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“Health capital norms and intergenerational transmission of non-communicable chronic diseases”

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Health capital norms and intergenerational transmission of non-communicable chronic diseases*

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Abstract

We look at how social norms regarding health affect the dynamics of an epidemic of NCDs. We present an overlapping generations model in which agents live for three periods (childhood, adulthood and old age). Adulthood consumption choices have a impact on the health capital of the following period, which is in part inherited by their offspring and affects their offsprings' probability of developing a NCD. As a result of this intergenerational externality, agents would choose lower health conditions and higher unhealthy activities than that which is socially optimal. In addition, parental choices affect their own old age health capital with which their offspring compare their own. A social norm imposing agents to be as healthy as the previous generation balances the negative effects of unhealthy adulthood choices. Fiscal policies alone or combined with public policies regarding social norms can be used to restore optimality. Our results underline the interplay between sin taxes and health-related social norms.

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1 Introduction

By 1940 infectious diseases were overtaken by non-communicable chronic diseases (NCDs) as the major cause of death in the US (Ritchie and Roser, 2017). Presently, NCDs account for 70% of worldwide deaths. However, the WHO estimates that 80% of NCDs' premature deaths are preventable. Prevention would imply a change in the most important risk factors of NCDs, such as unhealthy eating, smoking and physical inactivity.

Despite major past and present health threats, life expectancy has been increasing steadily for the last two centuries. The average life expectancy in the OECD was 80.7 in 2017, 10 additional years than in 1970 (OECD, 2019). Increasing life expectancy is not only an effect of important reductions in child mortality; life expectancy has increased for all age groups. Moreover, individuals are not only living longer, they are also living in better health, and in 2019, the average person in the world was expected to live five more healthy years than in 2000.[1]

Increasing life and healthy life expectancy may lead to the belief that *one should be at least as healthy as the previous generation.* In this paper we look at how such a common belief, or social norm, may affect the dynamic of an epidemics of NCDs emphasizing its intergenerational determinants. Additionally, we analyze how policy instruments can be used to enhance welfare, and in particular, we focus on the role of fiscal policies and social norms.

From social norms, we understand a pattern of behavior that is self-enforcing at the group level, as defined by Young (1993). We focus on health capital as the dimension of comparison and consider the reference group to be the previous generation. It is undoubtedly problematic to encompass all of the dimensions of health in a single measure but commonly used proxies for health capital are, obviously, life and healthy life expectancy, but also height (see, among others, Case and Paxson, 2008; and Deaton, 2008) and body mass index (BMI) (see, for instance, WHO, 2018). However, the existence of a social norm, such as increasing health capital with regard to previous cohorts, remains a relevant scientific question. It cannot be denied, however, how startling it was to observe the decrease in the US life expectancy at birth by less than six months for four consecutive years from 2014.[2] Both the media and the scientific community have discussed the subject extensively, as if losses in life expectancy do not occur in this present age (see Woolf and Schoomaker, 2019). Such reaction suggests the existence of a socially accepted norm as regards the adoption of health improvements with respect to previous cohorts.[3]

[1]https://www.who.int/data/gho/data/indicators/indicator-details/GHO/gho-ghe-hale-healthy-life-expectancy-at-birth, accessed January 20, 2021.

[2]https://data.oecd.org/healthstat/life-expectancy-at-birth.htm

[3]It is still too soon to understand the full effect of the Covid-19 pandemic on life expectancy but,

Social norms have been identified in health related behaviors such as alcohol consumption (Perkins and Berkowitz, 1986), smoking (Rodríguez-Planas and Sanz-de-Galdeano, 2019), or eating behaviors (see Higgs, 2015 for a survey on the psychologic aspects of social norms of eating behavior). Moreover, other contributions focus on the role of social norms on BMI (see, for example, Etilé, 2007 and Dragone and Savorelli, 2012).

In this paper we consider a social norm with respect to health capital, which can bee seen as encompassing all health-related behaviors. We assume the reference group to be the previous cohort: this means that individuals compare their own life-expectancy to that of previous cohorts. This has been a well-accepted assumption in the literature since Hamermesh (1985). Hamermesh (1985) was a pioneer in attempting to understand whether individuals are realistic in forming their expected life horizons over which they maximize. He concludes that individuals use information regarding past cohorts' life expectancy (reflected in their contemporaneous life tables) to infer information on subjective life expectancy. His results were revalidated by Hurd and McGarry (1995), with a larger and more representative 1992 sample of individuals born from 1931 to 1941. Additionally, they found that subjective life expectancies are correlated with own parents' longevity experience.

