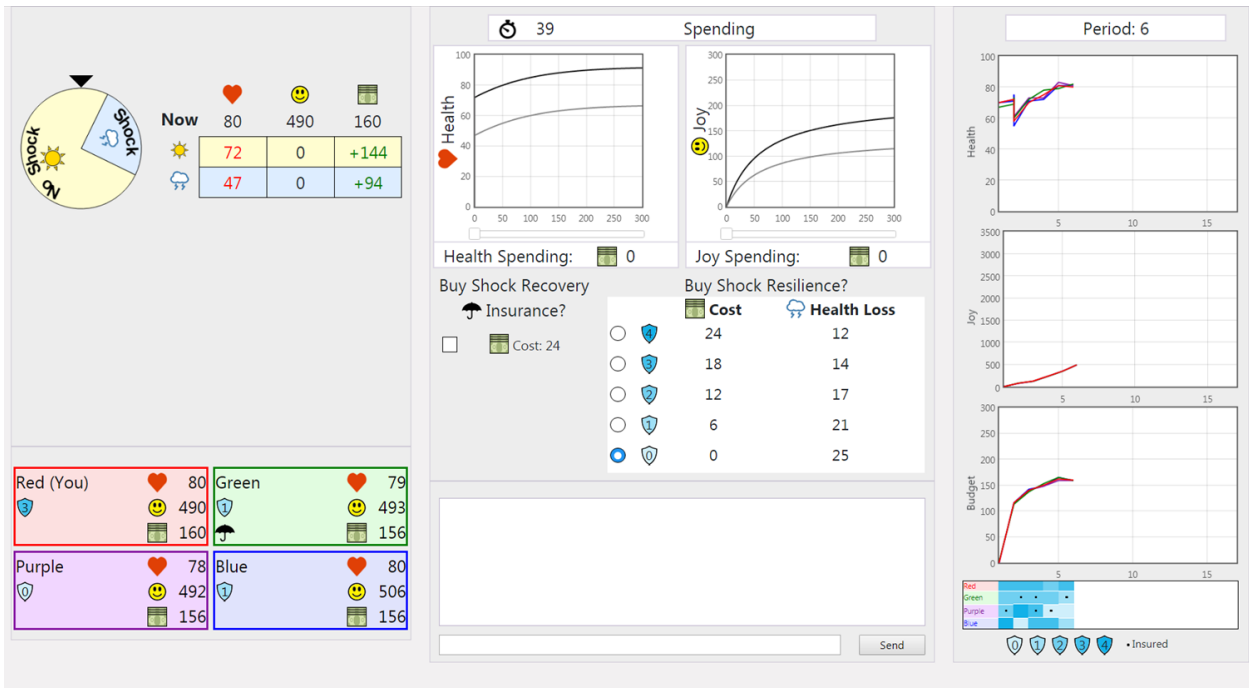
To explore the heterogeneous impacts of insurance plans we create two types of variation in the population. A Subject is either high or low income. Actual income for both types is health multiplied by their type constant. The constant  $\Omega^c$  for the high-income type was 200, 1.25 times greater than the one for the low-income type, 160. While we refer to the types as high and low, both types had sufficient income to purchase insurance so might be better described as high and middle income. For all levels of health below 35, the subjects received the minimum income, the same amount as if they had a health of 35. For both income types we increase the probability of health shocks during the second half of life when the subjects become old, creating an addition level of variation.

Under the ‘employer’ insurance plan, the employer paid 75% of the insurance premium cost, which subsidy was fully funded through wage reductions that were universally imposed on all employees, regardless of whether the individual chose to purchase the insurance. All employees were offered the opportunity to purchase insurance at a fixed cost that was approximately 25% of the real cost of insuring the average person in the pool. The constant deduction rate across incomes (18%) meant that the system transferred contributions from high to low income, while the constant premium cost regardless of age transferred contributions from young to old. Calculations of exact amounts are in Table A.3. Our environment is mathematically equivalent to an overlapping generations’ model<sup>3</sup>.

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<sup>3</sup>The employer age transfers did not require any delay, and could have transferred from young to old within a period had, there been subjects of both types within periods. However, we avoided the logistical complications required to have subjects of varying ages.

Figure 2: Subject Interface



### 2.3 Experimental interface

Figure 2 shows the experimental interface seen and manipulated by the subjects. The heart icon represents health. The happy face denotes joy. Each shows the present value, and the resulting values next period with and without a shock. Income is in the top left and is the first number under the money icon. Money can be allocated to health or joy by moving the respective sliders below the graphs in the top center. The graphs allow the subject to see the diminishing marginal returns of both. Subjects make insurance and resilience decisions by checking boxes below the graphs. Remaining budget and potential outcomes update dynamically with each decision. Any unallocated money is saved, and added to income next period. Saving is possible for any number of periods but not across lives. Savings held at the end of life were lost. Subjects were paid based on the sum their received joy across all periods and lives.

In the shock stage, the wheel in the upper left corner spins. If the pointer lands on the section with the storm cloud icon, the subject receives a shock. The shock section of the wheel is proportionately larger during the second stage of life to convey the increased probability of a shock. Subjects could see what health and joy would be with a shock on the middle line in the upper left

corner; the lower lines in the graphs represent values when shocked. The outcome stage is when the subjects receive joy and income. It was a separate stage to make it clear that both were based on the subjects' health, including reductions from any shock received that period. In the final stage, if the subject had bought insurance that period, health was restored to its pre-shock level. If the subject was uninsured or self-insuring through savings, they could pay to restore their health in the first stage of the next period. Income and savings in the experiment had no direct impact on subject payments.

Subjects are organized into groups of four individuals with the same income type. The right side of the screen shows the group history for the present life. There are graphs for health, cumulative joy, and budget. Each graph has a colored line for each group member that corresponded with the member's tile color and label. The bottom right corner displays each member's fitness history in a heatmap style graph, with dots indicating insurance purchase decisions. The numbers in the shield indicate resilience levels. The umbrellas indicate being insured. These icons correspond to ones used in spending decisions.

Subjects could choose whether to chat with other group members through text. The bottom center is the chat section. Chat is available at all times including in pauses between lives. Even though subjects can chat, subject payouts from the experiment depend solely on individual performance. There is no financial reward to sharing information, nor is there any incentivized competition giving reason to withhold information.

After thorough on screen and audio instructions, subjects participate in three practice lives of 4, 16 and 16 periods, before engaging in the two longer 32 period lives that we analyze. All periods for all lives are paid. A subject who dies (i.e. Health = 0) in a particular life must wait until all the other subjects in the experimental session complete that life, but can chat with other group members and observe all their actions.

## **2.4 Procedures**

We ran 12 experimental sessions at the Economic Science Institute (ESI) Lab at Chapman University between April 24<sup>th</sup> and May 16<sup>th</sup>, 2018. Eight sessions had 24 subjects, two had 20, one had 16

and one had 12.<sup>4</sup> Subjects were recruited via email from a database of subject volunteers ESI maintains. Table 1 shows the 2x2 treatment design and number of subjects in each cell. Sessions lasted 120 minutes. Average subject earnings were \$36.79, including the \$7 show-up fee.

Table 1: Subjects per treatment cell

	Treatment	
	Actuarial	Employer
Low-Income	64	68
High-Income	64	64

Table 2 lists insurer details by treatment. The premium in the Actuarial treatment was the expected cost plus 10% (to model administrative costs). Cost was always \$9 in the Employer treatment. Subjects in the Employer treatment received only 82% of the income they would have received in the Actuarial treatment. (The ‘employer’ decreased wages by 18% to fund the insurance subsidy.) Withheld income is the mean of the total difference in income across subjects’ lifetimes. Insurer revenue is defined as the sum of all premiums paid (in both treatments) plus all income reductions to subjects (in the employer treatment). Profit is defined as revenue minus the total amount paid to the subjects to recover from insured shocks. The profit rate is the profit divided by the revenue. The actuarial treatment had a slightly lower profit rate (7.3%) than designed, because, by chance, the stochastic shock rate on the periods when subjects did not buy insurance was lower than the rate during periods when insurance was purchased. The insurer profit rate in the employer treatment (5.2%) was lower than in the actuarial treatment, however, the revenue stream was larger due to much increased subscription, so overall the insurer made more profit under the employer plan (\$48) than the actuarial plan (\$36). The table demonstrates that the subsidies under the employer plan were completely funded, and no ‘external’ resources were required.

