Effect of Physician-Assisted Suicide and Euthanasia on Unassisted Suicide *

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Abstract

Starting in 2002, both the Netherlands and Belgium legalized euthanasia and physician-assisted suicide (PAS), alternative options to natural death. Although euthanasia is illegal in the United States, several US states have legalized physician-assisted suicide, beginning with Oregon in 1997. This paper is concerned with the deterrent effect of euthanasia, or physician-assisted suicide, on the unassisted suicide rate in a theoretical model. The theoretical model of this paper is based on the modification of Grossman's (1972) model of demand for health. Through theoretical analysis, this paper demonstrates that legalizing euthanasia, or physician-assisted suicide, has a deterrent effect on the unassisted suicide rate for both young adults and elderly people. The analysis is consistent with the result of the previous theoretical model from Posner (1995). Also, the result explains the empirical result on the substitution effect from assisted suicide to unassisted suicide in Girma and Paton (2022).
Keywords: *euthanasia; Grossman model; PAS; young adults suicides.*

1 Introduction

Beginning in 2002, both the Netherlands and Belgium legalized the practice of euthanasia and physician-assisted suicide (PAS) (Wittenberg-Cox, n.d.). Following the Netherlands and Belgium, several other countries, such as Luxembourg and Colombia, also validated the practice of euthanasia ("Infographic" 2022). Additionally, the District of Columbia and ten states in the U.S. endorsed physician-assisted Suicide (PAS) (Research 2014). The first was Oregon in 1997, and the rest of the states include California, Colorado, Hawaii, Montana, Maine, New Jersey, New Mexico, Vermont, and Washington (Research 2014). Much earlier elsewhere, Switzerland legalized PAS in 1942 ("Switzerland," n.d.).

What stands out in this list is the growth in the awareness of human autonomy and respectfulness in people's choice of death. Euthanasia is defined as the specific medical practice that discontinues a patient's life contingent on the voluntary request of the patient (Deliens and Wal 2003). According to the Netherlands' government website, such medical practice has two forms. The first form of legalized medical behavior is, upon the voluntary request of an individual, a doctor may inject a lethal dose of a specific type of drug into patients; this form is generally called 'euthanasia.' 'Physician-assisted suicide' occurs when a doctor offers a lethal dose of specific drugs to patients, and the patient then decides if and when to take the drugs (Veiligheid, n.d.). In either case, the doctors need to report the case to the Regionale Toetsingscommissies Euthanasie, which is the Regional Review Committee on Euthanasia. According to the survey of Regionale Toetsingscommissies Euthanasie, the population who received

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euthanasia in 2000 was 2,123, but the population increased to 8,720 in 2022 ("Netherlands," n.d.). Even though euthanasia and physician-assisted suicide (PAS) are different in forms and limitations, since this paper does not discuss the political effects or ethical meaning of these two forms, the rest of this paper uses "assisted suicide" to indicate both forms.

With an increasing trend in public acceptance of assisted suicide, assisted suicide is increasingly controversial because of the social outcome of legalizing it. Prof. Richard Posner can represent the supporters of assisted suicide in this debate, arguing that legalizing assisted suicide may produce a positive externality in social outcomes in his book *Aging and Old Age*. Posner (1995) argues that legalizing assisted suicide will lower the unassisted suicide rate of the elderly population because elderly people's expected utility will be higher if they receive assisted suicide in the future, compared with the lower expected utility if they commit unassisted suicide. The opponents of Posner's (1995) argument propose that legalizing assisted suicide may increase the total suicide rate. Girma and Paton (2022) are representatives of the opponents, and they duplicate the theoretical model of Posner and reexamine it empirically. They use a synthetic control model and find that legalizing assisted suicide significantly increases the total suicide rate, both assisted and unassisted, for people older than 64.

However, neither research specifically discusses the effect of assisted suicide on young adults or explains the mechanism of how assisted suicide increases the total suicide rate among elderly people. Posner's (1995) theoretical model mainly deliberates on the effect of assisted suicide on the unassisted suicide rate of elderly people who are diagnosed as having a severe disease. However, Posner's model is contingent on an uncertain diagnosis, which means the patients are uncertain about how accurate the diagnoses are. In the empirical result, the effect of assisted suicide on elderly people's unassisted suicide rate is negative but noisy (Girma and Paton 2022). Moreover, the empirical result from Girma and Paton (2022) shows a noisy and insignificant coefficient of assisted suicide on young adults within the 18-35 range, and the statistical result does not differ from overall suicide to unassisted suicide.

This paper is interested in establishing a theoretical model investigating the psychic effect of legalizing assisted suicide on both young adults and elderly people, which are the two groups with the highest suicide rate. According to the study by Farmani et al. (2023), during 2019, the highest suicide rate appears among adults in the 18-39 age range, and factors that may increase the risk of suicide include family circumstances and disease history. However, in 2022, elderly people's suicide rate exceeded young adults' suicide rate ("Suicides among Older Adults Drove U.S. Tally to Historic High - Los Angeles Times," n.d.). This paper focuses on how the assisted suicide option may alter young adults' and elderly people's decision-making process in committing suicide. The methodology of this paper is based on an extension of Grossman's (1972) model of demand for health [1].

In the following of this paper, section II introduces related previous works of literature and their limitations. Section III introduces the model setup based on Grossman's (1972) model and this paper's modification of his model for discussing the effect of assisted suicide. Section IV discusses the effect of assisted suicide on elderly people. Section V concludes.

1. Due to the reputation and wide use of this model, it can also be called the Grossman model of health demand.

2 Related Literature

As noted by Griffiths, Weyers, and Adams (2008), assisted suicide was legalized in the Netherlands and Belgium in 2002. In both the Netherlands and Belgium, the applicants must be adults capable of making rational decisions and experiencing unsolvable and intolerable pain. After years of debating, the assisted suicide practice developed a mature and explicit process of evaluation. In the practice of assisted suicide, the application includes multiple evaluations from a primary doctor for the patients and a secondary doctor who is not involved in making a treatment plan for the patient, which ensures the secondary doctor's objectivity in assessing the validity of assisted suicide (Deliens and Wal 2003)

As mentioned in the introduction, the debates in economics mainly center on the concern of legalizing assisted suicide as an encouragement for people who have suicidal impulses, and a more critical question is whether assisted suicide has a deterrent effect on suicide attempts. In Posner's (1995) model, he models the impact of assisted suicide on elderly people when an inexperienced doctor informs them that they only have a few months left to live, assuming they do not seek other doctors' diagnoses [2]. The model also assumes once the elderly people give up the current suicide attempt opportunity, they will not have any future opportunity to seek unassisted suicide [3]. Posner (1995) shows that legalizing assisted suicide may deter these people's unassisted suicide attempts, given the change in the expected utility. The expected utility will be higher if the people wait until they need assisted suicide instead of committing unassisted suicide before that. When assisted suicide is not accessible, people are more likely to commit unassisted suicide. They perceive unassisted suicide may generate less negative externality for their families because future medical treatments may generate long-term financial burdens and emotional stress for the whole family, and future medical treatments may not ensure recovery. Assisted suicide offers an alternative chance of committing suicide in the future, which respects people's decisions to discontinue future treatments and end their lives when they are severely sick, so the expected utility of waiting for assisted suicide is higher (Posner 1995). However, this argument has two limitations. It cannot explain the condition when the diagnosis is accurate, and it cannot explain how assisted suicide may affect suicidal impulses due to non-medical reasons among young adults [4].

