Moral Hazard in Prevention and Treatment
A Reference Dependent Model

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Abstract
Moral hazard describes the changes of behaviors in prevention and treatment caused by health insurance. Cheaper treatments may discourage preventive efforts (ex-ante moral hazard), and encourage patients to spend more (ex-post moral hazard). The Von Neumann-Morgenstern utility function, adopted by standard economic analyses to study individual decisions, has inconsistent predictions with what people actually behave regarding prevention and treatment. People could be driven bankrupt by chronic diseases, and have extraordinarily strong preferences over expensive medical products. Motivated by the rising academic interest in moral hazard as well as the puzzles that are difficult to explain by conventional utility theories, this paper endeavors to apply the reference dependent model to analyze the decision of prevention and the demand for treatment. It also studies the effect of health insurance, and sheds lights on the design and regulations of health insurance.

In the prevention problem, optimal level of preventive effort is determined solely by one’s concerns over his future health, the expected medical expenses do not distort the incentives of prevention. Thus, a pooling insurance that reduces the cost of treatment universally will not create ex-ante moral hazard.

As for treatment, reference dependent model can well explain the phenomena of medical bankruptcy and patients’ unreasonable preferences over expensive medical products, and it favors coinsurance policies over deductibles.

JEL classification: D1, D8, I1.

Keywords: Moral hazard, reference dependence, prevention, medical demand, health insurance.

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1 Introduction

Moral hazard is one of the central issues in health economics. It describes the changes in behaviors in prevention and treatment. Due to asymmetric information (Arrow, 1963), the insurance provider does not know about the preventive behaviors, health status or reasons for the usage of healthcare of the insured. Specifically, health insurance influences consumers’ incentives via two channels. As potential treatments become cheaper, health insurance may decrease the level of preventive efforts that are taken in order to reduce the likelihood of future diseases, known as “ex-ante moral hazard” (Ehrlich & Becker, 1972).” On the other hand, ex-post moral hazard rises when the price of healthcare are effectively reduced by cost-sharing, as a result of which people demand more healthcare than they do without insurance (Pauly, 1968, 1974).

In prevention, health insurance generally encourages the use of “preventive care,” such as vaccinations and the screening or detection of breast cancer (Pagán, Puig, & Soldo, 2007; Courbage & de Coulon, 2004), but decrease the level of “preventive efforts,” such as physical exercise and abstention from smoking (Klick & Stratmann, 2007; Stanciole, 2008). However, not all evidence confirms the existence of ex-ante moral hazard. Courbage and de Coulon (2004) failed to detect any ex-ante moral hazard; Dave and Kaestner (2009) found ex-ante moral hazard effect for men only, and in the ongoing Oregon Health Insurance Experiment with real monetary coverages, no ex-ante moral hazard is detected (Finkelstein, Taubman, & Wright, 2011).

As a rule, ex-ante moral hazard is more likely to occur for diseases where preventive efforts are difficult to implement, such as following a strict diet, exercise a lot, or keeping away from smoking (Yilma, van Kempen, & de Hoop, 2012). And the inadequacy of such preventive behaviors is largely responsible for the proliferation of non-communicable diseases (or chronic diseases, NCDs henceforth), which “are of long duration and generally slow progression,” and do not transmit among people through infectious ways (WHO, 2015b). Major types of NCDs include heart disease, stroke, cancer, diabetes and chronic lung disease (WHO, 2015a). NCDs have been identified as the primary cause of deaths all over the world (Choi et al., 2008; NHFPC, 2015), and they lead to inequality in health and wealth (Alwan & Others, 2011). The prevalence of NCDs–partly because of the increased life expectancy—is an important factor that contributes to the size and rapid growth of the healthcare cost (Deloitte, 2016). The long duration of NCDs make people suffer from expensive treatment regimens and prolonged individual cares, which accounts for a considerable share of the global healthcare expenditure. In the review of Muka et al. (2015), healthcare spending for cardiovascular diseases ranges from 12-16.5%, and
other NCDs accounts between 0.7 and 7.4%. The control of ex-ante moral hazard is thus crucial, in that the most cost-efficient and effective form of intervention for NCDs is prevention, i.e. “to lower the prevalence of the major risk factors through population-wide methods directed at everyone, and to target treatment to people at high risk of NCDs” (Beaglehole et al., 2011). One estimation suggest that were all the risk factors eliminated, there would be a drastic decrease of NCD prevalence (International Federation of Pharmaceutical Manufacturers and Associations, 2011).

Ex-post moral hazard contributes to the rapid growth of health care expenditure, which imposes tremendous pressure on the fiscal sustainability of the healthcare system, in both developed and developing countries (OECD, 2015; Collins, Doty, & Davis, 2004; Jakovljevic & Getzen, 2016). The expanding healthcare demands have placed a worldwide pressure for cost reduction and healthcare reform, and it will continue to intensify during the economic recovery after the global credit crisis (Porter, 2013). Empirical evidence consistently confirms the ex-post moral hazard effect of health insurance. The revolutionary and pioneer research is the RAND health insurance experiment between 1974 and 1981 by Manning, Newhouse, and Duan (1987), who gave a robust result which rejects the null hypothesis that health spending does not respond to the out-of-pocket price (Aron-Dine, Einav, & Finkelstein, 2013). Studies with natural experiments also confirm that healthcare utilization respond negatively to the changes of medical prices (e.g. van Dijk et al., 2013; Nolan, 2007; Voorde, 2001).

The high cost of healthcare—large out of pocket expenses and informal payments—put people with ordinary income at the risk of impoverishment. The shocks to income brought by illness are depleting the financial resources of households, in US, for example, medical bills is one of the major financial catastrophes to households. Medical debt is commonly affecting 29 million nonelderly adult Americans, with and without health insurance (Doty, Edwards, & Holmgren, 2005). In some cases, medical debt contributes to the collapse of creditworthiness which forces some people to declare personal bankruptcy. Personal bankruptcies in US are growing rapidly with medical bills being the biggest cause: in 2007, 62% filed bankruptcies are due to medical bills (Himmelstein, Thorne, Warren, & Woolhandler, 2009), and most of those who declared for bankruptcy were “middle-class, well-educated home-owners” (Tamkins, 2009). Even health insurance “doesn’t buffer consumers against the financial hardship” (Magan, 2013). As for people with NCDs, additional to the deprivation of their health and productivity (Abegunde & Stanciole, 2006), the financial burden is remarkably substantial: the likelihood to go bankruptcy for cancer patients are 2.65 times higher than people without cancer (Ramsey, Blough, & Kirchhoff, 2013). Chronic diseases even drive people to commit suicide in rural China (Yao, Chen, & Du, 2012; Bai, 2006). And such phenomena cannot be ex-
plained with a concave utility function with health and wealth being its arguments, not to mention the conventional approaches where illnesses are assumed to be shocks to income only (Zweifel & Manning, 2000). Besides medical bankruptcy, the market of medical devices in China offers another interesting puzzle. In China, people can choose between imported medical devices and domestically manufactured ones. The imported offers higher quality in general, but the differences are getting smaller and smaller. Despite the fact that the imported devices are more expensive and usually not covered by the insurance, people demonstrate strong preferences over them—70% of the high-end market are occupied by imported products (W. Liu, 2014). For example, in the market of stent, an appliance for treating coronary diseases, even told by their physicians that domestic made stents, more than 50% cheaper than the imported, have almost the same quality, many people are still reluctant to use made-in-Chinas (Huang, 2014). In a recent survey of 821 Chinese physicians, more than 30% reported that when choosing the brand of stents, there is no involvement of patients’ economic statuses (Dxy Vote, 2015). Similarly, in the market of anti-tumor drugs, imported drugs are more often chosen. Given that the share of the domestic drugs have increased due to the improved quality, in the year of 2014, imported drugs occupied more than 50% of the market in the major Chinese cities; for the drugs which do not have patent protections¹, imported drugs have similar shares with domestic ones (Southern Medicine Economic Institute, 2015). The unreasonably high preference over imported products is also difficult to explain by the standard utility theories. These puzzle stated appeal for new descriptive theories to investigate people’s decisions regarding their prevention and treatment.

Motivated by the rising academic interests in ex-ante and ex-post moral hazard, this paper endeavors to apply the reference dependent model to analyze the decision of prevention as well as the demand for treatment. It also studies the effect of health insurance, and sheds lights on the design and regulations of health insurance. By virtue of reference dependent model, people’s preventive decisions are found to be solely driven by their concerns about health, and a pooling insurance policy does not create ex-ante moral hazard; as for treatment, the model predicts the absence of income effect in demand, and favors coinsurance over deductible insurances to control ex-post moral hazard. The explanations for puzzles and policy implications are also discussed.