## 2.5 Data Analysis

Our regressions on insurance purchase and survival will use a panel data probit model:

$$Y_{it} = \Pi(\phi_i + \tau_i + \nu_i + \varepsilon_{it})$$

<sup>4</sup>When there were fewer than 24 subjects, the number of subjects was a multiple of four so that all subjects had equal-sized groups. The subjects, who remained after the maximum number of groups of four was formed, were paid a show-up fee and allowed to depart.

Table 2: Treatment Details

	Actuarial	Employer
Premium	1.1 * $E(Cost_{it})$	\$9
Subject Income	100%	82%
Withheld Income	0	654
Premiums Collected	442	259
Total Revenue	442	913
Benefits Paid	409	865
Insurer Profit	\$32	\$48
Profit Rate	7.3%	5.2%

where  $\phi_i$  is a vector of sub-population binary variables indicating the subject's age within the experiment life {young, old} and income type {low, high};  $\tau_i$  is vector of binary variables indicating belonging to a particular sub-population and being in the employer-based insurance treatment;  $\nu_i$  is an individual error term; and  $\varepsilon_{it}$  is period and subject specific error term. Errors are clustered according to which shock sequences (there were only twelve) the subjects experienced.

Our regressions on resilience, health, savings and joy will use a panel data model:

$$Y_{it} = \phi_i + \tau_i + \nu_i + \varepsilon_{it}$$

where the variables have the same specifications, but there is no link function.

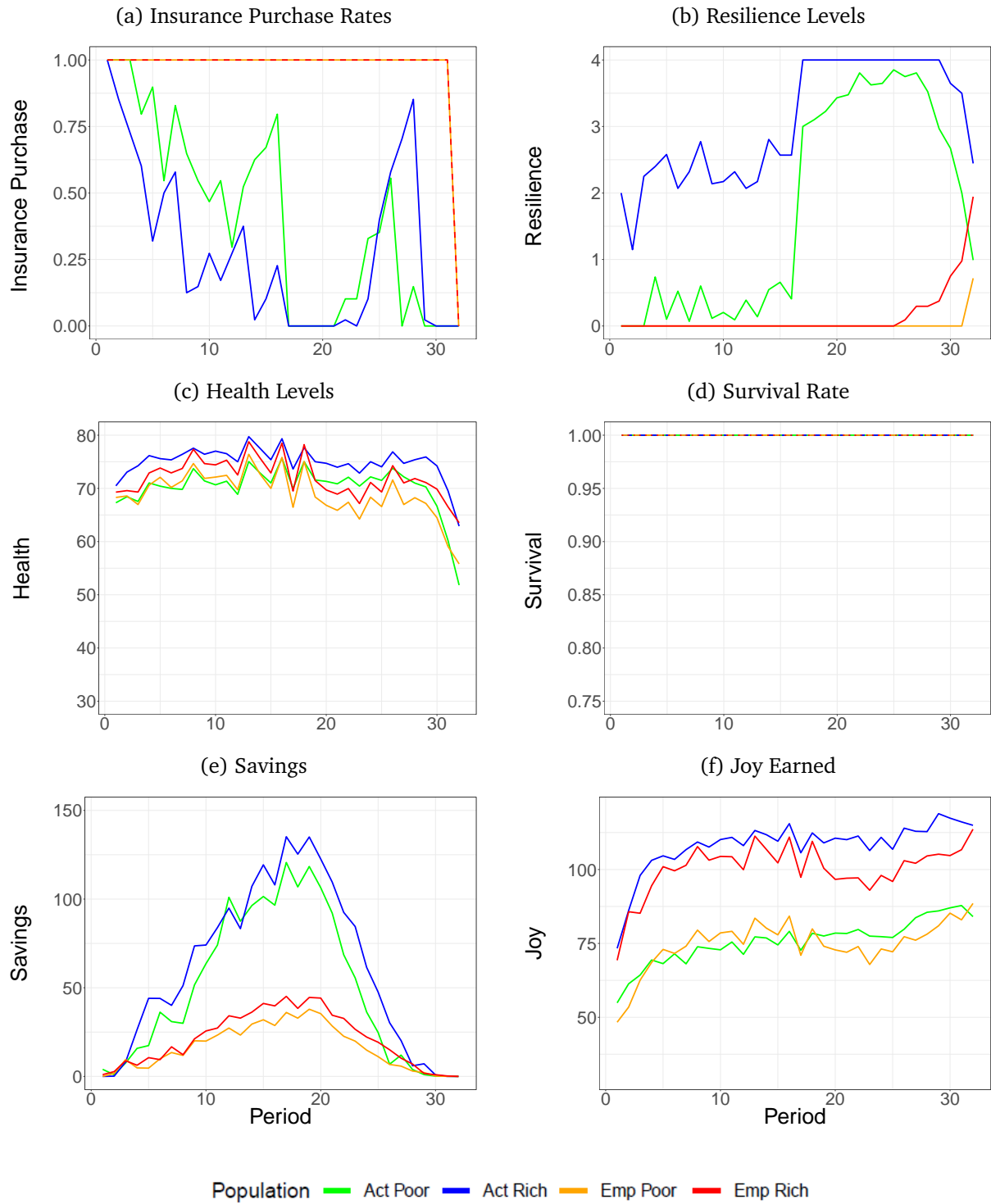
### 3 Results

#### 3.1 Theoretical results from dynamic program

Figure 3 shows optimal results from dynamic program for the four treatment groups, based on the 12 shock patterns to which experimental subjects were exposed. Red and orange plot the welfare maximizing strategy (i.e. maximizing expected lifetime joy) in the employer treatment for high and low income, respectively, and blue and green do so for the actuarial for high and low income, respectively.

**Insurance Purchase** – Panel 3a plots the proportion of simulated subjects purchasing insurance in each period. Consistent with theory, purchase rates are higher in the employer treatment. The

Figure 3: Results from Dynamic Program



DP predicts insurance purchase for all subjects in the employer treatment, regardless of income, whereas in the actuarial treatment, the proportion purchasing insurance is about 50%, generally decreasing across life. In the actuarial treatment, a greater proportion purchase insurance in the low than the high-income treatment. Generally, the DP tended to self insure so did not purchase unless it encountered shock realizations which depleted the savings required for self insurance.

**Resilience** - Panel 3b plots mean resilience level to shocks. In the employer treatment, there is the moral hazard predicted. Both income types make no resilience purchase until starting the endgame whereas in the actuarial treatment, both high and low-income subjects invest in resilience. In the actuarial treatment, consistent with theory, investments in resilience increase when shock probabilities increase in the second half of life, but to a lesser extent among the lower income subjects.

**Health** - Panel 3c shows that the DP predicts relatively small differences in health levels between treatment groups. Health levels are smoothed across life except for a sharp decrease in the end of life. It also takes a couple periods in the beginning of life to achieve optimal levels. This is an artifact of the chosen starting health level; had we chosen a higher starting level, there would be no build up period.

**Survival** - Panel 3d shows that given the model parameters used, it is not optimal to die before period 32 in any of the four treatments.

**Savings** - For all treatment groups, Panel 3e reveals that the DP predicts savings will increase through the first half of life and then decrease in the second half of life. Transferring money from early period to later period allows for the smoothing of consumption and health levels. Optimally, savings will be about four times as high in the actuarial than in the employer treatments. The relative benefit from employer insurance to the income withheld is negative when 'young' and positive when 'old', so the treatment transfers funds without active 'savings' required. The effects of income on savings are much smaller in comparison.

**Joy** - DP predictions in Panel 3f indicate that more joy is obtained in the actuarial than in the employer treatment. However, there is an interaction between insurance treatment and income with larger differences between insurance treatments among the higher income groups. The DP largely smooths joy across life. Joy investments are low in the beginning of life when the priority is increasing health and therefore income. Conversely, at the end life joy is increased.