Opponents of Posner's argument, Girma and Paton's (2022) model examines the treatment effect of legalizing assisted suicide on U.S. states that passed the law and uses a synthetic control to model the treatment states' suicide rate if assisted suicide was not legalized. The model examines the lagged effect of assisted suicide law from 0 to 7+ years after the law was legalized, but the research does not find robust evidence on impacts of assisted suicide on unassisted suicide (Girma and Paton 2022). Aside from Girma and Paton (2022), Jones and Paton (2015) use panel data from 1990 to 2013 and find that assisted suicide significantly increases total suicide rate among people who were older than 65 years old. However, this paper also does not explain the mobility between assisted suicide and unassisted suicide.

2. Posner (1995) points out that mistaken diagnosis is common even for experienced doctors.

3. When people enter hospitals for further medical treatments, the cost and difficulty of committing unassisted suicide will be higher, so the second assumption is also realistic (Posner 1995)

4. The negative externality of a young and healthy person's suicide may be higher for the whole family since their suicide attempts may generate emotional stress and future income shortage for their parents

Additionally, both Girma and Patron and Jones and Paton may face measurement errors and omitted variable bias for using suicide rates in the U.S. First, readers may need to be aware that the cost and public acceptance of assisted suicide are different in the U.S. compared to the Netherlands or Belgium. In the Netherlands and Belgium, due to high public acceptance, health insurance would cover the cost of assisted suicide (Nov 05, n.d.). However, in the U.S., the cost may be as high as $ 3000 to $ 5000 in California ("In California, Government to Pick Up the Tab for 'Death with Dignity'," n.d.). Different costs in the application and the differing degrees of public acceptance may add complexity to this topic. Second, the measurement error appears in the selection of the sampling year. The years in this research are from 1990 to 2019. However, between 1998 and 2015, 40% of assisted suicide in Oregon had incomplete reports ("Despite Increasing Global Legalization of Physician-Assisted Suicide, Use Remains Rare, Penn Study Finds - Penn Medicine," n.d.). For example, some attempts at assisted suicide might be unsuccessful but unreported. Lost data in detailed reports of assisted suicide may introduce underestimation of the effect.

To remove the concern and complexity, Nanner (2021) investigates the effect of legalizing assisted suicide on the overall suicide rate in Belgium. Nanner (2021) uses the synthetic control model to study the treatment effect of the total number of suicides, before and after Belgium legalized assisted suicide compared with other European countries that did not legalize assisted suicide. In Nanner's (2021) model, compared with other countries that did not pass assisted suicide, legalizing assisted suicide does not significantly increase the total number of suicides. However, this paper also does not explain the mobility between assisted suicide and unassisted suicide. In conclusion, the difference between this paper and previous literature is this paper combines the model of policy change with the demand for health to explain the mobility between unassisted suicide and assisted suicide among both young adults and elderly people, which is ignored in most empirical analyses.

3 Methodology

3.1 Model Setup

The modeling setup in this paper is the modification of Grossman's (1972) model of the demand for health capital. The difference between this model and Grossman's (1972) model is: first, this model simplifies Grossman's model into a two-period model, and second, this model adds the consideration of consumption of health capital, which is ignored in Grossman's model for simplicity. This section assumes the individual is a young adult who does not have physical pain or suffering [5]. Furthermore, this section explains why young adults without suicidal impulses will not have suicide attempts. Section 3.2 explains how suicidal impulses may convert into suicide attempts and how legalizing assisted suicide may deter suicide attempts.

5. The discussion on people who suffered from long-lasting physical pain is elaborated at the end of section III and section IV

In Grossman's (1972) model, the utility function for an individual is

$$U = U(\phi_i H_i, Z_i)$$

Since this model is a two-period model, the utility model from period t = 0 to t =1 is

$$U = U(\phi_0 H_0, Z_0) + \frac{U(\phi_1 H_1, Z_1)}{1+r}. \tag{1}$$

In equation (1), r represents the interest rate, so $\frac{1}{(1+r)}$ represents the discount rate. The utility function is composed of the current utility and the expected utility in the next period. The utility in each period i is determined by the number of healthy days, denoted by $\phi_i H_i$, and the aggregated consumption at period i, denoted by Z_i. In Grossman's (1972) model and equation (1), Z_i includes all the other consumption that may increase utility at period i, such as having a fine meal. ϕ_i represents how many more healthy days a person can have after health capital increases. Given H_i represents this person's level of health at time i, $\phi_i H_i$ represents the number of healthy days in each period. For example, if health capital represents the number of tests in adult health screens. If a person lowers blood pressure from high to normal, the health capital of this person increases. Decreasing blood pressure may lead to fewer days in pain for this person, which means healthy days increase.

According to Grossman's (1972) model, the amount of health capital increases according to changes in health investment. The health investment is a function of the amount of health care and time inputted for health care. Additionally, as assumed in Grossman (1972), the investment function exhibits constant returns to scale, meaning increases in both health care and time input will lead to increases in investment in the same proportion.

$$I_i = I(M_i, TH_i) \tag{2}$$

In equation (2), M_i indicates the amount of health care, such as medical treatment, and TH_i indicates time inputs for maintaining health care inputs. While health capital is positively correlated with health investment, it is negatively correlated with age-related depreciation, denoted by δ_i in equation (3). People with higher age may experience a reduced physical mobility and recovery rate (Grossman 1972).

$$H_{i+1} - H_i = I_i - \delta_i H_i, \tag{3}$$

Grossman's (1972) utility function can be combined with traditional utility functions in that it includes the contribution of other consumption, denoted by Z_i. The input function of Z_i depends on physical entities of consumption, such as food and hotel, denoted by X_i, and the time input of the consumption process, denoted by T_i.