The rest of the paper proceeds as follows. Section 2 introduces the reference dependent model, and reviews the empirical evidence in health economics. Section 3 elaborates the application of reference dependent model in prevention and treatment, and contrast the results with the predictions of standard utility theory. Section 4

¹Among the 49 common anti-tumor drugs listed by WHO, China can produce 40 anti-tumor drugs (J. Liu & Tao, 2011).
2 Reference Dependent Preferences and Its Empirical Supports

2.1 The model

In psychology, people’s perceptions, decisions exhibit dependence on reference points. Kahneman and Tversky (1979) transferred this phenomenon into economics, motivated by the compelling and replicable violations of the Von Neumann-Morgenstern expected utility theory (EUT) (e.g. Starmer, 2000, for a review). Reference dependent model captures the three fundamental features of human cognition, framing, loss aversion and diminishing sensitivity, and they underly much of the empirically observations in decision making. It then becomes the most influential alternative theory on decisions under uncertainty (see the review of Barberis, 2013). Reference dependence means that people do not evaluate final outcomes but instead, they frame each outcome as gains or losses in contrast with a reference point. The decisions largely depend on the position of reference points, which may be updated according to new informations. Besides the so called framing effect, there are two other important characteristics in the reference dependent model—loss aversion and diminishing sensitivity. Loss aversion has been consistently identified as “important aspect of human choice behavior” (Rabin, 1998; Camerer, 2005, cited in Weber & Johnson, 2008). It means that people are more averse to losses than their appreciation to gains of the same size, and is identified in decisions over health outcomes (Bleichrodt & Pinto, 2002; A. E. Attema, Brouwer, & l’Haridon, 2013). Regarding diminishing sensitivity, it characterizes the fact that people are more sensitive to changes near the reference point than those that are remote. Schmidt (2012) provided many empirical studies in various decision scenarios that confirms framing, loss aversion and diminishing sensitivity. Later, Tversky and Kahneman (1991) extended reference dependence, loss aversion and diminishing sensitivity to the analysis of riskless choice, and Loewenstein (1988) further demonstrated the applicability of the model in intertemporal choices.

Kahneman and Tversky (1979) proposed the following value function

\[
V(x) = \begin{cases} 
 v(x) & \text{if } x \geq 0 \\
 -\lambda v(-x) & \text{if } x < 0 
\end{cases}
\]

where \( x > 0 \) are gains and \( x < 0 \) are losses perceived with respect to a reference point, \( v : \mathbb{R}_+ \to \mathbb{R}_+ \) is a weakly concave, twice differentiable increasing function.
The value at the reference point is normalized to 0 \((v(0) = 0)\), and \(\lambda > 1\) is the parameter of the degree of loss aversion. Figure 2.1 depicts its shape.

\[ V(x) < -V(-x), \forall x > 0. \]

Diminishing sensitivity implies people to be risk averse over gains and risk seeking over losses. Tversky and Kahneman (1992) further provided a power form of the value function,

\[ V(x) = \begin{cases} 
  x^\beta & \text{if } x \geq 0 \\
  -\lambda(-x)^\beta & \text{if } x < 0
\end{cases} \]

2.2 Empirical evidence in health economics

The descriptive deficiency of EUT in health domain is widely acknowledged. As Bleichrodt, Abellan-Perpiñán, Pinto-Prades, and Mendez-Martinez (2007) pointed out, “using expected utility to analyze responses to utility measurement tasks in spite of its poor descriptive standing can lead to biased utilities, and decision analyses based on these biased utilities may result in incorrect recommendations (p.469).” Violations of EUT in the field of health economics have been extensively observed in the process of health utility measurement (e.g. Llewellyn-Thomas et al., 1982; Mölken, 1995; Stalmeier & Bezembinder, 1999; Pinto-Prades & Abellán-Perpiñán, 2005). The problem is, under EUT, theoretically equivalent assessment procedures produce systematically different utilities. Bleichrodt, Pinto, and Wakker (2001) argued that loss aversion were one of the key factors that caused the inconsistencies in
the valuation of different health state, and Oliver (2003) confirmed this by studying the choices of life durations (see also Doctor, Bleichrodt, & Miyamoto, 2004).

There are attempts using reference dependence to correct the biases in health utility measurement based on EUT. For example, after adjusting for loss aversion, Bleichrodt et al. (2001) showed that the health valuation methods lead to higher internal consistency, in the sense that theoretically equivalent methods give similar results. The adjustments based on reference dependent model are further supported by Osch (2004); van Osch, van den Hout, and Stiggelbout (2006); Bleichrodt et al. (2007).

In addition to loss aversion, framing effects are also well recognized in medical decision making. People exhibit patterns of reference dependent preference when valuing health states and life durations (Verhoef, De Haan, & Van Daal, 1994; Bleichrodt & Pinto, 2005; Happich, Mook, & Lengerke, 2009), and patients’ treatment choices are found to be influenced by the position of reference point (Stiggelbout, Kiebert, & Kievit, 1994; Prosser & Kuntz, 2002; Winter & Parker, 2007). For example, Winter and Parker (2007) discovered that variations in the accessibility of life-prolonging treatments among people are explained by the different reference points. Patients with lower reference point expressed stronger preferences for life-prolonging treatments, especially in the worse-health scenarios. Furthermore, in the context of chronic diseases, the utility function also exhibits diminishing sensitivity, it is concave in gain and convex in loss domains (Bernstein, 1999). Several public health intervention studies have demonstrated how the frame of the outcome would in practice influence the choice of individuals, such as in the preference for becoming pregnant (Pauker, Pauker, & McNeil, 1980), lung cancer treatment methods (McNeil & Pauker, 1982), vaccinations (Slovic, Fischhoff, & Lichtenstein, 1982), breast cancer (Hughes, 1993; Siminoff & Fetting, 1989) and chemotherapy (A. O’Connor & Boyd, 1985; A. M. O’Connor, 1989). In their study of preferences over treatments for a hypothetical lung cancer, McNeil and Pauker (1982) interviewed outpatients, radiologists, and business major students to choose between surgery or radiation therapy. Surgery was assumed to have a 10% chance of perioperative death, but provides higher life expectancy upon survival. The outcome data was presented in terms of survival rates to some subjects, and in terms of mortality rates to some others. Loss aversion implies that surgery would seem less attractive if the risk was presented in terms of death. Indeed, the author found that all the three groups selected radiation more frequently when the outcomes of each therapy were presented in terms of mortality (45% v.s. 25%).

Rothman, Bartels, Wlaschin, and Salovey (2006) labeled such phenomena as “message framing,” that medical decision making is influenced by how the health information are framed. A health message that emphasizes the benefits of taking
the action is “gain-framed,” and the one emphasizes the costs of not taking is “loss-framed.” A gain-framed statement can refer to both good things that will happen and the bad things that will be avoided, whereas loss-framed statements can refer to bad things that will happen and good things that will not happen. Reference dependence predicts risk aversion in gains and risk seeking in losses, and what they find is consistent with it, “When people are considering a behavior that they perceive involves some risk of an unpleasant outcome (e.g., it may detect a health problem), loss-framed appeals should be more persuasive. When people are considering a behavior that they perceive involves a relatively low risk of an unpleasant outcome (e.g., it prevents the onset of a health problem), gain-framed appeals should be more persuasive” (p.s205). The authors also list several studies in line with their predictions. In practice, more gain-framed messages are used to promote prevention behaviors (exercise, diet, no smoking), and more loss-framed messages are used to promote detection behaviors.

There are direct comparisons of the performances between EUT and reference dependent model. Abellan-Perpiñan, Bleichrodt, and Pinto-Prades (2009) investigated the potential of reference dependent model to lead to better health evaluations. They calculated the utility values based on the two models, and compared the predictions with the directly elicited rankings. Results indicate that reference dependent model outperforms EUT when considering preferences over risky prospects—“The consistency of prospect theory with directly elicited choices and rankings is much higher than that of expected utility.” (p.1046) However, it did not provide better performance when predicting intertemporal decisions. In the context of health insurance decisions, Marquis and Holmer (1996) also claimed reference dependent model provides better fit than EUT with RAND study data. Their results suggest that enrollment in a hypothetical insurance does not depend on household income and premium levels, but rather on the expected payoff that the subjects will receive when sick. When facing risky prospects in people’s decisions of insurance demand, it is found that “prospects are evaluated as gains and losses from a reference point rather than as final wealth states, that the evaluation of gains and losses is asymmetric, and that individuals exhibit risk-seeking behavior in the domain of losses” (p.426).