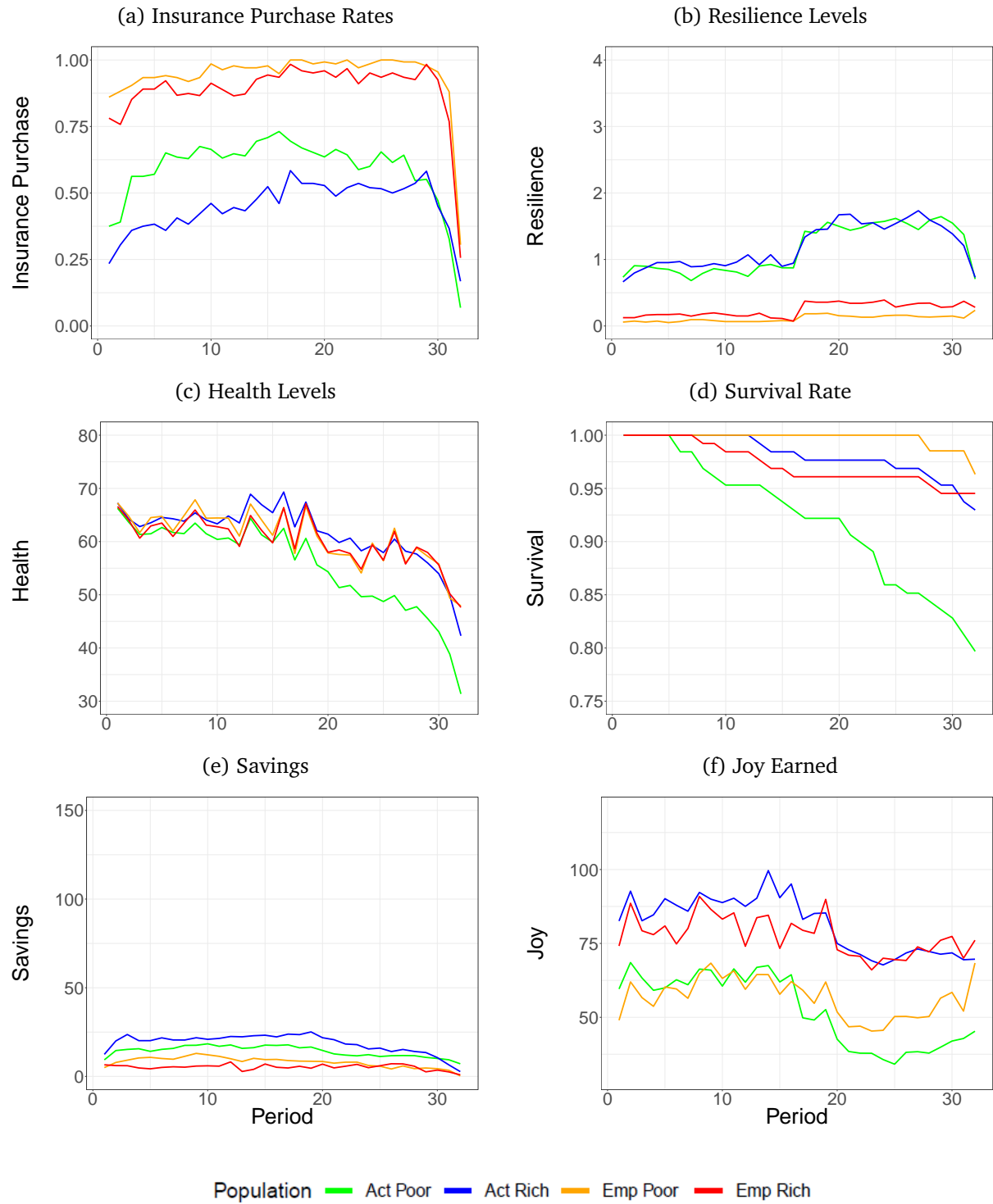
Together, the theoretical results reveal that optimal strategies depend on both insurance plan and income, and change dynamically through life. The decreased premium costs in the employer treatment through the subsidy result in the universal purchase of insurance and reduced savings, and resilience. Reduced investments in resilience reflect moral hazard in that at the individual level, premiums do not change with respect to expected insurer costs. The actuarial plan with greater individual responsibility requires a complex dynamic mix of savings, resilience and investments in health. However, since it is unconstrained by an imposed employer subsidy, it results in greater total welfare, especially for the high income group. Interestingly, the DP also predicts greater insurance purchase in the actuarial low income treatment, as there is less ability to buffer shocks through savings or investments in resilience.

### 3.2 Subject results

Figure 4 presents temporal plots of mean subject data akin to the plots of DP data in Figure 3. (Table A.1 of the Appendix provides the summary statistics for the subject data plotted.) The degree of correspondence between the DP and subject path varies according to insurance type, income level and variable. We provide detailed analysis organized by variable below. Table 3 reports regression results that provide statistical tests of the differences between the results represented in the graphs. The six table columns labels (a-f) correspond respectively to the six panels in the graphs. For all columns, estimates are reported for seven binary indicator variables. The first three variables represent the four sub-populations resulting from interacting age and income (low-income young is the omitted sub-population), so each variable provides an estimated impact of belonging to that sub-population relative to the omitted one. The remaining four variables indicate both belonging to a particular sub-population and being in the employer-insurance treatment, so they estimate specific effect (of insurance type) for each of the four sub-populations.

**Insurance Purchase** – Qualitatively, the paths of subject decisions match those of the DP, including the endgame effect. In contrast to the actuarial treatment, nearly all subjects of both income groups in the employer treatment purchased insurance every period except the last, as predicted by the DP. The greatest difference between the DP predictions and subject behavior is in the actuarial treatment. Actuarial subjects purchased less insurance than is optimal in the first quarter of life

Figure 4: Results from Subjects



and more than is optimal in the second and third quarters of life. Low-income subjects purchased insurance at greater rates than high-income subjects.

Column (a) of Table 3 presents estimated marginal effects of a probit regression on insurance purchase. In the actuarial treatment, the low-income, young subjects purchase insurance at the highest rates, because they are most vulnerable, having the least savings and future disposable income with all future periods at stake. The difference between the purchase rate and each of the other three sub-populations is statistically significant, as is reported in the first three rows. The sizes of the estimates are consistent with their relative vulnerability. Subjects in all sub-populations are statistically significantly more likely to purchase insurance in the employer treatment.

**Resilience** – As predicted by the DP and theory, subjects invest more in resilience in the actuarial than in the employer treatment (the moral hazard effect), and investments in resilience increase in the second half of life when the shock rate increases (Panel b). Again, however, subjects in the actuarial treatment diverge more from the predictions of the DP by under-investing. Whereas the DP predicts an increase to a resilience level of almost four for both low and high income subjects, their observed resilience levels are less than 1 for the first half of life and only increase to a mean of about 1.25 in the second half of life. Column (b) of Table 3 reports coefficient estimates from a linear regression on resilience (ordered probit results are in the Appendices). Subjects maintain higher resilience during the second (old) half of life, as can be seen in Row 1 and 3. Consistent with moral hazard, the difference across insurance treatments is statistically significant for all four sub-populations, and the difference is larger in the second half of life.

**Health** – Like the DP, subjects maintained relatively high levels of health throughout life (Panel c). However, subjects in all treatments under-invest in health in the early periods of life, resulting in lowered income throughout life because of less joy realized during later periods of life. Again, subjects in the actuarial treatment, especially low-income subjects, differ more from the DP than those in the employer treatment.

Column (c) of Table 3 reports coefficient estimates from a linear regression on health. Health is over 13 points lower for low-income old subjects. The employer treatment largely diminishes this effect, so the difference is only a third of that in the actuarial treatment.

**Survival** – 91% all of subjects survived through both lifetimes, close to the DP, which had perfect survival employing optimal decision making regardless of shock sequence experienced. Some

Table 3: Regression estimates for baseline differences and treatment effects

VARIABLES	(a) Ins. Purchase	(b) Resilience	(c) Health	(d) Survival	(e) Savings	(f) Joy
Low Income Old	-0.0760*** (0.0201)	0.532*** (0.0886)	-13.14*** (1.669)		-1.542 (3.169)	-22.10*** (2.788)
High Income Young	-0.150*** (0.0364)	0.0991 (0.0950)	3.132* (1.656)		5.692** (2.649)	25.93*** (2.006)
High Income Old	-0.0852*** (0.0262)	0.676*** (0.0966)	-4.008 (2.591)	0.117** (0.0527)	1.373 (2.881)	10.15** (4.136)
Emp * Low Young	0.372*** (0.0362)	-0.692*** (0.0496)	2.410 (1.797)		-5.645 (3.739)	-3.016 (2.303)
Emp * Low Old	0.408*** (0.0340)	-1.144*** (0.0716)	8.401*** (2.579)	0.127*** (0.0244)	-7.906*** (2.897)	11.62*** (2.743)
Emp * High Young	0.414*** (0.0293)	-0.711*** (0.0863)	-2.103* (1.267)		-15.61*** (1.925)	-8.239*** (2.336)
Emp * High Old	0.352*** (0.0258)	-1.124*** (0.0847)	-0.481 (2.138)	0.0224 (0.0686)	-10.81*** (1.619)	0.252 (3.803)
Observations	16,640	16,640	16,640	455	16,640	16,640
Sequence Controls	Yes	Yes	Yes	Yes	Yes	Yes
Log Likelihood	-6139			-127.9		
Rho	0.513	0.467	0.461	0.0949	0.612	0.220
P-value		< .001	< .001		< .001	< .001
Number of Subj. Lives		520	520		520	520

Clustered (on Shock Sequence) standard errors in parentheses \*\*\* p<0.01, \*\* p<0.05, \* p<0.1

subjects died due to under-investments in health and resilience, especially in the low-income actuarial treatment in which 20% died.