$$Z_i = Z(X_i, T_i) \tag{4}$$

$$\int_0^1 \frac{P_i M_i + V_i X_i + W_i(TH_i + T_i + TL_i)}{(1+r)^i} = A_0 + \int_0^1 \frac{W_i \Omega}{(1+r)^i} = R \quad (5)$$

$$P_0 M_0 + V_0 X_0 + W_0(TH_0 + T_0 + TL_0) + \frac{P_1 M_1 + V_1 X_1 + W_1(TH_1 + T_1 + TL_1)}{1+r} = R \quad (5')$$

Given the utility function, equation (5) is the budget constraint function of Grossman's (1972) model in a two-period setting. In equation (5), P_i denotes the price of health care, V_i represents the cost for increasing market productivity, such as tuition; W_i represents wage, Ω represents time in each period [6] and TL_i represents sick time. This budget constraint represents the total wealth one person can earn for his/her lifespan, denoted by R. The right side of equation (5) represents total monetary income and initial property assets. The left side of the equation represents the monetary value of total consumption, investment, and time input for nonmarket production (Grossman 1972).[7]

Given the utility function and budget constraint, to optimize investment in health, the two-period Lagrangian function is

$$\begin{aligned} L =& U(\phi_0 H_0, Z_0) + \frac{U(\phi_1 H_1, Z_1)}{1+r} + \\ & \lambda[R - (P_0 M_0 + V_0 X_0 + W_0(TH_0 + T_0 + TL_0) + \\ & \frac{P_1 M_1 + V_1 X_1 + W_1(TH_1 + T_1 + TL_1)}{1+r})] \end{aligned} \quad (6)$$

The first order condition of equation (6) on investment in health in t = 0 is 0 when

$$\frac{\partial L}{\partial I_o} = 0 + \frac{Uh_1 G_1}{\lambda(1+r)} = \pi_0 - \frac{G_1 W_1}{1+r} \quad (7)$$

$$\pi_0 = \frac{Uh_1 G_1}{\lambda(1+r)} + \frac{G_1 W_1}{1+r} \quad (7')$$

According to Grossman's (1972) model, in equations (7) and (7'), π_0 represents the marginal cost of health investment in t = 0, where $\pi_0 = \frac{\partial(P_0 M_0 + W_0 TH_0)}{\partial I_0}$. Since P_i and r_i are exogenous in this model, the marginal cost is exogenous and constant. G_1 indicates the marginal return of each unit increase in health capital at t = 1, equivalent to ϕ_1. In that case, The multiplication of G_1 and W_1 serves as the marginal increase in wealth with each unit increase in health capital in t = 1. The multiplication of G_1 and Uh_1 serves as the marginal utility increase with each unit increase in health capital in t= 1, where $h_i = \phi_i H_i$ and $Uh_i = \frac{\partial U}{\partial h_i}$. Uh_i, different from W_i, only indicates the utility in being healthy and suffering from less physical pain (Grossman 1972).

Since Uh_i only represents the utility of being healthy, the inverse of Uh_i is correlated with the perceived pain of committing suicide, denoted by D_i [8]. D_i is the inversion of both Uh_i

6. Since this model is a two-period setting, each period represents about 40 years
7. This paper does not consider the situation of bequests. The total value will break even.
8. Uh_i is the flow of change in people's mood with the change in their health status, and D_i can be seen as a

and G_i and is positively correlated with λ. λ represents the shadow value of wealth, which represents people's attitude toward their wealth. When λ is high, people value their wealth more. In that case, they may perceive suicide to be more painful since they will lose all their wealth in death [9].

In equation (8), Uh_i and G_i are the denominators of the equation. When the absolute value of Uh_i increases, the absolute value of D_i would decrease. The absolute value of Uh_i represents each unit increase in health, which brings a higher utility of being healthy. Since U_i is increasing and concave in health capital, the high marginal utility of being healthy indicates a low health level or severe sickness (Grossman 1972). When people suffer from severe sickness, their utility is more sensitive to their health status. For example, higher blood sugar rarely affects the utility of a healthy person, but it brings more pain to a person who has diabetes. When the pain of being alive increases, the perceived pain of dying in suicide decreases (Mystakidou et al. 2005). Suppose a person is diagnosed with cancer; the person may foresee a long-lasting treatment and financial burden with no guaranteed recovery. Compared with long-lasting pain physically and financially, suicide is perceived to be shorter in pain and "cost-saving." In that case, many patients with severe sickness commit suicide instead of continuously pursuing medical treatments.

When the absolute value of G_i increases, the absolute value of D_i decreases. Given $G_i = \frac{\partial h_i}{\partial H_i}$, and h_i is an increasing and concave function of H_i, G_i is decreasing in H_i (Grossman 1972). When the absolute value of G_i increases, H_i decreases, indicating a low health level or severe sickness. Additionally, G_i represents the change of healthy days due to a one-unit health status change. When G_i is high, any minor discomfort may develop long-term pain. Higher blood sugar, for one, does not necessarily cause diabetes for a healthy person, but high blood sugar may be fatal for people with severe diabetes. Given the high risk and instability of health status, people with high G_i may also see suicide as a solution for their suffering.

In this section, since the agent is a healthy young adult, both Uh_i and G_i are low, and the perceived pain in committing suicide is high.

$$D_i = \frac{\lambda}{Uh_i G_i} \tag{8}$$

Substituting equation (8) into equation (7), the equilibrium holds when

$$\pi_0 = \frac{G_1 W_1}{1+r} + \frac{1}{(D_1(1+r))} \tag{9}$$

$$1 + r = \frac{G_1 W_1}{\pi_0} + \frac{1}{\pi_0 D_1}. \tag{9'}$$

Equation (9') holds when switching $1 + r$ and the marginal cost of investment.

Grossman's (1972) model assumes interest rate, marginal cost, and wage rate are exogenous. In other words, according to equation (9'), the equilibrium depends on G_1 and D_1.

stock of people's fear to death

9. This paper and Grossman (1972) assumes λ is exogenous

When the agent is healthy and does not have suicidal impulses, the health level this agent wants to achieve is $H*$ in Figure 1.