2.3 Reference point in health, and its adaptation

2.3.1 Location of reference points

In the reference dependent model, the reference point plays an essential role in decision making. In their first paper that introduces reference dependence, Kahneman and Tversky (1979) pointed out several determinants of reference points, such as
status quo, social norms, and aspiration levels. However, in decisions about health, there are no consensus about the location of reference point. Findings suggest that it is reasonable to assume the goal of the individual (Heath, Larrick, & Wu, 1999; van Osch et al., 2006), or the “aspiration level of survival” (Miyamoto & Eraker, 1989), as the reference point\(^2\); current health status is often used as well (Lenert, Treadwell, & Schwartz, 1999). One can also expect that the lowest outcome (A. Attema, 2012; Bleichrodt et al., 2001), or the sure outcome (Osch, 2004; Osch & Stiggelbout, 2008) being the reference point.

Evidences evince that the health status is one of the key determinants of the location of the reference point. Froberg and Kane (1989) studied patients’ valuations, and find that “patients with a particular condition often assign it higher utility than do persons without the condition. (p.681)” Dolan (1996) further confirmed that people with poorer health generally give higher valuations to the same health states, and suggests that the current health status has important effects. In general, healthy people has higher reference points, and whereupon regard any sickness as losses; sick people, with lower reference point, in contrast, perceive to have less losses (see Treadwell & Lenert, 1999, for a comprehensive review). Lenert et al. (1999) demonstrated how reference dependent value function could explain the differences in the preferences for health conditions between patients and the general public.

For example, consider two 50-year-old individuals. One is healthy, expecting living up to 80; whereas the other is diagnosed with cancer, and told by his oncologist that he was left with 10 years or thereabouts. Figure 2.2 illustrates their value functions. The reference point of the healthy agent is his remaining life expectancy, i.e. 30 yrs; whereas the individual with cancer is likely to have a lower reference point. Thus, for the same outcome, the cancer patient always have higher valuation than the healthy individual.

### 2.3.2 Dynamic inconsistency and reference point adaptation

Adaptation helps to explain the differences in valuations (Adang, 2001). There is a recalibration of reference point in response to the changes of the health. The cancer patient in Figure 2.2 has a lower reference point, if he has adapted to his post-diagnosis health, by setting his reference point to 10 yrs to be more consistent with his post-diagnosis prognosis (Weinfurt, 2007). The evolution of reference point both over time and with respect to new information about health, is called “reference point adaptation,” and was first recognized in experiments using monetary gambles.

One of the earliest experiment conducted by Tversky and Shafir (1992) detected

\[^{2}\text{van Osch et al. (2006) explores the reference point by detecting the point of inflection of preferences, and Miyamoto and Eraker (1989) directly asked the subjects whether they view a certain amount of years as gains or losses.}\]
the shift of reference point by imaginary monetary gambles. Barkan and Busemeyer (2003) extended the experiment with real monetary payoffs using the same gambling paradigm, and the model comparisons suggest that a shifted reference point provides the best account for the findings. In sequential monetary gambles, there is a tendency that people prefer riskier gambles after financial losses, and choose safer options after a monetary gain, and it underlies some important phenomena such as the gambler’s fallacy. The gambler’s fallacy contribute to explain why a gambler keeps gambling in the face of mounting losses, believing the imminent return of their “luck” after series of losses (Sharpe & Tarrier, 1993). The chasing-loss pattern are commonly observed not only in monetary gambles (Barkan & Busemeyer, 2003; Tversky & Shafir, 1992), but also in many decision scenarios, such as securities trading (Brown, Harlow, & Starks, 1996; Seo, Goldfarb, & Barrett, 2010) and horse race betting (Hausch, Ziemba, & Rubinstein, 1981). Such findings are also corroborated by fMRI\(^3\) records (Campbell-Meiklejohn, Woolrich, Passingham, & Rogers, 2008; Xue, Lu, Levin, & Bechara, 2011; Hytönen et al., 2014)\(^4\).

In finance, different assumptions are used to model reference adaptation. Bowman, Minehart, and Rabin (1999) studied the effect of loss aversion on the consumption and saving behavior, assuming people adjust their reference points according to recent consumptions. Similar adjustment is also assumed in the domain of security trading. Chen and Rao (2002) suggested that people’s reference points react to stimulus, but insufficiently; Gneezy (2005), using real market data, found out that people are most likely to use historical peaks as the reference point; Arkes, Hirshleifer, Jiang, and Lim (2008) tested the magnitude of reference point adaptation.

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\(^3\)Abbrev. for functional magnetic resonance imaging

\(^4\)However, there are also experiments revealing the opposite result, people are loss averse after losses, and risk seeking after gains, also known as “the house money effect” (e.g. Thaler & Johnson, 1990).
they note faster adaptation of the reference point to gains than losses of equivalent sizes.

In health, reference point adaptations are consistently documented. Women’s reference point shifts in their decisions of anesthesia use during childbirth, they preferred to avoid using anesthesia during childbirth when asked one month before labor and during early labor; however, during active labor their preferences suddenly shifted toward avoiding pain. Their preference shifted again toward avoiding the use of anesthesia when evaluated at one month postpartum (Christensen-Szalanski, 1984). Besides, people chase losses with respect to their health—they become risk-seeking as their health declines (A. M. O’Connor, 1989), and may even prefer aggressive Phase I trials\(^5\) that their physicians themselves report not to participate (Meropol et al., 2003; Gaskin et al., 2004).

The aggressiveness of terminally ill patients is well explained by prospect theory with an evolving reference point determined by pre- and post-diagnosis life expectancies (Rasiel, Weinfurt, & Schulman, 2005). Figure 2.3 depicts the value functions of two patients who are diagnosed with life-threatening conditions. Patients were both healthy before. For a recently diagnosed patient, since adaptation takes time, his prognosis reference point is likely to remain close to his pre-diagnosis life expectancy (30 yrs), so he will perceive all other prognoses as losses, and his risk-seeking behavior is explained by the convexity of his value function, as the left panel depicts. By comparison, for the patient who has already recalibrated his reference point to a more realistic level\(^6\), he will appear to be risk averse, as shown by the right panel. The authors also noted that how much the reference point will shift in response to


\(^6\)This reference point may or may not equal actual life expectancy.
the new conditions depends on lots of factors, such as how recently the patient was diagnosed, his health before the recent diagnosis, etc. It sometimes happens that the patient has to choose treatments for his life-threatening condition while he has not adapted to his post-diagnosis prognosis, then he is willing to take a considerable amount of risks, as the what problem gamblers always do to win back their money (Page, Savage, & Torgler, 2013; Genesove & Mayer, 2001; Odean, 1998).

3 Model

Assume individuals are homogeneous, and initially healthy. The timing of the decision is shown in Figure 3.1. Each individual lives for two periods, young \((t = t_0)\) and old \((t = t_1)\). In the first period, the individual decides his lifestyle, measured by the level of preventive efforts \(e \in \mathbb{R}_+\). He also pays the premium \(P\) in the first period. This paper studies the case of compulsory insurance, as shall be explained later, \(P\) will not enter into the decision problem. \(e\) will determine the probability of illness in the second period, denoted by \(\pi(e)\). If the individual is diagnosed with NCDs, he is going to decide the level of treatment, measured by his medical expenses \(M\). Furthermore, assume the individual uses his status quo in each period as reference point.

3.1 The value function for NCDs

In most studies, health insurance are modeled merely as a protection against uncertain medical expenses, and the insurance demand or regulations are studied using a utility function with income being its unique argument. It works for curable diseases, since after what people get fully recovered by paying for treatment. The impact of such diseases can be treated as shocks to income only. In this paper, nevertheless, since risky health behaviors \((e)\) will affect the likelihood of chronic diseases that are non-curable, the occurrence of such illness will cause not only income
losses to the individual, but irreparable health damages as well. The irreparable damage in health could be measured in terms of reduced productivity, pains and sufferings, and loss of life span (Abegunde & Stanciole, 2006). Taken the premature deaths caused by NCDs into account (Suhrcke, Nugent, Stuckler, & Rocco, 2006), this paper uses quality adjusted life expectancy (detailed elaborations in the next section) as the measure in health dimension, and perceived gains or losses in wealth are the arguments in wealth dimension. On that account, the insurance could only protect the individual in the wealth dimension, if the NCDs occur; there are no ex-ante instruments for the individual to hedge the risks in the dimension of health.