Column (d) of Table 3 reports probit estimates on whether the subject was alive at the end of the 32 period life, so there are no estimates for young subjects. Sixty-five subject lives were dropped from the regression because their innocuous shock sequences perfectly predicted survival. Under the actuarial treatment, being high-income increased a subject's chance of survival by 11.7%. Employer insurance closes the income survival gap as fewer low-income subjects die prematurely. There is no reason that low-income subjects should be more likely to survive, and the difference is not significant.

**Savings** - As predicted by the DP, subjects in the actuarial treatment save more than those in the employer treatment, and high-income subjects save more than low-income subjects (Panel e). However, compared to the DP, subjects in all treatment groups under-invested in savings, and none of the treatment groups supported the DP prediction of a dramatic increase in savings during

the first half of life followed by a decrease in savings during the second half of life. Again, the divergence between DP predictions and subject behavior was greatest for the actuarial treatment: only 20 out of 256 subjects in the actuarial plan had savings of 75 or more (near optimal) at midlife (period 16).

Column (e) of Table 3 shows regression estimates of how savings differed by sub-population. Only the high-income young had a statistically significant difference in savings. The employer treatment reduced savings for all four sub-populations, but the reduction for low-income young subjects was not statistically significant. The relatively small savings estimates highlight the fact that the subjects did not optimize savings in any of the treatments. The largest sub-population mean savings estimate is only 16, whereas optimal behavior would have produced a regression estimate of about 80 (half the peak savings).

*Joy* – Subjects in all four treatment groups experience less joy than achieved by the DP. This is due mostly to the under-investments in health, savings and resilience early in life. The results also reveal an interaction between the income and insurance treatments. As predicted by the DP, joy is higher in the actuarial than in the employer treatment for higher income subjects, especially during the first half of life. However, in contrast to the DP, low-income subjects realized less joy in the actuarial than in the employer treatment, particularly during the second half of life.

Column (f) reports estimated difference in joy earned within period. Young earn more than old and high-income earns more than poor. The only two of the estimates for insurance effects are statistically significant.

### **3.3 Treatment effects on lifetime utility**

As these the cumulative impact not clear from period estimates, Table A.2 provides estimated cumulative effects of the insurance and income treatments over the 32 period life. In regressions (see section A.2), impact of employer insurance was 128 for high-income subject, 138 for low-income subjects, and -5 overall. It is only statistically significant for low-income subjects. These results underscore the transfers of welfare that occurred in our test environment (see section A.3 of the Appendix for a detailed economic breakdown of the transfer and moral hazard effects).

Table 4 compares mean joy earned in the Actuarial and Employer Treatments by DP maximiz-

ers and human subjects. The results confirm significant interaction between income and insurance treatment in obtaining joy. As predicted by the DP, high-income subjects obtained more joy in the actuarial than in the employer treatment. But contrary to the DP prediction, low-income subjects did absolutely better in the employer than in the actuarial treatment. As such, differences in obtained joy between low and high-income subjects were significantly greater in the actuarial than in the employer treatment, with low-income subjects obtaining 73% of the joy high-income subjects obtained in the employer treatment, but only 64% in the actuarial treatment. Similarly, if we compare subjects performance relative to optimal, low-income actuarial is the clear outlier, at only 69%, whereas the three groups are at  $75\% \pm 1\%$ .

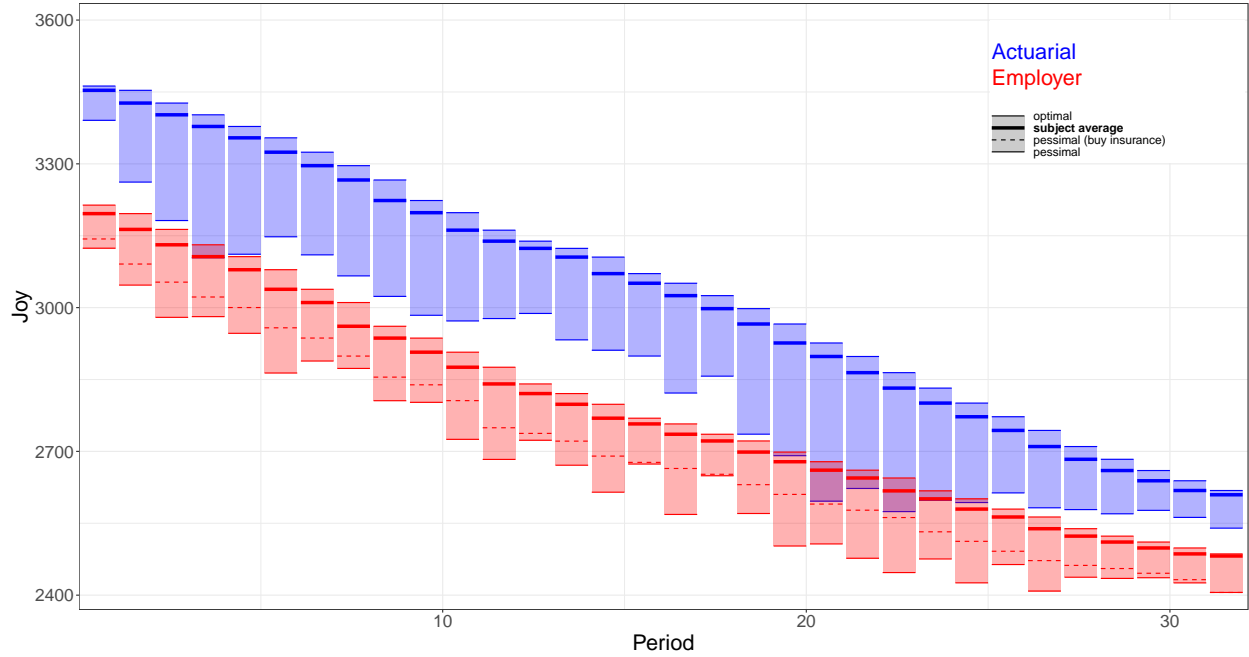
Table 4: Obtained Mean Joy

	Low Income			High Income			Low/High	
	Subj	DP	Subj/DP	Subj	DP	Subj/DP	Subj	DP
Employer	1816	2391	0.76	2482	3213	0.77	0.73	0.74
Actuarial	1679	2423	0.69	2609	3462	0.75	0.64	0.7
Emp/Act	1.08	0.99		0.95	0.93			