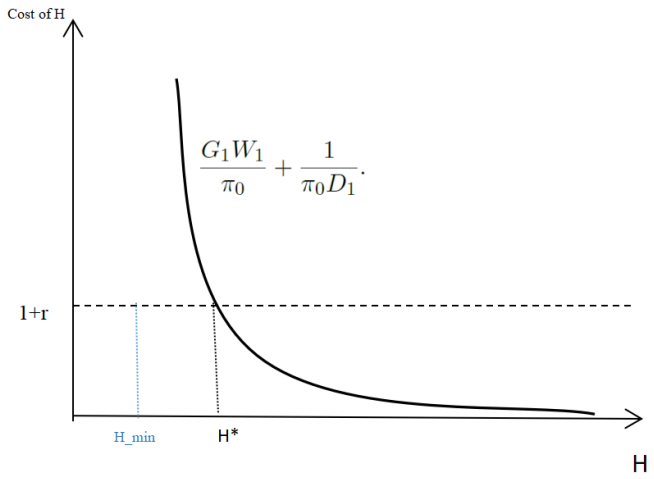

Figure 1: decision-making in health with no suicidal attempt

In Figure 1, the interaction between the left and right sides of equation (9′) decides the desired health status of the agent, given the agent does not have suicidal impulses. H_{min} indicates the health status where the agent prefers death to being alive. When H in the x-axis overlaps or is lower than H_{min}, the agent may have suicide attempts (Grossman 1972). In Figure 1, H^* is larger than H_{min}, which exemplifies the assumption that the agent is not willing to commit suicide. The following section will show how suicidal impulses may lead to suicide attempts and the intervention effect of assisted suicide.

3.2 The intervention from assisted suicide

According to the study by Farmani et al. (2023), the highest suicide rate appears in the age group of 18 to 39 years old, and the factors that may increase the risk of suicide include family circumstances and disease history. Shocks from these factors, such as partner abuse, may have three impacts on the model: first, the shock may add an extra discount rate, denoted by μ, in future utility and income in that individuals with suicidal impulses may underestimate future income and utility. Second, the shock directly decreases perceived pain in suicide, and this effect will both lower D_0 and raise H_{min} at t = 0. Third, the shock may increase current consumption and health investment due to the psychological compensatory mechanism. For example, when people are under high mental pressure and low self-esteem, they are at a higher risk of developing binge eating (Heatherton and Baumeister 1991). Additionally, the increase in health investment indicates people's awareness of their suicidal impulses and the behaviors of seeking professional help [10]. Such a compensatory mechanism may raise the marginal cost of health investment and other consumption, depending on the difference in compensatory

10. According to the availability of professional mental help and social acceptance of mental illness, people may not always be able or willing to seek help in reality. For simplicity, this paper assumes the accessibility of professional mental help.

behavior of different people.

According to the first effect, the new utility function adds μ to the future utility:

$$U = U(\phi_0 H_0, Z_0) + \mu \frac{U(\phi_1 H_1, Z_1)}{1+r} \tag{10}$$

In addition to the discount on U_1, people with suicidal impulses also have an additional discount in front of total income in t = 1. In other words, people with suicidal impulses may underestimate or ignore the positive externality of their existence to their families and the negative externality of their suicides. For example, young adults' suicides may trigger their parents' depression.

Last but not least, according to the third effect, people with suicidal impulses may increase their current investment in health and other forms of consumption to compensate for the disutility brought by the shock. For example, people may develop binge eating, and they may seek help from psychiatrists. In equation (11), the effect appears on the budget constraint: people increase their health investment and time input by θ_1, and people increase their other consumption and time input by θ_2, given $\theta_1 \geq 1$ and $\theta_2 \geq 1$. However, such an increase fails to raise utility at period 0 since the rise is offset by disutility brought by the shock at period 0 [11].

$$\begin{aligned} L =& U(\phi_0 H_0, Z_0) + \mu \frac{U(\phi_1 H_1, Z_1)}{1+r} + \\ & \lambda[R - (\theta_1 P_0 M_0 + \theta_2 V_0 X_0 + W_0((\theta_1 T H_0 + \theta_2 T_0 + T L_0) + \\ & \mu \frac{P_1 M_1 + V_1 X_1 + W_1(T H_1 + T_1 + T L_1)}{1+r})] \end{aligned} \tag{11}$$

The new Lagrangian after adding μ and θs is shown in equation (11). After differentiating the function, the new equilibrium condition is shown in equation (12). In the left-hand side of the equation (12), the cost of health increases after μ is added because $\mu \in [0, 1]$. People who are more pessimistic about their future utility may see their current health investment as less valuable. Additionally, the demand for health may shrink since $\theta_1 \pi_0 \geq \pi_0$ [12]. In other words, when the increase in consumption and health investment forms a higher financial burden for people and their families, people may instead have higher suicidal impulses. According to Taber, Leyva, and Persoskie (2015), the cost of mental services is people's top concern when they consider professional mental help.

$$\begin{aligned} \theta_1 \pi_0 &= \mu \frac{G_1 W_1}{1+r} + \mu \frac{1}{D_1(1+r)} \\ (1+r)/\mu &= \frac{G_1 W_1}{\theta_1 \pi_0} + \frac{1}{D_1 \theta_1 \pi_0} \end{aligned} \tag{12}$$

11. In reality, most of the time, the compensatory mechanism may not be sufficient to offset the disutility from the shock. This paper assumes perfect compensatory for simplicity

12. Both θ_1 and θ_2 are constant by assumption. In reality, people may change or increase their compensatory behaviors. This paper makes this assumption for simplicity

Combining these three effects, since the discount rate $\mu \in [0, 1]$, in Figure 2, the horizontal line, which represents the health investment cost at t = 0, shifts upward. Second, since the shock decreases perceived pain in suicide, $H'_{min} > H_{min}$. Lastly, due to the compensatory mechanism, the marginal cost of health investment increases, which causes the demand curve to shift downward. With these three effects, H'^{*} overlaps with H'_{min} in Figure 2. This figure explains how suicidal impulses convert into suicide attempts.

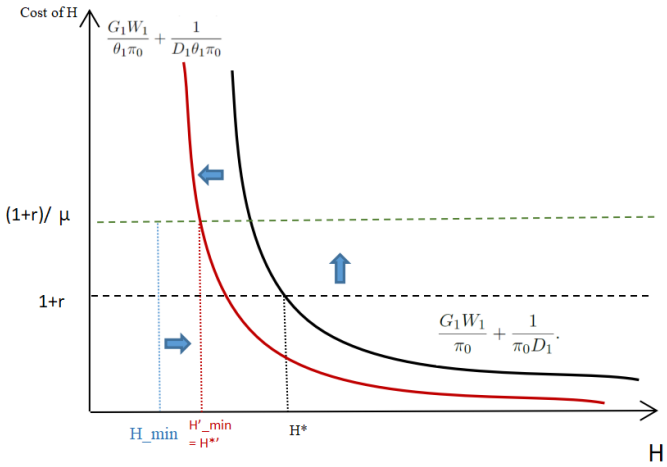

Figure 2: decision making in health with suicidal attempts

Legalizing assisted suicide may deter suicide attempts since it may directly lower the perceived pain of dying later. When people perceive a much less painful option in the future, they are less likely to attempt suicide before that.