For decisions that consist of more than one attributes, the first step is to determine whether an attribute yields a gain or a loss. One way is to compress the multi-attribute outcome into a single dimension, and see if it is a gain or a loss as a whole. Such approach is used by Zank (2001) and Bleichrodt and Miyamoto (2003). Another method is to assume a reference point for each attribute, and evaluate the alternative as gains or losses on each dimension. This “attribute-specific evaluation (Bleichrodt, Schmidt, & Zank, 2009)” is commonly assumed in empirical studies (e.g. Payne, Laughhunn, & Crum, 1984; Fischer & Kamlet, 1986), and its descriptive accuracy is generally acknowledged (Tversky & Kahneman, 1991; Bateman, Munro, Rhodes, Starmer, & Sugden, 1997; Bleichrodt & Pinto, 2002). As the consequences of NCDs involve in both health dimension and wealth dimension, and it is difficult to find a universal measurement to evaluate health and wealth in a single dimension, therefore, this paper adopts the attribute-specific evaluation method to analyze the decisions with NCDs.

For the notations, let $S$ denote the set of states of nature. Then $S = \{\text{sick, healthy}\}$, only two states are possible, either with NCDs, or not. Uncertainty is only faced in the first period, when the individual decides his level of preventive efforts, which affects the probability distribution of future states. Let $C_h$, $C_w \subset \mathbb{R}_+$ denote the set of outcomes in dimensions of health and wealth respectively, and the outcome is denoted by $c = (c_h, c_w) \in C_h \times C_w$. And it can be immediately deducted that across states, $c_h^{\text{sick}} < c_h^{\text{healthy}}$, since the occurrence of NCDs reduces life years; and $c_w^{\text{sick}} \leq c_w^{\text{healthy}}$, because of the medical expenses. More specifically, $M$ is defined such that

$$c_w^{\text{healthy}} = Y - P, \ c_w^{\text{sick}} = Y - P - M.$$  

Here I assume that NCDs affect one’s wealth level via only one channel, the medical expenses. The effect of reduced earnings, medical leave, etc., is not considered in this paper.

In each period, the status quo of the decision maker serves as the reference point, denoted by $r = (r_h, r_w) \in C_h \times C_w$. The outcomes $c$ are then evaluated as gains or
losses, compared with $r$. Mathematically, $c_i > r_i$ will be perceived as gains in that dimension, and $c_i < r_i$ as losses, $i \in \{h, w\}$. The reference dependent utility function, $U(c, r) : C_h \times C_w \to \mathbb{R}_+$, represents the preference relations: $\forall x, y \in C_h \times C_w$, given a fixed reference point $r$, $x \succ y \iff U(x, r) \geq U(y, r)$. This paper keeps in line with the assumption that utilities are derived from changes with respect to reference points, thus the utility function is decomposed into a two-dimensional value function in the equation below

$$U(c, r) := V(c_h - r_h, c_w - r_w).$$

(3.1)

where $V : \mathbb{R}^2 \to \mathbb{R}$, and increases with respect to its arguments.

### 3.2 Prevention: Choice of lifestyles

#### 3.2.1 Assumptions

Denote the reference point in $t_0$ by $r_0 = (r_h(e), r_w(e))$. The reference points, or the status quo in the first period, is the individual’s expectations of his future health and wealth. The decision variable in the first period is the level of preventive effort, $e$. Its impacts on the well-being of the individuals are expressed in two channels. Firstly, it determines the likelihood of the sick state in the next period ($\pi(e)$). It has to be noted that there are many other factors than $e$ that can affect the likelihood of NCDs, such as genes, environment, mental states, etc. Therefore, one cannot completely eliminate the risks of NCDs’ future occurrence by exerting a high $e$. Assume $\pi(0) < \pi(e) \in (0, 1)$, where $\pi'(e) < 0 \leq \pi''(e)$. Secondly, it affects the payoffs in health. Compared with no efforts, empirical evidence shows that a positive $e$ is costly, denote the cost by $\alpha(e)$. It is arguable that, for some people with special preferences, preventive efforts may happen to be enjoyable, such as for vegetarians and sports fans. However, the widespread NCDs strongly demonstrate the difficulty of preventive efforts for the majority. See Proposition A.1 in Appendix A for the formal proof.

The outcomes in each states, $c^s$, $\forall s \in S$, is independent of $e$. Assume the individual feels to have losses when imagining himself in the sick state, and feels gains in the healthy state

$$c_h^{\text{sick}} < r_h < c_h^{\text{healthy}}$$

(3.2)

Let $H > 0$ denote the size of gains. Then $H(e) = c_h^{\text{healthy}} - r_h(e)$, and $\alpha(e)$ is defined as

$$\alpha(e) := H(0) - H(e).$$

(3.3)

$H_0 > H(e)$ implies that longevity brings larger gain to indulgent agents. This prediction could be interpreted in the way that the agent has been living without paying extra efforts. Imagine, for example, both a vegetarian and a drug abuser
lived for 90 years. Ceteris paribus, whose life is more enjoyable? The “price” for living healthily and abstentiously is a high effort level, such as regular exercise, healthy diet, and abstention from alcohol and tobacco, and they are associated with discomforts.

Let \( h > 0 \) denote the size of losses in health. Analogously, \( h(e) = r_h(e) - c_h^{\text{sick}} \), and it follows that

\[
\alpha(e) = h(e) - h(0)
\]  

(3.4)

The losses under abstention is larger (in size) because the preventive efforts turn out to be in vein. Imagine again about the vegetarian and the drug abuser. Now they are diagnosed with NCDs at their middle ages. Who will feel more frustrated? The abstentious agent took efforts for a decreased probability of illness, but it did not pay back. Such “default” of health investment makes the occurrence of illness under abstention worse than that under indulgence.

Equation 3.3 and 3.4 together implies that

\[
r_h(e) = r_h(0) + \alpha(e).
\]  

(3.5)

It offers an alternative interpretation of the effects of preventive efforts. Intuitively, an individual with a high effort level should have a higher expectation about his future health, as the expectations in the first period serves as the reference point, a high effort level shifts the reference point (in health) up, and the amount is measured by the cost of efforts \( \alpha \).

Except the two channels mentioned above, individuals with different lifestyles are assumed to be all the same in \( t_0 \), the other differences associated with different lifestyles, such as appearance, vitality, emotional states, etc., are assumed to be irrelevant with one’s well-being. The framing in health dimension is illustrated in the picture below:

![Figure 3.2: Graphical Illustration of framing in health](image)

In the dimension of wealth, the status quo is his expectation at \( t_0 \) about his future disposable income, that is his income endowment \( Y \) net of the insurance premium \( P \) and the expected medical expenses \( \pi(e)M \)

\[
r_w(e) = Y - P - \pi(e)M
\]  

(3.6)
as illustrated in Figure 3.3

\[
\begin{array}{ccc}
\text{Y} - P - M & r_w(e) & \text{Gain} \\
\text{Y} - P - \pi(e)M & \text{Loss} & \text{Y} - P
\end{array}
\]

Figure 3.3: Graphical Illustration of framing in wealth

Thus the gain is \( \pi(e)M \), i.e. the saved expected expenses; and the loss (in size) is \( (1 - \pi(e))M \), the medical expenses “in surprise.” The gains and losses are summarized in Table 1. Note here that \( P \) changes the payoffs in neither states, and is thus irrelevant.

<table>
<thead>
<tr>
<th>Ref/Expectation</th>
<th>Gain</th>
<th>Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Health</td>
<td>( r_h(e) )</td>
<td>( H(e) )</td>
</tr>
<tr>
<td>Wealth</td>
<td>( r_w(e) )</td>
<td>( \pi(e)M )</td>
</tr>
</tbody>
</table>

Table 1: Ex-ante payoffs

It is explained above that gains in health for indulgent lifestyle is higher, and losses are smaller (in size). Here, it is straightforward to conclude from Table 1, that the gain/loss magnitude in wealth have the same relationship, as \( \pi'(e) < 0 \).

To capture loss aversion and diminishing sensitivity, let \( V(c_h - r_h, c_w - r_w) := V(h, w) \), where

\[
V(h, w) = \begin{cases} 
  v(h, w) & \text{if } (h, w)^T \geq 0 \\
  -\lambda v(-h, -w) & \text{if } (h, w)^T < 0 
\end{cases}
\] (3.7)

where \( \frac{\partial v}{\partial h} > 0, \frac{\partial v}{\partial w} > 0, \frac{\partial^2 v}{\partial h^2} < 0, \frac{\partial v}{\partial w^2} < 0. \)

Notice that in the ex-ante prevention problem, there are no gain-loss trade-offs, in other words, there are no cases where the agent has gains in one dimension, and simultaneous losses in the other. Arguments in the value function is either both positive or both negative.