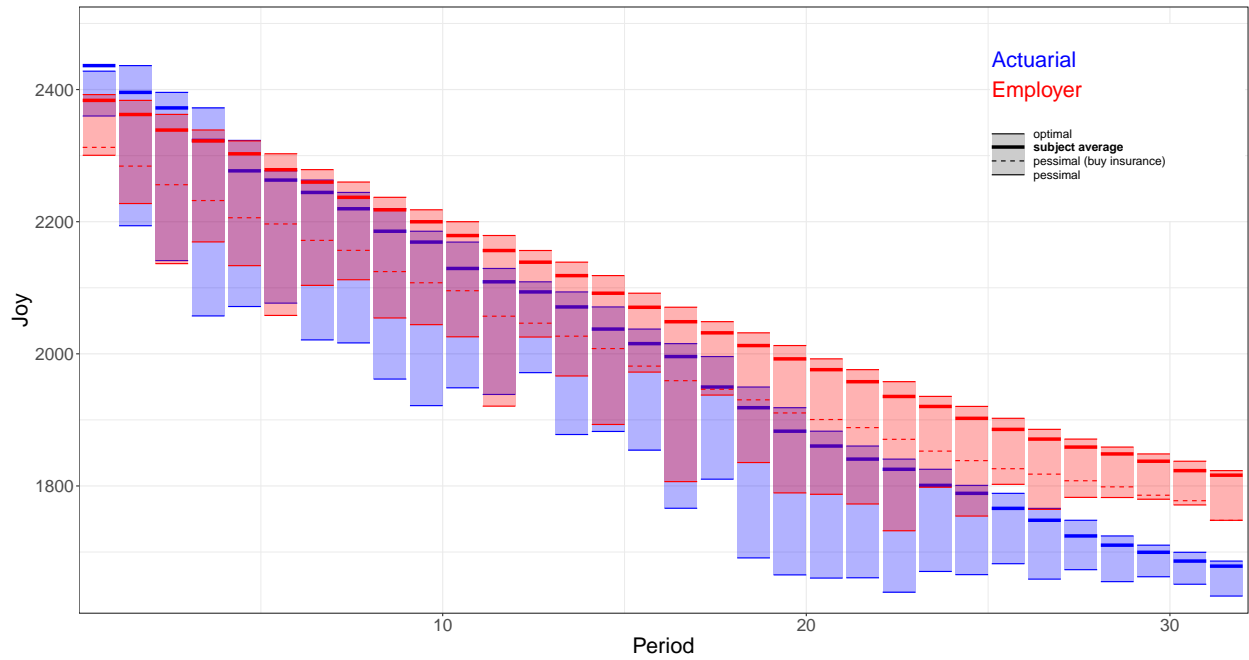
Figure 5 illustrates how subject behavior results in utility losses relative to optimal play, and how those losses accrue across life. Results for high- and low-income subjects are presented in Panels 5a and 5b, respectively. Within panels, the blue bars plot actuarial values and the red bars plot employer values. For each subject in each period, we calculate the best and worst decisions that subjects could make for maximizing joy over the remainder of their life, taking into account current health and savings. Given the joy actually earned in previous periods, the top of each period-bar (‘optimal play’) is the mean across all subjects of total lifetime joy that each subject could obtain by making the best possible decision in that period and then playing optimally for the remainder of life. The bottom of each bar represents ‘pessimal play’ for that period. It is the mean outcome associated with the worst possible decision in that period, but then playing optimally for the remaining periods of life. The bold line within each bar is the mean of observed actual play. The distance from the top of the bar to the subject mean line shows the mean amount of joy lost for that period, compared to optimal play. The sum of all those losses is equal to the distance from the top of the bar in period 1 to the observed bold line in period 32, and can be thought of the total lost joy associated with making the observed rather than optimal decisions. The distance from

Figure 5: Joy earned by subjects compared to optimal

(a) High income subjects



(b) Low income subjects



the subject play to the pessimal line shows how much more joy subjects could have lost by making worse decisions; and the total length of the line shows the spread between the worst and best decision. Finally, the dotted lines in the red employer bands show the mean expected aggregate joys with a pessimal decision, but are conditional on subjects always buying insurance.

Three conclusions are evident from Figure 5:

1. The length of the vertical bars is greater for the actuarial treatment than for the employer treatment for both income levels, indicating a greater potential for costly errors in decision making. This difference becomes even more extreme if the employer bars are limited to the dotted (buy insurance) regions – a decision nearly all subjects made in the employer treatment.
2. As life progresses potential aggregate joy in the actuarial treatment decreases more than in the employer treatment. This impact is much larger for low-income subjects for whom the actuarial bars starts above the employer bars but quickly fall and stay below, revealing the greater cost of non-optimal decisions under constrained income.
3. In any given period mean subject performance is generally much closer to the optimal than the pessimal decision, but across life these slightly non-optimal decisions accumulate to considerable losses in aggregate joy.

## 4 Discussion

Our first major finding is that *the employer treatment reduced utility differences between high- and low- income subjects and between the first (low-shock-risk) and second (high-shock-risk) phases of subjects lives*. These reductions in disparities were due to transfers and risk sharing. The fact that insurance premiums did not change as subjects ‘aged’ in the employer treatment resulted in de facto transfers from young to old which, in turn, resulted in greater smoothing of joy realized throughout life. Transfers from higher to lower income subjects in the employer treatment also had a direct impact on respective joy earned, reducing the difference between high- and low-income subjects. Of particular significance, is that the individual responsibility in the actuarial treatment was particularly detrimental to the lower income subjects. Even though their income was only 25%



lower, a much greater proportion of the low-income subjects died before the end of the 32 period life and the total joy they obtained was 36% lower than high-income subjects.

Risk sharing in the employer plan meant that insurance was always affordable even to subjects who had high expected cost and low income due to poor choices. Thus, subjects in the employer plan were able to protect themselves from shock and survive, whereas in the actuarial plan below a particular health (income) level recovery and survival is impossible. These results are consistent with the expectations that the incentives entailed by individual responsibility reduce health care costs through increased investment in prevention, but are associated with increased health disparities both between old and young and between rich and poor.

A second finding is that *endogenous investments in health interact with the institutional and economic environment in ways suggested by the DP's welfare maximizing agents*. The experimental treatments manipulating how health insurance premiums are determined and subject income affected their decisions about how much to invest in health and whether to buy insurance. While there are several laboratory experiments in which individuals must make dynamic decisions in multi-period lives (Ballinger et al., 2003, Gillet et al., 2009, Carbone and Infante, 2014, 2015), our environment presented the additional complications of random shocks and multi-variate allocations. Yet, subjects are still able to engage in arbitrage between present and future utility gains, and they are able to buffer against risk through savings, resilience and the purchase of insurance. Below is a summary of the predictions from the DP, to which subject behavior conformed qualitatively (see Tables A.5 and A.6 for a complete summary of our results):

1. Subjects invested in health, insurance, and resilience in ways that kept 91% of them alive throughout their 32 period lifetimes, with sufficient patience and forethought to smooth consumption throughout life.
2. Subjects discontinued investment in health as the endgame approached.
3. Subjects in the employer treatment purchased more insurance but invested less in resilience than in the actuarial treatment, resulting in greater total insurance payouts.
4. Low-income subjects purchased more insurance than high-income subjects, particularly in the actuarial treatment.
5. High-income subjects earned more in the actuarial than in the employer treatment.

However, there were some important deviations from the welfare maximizing investment patterns suggested by the DP:

1. Subjects under-invested in health at the beginning of life and over-invested in health at the end of life in all treatments.
2. Subjects under-invested in resilience throughout life in the actuarial treatment, undervaluing the marginal effects of resilience in reducing the size of a health shock.
3. Subjects in the actuarial treatment deviated from the predictions of the DP more than subjects in the employer treatment, especially with respect to savings and resilience.
4. Low-income subjects in the actuarial treatment had less cumulative joy than in the employer treatment, even though the DP predicted they would earn more joy.

Although the actuarial environment has higher potential maximum joy, because choices are not constrained by an obligatory employer tax to subsidize health insurance premiums, subjects in the actuarial environment performed relatively worse, compared to their DP optimum, than those in the employer environment. The greater deviation between the predicted and observed behavior in the actuarial treatment suggests that the increased complexity of the decision environment in the actuarial treatment reduces subjects' abilities to optimize their choices dynamically. Our results are consistent with a related literature, originating with [Iyengar and Lepper \(2000\)](#) and summarized by [Chernev et al. \(2015\)](#), showing the number of choices negatively impacts on quality of choice. Our findings are also consistent with research finding poor comprehension of health insurance a strong preference for simpler plans ([Loewenstein et al., 2013](#)). Theoretical gains from plans that eliminate moral hazard assume sophisticating in long term planning that most people are incapable of so such gains are unlikely to be realized. This is despite that stated-effort levels for fitness are likely to exceed real effort levels, and give the actuarial plan a "best shot" at outperforming the employer plan which is subject to moral hazard. Fitness that requires distastefully exercise or restriction of pleasurable consumption is likely to be lower. Fitness is already near zero in the employer plan so reduction will be greater in the actuarial plan decreasing subjects' outcomes in that plan.

Several findings raise questions that should be addressed in future research. One question concerns the interpretation of moral hazard. While subjects invested more in resilience in the

actuarial than the employer treatment, as predicted by moral hazard, they still invested much less than DP predicted. This finding suggests that providing premium discounts for subjects to engage in healthier behavior that lowers the expected cost of health shocks would have some effect on their behavior, but it would be a smaller effect than would be predicted by DP maximizer behavior. Individual responsibility in a complex decision environment with unpredictable shocks may result in underinvestment in the future, and not generate the expected efficiency gains, associated with incentives to invest in health. Admittedly, the subjects in our experiment were not informed about how insurance was priced—they were told they would have the option buy insurance and the price would shown on the screen. The intention was avoid any experimenter demand effects. A byproduct is a reduced saliency of the role of fitness in insurance price. However, despite not being told, the interface dynamically updated the price of insurance when the subject changed fitness level. However, given that less than 3% of Americans follow four major guidelines for healthy behavior [Loprinzi et al. \(2016\)](#), our findings are consistent with empirical patterns observed in the real world. This raises the question of why direct economic incentives produce smaller than expected effects on health maintenance. More importantly, it also raises the question of what other incentives might produce larger effects.