Since assisted suicide is contingent on patients who suffer from great pain, legalizing assisted suicide only lowers the perceived pain when t = 1, denoted by D_1. Since D_1 is the inverse function of Uh_1 and G_1, decreases in D_1 shift the demand curve of health upward

$$(1 + r)/\mu = \frac{G_1W_1}{\theta_1\pi_0} + \frac{1}{(D_1 \downarrow)(\theta_1\pi_0)} \tag{13}$$

In Figure 3, the dashed red curve represents the new demand curve. In the intersection of the new demand curve with the cost of health capital, the new steady state H^{**} shifts away from H'_{min}. In this section, this paper exemplifies the effect of assisted suicide, given the individual is a healthy young adult. Through the model, this section shows that the expectation of having "a good death" at the later stage of life would deter young individuals from attempting suicide.

However, this discussion is contingent on young individuals who are healthy physically, but it ignores the effect of assisted suicide on young people who suffer from long-lasting health shock. When young people suffer from a long-lasting health shock, according to Mystakidou et al. (2005), depression and anxiety increase with the length of sick time. Relatively greater mental suffering and physical suffering might lower people's fear of suicide, indicating D_0 decreasing. Prolonged mental suffering may also cause prolonged and more intense behav-

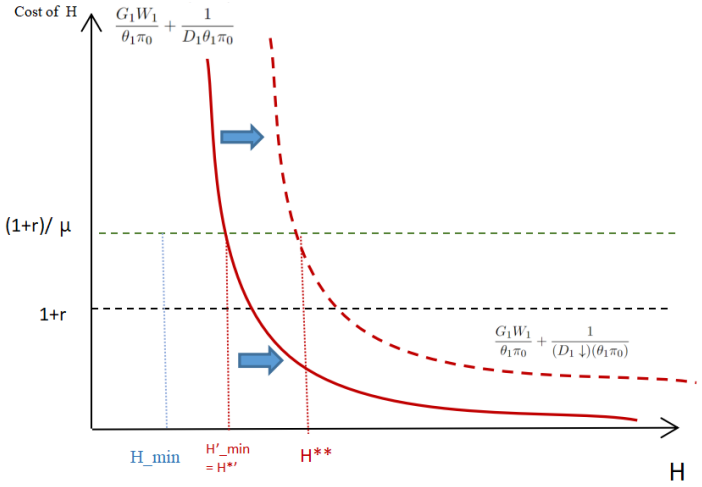

Figure 3: decision making with legalized assisted suicide

iors for compensation, which may cause negative externalities in the long run. For example, increasing the use of drugs for mental illness in the long term may develop higher drug tolerance and drug dependency.

Additionally, when people suffer from long-lasting pain, the cost of waiting increases their discounting of the future. Assuming the health shock happens in t=0, people may perceive the pain of committing suicide in the short term as less painful than considering committing suicide in the future. If they consider committing suicide in the future, they would need to suffer from pain and side effects in treatment for a longer period. As a result, μ is closer to 0, and the cost of further health investment is higher.

However, the expectation for future recovery may increase μ. If the chance of recovery in the future is high or if an experimental treatment is not painful, people may be willing to seek future treatments and are more patient [13]. In that case, for people who have suicidal impulses due to the health shock, if the expectation of the effectiveness of future treatments is insufficient to offset the fear of long-lasting treatment and the cost of compensatory behaviors, these people may commit suicide.

Legalizing assisted suicide may have two deterrent effects for their suicide attempts. First, legalizing assisted suicide may decrease D_1, which may increase the demand to keep living for one more period. Second, legalizing assisted suicide may alleviate people's fear of the future. Legalizing assisted suicide guarantees people that if they suffer from severe pain in the future, they could choose to end their lives at a much lower "cost."

If people believe assisted suicide is sufficient to offset the fear of long-lasting treatment and the cost of compensatory behaviors, then legalizing assisted suicide is effective in deterring suicides for these people. If they perceive assisted suicide is insufficient to offset their prolonged pain and the cost of compensatory behaviors, they may commit suicide before the next period or apply for assisted suicide during the first period.

13. The further discussion of the chance of recovery and the side effects of treatment is discussed in the next section

The difference between these two cases depends on people's expected shock length. For short-term shocks and short-term suicidal impulses, legalizing assisted suicide is more effective since the expectation of assisted suicide only needs to offset the increase in the discount rate and compensatory behaviors temporarily. However, in the long-term shock, the expectation of assisted suicide has to offset the opportunity cost of waiting for assisted suicide. This uncertainty may explain the noise in the effect of legalizing assisted suicide to unassisted suicide in Girma and Paton (2022).

Additionally, this discussion is contingent on short-term suicidal impulses that ignore suicidal tendencies due to more severe mental illness, such as severe depression. Unlike temporary suicidal impulses, mentally ill patients suffer from both clinical physical symptoms and mental pain ("Mental Disorders," n.d.). The patients also suffer from side effects from medical treatments and medicines. For example, people with depression and anxiety commonly have insomnia. The common side effects of mental illness medicines include headache and skin inflammation ("What Are the Real Risks of Antidepressants?," n.d.). In that case, this paper does not distinguish patients with severe mental illness and severe physical illness. Due to the nature of mental illness, people with severe mental illness may have a higher discount and more intense compensatory behaviors in the future.

4 Effect of Aging

In the section above, this paper discusses the effect of assisted suicide on young adults under mental and physical shocks. This section explains how assisted suicide is expected to change elderly people's decisions on suicide and the mechanism for why legalizing assisted suicide may increase the total suicide rate among elderly people (Girma and Paton 2022). Additionally, this section explains how assisted suicide may encourage elderly people to receive more medical treatments instead of giving up when they are sick.