### 3.2.2 Choice of lifestyles and ex-ante moral hazard

For the optimal preventive effort level, the problem is described as follows: the agent is considering to choose some \( e \in \mathbb{R}_+ \) to lower \( \pi(e) \), where \( \pi_0 := \pi(0) > 0 \). Compared with paying no efforts (indulgent lifestyle), a positive \( e \) directly incurs discomfort \( \alpha(e) \), with \( \alpha' > 0, \alpha'' > 0 \). If he pays no effort, in the case when illness does not occur, the individual is going to gain \( \pi_0 M \) in wealth, and \( H_0(0) \) in health, and lose \( (1 - \pi_0)M, h_0(0) \) when illness occurs. A positive effort level decreases the gains in the healthy state, and increases the sizes of losses in the unhealthy state, in both dimensions. If the individual make some efforts so that the probability of
illness is decreased to $\pi(e)$, the direct consequence is that the monetary gains $\pi(e)M$ gets smaller, and monetary losses $(1 - \pi(e))M$ get larger. In health dimension, the gain of healthy state is “dopamine adjusted” to $H_0 - \alpha(e)$, as the longevity through efforts is not as good as reaping without sowing; and the loss brought by sickness is increased to $h_0 + \alpha(e)$, as the savings for future health fail to pay back.

Empirical studies of reference dependent models often assumes power utility function (e.g. Tversky & Kahneman, 1992). Fetherstonhaugh, Paul, Johnson, and Friedrich (1997) detects diminishing sensitivity when people evaluate alternatives related to their lives, and give psychological explanations for the prevalence of power perception functions. Also see Wakker and Zank (2002) for its preference foundations under reference dependence. Extending the power function to two dimensions, let

$$V(h, w) = \begin{cases} 
  h^{\beta_1} \cdot w^{\beta_2} & \text{if } (h, w)^T \geq 0 \\
  -\lambda|h|^{\beta_1} \cdot |w|^{\beta_2} & \text{if } (h, w)^T < 0 
\end{cases}$$

where $\beta_1, \beta_2 \in (0, 1)$ are the parameters of diminishing sensitivity. Then the problem of the individual is written as

$$\max_{e \in \mathbb{R}^+} [1 - \pi(e)][H_0 - \alpha(e)]^{\beta_1}[\pi(e)M]^{\beta_2} - \lambda\pi(e)[h_0 + \alpha(e)]^{\beta_1}[(1 - \pi(e))M]^{\beta_2}$$

which simplifies to

$$M^{\beta_2}[1 - \pi(e)]^{\beta_1}[(H_0 - \alpha(e))^{\beta_1} - (h_0 + \alpha(e))^{\beta_1} \left( \frac{\pi(e)}{1 - \pi(e)} \right)^{1-\beta_2}]$$

The important feature of Equation 3.10 is that $M$ is merely a scaling factor. The preventive effort level is solely determined by the individual’s concern about his health. This implies that price changes of medical treatment due to health insurance will not distort the incentives of preventive efforts, as long as the changes of prices is independent of $e$. The intuition is straightforward: health insurance can only protect the losses in wealth dimension, leaving the payoff in health dimension unaffected. Thus for individuals who care both health and wealth, their preventive effort level is not affected by cost sharing insurance plans. Formally it summarizes as follows

**Proposition 3.1** (Pooling insurance and ex-ante moral hazard). *A pooling insurance plan does not distort agent’s incentive for preventive efforts, hence, there are no ex-ante moral hazard caused through the channel of loss aversion.*
3.3 Treatment: Demand for medical care

3.3.1 Assumptions

In the second period, the longevity scenario is trivial. The agent is enjoying his remaining years without paying for medical treatments. While in the sick scenario, there are gain-loss trade-offs. If the NCD-diagnosis is positive, then the status quo has to be updated according to the new information. Assume the agent’s reference points has been fully updated to the post-diagnosis prognosis. Let \( r' = (r'_h, r'_w) \), then \( r'_w = Y - P \), the disposable income; and \( r'_h \) is the reduced life expectancy caused by NCDs. Life years preserved by medical treatment are denoted by \( H(M) \), and it depends on the medical expenses \( M \), assume \( H' > 0 \), \( H'' < 0 \). Let \( c' = (c'_h, c'_w) \) denote the outcome in the second period, then \( M \) will determine the final outcomes in both dimensions:

\[
c'_h(M) = r'_h + H(M), \quad c'_w(M) = Y - P - M.
\]

In the problem of treatment, life years preserved by treatment, \( H(M) \), will be framed as gains in health; and \( M \), the out of pocket expenses, as losses in wealth. If insured, the loss would be the net amount paid by the patient.

The reference dependent utility function is then \( u(H, M) \) where \( \frac{\partial u}{\partial H} > 0 \), \( \frac{\partial u}{\partial M} < 0 \). Here, the losses and gains here are measured in incomparable dimensions, thus loss aversion is irrelevant when making treatment decisions. To capture diminishing sensitivity, assume \( \frac{\partial^2 u}{\partial H^2} < 0 \), \( \frac{\partial^2 u}{\partial M^2} < 0 \). Assume further, \( \lim_{H \to 0} \frac{\partial u}{\partial H} = +\infty \), \( \lim_{M \to 0} \frac{\partial u}{\partial M} < +\infty \), so that it is always optimal that \( M^* > 0 \), the patient is always going to spend something for medical treatments. Also noted that the choice of treatments is beyond the scope of this paper—it focuses on the demand of medical resources, thus I assume there is only one treatment method available, and the ex-post decision is made without uncertainty.

3.3.2 Demand for treatment and ex-post moral hazard

The problem of medical care demand is

\[
\max_{M \leq Y} u(H(M), M)
\]  (3.11)

Assume interior solution, then the first order condition reads

\[
\frac{du}{dM} = \frac{\partial u}{\partial H} H'(M) + \frac{\partial u}{\partial M} = 0 \implies \frac{\partial u}{\partial H} H'(M) = -\frac{\partial u}{\partial M} \]  (3.12)

The LHS is the marginal gain of health from the additional medical expenses, and the RHS is the marginal cost. Suppose \( M^* \) is the optimal solution to Equation 3.12.
Proposition 3.2 (Existence and uniqueness of interior solution). If $\frac{\partial^2 u}{\partial H \partial M} < 0$, then there will be a unique, interior solution to Equation 3.11.

Proof. The second order condition then becomes

$$\frac{d^2 u}{dM^2} = \left( \frac{\partial^2 u}{\partial H^2} H'(M) + 2 \frac{\partial^2 u}{\partial H \partial M} H''(M) + \frac{\partial^2 u}{\partial M^2} \right) - \frac{\partial u}{\partial H} H'(M) + \frac{\partial u}{\partial H} H''(M) - \frac{\partial^2 u}{\partial M^2} < 0 \quad (3.13)$$

is satisfied, guaranteeing the existence and the uniqueness of the interior solution. Q.E.D.

The cross derivative, $\frac{\partial^2 u}{\partial H \partial M}$ denotes the relationship between the marginal utility of medical expenses and health states. If it is negative, then a healthier patients would be hurt more by additional medical expenses, which makes sense.

Under the assumption of negative cross derivative, it can be easily checked that LHS of Equation 3.12 is decreasing, and the RHS is increasing with respect to $M$. The marginal benefit of medical expenses is thus decreasing, the marginal cost is increasing, which implies that the individual will finally stop spending on medical treatments at $M^*$. Unlike in the conventional model where the desired level of medical service depends on the level of wealth (Grossman, 2000), Equation 3.12 indicates that optimal medical spending is independent of one’s wealth (or productivity). Optimal $M$ is determined by the shape of the value function and the health production function $H(M)$, and individuals that differ in productivity or wealth should be treated equivalently. This argument also justifies the needs for redistribution in the wealth dimension.

However, due to the limited amount of income one owns, the individual might not be able to reach the stopping point. For those whose budget constraint in Equation 3.11 is binding, an insurance policy that enables the individual to purchase more medical service is welfare improving. Such effect is also raised by Nyman (1999) labeled as the “access value.” As long as the LHS of Equation 3.12 is greater than the RHS, the individual will not stop spending on treatments until they become unaffordable, engendering the problem of medical bankruptcy.

Proposition 3.3 (Demand for treatment). Individuals with homogeneous preferences demand the same amount of medical treatment, determined by Equation 3.12, despite the difference in their incomes. For people whose budget constraint is binding, i.e. $Y \leq M^*$, there will be a corner solution that $M = Y$, and they are led to bankruptcy by medical bills.