Another issue provoked by our results concerns whether a hybrid insurance system, combining elements of the actuarial and employer systems might produce the greatest social welfare. The employer-based system aims to increase social welfare by decreasing the complexity of the decision space and by seamlessly implementing the transfer from the young to the old and from higher to lower income individuals. The actuarial system incentivizes health investments, and therefore aims to increase social welfare by decreasing average premium costs and the actual burden from repairing health shocks. Might an Employer-based system with premium incentives for health behavior outperform the two systems we investigate here?

A final question concerns health insurance purchase. Subjects in the low-income actuarial treatment purchase more insurance than those with higher income, as predicted by the DP. This apparently reflects a greater gain from buffering risk as income decreases in our environment. The experimental result seems somewhat contrary to observational data findings in which low-income individuals are less likely to be insured ([Berchick et al., 2018](#)). We first note that subject decisions qualitatively match DP decision; subjects in the low-income treatment insured at higher rates, but

had lower resilience relative to high-income subjects, so were correctly allocating given the variation in marginal benefits. We do not know, however, if an even lower income treatment would have reversed this effect. One potential implication of our results is that low income individuals in the world outside the laboratory are more risk sensitive than higher-income individuals. It may be that impediments to the purchase of health insurance, such as financial constraints, income interruption, under-forecasted expenditures, and difficulties interacting with governmental agencies, may better explain SES effects on health insurance coverage than insensitivity to risk. Such effects may force lower income people to insure through informal mechanisms, even at considerable expense, to prevent the extremely harsh consequences a negative shock would cause them (Banerjee and Duflo, 2007). This issue deserves further experimental investigation.

The limitations of our study should be considered in interpreting these results. First, virtual ‘health’ in an experimental environment may be experienced very differently than real-world health. Behaviors, such as diet, exercise, and tobacco, alcohol and drug use, may be experienced and motivated differently than moving levers to pay for improved health in an economics laboratory. What is very encouraging, however, is that our subject behavior matched most of the qualitative predictions of the DP welfare maximizers, and deviations from maximizer behavior, such as under-investment in health and resilience, are commonly observed in the real world. Nevertheless, assessments of the experimental environment’s validity with respect to actual health behavior are necessary for evaluating the productivity of the approach. Two future experiments we plan to implement to test validity are: 1) perform multi-day experiments that substitute real-effort, accelerometer-measured exercise for investments in resilience while maintaining other features of the experimental protocol; and 2) conducting the experiments with other ethnic and SES groups as opposed to university students to evaluate the generality of the findings.

While it was employed to enhance treatment effects, a design limitation might be that all subjects were endowed an initial health stock of 70/100 at the beginning of the experiment. Many subjects tended to maintain this stock with small deviations ( $\pm 5$ ) from period to period until the endgame in which they allowed it to deteriorate. It is unclear whether they would have maintained a higher, ‘near optimal’ level of 75-80 if that were their initial allocation, or whether and how quickly they would have allowed their health to deteriorate if their initial stack was higher than optimal. However, the experiment had three training lives and chat groups with complete

public information on like-subjects' behavioral choices. This allowed the subjects to jointly explore their strategy space, prior to the 32 period lifetimes. This suggests that the behavioral proclivities observed are not the results of anchoring effects.

Finally, the disposable income differences between the treatment groups were relatively small ( $80 \Leftrightarrow 100$ ), compared to potential income differences in the real world. It is possible that the effects we found are limited to small differences in income and that expanding the difference might lead to non-monotonic relationships.

## 5 Conclusion

These results have theoretical, policy and methodological implications. Even though in theory and under optimal play the actuarial plan had higher potential life satisfaction, we find that it did not outperform the employer plan in our experiments. The gains in efficiency due to individual responsibility in the actuarial were modest, because subjects under-invested in savings and resilience to shocks, compared to optimal play. The low fitness observed in the actuarial treatment suggests concerns about moral hazard are overemphasized in policy debates. On the other hand, the employer plan resulted in a simpler decision space and significantly reduced disparities between income levels and phases of life. Thus, in this application, the advantages of risk-sharing and transfers appear to outweigh the gains from incentives for individual responsibility.

The findings from this experiment illustrate the benefits of the experimental laboratory, as a complement to existing research methods. This method allows us to simulate a complex, multi-variate dynamic health decision environment and assess lifetime effects. At the same time, it permits controlled experimental manipulations of policy alternatives whose evaluation is not impeded by selection biases. A major challenge that confronts this experimental approach is whether it can be applied with validity to real-world health behavior. Validity assessment is a clear next step, but the results obtained so far are encouraging.

There is ample scope for mutual translation from such experiments to observational research and real policy manipulations. Hypotheses generated from population-based studies could be tested with controlled laboratory experiments, and findings from laboratory studies can motivate new analyses of population data. Such experiments can be used to explore whether policies that under

consideration will result in expected effects and have unintended and unexpected consequences. Similarly, the results of existing policy experiments, such as Romneycare and the ACA, can inform new experimental treatments to isolate causality and to assess modified policy alternatives.

More broadly, the experimental environment can be adapted to address other issues in which observational studies were unable to reach conclusive findings due to insufficient data or co-linearity of important variables. There is the potential to disentangle, for example, the relationship between education and health, as well as conduct experiments addressing chronic disease and how social norms and learning impact health decisions. These factors potentially interact with insurance policy. We advocate that environments like ours are a low-cost alternative to understanding these nuances of health behaviors before proceeding to field studies and wholesale policy changes.

## Appendices

### A.1 Summary statistics

Table A.1 presents the descriptive statistics regarding subject decisions and outcomes for the four experimental treatments in the first and second halves of life.

Table A.1: Summary Statistics

	Low Income				High Income			
	Actuarial		Employer		Actuarial		Employer	
	Young	Old	Young	Old	Young	Old	Young	Old
Insurance Purchase	0.61	0.60 <sup>a</sup>	0.94	0.98 <sup>a</sup>	0.40	0.51 <sup>a</sup>	0.88	0.94 <sup>a</sup>
Resilience	0.78	1.48	0.07	0.15	0.86	1.48	0.15	0.33
Health	63.91	56.16	64.42	57.61	65.36	60.05	63.79	60.13
Savings	15.92	12.46	9.91	6.11	21.04	16.29	5.51	5.00
Joy	79.75	82.16	79.75	82.16	79.75	82.16	79.75	82.16
Income	102.31	94.79	83.33	78.09	129.52	124.64	103.33	100.63
Average Lifetime	29.4		31.9		31.4		31.1	
Premature Deaths	26		5		9		7	

<sup>a</sup> Excluding last period.

### A.2 Cumulative joy

Table A.2: Coefficient estimates from regressing cumulative Joy on insurance type

VARIABLES	(1)	(2)	(3)
	Low Income	High Income	All
Employer	137.7*	-127.8	-5.127
	(72.75)	(90.03)	(76.43)
Observations	264	256	520
# of Subjects	132	128	260

Robust standard errors in parentheses  
 \*\*\* p<0.01, \*\* p<0.05, \* p<0.1

### A.3 Transfers

Table A.3 provides calculations of the transfers in the employer based insurance. Profit ( $\pi$ ) per period for each group of subjects is the Insurer's "Payout" less Withheld (from subjects' income) and Premium paid. Sum-zero subtract one quarter of \$6.43 of insurer profit from each group. This

column sums to zero and is the inter-group transfers. Mean transfers from young to old are \$7.65, and \$3.60 from high to low income.

Table A.3: Transfer Calculations

Group	Payout	Withheld	Premium	$\pi/period$	Sum Zero
Low Inc. Young	21.54	19.43	8.46	-6.34	-4.74
Low Inc. Old	36.51	17.73	8.46	10.32	11.93
High Inc. Young	19.43	23.7	7.9	-12.17	-10.56
High Inc. Old	32.26	22.45	8.05	1.76	3.37
Total	109.75	83.31	32.87	-6.43	0

#### A.4 Supplemental regressions

Table A.4 report coefficient estimates and level cut points from ordered probit regressing Resilience on insurance type, as robustness check to the regression on resilience as continuous variable, reported in the main text. Estimates are consistent with the continuous version. In all cases employer insurance reduces resilience.