When people age, their investment in health is increasingly risky. Risks increase because people's recovery rate is lower with age, and people are more sensitive to the side effects of medical treatments. According to these risks, this section modifies the original assumption of the investment function to an expected return function in health investment.

$$I_i = q_i I_i + (1 - q_i)(-\psi_i I_i) \tag{14}$$

In equation (14), the new investment function represents that health investment could have q_i probability that the investment increases the well-being of this person, but there exists $(1 - q_i)$ probability that the treatment brings high side effect which depreciates health more. The severity of side effects is denoted by ψ_i. ψ_i could be greater than 1, which means the side effects of medical treatments may exceed the recovery effect of the treatments. When ψ_i is high enough, people may die from side effects. The determinants of side effects include age, past drug use, allergic history, and so on (Alomar 2014). For simplicity, this paper assumes that ψ_i only depends on age and increases with age. Moreover, q_i decreases with age because elderly people are likely to be more tolerant of the treatment effects of medicines. For example, elderly

people may need to take larger doses of sleep aid than young adults. [14]

Given expected investment with probability, the change of H_i from i to $i+1$ is

$$H_{i+1} - H_i = q_i I_i - (1 - q_i)\psi_i I_i - \delta_i H_i. \tag{3'}$$

Equation (3') represents that the change in health status depends on the effectiveness of health investment, the side effects, and the depreciation rate. If rewriting the two-period Lagrangian function with the new investment function and utility function, the equilibrium holds when

$$\begin{aligned} \theta_1\pi_0 &= (\frac{Uh_1G_1}{\lambda(1+r)} + \frac{G_1W_1}{1+r})(q_0 - \psi_0(1-q_0)) \\ \frac{1+r}{(q_0 - \psi_0(1-q_0)} &= \frac{Uh_1G_1}{\lambda\theta_1\pi_1} + \frac{G_1W_1}{\theta_1\pi_0} = \frac{1}{D_1\theta_1\pi_0} + \frac{G_1W_1}{\theta_1\pi_0} \end{aligned} \tag{15}$$

The left-hand side of equation (15) is the marginal cost of health investment at t = 0 given q_0 and ψ_0. Assume q_0 and ψ_0 is high at t = 0, $(q_0 - \psi_0(1-q_0)$ is low at t = 0, and the marginal cost of health investment at t = 0 is high. [15]. When the chance of successful treatment is low, and the side effects are high, the expected cost of seeking medical treatment is higher. Given the higher cost, the horizontal line in Figure 4 shifts upward. The right-hand side of equation (15) is the demand function, adding people's compensatory behaviors. For example, when people's bodily function decreases, some may need to increase their calcium and vitamin supplements dose.

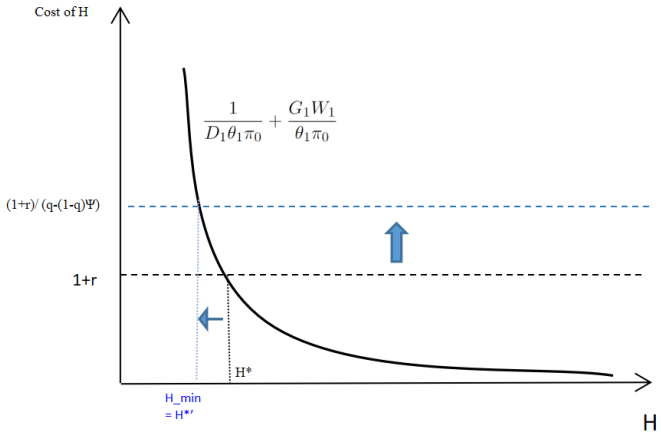

Figure 4: decision making when investment is risky

According to Figure 4, after the cost of health investment increases, H_i overlaps with H_{min}

14. The establishment of the investment function is similar to Posner (1995) model in that Posner assumes the probability is on the uncertainty of diagnosis

15. Under the two-period model assumption, t = 0 can be treated as the period before the last period

[16]. When the cost of health investment is high, the expected chance of recovery in the future and financial burden is so high that some people stop seeking further medical treatments, which may lead to suicidal attempts.

However, aside from the cost of medical treatments, people's elasticity and their attitude toward risk may also determine their decision-making in health investment and suicide attempts. Equation(16) represents an individual's elasticity of demand, denoted by ϵ, for health capital, which is determined by the change of decision in health investment according to the change of cost in health investment.

$$\epsilon = \frac{\partial ln H_0}{\partial ln \frac{(1+r)}{q_0 - \psi_0(1-q_0)}} \tag{16}$$

$$ln(1+r) - ln(q_0 - \psi_0(1-q_0)) = ln(\frac{G_1 W_1}{\theta_1 \pi_0} + \frac{1}{D_1 \theta_1 \pi_0}) \tag{17}$$

In equation (17), for simplicity, $\frac{G_i W_i}{\pi_{n-1}}$ is omitted. This term is omitted in this section because people under higher health risk may be temporarily absent from market productivity, such as when they are retired. Moreover, the non-market productivity is kept and shown in the second term. After retirement, most elderly people's utility mainly depends on the utility of being healthy. Being healthier enables them to have more time spent with their families or friends. In that case, equation (17) could be written as

$$ln(1+r) - ln(q_i - \psi_i(1-q_i)) = ln(\frac{1}{D_i \theta_1 \pi_{i-1}}) = ln1 - lnD_i - ln\pi_{i-1} - ln\theta_1$$
$$ln(1+r) - ln(q_i - \psi_i(1-q_i)) = -ln\lambda + lnUh_i + lnG_i - ln\pi_{i-1} - ln\theta_1 \tag{18}$$

In Equation (18), since $D_i = \frac{\lambda}{Uh_i G_i}$, lnD_i can be rewritten as $ln\lambda - lnUh_i - lnG_i$. Given utility on health is an increasing and concave function and $h_i = \psi_i H_i$, the utility function of an agent at any period i is

$$U_i = \beta_0 + \beta_1 (h_i)^\alpha + \beta_2 (Z_i)^c \tag{19}$$
$$Uh_i = \alpha \beta_1 (h_i)^{\alpha-1} = \alpha \beta_1 (\phi_i H_i)^{\alpha-1} \tag{20}$$
$$0 < \alpha < 1$$
$$0 < c < 1$$

In equation (19), utility at period i is a quadratic function determined by total healthy days and the other human capital components. β_0 represents that given an agent's healthy days and the other human capital is eliminated, the baseline utility of the agent is β_0. The parameters β_1 and β_2 represent the coefficients of the healthy days and the other human capitals. While

16. Since age-depreciation is a more gradual process than the shocks in the previous section, this section does not assume a change in $H_m in$

α and c represent the agent's attitude toward risk in the investment of health and other human capital. The higher the α or c is, the less risk-averse the agent is toward investment in health or other human capital. If the exponential is greater than 1, the agent is risk-seeking. In Grossman's (1972) model, the utility function is concave, so both α and c are greater than 0 and smaller than 1. The agent is risk-averse in all investments by assumption.

In equation (20), by differentiating U_i over h_i, Uh_i demonstrates the marginal change of utility given change in health days. Since α is smaller than 1, $\alpha - 1$ is negative. The agent has a diminishing marginal utility of being healthy. Moreover, since $h_i = \phi_i H_i$, equation (20) can be written in terms of H_i. The change of Uh_i due to the change in H_i is shown in equation (20).