Proposition 3.3 denies the existence of income effect in the problem of treatment. It manages to explain why Chinese patients have incredible preferences over imported medical products.
Insurance against medical bankruptcy

The effect of ex-post moral hazard can be either enhancing or deteriorating welfare, in ex-post point of view. In the case when \( Y < M^* \), an insurance policy that makes the individual reach \( M^* \) is efficient. For example, the problem of a patient with a coinsurance policy \((c, P)\) will be

\[
\max_{M} \quad u(H(M), cM) \\
\text{s.t.} \quad cM \leq Y - P
\]

and the FOC becomes

\[
\frac{\partial u}{\partial H} H'(M) = -c \frac{\partial u}{\partial M}
\]

The LHS of Equation 3.15 is the same as that of Equation 3.12, yet the RHS is smaller in Equation 3.15. Optimal spending of \( M \) increases as LHS is decreasing. And a smaller \( c \) will correspond to a larger \( M \) in optimum, \( M^*_I > M^* \), and the difference \( M^*-M^*_I \) represents the ex-post moral hazard, as Figure 3.4 shows.

![Figure 3.4: Optimal Medical Spending when Individuals Differ in Effectiveness](image)

The maximum the individual can spend with insurance is \( \frac{Y-P}{c} := \overline{M} \). Thus the optimal coinsurance should satisfy

\[
\overline{M} \geq M^*
\]

Assuming actuarially fair insurance premium, \( P = \pi(1-c)M \), the optimal coinsurance rate can then be characterized

**Theorem 3.4** (Optimal ex-post coinsurance rate). *With actuarially fair insurance policy, the optimal coinsurance should satisfy Equation 3.16, which implies*

\[
c^* \leq c^*_0 := \frac{Y - \pi M^*}{(1-\pi)M^*}
\]
where $\pi$ is the probability of illness, predetermined by $e \in \mathbb{R}_+$, i.e. the preventive efforts that the individual has chosen in $t_0$.

Note that if $Y < M^*$, then the RHS of Equation 3.17 is smaller than 1, meaning that $c_0^* < 1$. In contrast, if $Y \geq M^*$, then there will be no need to have insurance, $c_0^* = 1$. Moreover,

$$\frac{\partial c_0^*}{\partial \pi} = \frac{M^* (Y - \pi M^*)}{(M^*(1 - \pi))^2} - \frac{M^*}{M^* - \pi M^*} = \frac{Y - M^*}{(1 - \pi)^2 M^*}$$ (3.18)

If $Y < M^*$, then $\frac{\partial c_0^*}{\partial \pi} < 0$; the coinsurance rate is decreasing with $\pi$ meaning that indulgent agent should get more generous plans!

Equation 3.18 tells us that poor ($Y < M^*$) people should be offered with generous plans, their coverage should increase with their illness probability; while the rich should be punished if they engage themselves in indulgence, their insurance coverage is decreasing with his illness probability. In this model, the demand for medical services ex-post does not depend on their income but instead, their insurance coverage does.

People generally view a deductible as losses (Johnson, Hershey, Meszaros, & Kunreuther, 1993). With a deductible insurance $(D, P)$, the individual’s value function becomes

$$u(H(M), D)$$ (3.19)

where $D$ is specified in the insurance contract in $t_0$. Thus the utility is strictly increasing with $M$, the individual’s medical spending will be $+\infty$ as long as $D \leq Y - P$. Thus an effective deductible insurance (including full coverage) is too generous to be optimal.

**Proposition 3.5** (Optimal ex-post insurance policy). Both coinsurance and deductible insurance policy enables patients to consume more than they could before being insured, however patients with the protection of deductibles will demand infinite amount of medical resources. Therefore, a coinsurance policy is a better form ex-post.

**Contrast with EUT** In the framework of EUT, insurance is welfare-improving because individuals have risk-averse preferences. With moral hazard, the maximization of ex-post utility leads too much utilization of medical resources, because the premiums that depend on the ex-post demand are paid ex-ante, and thus are treated as exogenous. Since the preference of EUT are defined over the absolute level of health and wealth (instead of changes in reference dependent model), the demand for medical treatments will not exceed one’s disposable income, and thereupon, NCDs such as cancers should not increase the risk of medical bankruptcies for a rational
EUT agent, contradicts to the findings of Ramsey et al. (2013). Apart from that, neither can the dependence of medical demand on income explain the high market share of imported products in China.

Proposition 3.5 denies the optimality of deductible insurance, opposite to the predictions of EUT. In the absence of moral hazard, Arrow (1963) first showed that the optimal health insurance contract takes the form of full insurance above a deductible, if insurance is not actuarially fair. Later, Arrow's theorem of the deductible remains at work in a setup with ex-post moral hazard (Drèze & Schokkaert, 2013). In the framework of EUT, expected utility maximization requires equalizations of marginal utilities (of either health or wealth) across states, which induces a universal stop-loss if the insurance premium is not actuarially fair. At the first glance, the infinite demand with deductible insurance seems implausible, as in reality, patients do not spend infinite amount even protected by deductibles. Nevertheless, it does not conflict with the prediction of Equation 3.19. One’s medical spending is certainly bounded, by a country’s GDP for example, and what’s more, patients cannot spend without physician’s prescriptions. Equation 3.19 thus serves as a justification for third-party interventions complementary to the deductible insurance, in order to control ex-post moral hazard.

As for coinsurance, a welfare-improving co-insurance rate is determined by factors including demand function, degree of risk aversion, and the marginal utilities in different states of health (McGuire, 2011). Expressly, it decreases with demand elasticity and degree of risk aversion, and increases with the discrepancy of marginal utilities between healthy and sick state. It is thus possible that an optimal coinsurance rate is 0, if the marginal utility of income in the sick state is high enough. In this paper, by assuming away risk aversion, insurance is not necessary for the rich whose \( Y > M^* \). On the other hand, for the poor \( Y < M^* \), a coinsurance policy is necessary, otherwise they will be driven bankrupt by their demand for medical treatment. The optimal coinsurance rate is characterized by Theorem 3.4. However, full insurance corresponds to zero deductible, and is thus never optimal.

### 3.4 Optimal insurance for prevention and treatment

Given an exogenous distribution of \( Y \), \( c_0^* \) is increasing with \( Y \), meaning that poorer people have a more generous insurance protection. Note that according to Proposition 3.1, the coinsurance rate should be independent of \( \pi \) to eliminate moral hazard, as a result, the optimal coinsurance rate should be a profile of \( c^*(Y) \), and \( c^*(Y) > 1 \) implies a redistribution from the rich to the poor. The incentives to labor supply created by such insurance policy is beyond the scope of this paper.

It is important to note that \( c_0^* < 1 \) increases the demand for the poor, they
effectively receive more treatments, but may still demand above $\bar{M}$, indicating that people go bankrupt again albeit protected by insurance policies, as Himmelstein et al. (2009) suggested. Although such insurance policies cannot eliminate medical bankruptcies completely, it reduces them, and allows patients to have access to the resources that were not affordable, such as the imported products for Chinese patients.

There is not much literature on the welfare analysis with reference dependent models (Prospect Theory for example), I am looking for useful articles to see whether I can have more lights on the welfare implications of this model.

4 Conclusion and Discussions

With the reference dependent model, this paper managed to explain several puzzles that could not be explained by the expected utility theory, and sheds lights on the design of insurance policy. As is suggested by the model, a deductible insurance may encourage patients to demand too much medical resource, it is reasonable to attribute the rapid growth of the health care cost to the stop-loss policies that are common in insurance contracts. For preventive behaviors, this paper evinces that the optimal level of preventive efforts are entirely determined by people's concerns over their health, and in consequence, health insurance does not distort preventive incentives, as long as the cost-sharing scheme is not contracted according to prevention. And it is usually the case, when insurance contract is made, neither the preventive behaviors nor the probability of future illness can be observed. Moreover, conventional analyses usually link risky health behaviors to myopia, irrationality, time-inconsistency, etc. Antithetically, this paper controverts that those unhealthy lifestyles result from the trade off between gains and losses in the dimension of health and wealth, and the location of reference point is a key factor that pins down the optimal level of preventive efforts. In reality, other factors such as parental rearing and the community atmosphere also . Correspondingly, reference dependent model helps to understand the inter-generation transmissions of NCDs as well as its cross-regional epidemics.
A Cost of effort

Proposition A.1. Assume the lifestyle will not shape the preference of the individual, then healthy lifestyle (abstention) is more costly than indulgence, i.e. $\alpha(e) \geq 0$.

Proof. The utility maximization problem of the indulgent person is

$$\max_{x \in X} u(x)$$

subject to a budget constraint. Where $x$ is the consumption bundle chosen from the feasible set $X$, and $u : X \to \mathbb{R}$ is the utility function.

Mathematically, exerting preventive efforts refers to keeping away from the unhealthy consumptions in the broadly defined commodity set $X$, such as tobacco, drugs, fat foods, and even time lying in the couch watching TV. Denote the consumption set of the abstentious individual as $X_A$, then the problem of the abstentious individual is

$$\max_{x \in X_A} u(x)$$

Since $X_A \subset X$, one has $\max_{x \in X} u(x) \geq \max_{x \in X_A} u(x)$. Thus, denote the difference by $\alpha$, one has $\alpha \geq 0$.