#### A.5 Results summary

All treatment effects, for both optimally computed (DP maximizers) and observed (human subjects), are summarized in the following tables: In both tables, sign denotes direction of effect, number of signs denotes size of mean effect relative to its range and variation. Blank cells indicate no meaningful effect. Survival is calculated only for the old. Table A.5 reports difference between DP joy maximizers and the human subjects.

Table A.6 has three sections. In each section, there is a column for the within DP joy maximizer comparison and a column for the within human subject (HS) comparison. The top section reports the differences between the employer and actuarial treatments. The middle section reports the differences between old and young. The bottom section reports the difference between high and low income.



Table A.4: Estimates from ordered probit regressing Resilience on insurance type

	(1) Young Low Income	(2) Young High Income	(3) Old Low Income	(4) Old High Income
Employer	-1.217*** (0.0971)	-1.283*** (0.100)	-1.090*** (0.110)	-1.154*** (0.0861)
/cut1	0.408*** (0.0579)	0.0527 (0.0770)	0.181* (0.0940)	-0.216*** (0.0799)
/cut2	0.708*** (0.0617)	0.259*** (0.0764)	0.638*** (0.0856)	0.0874 (0.0579)
/cut3	1.232*** (0.0853)	0.662*** (0.0518)	1.148*** (0.0905)	0.606*** (0.0786)
/cut4	1.647*** (0.0954)	1.094*** (0.0575)	1.850*** (0.136)	1.286*** (0.110)
Observations	4,224	4,224	4,096	4,096

Robust standard errors in parentheses

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Table A.5: Effect Size, (DP Maximizers - Human Subject)

Income Type	Ins. Type Age	Insurance Purchase	Resilience Investment	Health Investment	Survival to period 32	Total Savings	Total Joy Consumed
Low	Act/Yng	+	-	+		+++	+++
	Act/Old	--	++	++	+++	+++	+++
	Emp/Yng			+		+	++
	Emp/Old			++	+	+	++
High	Act/Yng		++	+		+++	++
	Act/Old	--	+++	++	+	+++	++
	Emp/Yng	-				++	++
	Emp/Old				+	++	++

Legend: sign notes direction. -/+ small but meaningful, - -/+ ++ moderate, - - -/+ +++ large difference

Table A.6: Effect Size for all Treatment Comparison

		Insurance Purchase		Resilience		Health		Survival		Savings		Joy	
Compare	Subgroup	DP	HS	DP	HS	DP	HS	DP	HS	DP	HS	DP	HS
Emp-Act	Yng Low	++	++	-	-		+			--	-		+
	Old Low	+++	++	--	-		++		+++	--	-	-	-
	Yng High	+++	++	--	-		-			--	-	-	-
	Old High	+++	++	--	-				+	--	-	--	--
Old-Yng	Act Low	---		++	+	-	--					++	++
	Act High	--	+	++	+	-	--					+	+
	Emp Low			++			-					+	+
	Emp High			++	+		-						+
High-Low	Act Yng	--	--	+++	+	+	+			+	+	+++	+++
	Act Old		-	++	+	+	++		+++			+++	+++
	Emp Yng				+	+	+			+	-	+++	+++
	Emp Old			+	+	+	+		-	+	+	+++	+++

Legend: sign notes direction. -/+ small but meaningful, -/ ++ moderate, -- -/+++ large difference

## A.6 Decomposition

**Moral Hazard and Joy Transfers** – Subjects under the Employer treatment (especially Low-income) were able to perform relatively better, compared to maximizers, than their actuarial counterparts. This indicates that the subsidies and implicit transfers provided under the employer plan, from high to low-Income and from young to old subjects, are having a marked effect even though all subjects tend to underinvest in resilience. Because actuarial insurance bases its premiums on individual subject resilience and health, there is by definition no moral hazard and no welfare transfers between categories of actuarial subjects. But considering the degree to which the actuarial subjects fall ‘behaviorally’ short of optimal resilience investment, we can assume that that employer subjects underinvesting to any greater extent are falling subject to moral hazard.

The mean percentage by which actuarial subjects underinvest in resilience was 54%. Premiums in the employer insurance treatment were pre-calibrated to be profitable despite anticipated underinvestment in resilience. To measure subject-induced moral hazard under the employer treatment, we simply calculated the insurer’s expected profit and the subjects’ expected joy for every level of health and resilience the subject could have had. We then calculated how much the insurance company could have transferred to the maximizer/subject conditional on her investing in each re-

Table A.7: Employer Subjects' Decomposition of Joy Obtained

	Low Income		High Income	
	DP	Subjects	DP	Subjects
<b>Actuarial Joy</b>	<b>2423</b>	<b>1679</b>	<b>3462</b>	<b>2609</b>
Selection Bias	0	0	0	0
Transfer Young → Old	-31	4	-25	1
Transfer High → Low	99	66	-75	-112
Admin Fees	-27	-21	-37	-14
Moral Hazard	-80	-57	-96	-63
Health Modified Joy	0	27	0	23
Death Prevention Joy	0	173	0	11
Total Adjustments	-39	193	-233	-154
(% Actuarial Joy Obtained)	(-1.6%)	(+11.5%)	(-6.7%)	(-5.9%)
Residual Joy	-21	-56	-16	27
(% Actuarial Joy Obtained)	(0.3%)	(-8.2%)	(-0.5%)	(+4.9%)
<b>Employer Joy</b>	<b>2391</b>	<b>1816</b>	<b>3213</b>	<b>2482</b>

silience level in order for the insurer to have the same expected profit as it does when subjects have a fitness of 0. Finally, we calculated how much more expected joy the subject could have earned with the conditional transfer. We defined potential moral hazard costs as the gain in expected joy between a subject's optimal resilience level and observed (mean) levels in actuarial subjects. We then calculated how high expected joy level would have been if there were transfers and the subjects maintained the fitness level that actuarial subjects maintained, which was 46% of the potential moral hazard cost. The balance, 54% of the transfer benefits, can be attributed to the behavioral proclivity to underinvest in resilience, even when there are incentives to invest, as in the actuarial treatment.

Using this information and mean expenditures on the various possible investments, Table A.7 below decomposes the mean components of joy obtained under the employer treatment, relative to the actuarial treatment, by considering the insurance subsidies provided and received.

The first line of Table A.7 shows the mean joy amounts at the end of life for the each income group in the actuarial Treatment. The last line shows the corresponding means in the employer treatment. Each intermediary line is the estimated impact of one difference between treatments. We saw no selection bias in the employer treatment, neither in the DP nor human subjects, meaning young and old purchase insurance at near identical rates. The third line reports estimates for the

benefit of consumption smoothing from the transfers from young to old netted across life. The human subjects benefit mildly from these. The DP is actually hurt by the transfers. The DP has the foresight to save to smooth consumption, so the imposed transfers constrain its ability to adjust savings according to the stochastic shock pattern experienced. The fourth line reports the estimated impact of the transfers from rich to poor: the effects are strong and all in the correct direction. The administration fee line is the estimation of the cost in joy to the employer subjects of the profit the insurer extracts. Moral hazard is the estimated impact on joy of maintaining resilience at a lower level, which may be individually optimal but socially costly. The Health Modified Joy line is the estimate of how much higher health in the Employer versus actuarial treatment benefits subjects by increasing their joy: DP maximizers do not display this effect. The Death Prevention Joy line is the estimate of how much extended life in the employer versus actuarial treatment benefits subjects by increasing their joy: again, DP maximizers do not display this effect. The Residual Joy is the unexplained difference between observed joy in the actuarial and employer treatments after accounting for the Total Adjustments.

**Subjects** The young to old transfer was estimated by averaging the consumption across the young and old periods, and taking the difference between the smoothed and unsmoothed consumption. Admittedly, this is only part of the benefit of the transfer—the amount applied to consumption. The other part is the benefit gained by applying some of the transfer to increasing health. This is the health modify joy line, which is the difference in the amount of joy actuarial consumption would have resulted in between employer treatment levels of health and the level in the actuarial treatment. The rich to poor transfer was calculated by taking the difference between consumption if was increased by  $(\text{transfer} + \text{mean income})/\text{mean income}$ . Admin was found by the same method as the previous transfer but with the amount of the increase in profit in the employer treatment relative to the actuarial. Prevent death is the difference in expected mean joy at the end of life including or not including subjects who died early.