From equation (20'), by adding the natural log on both sides, each percent point increase in health is correlated with $\alpha - 1$ percent point change in Uh_i.

$$lnUh_i = ln(\alpha\beta) + (\alpha - 1)ln\phi_i + (\alpha - 1)lnH_i \tag{20'}$$

By substituting $lnUh_i$ in equation (20') to equation (18), since $D_n = \frac{\lambda}{Uh_n G_n}$, the change of marginal cost is

$$\begin{aligned} ln(1+r) - ln(q_i - \psi_i(1-q_i)) = -ln\lambda + \\ ln(\alpha\beta) + (\alpha-1)ln\phi_i + (\alpha-1)lnH_i + lnG_i - ln\pi_{i-1} - ln\theta_1 \end{aligned} \tag{21}$$

Given G_i is the differentiation of h_i on H_i, and h_i is increasing in H_i, the assumed function of h_i is

$$h_i = \Omega - B(H_i)^{-C} \tag{22}$$

$$G_i = BC(H_i)^{-C-1}, \tag{23}$$

where BH^{-C} represents sick time in each period (Grossman 1972). Equation (22) means the healthy time at period i is the total time in period i minus the time lost in sickness. Intuitively, C can be interpreted as the robustness of the immune system, and B can be interpreted as the chance of getting sick. For example, if a person is exposed to a high-risk environment but has a relatively robust immune system, this person may get sick relatively often but recover fast, and the sick time may be moderate. In contrast, if a person's immune system is relatively weak, even though this person may rarely exposed to the chance of getting sick, the time lost in sickness may be relatively high. This intuition is also applicable to equation (23). In equation (23), if the person's immune system is strong, C is higher, and $-C - 1 = -(C + 1)$ is relatively larger in absolute value. If the health status is fixed, people with higher C and lower B will have lower G_i. Low G_i represents the person in a relatively healthy status. Assuming both B and C are fixed, the change of G_i is $lnG_i = lnBC - (C + 1)lnH_i$. Combining the change of G_i and Uh_i above, the change of marginal cost is:

$$ln(1+r) - ln(q_i - \psi_i(1-q_i)) =$$
$$ln(\alpha\beta) + (\alpha-1)ln\phi_i + (\alpha-1)lnH_i + lnBC - (C+1)lnH_i - ln\pi_{i-1} - ln\theta_1 \quad (24)$$

From equation (24), the demand elasticity of health is

$$\frac{\partial lnH_0}{\partial ln\frac{(1+r)}{q_0-\psi_0(1-q_0)}} = \frac{1}{C-\alpha+2}, \quad (25)$$

Equation (25) could amplify how the elasticity of demand in health may affect people's decision-making in seeking medical treatment. The elasticity of people's demand for health depends on the robustness of their immune system, denoted by C, and people's attitude toward risk in health investment, denoted by α. People with stronger immune systems, such as athletes, tend to be more inelastic in their demand for health. However, since this paper assumes C is exogenous, the change in the elasticity of demand in health depends on α (Grossman 1972). People who are more risk-averse toward health investment are more inelastic in their demand for health since they may have a stronger will for a stable health status. For example, doctors tend to be more conscious in choosing medicines when they face patients who have multiple allergic sources or past medical history. These patients are also more sensitive to changes in riskiness in health investments.

Graphically, these people are more sensitive to changes in riskiness because their demand for health investment is flatter, as shown by the black curve in Figure 5. When the chance of successful treatment decreases and the severity of side effects increases, the decrease in health demand is so high that these people may stop seeking further medical treatments.

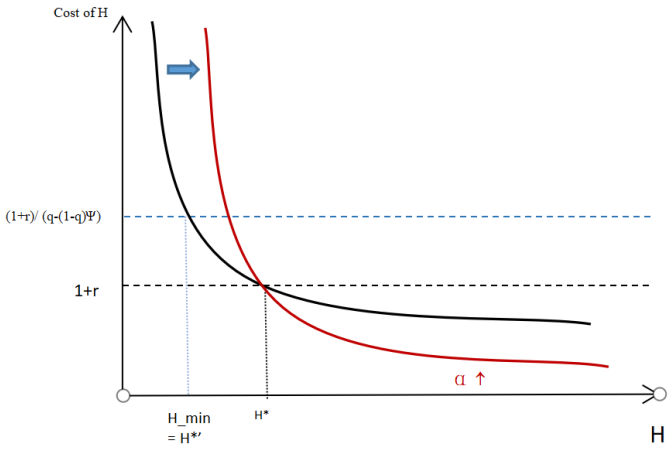

Figure 5: Decision making for elastic demand and inelastic demand

In contrast, if people are more elastic in their demand for health, they are relatively less risk averse to the risks in treatment. The demand curve will be steeper, denoted by the red curve in Figure 5. In Figure 5, the intersection between the red curve and the horizontal line is still higher than H_{min}. Even though the change in cost may decrease health demand, these people

keep investing in health treatments even though they see increasing risks.

Legalizing assisted suicide may deter people from giving up treatments or investment in health through two effects. First, legalizing assisted suicide supplies an alternative option of death, and the alternative option of death offsets the concern of increasing in ψ_i. Under the condition of no legalized assisted suicide option, while ψ_i is high enough, side effects may cause death. Under the condition that assisted suicide is legalized, the second term in the investment function, $(1-q)(\psi_i I_i)$, could be omitted. After the second term is omitted, the magnitude of the shift in the horizontal curve is smaller.

Second, legalizing assisted suicide may decrease the risk aversion of people who are inelastic in their demand for health. Given $D_i = \frac{\lambda}{Uh_i G_i}$, the change of expected pain of suicide can be written as

$$lnD_i = ln\lambda - ln(\alpha\beta) - (\alpha-1)ln\phi_i - (\alpha-1)lnH_i - lnBC + (C+1)lnH_i \tag{26}$$

According to equation (26), after assisted suicide is legalized, the expected value of D_i decreases largely since people are eligible to apply assisted suicide if any severe side effect happens, and lnD_i decreases substantially. After lnD_i decreases, α increases to keep the equivalence between the two sides. Given α increases, the elasticity of demand for health increases, and people are less risk averse toward investment in health. Furthermore, the increase in elasticity shifts the demand curve from black to red in Figure 5, which may deter elderly people from giving up treatment. Intuitively, if the expected pain in dying after medical treatment is lower, people are likely to be less afraid of risks.