For most of the people, given the prevalence of NCDs, their $\alpha$ would be strictly positive. For the minority, who enjoys a healthy lifestyle, they will not choose the unhealthy commodities in $X$, their $\alpha = 0$.

B Prevention problem with general value function

Thus, the problem of the individual is

$$\max_{e \in \mathbb{R}^+} [1 - \pi(e)]v[H_0 - \alpha(e), \pi(e)M] - \lambda \pi(e)v[h_0 + \alpha(e), (1 - \pi(e))M]$$ (B.1)

The first order condition is then

$$(1 - \pi(e)) \left[ -\alpha'(e) \frac{\partial v}{\partial h} (H_0 - \alpha(e), \pi(e)M) + \pi'(e)M \frac{\partial v}{\partial w} (H_0 - \alpha(e), \pi(e)M) \right]$$

$$-\pi'(e)v (H_0 - \alpha(e), \pi(e)M)$$

$$-\lambda \pi(e) \left[ \alpha'(e) \frac{\partial v}{\partial h} (h_0 + \alpha(e), (1 - \pi(e))M) - \pi'(e)M \frac{\partial v}{\partial w} (h_0 + \alpha(e), (1 - \pi(e))M) \right]$$

$$-\lambda \pi'(e)v (h_0 + \alpha(e), (1 - \pi(e))M) = 0$$ (B.2)
The FOC describes the trade off that the individual faces—Due to framing, preventive efforts worsen the payoff in both healthy and unhealthy states, which makes it less attractive compared with staying indulgent; in the opposite, preventive efforts reduce the likelihood of the unfavorable outcome, which is appealing to a loss-averse agent.

The first and third line of Equation B.2 are negative, and the second and fourth line are positive. The marginal gain to increase preventive efforts is obtained through the decreased probability of sickness. It is more likely to end up with healthy state $-\pi'(e) v (H_0 - \alpha(e), \pi(e) M)$, and less likely to end up with unhealthy state $-\lambda \pi'(e) v (h_0 + \alpha(e), (1 - \pi(e)) M)$. On the other hand, a decreased $\pi(e)$, in the healthy state, reduces both the perceived gains in wealth—the expected savings of medical expenses are decreased by $\pi'(e) M \frac{\partial v}{\partial w} (H_0 - \alpha(e), \pi(e) M)$; and the perceived gain in health—the increased efforts reduced the comfortability of the life years by $-\alpha'(e) \frac{\partial v}{\partial w} (H_0 - \alpha(e), \pi(e) M)$, and they are weighted by the probability $1 - \pi(e)$. In the state of illness, a higher effort level increases the size of losses, not only in health—the health investment in default is increased by $\alpha'(e) \frac{\partial v}{\partial w} (h_0 + \alpha(e), (1 - \pi(e)) M)$, but also in wealth—the reference point $Y - \pi(e) M - P$ moves to the right due to the decreased probability, the occurrence of illness then becomes more unacceptable, and the reduce is measured by $-\pi'(e) M \frac{\partial v}{\partial w} (h_0 + \alpha(e), (1 - \pi(e)) M)$. The increased loss in sick state is weighted by $-\lambda \pi(e)$, the probability of sickness scaled by the index of loss aversion.

Rearranging Equation B.2 as marginal benefits equals to marginal costs, it becomes

$$-\pi'(e)[v (H_0 - \alpha(e), \pi(e) M) + \lambda v (h_0 + \alpha(e), (1 - \pi(e)) M)]$$

$$= (1 - \pi(e)) \left[ \alpha'(e) \frac{\partial v}{\partial h} (H_0 - \alpha(e), \pi(e) M) - \pi'(e) M \frac{\partial v}{\partial w} (H_0 - \alpha(e), \pi(e) M) \right]$$

$$+ \lambda \pi(e) \left[ \alpha'(e) \frac{\partial v}{\partial h} (h_0 + \alpha(e), (1 - \pi(e)) M) - \pi'(e) M \frac{\partial v}{\partial w} (h_0 + \alpha(e), (1 - \pi(e)) M) \right]$$

(B.3)

**Definition B.1.** Some definitions about the effect of efforts, in Equation B.2

1. **Health framing effect** describes the effect that decrease gains and increase losses in the dimension of health, expressed as

$$-(1 - \pi(e)) \alpha'(e) \frac{\partial v}{\partial h} (H_0 - \alpha(e), \pi(e) M) - \lambda \pi(e) \alpha'(e) \frac{\partial v}{\partial h} (h_0 + \alpha(e), (1 - \pi(e)) M)$$

(B.4)

2. **Wealth framing effect** describes the effect that decrease gains and increase
losses in the dimension of wealth, expressed as

\[(1 - \pi(e))\pi'(e)M \frac{\partial v}{\partial w} (H_0 - \alpha(e), \pi(e)M) + \lambda \pi(e)\pi'(e)M \frac{\partial v}{\partial w} (h_0 + \alpha(e), (1 - \pi(e))M)\]  

\[(B.5)\]

3. **Loss aversion effect** describes the effect that \(e\) reduces the probability of ending up with NCDs, expressed as

\[-\pi'(e)[v(H_0 - \alpha(e), \pi(e)M) + \lambda v(h_0 + \alpha(e), (1 - \pi(e))M)]\]  

\[(B.6)\]

Health framing effect and wealth framing effect constitute the cost side of preventive efforts, and loss aversion effect constitute the benefit side. However, it is unclear how do costs or benefits change with respect to \(e\). The sign of second order is unclear. And it is even more difficult to determine the conditions that make Equation C.1 negative.

Then the ex-ante problem is to compare

Abstention \( EV_1 = \max_{e \in \mathbb{R}_+} [1 - \pi(e)]v[H_0 - \alpha(e), \pi(e)M] - \lambda \pi(e)v[h_0 + \alpha(e), (1 - \pi(e))M]\)  

\[(B.7)\]

Indulgence \( EV_0 = (1 - \pi(0))v(H_0, \pi_0 M) - \lambda \pi(0)v(h_0, (1 - \pi_0)M)\)  

\[(B.8)\]

where \(M\) denotes the medical expense that will be optimally determined in \(t_1\), and \(\pi_0\), his background risk which may depend on his genetic disposition, job risk, living environment, etc. If \(EV_1 > EV_0\), the individual is going to exert some level of effort \(e \in \arg\max EV_1\), and if \(EV_1 < EV_0\), then the individual is better off staying indulgent.

The second order conditions are too complicated to draw any clues about the existence and uniqueness of the interior solutions. For the moment just assume one. See Equation C.1 in Appendix C, for details.

**Insurance**

The effect of insurance protection to the preventive efforts is even more complicated. As stated in Section 3.3.2, deductible insurance policies lead to abuse of medical resources, thus only coinsurance policy is studied here. A coinsurance rate \(c < 1\) changes the problem as

\[\max_{e \in \mathbb{R}_+} [1 - \pi(e)]v[H_0 - \alpha(e), c\pi(e)M] - \lambda \pi(e)v[h_0 + \alpha(e), c(1 - \pi(e))M]\]  

\[(B.9)\]

Note that the premium \(P\) is irrelevant, since it shifts all the points in Figure 3.3 to the left by \(P\).
And first order conditions (Equation B.2) becomes

\[
(1 - \pi(e)) \left[ -\alpha'(e) \frac{\partial v}{\partial h} (H_0 - \alpha(e), c\pi(e)M) + c\pi'(e)M \frac{\partial v}{\partial w} (H_0 - \alpha(e), c\pi(e)M) \right] \\
-\pi'(e) v (H_0 - \alpha(e), c\pi(e)M) \\
-\lambda\pi(e) \left[ \alpha'(e) \frac{\partial v}{\partial h} (h_0 + \alpha(e), c(1 - \pi(e))M) - c\pi'(e)M \frac{\partial v}{\partial w} (h_0 + \alpha(e), c(1 - \pi(e))M) \right] \\
-\lambda\pi'(e) v (h_0 + \alpha(e), c(1 - \pi(e))M) = 0
\]

(B.10)

Compared with no-insurance case, the effects are summarized below

**Proposition B.1** (Ex-ante effect of coinsurance).

1. **Health framing effect** is smaller in absolute value, assuming \( \frac{\partial^2 v}{\partial h \partial w} > 0 \)

\[
-(1 - \pi(e))\alpha'(e) \frac{\partial v}{\partial h} (H_0 - \alpha(e), c\pi(e)M) - \lambda\pi(e)\alpha'(e) \frac{\partial v}{\partial h} (h_0 + \alpha(e), c(1 - \pi(e))M)
\]