**DP** We calculated for the employer subjects net payments to the insurer, summing withholdings and premium paid less health regenerated from insurance, for each age and income combination. The administration cost is the adjustment required for the employer plan to have the same profit as the actuarial plan, \$-0.53 per subject per period. For the administration line we reran the DP adjusting the income each period by this amount. The young to old and low to high transfer lines

follow the same logic. After adjusting for the difference in administration costs, we found the mean for age or income and used that amount to adjust the DP's income. We report the difference in Joy earned with adjusted and unadjusted income. The Joy Modified income line is not calculated for the DP, because using method above the DP increases its income so this is already included. The prevent death line is not calculated because there were no lives under either treatment in which the DP died prematurely.

## References

- 20—20 Research. New CarePayment Research Conducted by 20—20 Indicates Concerns Regarding Healthcare Expenses, February 2018.
- Katherine Baicker and Amy Finkelstein. The Effects of Medicaid Coverage — Learning from the Oregon Experiment. *New England Journal of Medicine*, 365(8):683–685, August 2011. ISSN 0028-4793. doi: 10.1056/NEJMp1108222.
- T. Parker Ballinger, Michael G. Palumbo, and Nathaniel T. Wilcox. Precautionary saving and social learning across generations: An experiment. *The Economic Journal*, 113(490):920–947, 2003.
- Abhijit V. Banerjee and Esther Duflo. The Economic Lives of the Poor. *Journal of Economic Perspectives*, 21(1):141–168, March 2007. ISSN 0895-3309. doi: 10.1257/jep.21.1.141.
- Jeroen CM Barte and GC Wanda Wendel-Vos. A systematic review of financial incentives for physical activity: The effects on physical activity and related outcomes. *Behavioral medicine*, 43(2):79–90, 2017.
- Edward R. Berchick, Emily Hood, and Jessica C. Barnett. Health Insurance Coverage in the United States: 2017. Current Population Report P60-264, U.S. Census Bureau, 2018.
- Enrica Carbone and Gerardo Infante. Comparing behavior under risk and under ambiguity in a lifecycle experiment. *Theory and decision*, 77(3):313–322, 2014.
- Enrica Carbone and Gerardo Infante. Are groups better planners than individuals? An experimental analysis. *Journal of Behavioral and Experimental Economics*, 57:112–119, August 2015. ISSN 2214-8043. doi: 10.1016/j.socec.2015.04.006.

- Centers for Disease Control and Prevention. FastStats. Technical report, Centers for Disease Control and Prevention, September 2018.
- Centers for Medicare and Medicaid Services. National Health Expenditure Fact Sheet. Technical report, Centers for Medicare and Medicaid Services, February 2019.
- Alexander Chernev, Ulf Böckenholt, and Joseph Goodman. Choice overload: A conceptual review and meta-analysis. *Journal of Consumer Psychology*, 25(2):333–358, April 2015. ISSN 1057-7408. doi: 10.1016/j.jcps.2014.08.002.
- Consumer Financial Protection Bureau. Consumer credit reports: A study of medical and non-medical collections. Technical report, Consumer Financial Protection Bureau, Washington, D.C., December 2014.
- Charles Courtemanche, James Marton, Benjamin Ukert, Aaron Yelowitz, and Daniela Zapata. Effects of the Affordable Care Act on Health Behaviors after Three Years. Technical report, National Bureau of Economic Research, 2018.
- Charles J. Courtemanche and Daniela Zapata. Does Universal Coverage Improve Health? The Massachusetts Experience. *Journal of Policy Analysis and Management*, 33(1):36–69, January 2014. ISSN 1520-6688. doi: 10.1002/pam.21737.
- Amy Finkelstein, Nathaniel Hendren, and Erzo F. P. Luttmer. The Value of Medicaid: Interpreting Results from the Oregon Health Insurance Experiment. Working Paper 21308, National Bureau of Economic Research, June 2015.
- Ausmita Ghosh, Kosali Simon, and Benjamin D. Sommers. The Effect of Health Insurance on Prescription Drug Use Among Low-Income Adults: Evidence from Recent Medicaid Expansions. *Journal of Health Economics*, 63:64–80, January 2019. ISSN 0167-6296. doi: 10.1016/j.jhealeco.2018.11.002.
- Joris Gillet, Arthur Schram, and Joep Sonnemans. The tragedy of the commons revisited: The importance of group decision-making. *Journal of Public Economics*, 93(5):785–797, June 2009. ISSN 0047-2727. doi: 10.1016/j.jpubeco.2009.02.001.

- Xavier Giné, Dean Karlan, and Jonathan Zinman. Put Your Money Where Your Butt Is: A Commitment Contract for Smoking Cessation. *American Economic Journal: Applied Economics*, 2(4): 213–235, October 2010. ISSN 1945-7782, 1945-7790. doi: 10.1257/app.2.4.213.
- Michael Grossman. On the concept of health capital and the demand for health. *Journal of Political Economy*, 80(2):223–255, 1972.
- Institute of Medicine and National Research Council. *U.S. Health in International Perspective: Shorter Lives, Poorer Health*. Washington, DC, January 2013. ISBN 978-0-309-26414-3. doi: 10.17226/13497.
- Sheena S. Iyengar and Mark R. Lepper. When choice is demotivating: Can one desire too much of a good thing? *Journal of personality and social psychology*, 79(6):995, 2000.
- Ahmed W. Khwaja. Health insurance, habits and health outcomes: Moral hazard in a dynamic stochastic model of investment in health. In *Proceedings of the 2002 North American Summer Meetings of the Econometric Society: Labor Economics and Applied Econometrics*, Ed. David K. Levine and William Zame, 2002.
- Brandy J. Lipton and Sandra L. Decker. The effect of health insurance coverage on medical care utilization and health outcomes: Evidence from Medicaid adult vision benefits. *Journal of Health Economics*, 44:320–332, December 2015. ISSN 0167-6296. doi: 10.1016/j.jhealeco.2015.10.006.
- George Loewenstein, Joelle Y. Friedman, Barbara McGill, Sarah Ahmad, Suzanne Linck, Stacey Sinkula, John Beshears, James J. Choi, Jonathan Kolstad, David Laibson, et al. Consumers' misunderstanding of health insurance. *Journal of Health Economics*, 32(5):850–862, 2013.
- Paul D. Loprinzi, Adam Branscum, June Hanks, and Ellen Smit. Healthy Lifestyle Characteristics and Their Joint Association With Cardiovascular Disease Biomarkers in US Adults. *Mayo Clinic Proceedings*, 91(4):432–442, April 2016. ISSN 0025-6196, 1942-5546. doi: 10.1016/j.mayocp.2016.01.009.
- Marc S. Mitchell, Jack M. Goodman, David A. Alter, Leslie K. John, Paul I. Oh, Maureen T. Pakosh, and Guy E. Faulkner. Financial Incentives for Exercise Adherence in Adults: Systematic Review

- and Meta-Analysis. *American Journal of Preventive Medicine*, 45(5):658–667, November 2013. ISSN 0749-3797. doi: 10.1016/j.amepre.2013.06.017.
- Robert E. Moffit, Christopher Pope, and Whit Ayres. The National Debate over Government-Controlled Health Care. Technical report, The Heritage Foundation, Washington DC, February 2019.
- National Research Council. *International Differences in Mortality at Older Ages: Dimensions and Sources*. National Academies Press, Washington, DC, 2010. ISBN 978-0-309-15734-6.
- Organisation for Economic Co-operation and Development. Health at a Glance 2017: OECD Indicators How does the United States compare?, 2017.
- W. Kip Viscusi and William N. Evans. Utility functions that depend on health status: Estimates and economic implications. *The American Economic Review*, 80:353, 1990.
- Kevin G. Volpp, Leslie K. John, Andrea B. Troxel, Laurie Norton, Jennifer Fassbender, and George Loewenstein. Financial Incentive–Based Approaches for Weight Loss: A Randomized Trial. *JAMA*, 300(22):2631–2637, December 2008. ISSN 0098-7484. doi: 10.1001/jama.2008.804.
- Robert R. Weathers and Michelle Stegman. The effect of expanding access to health insurance on the health and mortality of Social Security Disability Insurance beneficiaries. *Journal of Health Economics*, 31(6):863–875, December 2012. ISSN 0167-6296. doi: 10.1016/j.jhealeco.2012.08.004.