Additionally, after assisted suicide is legalized, people's wish to live is higher. While α increases, according to $Uh_i = \alpha\beta_1(h_i)^{\alpha-1}$, Uh_i will increase. When the health status is fixed, if people's demand for health is more elastic, their marginal utility from being healthier is higher. When the health status is fixed, marginal utility from being healthier indicates patients' wish to live. Intuitively, suppose two patients suffer from the same level of pain. Compared with a conservative patient who is afraid of taking risky medicines, a patient who is willing to try more risky medicines has a higher wish to live. For example, since young adults have a higher wish to live, due to negative externalities and greater foregone utility of living a full life, they may tend to take "high risk and high return" medical treatments than the elderly.

With a higher wish to live and less fear of risks, assisted suicide may have a chance to increase national-level life expectancy. When people are less likely to give up treatments, their life expectancy mainly depends on the efficiency of the medical treatments and other society-level exogenous factors, including health insurance coverage and accessibility to professional medical aid.

This section explains how assisted suicide may deter elderly people from giving up medical treatments. However, if the elderly population has suffered from long-lasting diseases, legalizing assisted suicide may have a lower effect on them. Since they have been suffering from pain for a long time, they are likely to have a lower expectation of the perceived pain of death, and they are more likely to be eligible to apply for assisted suicide. In that case, the magnitude change in elasticity may not be sufficient to offset the opportunity cost. Instead of

seeking further treatments, they may decide to apply for assisted suicide.

This result is consistent with the previous result of assisted suicide. Girma and Paton (2022) finds that legalizing assisted suicide has an insignificant but mostly negative effect on unassisted suicide. However, legalizing assisted suicide has a significant and positive effect on the total suicide rate among the elderly population. In sum, legalizing assisted suicide increases the total suicide rate since the number of elderly applicants for assisted suicide increases. The increase in total suicide and assisted suicide rates may be the result of the high proportion of elderly people with chronic diseases. According to the CDC, more than 80% of the population over 65 years old have at least one chronic disease ("Health Policy Data Requests - Percent of U.S. Adults 55 and Over with Chronic Conditions" 2019).

5 Discussion and Conclusions

People have debated the efficiency and social externality of assisted suicide for the past decades. This paper is different from previous literature in that this paper explores the effect of assisted suicide on people's demand function for health. This paper uses Grossman's (1972) model of the demand for health capital but includes the consumption of health and the riskiness of health investments, which is ignored in the original model.

The first section of the model implies that legalizing assisted suicide has a deterrent effect on suicide attempts among young adults who do not suffer from underlying diseases. However, when these young adults confront a mental breakdown, they may feel desperate and pessimistic about their future income, and they may also face increasing financial burdens due to their compensatory consumption and need to seek professional mental help. These changes may induce suicide attempts if assisted suicide is not accessible.

Accessibility to assisted suicide lowers these people's perceived pain in death, contingent on future periods. Decreased perceived pain in the future increases these people's general demand for health. In that case, assisted suicide is significant in deterring suicide attempts for healthy people who face a relatively short-term mental issue. However, this deterrent effect is less significant among people who confront physical illness, such as cancer, which may require relatively long-term care. Suffering from physical illness decreases people's perceived pain in suicide and increases the perceived pain of waiting to die in the next period. Long-term compensatory behaviors may also generate negative externalities, such as drug tolerance. In that case, the deterrent effect is conditioned on comparing the magnitude of decreasing pain in the next period, the chance of recovery, and the magnitude of the cost of waiting.

In the second section of this paper, this paper explains how legalizing assisted suicide may affect elderly people's attitudes toward medical treatments. The analysis of the elderly population mainly focuses on the change of risks in health investment and the elasticity of demand for health. As age increases, investments in health might bring higher risks with severe side effects but a lower chance of recovery. The increase in riskiness brings higher variance to health status, which increases the cost of seeking medical treatments. People's attitude toward the increasing variance determines whether they seek medical treatments when sick. Elderly people who are more inelastic in the demand for health are likely to be more sensitive to the change in

risk. Since they are susceptible to the change in health investment costs, they are more likely to give up health investments. Legalizing assisted suicide would decrease the perceived magnitude of the change in the riskiness of health investments, and decreasing pain may reduce risk aversion among these people. When these people are less risk-averse, they are more likely to receive risky medical treatment.

Moreover, when people are more willing to take risky medical treatment, compared with conservative patients, these people have higher utility when the treatment is successful. The change in utility indicates a higher wish to live. However, this condition is contingent on relatively healthy elderly people. In the case of people with chronic diseases, the effect of assisted suicide may be less significant on them. These people are more likely to apply for assisted suicide instead of receiving more medical treatment.

These results are consistent with the empirical result and can explain the noisiness in Girma and Paton (2022). However, this paper has two limitations. First, Girma and Paton (2022) shows the effect of legalizing assisted suicide with lagged years of treatment. This paper did not discuss the lagged and long-term effects of legalizing assisted suicide. Second, this paper is limited to explaining the dynamics between assisted suicide and non-assisted suicide. In that case, it does not fully explain the mechanism of possible encouragement effect of legalizing assisted suicide in increasing the rate of assisted suicide. Future theoretical research can investigate the long-term effect of assisted suicide on assisted suicide rates and unassisted suicide rates.

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6 Appendix

Symbol	Meaning
U	Total utility over the lifetime for an individual
i	Age
H_i	Stock of health in period i
h_i	Total number of Healthy days in period i
G_i	Marginal product of healthy days with each one-unit increase of H_i
I_i	Gross Investment in Health
D_i	Perceived pain of dying in suicide
R	Total wealth over lifespan of an individual
ϕ_i	Increase in healthy days for each unit increase in health at age i
π_i	Marginal cost of gross investment
δ_i	Rate of depreciation
W_i	Wage Rate
A_0	Initial Stock of property asset
H_{min}	When people have suicide attempts
Z_i	Other human capital components or consumption
M_i	Medical care
X_i	Goods investments in the production of Z_i
P_i	Price of medical care
V_i	Price of X_{i}
r	Rate of interest
μ	Additional discount rate on future during shock
θ_1 θ_2	Parameter of additional investment in health and Z_i due to complementary mechanism
TH_i	Time input in gross investment in health
TW_i	Hours of Work
TL_i	Sick Time
T_i	Time input in producing Z_i or consuming Z_i
Ω	Constant length of each period
R	Total Wealth one can earn in his/her life
Uh_i	Marginal utility of healthy days
λ	Marginal utility of wealth
q_i	The probability of successful health investment
ψ_i	The severeness of side effect
ϵ_i	Elasticity of MEC schedule
α	Degree of risk-averse in health investment
c	Degree of risk-averse in the investment of other human capitals
B	Exposure to the riskiness of getting sick
C	Robustness of immune system of an individual