(B.11)

2. **Wealth framing effect** is unclear, the expression in the square bracket of Equation B.12 is larger due to concavity, and then scaled down by \( c \).

\[
c \left[ (1 - \pi(e))\pi'(e)M \frac{\partial v}{\partial w} (H_0 - \alpha(e), c\pi(e)M) + \lambda\pi(e)\pi'(e)M \frac{\partial v}{\partial w} (h_0 + \alpha(e), c(1 - \pi(e))M) \right]
\]

(B.12)

3. **Loss aversion effect** is smaller, as \( v(c, w) \) is increasing with both arguments.

\[
-\pi'(e) [ v (H_0 - \alpha(e), c\pi(e)M) + \lambda v (h_0 + \alpha(e), c(1 - \pi(e))M) ]
\]

(B.13)

A coinsurance rate’s effect is still unclear.
C Some equations of the prevention problem

The expression of second order condition of Equation B.1 (Section 3.2.2) is

\[-\pi''(e) \left[ \lambda v (h_0 + \alpha(e), (1 - \pi(e))M) + v (H_0 - \alpha(e), \pi(e)M) \right] + 2\lambda \pi'(e) \left[ \pi'(e)M \frac{\partial v}{\partial w} (h_0 + \alpha(e), (1 - \pi(e))M) - \pi'(e) \frac{\partial v}{\partial h} (h_0 + \alpha(e), (1 - \pi(e))M) \right] + 2\pi'(e) \left[ \alpha'(x) \frac{\partial v}{\partial h} (H_0 - \alpha(e), \pi(e)M) + \pi'(e) \frac{\partial v}{\partial w} (H_0 - \alpha(e), \pi(e)M) \right] - \lambda \pi(e) \left\{ -\pi''(e)M \frac{\partial v}{\partial w} (h_0 + \alpha(e), (1 - \pi(e))M) + \pi'(e)M \left[ \pi'(e)M \frac{\partial^2 v}{\partial w^2} (h_0 + \alpha(e), (1 - \pi(e))M) - 2\alpha'(x) \frac{\partial^2 v}{\partial h \partial w} (h_0 + \alpha(e), (1 - \pi(e))M) \right] + \alpha''(x) \frac{\partial v}{\partial h} (H_0 - \alpha(e), \pi(e)M) + \alpha'(x) \frac{\partial^2 v}{\partial h^2} (H_0 - \alpha(e), \pi(e)M) \right\} \]

+ (1 - \pi(e)) \left\{ \pi''(e)M \frac{\partial v}{\partial w} (H_0 - \alpha(e), \pi(e)M) + \pi'(e)M \left[ \pi'(e)M \frac{\partial^2 v}{\partial h \partial w} (H_0 - \alpha(e), \pi(e)M) - 2\alpha'(x) \frac{\partial^2 v}{\partial h \partial w} (H_0 - \alpha(e), \pi(e)M) \right] - \alpha''(x) \frac{\partial v}{\partial h} (H_0 - \alpha(e), \pi(e)M) + \alpha'(x) \frac{\partial^2 v}{\partial h^2} (H_0 - \alpha(e), \pi(e)M) \right\} \] (C.1)

The first order condition after assuming away diminishing sensitivity, in Section ??,

\[-\pi''(e) \left[ \lambda v (h_0 + \alpha(e), (1 - \pi(e))M) + v (H_0 - \alpha(e), \pi(e)M) \right] + 2\lambda \pi'(e) \left[ \pi'(e)M \frac{\partial v}{\partial w} (h_0 + \alpha(e), (1 - \pi(e))M) - \pi'(e) \frac{\partial v}{\partial h} (h_0 + \alpha(e), (1 - \pi(e))M) \right] + 2\pi'(e) \left[ \alpha'(x) \frac{\partial v}{\partial h} (H_0 - \alpha(e), \pi(e)M) - \pi'(e) \frac{\partial v}{\partial w} (H_0 - \alpha(e), \pi(e)M) \right] - \lambda \pi(e) \left\{ -\pi''(e)M \frac{\partial v}{\partial w} (h_0 + \alpha(e), (1 - \pi(e))M) + \pi'(e)M \left[ \pi'(e)M \frac{\partial^2 v}{\partial w^2} (h_0 + \alpha(e), (1 - \pi(e))M) - 2\alpha'(x) \frac{\partial^2 v}{\partial h \partial w} (h_0 + \alpha(e), (1 - \pi(e))M) \right] + \alpha''(x) \frac{\partial v}{\partial h} (H_0 - \alpha(e), \pi(e)M) + \alpha'(x) \frac{\partial^2 v}{\partial h^2} (H_0 - \alpha(e), \pi(e)M) \right\} \]

+ (1 - \pi(e)) \left\{ \pi''(e)M \frac{\partial v}{\partial w} (H_0 - \alpha(e), \pi(e)M) - \pi''(e)M \frac{\partial^2 v}{\partial w^2} (h_0 + \alpha(e), (1 - \pi(e))M) + 2\alpha'(x) \frac{\partial^2 v}{\partial h \partial w} (h_0 + \alpha(e), (1 - \pi(e))M) \right\} \] (C.2)

The second order condition of Equation ?? is

\[M \left\{ (2\pi(e) - 1)\pi''(e)[H_0 - e - \lambda(h_0 + e)] + 2\pi'(e) \left[ \pi'(e)[H_0 - e - \lambda(h_0 + e)] + (\lambda + 1)(2\pi(e) - 1) \right] \right\} \] (C.3)
D Comparative statics

D.1 Equation B.3

Take partial derivative of RHS wrt \( M \)

\[
(1 - \pi(e)) \frac{\partial^2 v}{\partial h \partial y} (H_0 - \alpha(e), \pi(e)M) [-\alpha'(e)\pi(e) + M\pi'(e)\pi(e)]
\]

\[-\lambda\pi(e) \frac{\partial^2 v}{\partial h \partial y} (h_0 + \alpha(e), (1 - \pi(e))M) [\alpha'(e)(1 - \pi(e)) - M\pi'(e)(1 - \pi(e))]\]

\[= \pi(e)(1 - \pi(e))(M\pi'(e) - \alpha'(e)) \left[ \frac{\partial^2 v}{\partial h \partial y} (H_0 - \alpha(e), \pi(e)M) + \lambda \frac{\partial^2 v}{\partial h \partial y} (h_0 + \alpha(e), (1 - \pi(e))M) \right] +<0\]

The derivative of RHS with respect to \( e \) equals to

\[
\lambda\pi'(e) \left[ \pi'(e)M \frac{\partial v}{\partial w} (h_0 + \alpha(e), (1 - \pi(e))M) - \alpha'(e) \frac{\partial v}{\partial h} (h_0 + \alpha(e), (1 - \pi(e))M) \right]
\]

\[+ \pi'(e) \left[ \alpha'(e) \frac{\partial v}{\partial h} (H_0 - \alpha(e), \pi(e)M) - \pi'(e)M \frac{\partial v}{\partial w} (H_0 - \alpha(e), \pi(e)M) \right]
\]

\[-\lambda\pi(e) \left[ -\pi''(e)M \frac{\partial v}{\partial w} (h_0 + \alpha(e), (1 - \pi(e))M) + M^2\pi'(e)^2 \frac{\partial v}{\partial w^2} (h_0 + \alpha(e), (1 - \pi(e))M) \right]
\]

\[-2\pi'(e)M\alpha'(e) \frac{\partial v}{\partial h} (h_0 + \alpha(e), (1 - \pi(e))M) + \alpha''(e)\frac{\partial v}{\partial h} (h_0 + \alpha(e), (1 - \pi(e))M) \]

\[+ \alpha'(e)^2 \frac{\partial^2 v}{\partial h^2} (h_0 + \alpha(e), (1 - \pi(e))M) \]

\[+[1 - \pi(e)] \left[ \pi''(e)M \frac{\partial v}{\partial w} (H_0 - \alpha(e), \pi(e)M) + M^2\pi'(e)^2 \frac{\partial v}{\partial w^2} (H_0 - \alpha(e), \pi(e)M) \right]
\]

\[-2\pi'(e)M\alpha'(e) \frac{\partial v}{\partial h} (H_0 - \alpha(e), \pi(e)M) - \alpha''(e)\frac{\partial v}{\partial h} (H_0 - \alpha(e), \pi(e)M) \]

\[+ \alpha'(e)^2 \frac{\partial^2 v}{\partial h^2} (H_0 - \alpha(e), \pi(e)M) \]

\[
(D.1)
\]
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