The social norm imposing *one to be at least as healthy as the previous generation* assumes a utility gain when individuals attain a higher health capital than the previous cohort. Therefore, another clarification is required, which concerns the utility gain when individuals behave accordingly to the social norm and live longer than the previous cohort. The literature on wellbeing supports this assumption. In fact, researchers have first noticed that well being does not improve with absolute levels of income or health, but instead with relative increases in each (see Easterling, 1974, 1995; Deaton, 2008 and, for a survey, Borghesi and Vercelli, 2010 and the references therein). Consequently, individuals' life satisfaction and wellbeing appear to be more a function of a model with income and health aspirations. In our setup, this is translated into a utility gain if individuals attain a higher health capital (life expectancy) than the previous cohort.

More precisely, we present an overlapping generations model in which agents live for three periods (childhood, adulthood and old age), and where the dynamics of the economy are based on health capital accumulation (Grossman, 1972). All economic decisions are made at adulthood and therefore parents decide upon their consumption levels and those of their offspring. More specifically, parents decide upon the consumption the levels of unhealthy goods (as, for example, salt, sugar, saturated fat but also second-hand smoking)

for instance, Andrasfaya and Goldman, 2021 estimate a 1.13-year decrease for the US population. The present health crisis is without doubt an extreme event, and the unprecedented political and societal responses world-wide are evidence of the importance that society attaches to health.

and preventative measures (physical activity, medical care, etc.) that affect the level of health capital of the following period. The health capital of the following period is in part inherited by their offspring. Therefore, choices in adulthood have a direct impact on the inherited health capital of their offspring. Additionally, adulthood choices also affect their offspring's probability of developing a NCD in old age. These two first mechanisms were previously present in Goulão and Pérez-Barahona (2014) and were used to suggest that the spread of NCDs can be rationalized as a result of the intergenerational transmission of modifiable risk factors. In addition, we assume here that parental choices in turn affect their offspring' inherited social norms; that is, parental choices affect their own old age health capital with which their offspring compare their own. We show that the social norm on health capital counterbalances the intergenerational transmission of a modifiable risk factor enhancing health capital and decreasing the probability of NCDs.

Specifically, we model the social norm on health capital by introducing a utility loss resulting from a comparison with the health of the past generations' health. We assume a model of health aspirations, where utility gains emerge from health improvements with respect to previous generation (except in Section 4, where we generalize the utility function). Therefore, from an individual's point of view, they prefer the lowest possible social norm; that is, no social norm at all. However, from the point of view of a social planner, a positive level of social norms is desirable as it allows the planner to internalize the intergenerational externalities. Using social norms as policy instruments raises several conceptual and practical questions. "Social norms interventions" aim to change the pattern of behavior that is self-enforcing at the group level. This approach has been followed in developing countries to try to change harmful practices, such as female genital mutilation, violence or child marriage (see Cislaghi and Heise, 2018 and the references therein). Such an approach would be translated in our model as an exogenous (policy driven) shock leading to a change in the health capital of the previous cohort. Another possibility is to assume that a policy maker can affect the degree of self-enforcement of the social norm. This corresponds to an exogenous (policy driven) shock resulting in a change of the social ties in the economy. Although we do not model this process (and assume it instead the result of a black box), it is interesting to acknowledge its implications. We show that the social norm can be used to offset the other intergenerational externalities due to the transmission of health capital and modifiable risk factors. In a way the social norm can be used along with taxes to decentralize the social optimum and, in particular, to escape health capital traps.

The remainder of the paper is organized as follows. Section 2 describes the economic environment. Then, individuals' choices and the particular role of social norms are analyzed in Section 3. In Section 4, we characterize the social optimum and discuss the role of public policies to restore optimality. Section 5 concludes.

2 Social norms on health capital

We assume a discrete-time infinity-horizon economy populated by overlapping generations of agents living for three periods: childhood, adulthood, and old age. Time is indexed by $t = 0, 1, 2, ..., \infty$, agents are identical within each generation, and there is no population growth (the size of each generation is normalized to 1).

Individuals have an expected lifetime utility function $U_t(c_t, v_t, h_{t+1}, n_t, \pi_t)$. At time t, adult agents care about consumption c_t and unhealthy consumption, v_t (or modifiable risk factors). They are also concerned about their health capital when old h_{t+1} (Grossman; 1972, 2000). We assume that individuals inherit from their parents' tastes with regard to health capital, which is similar to the model of aspirations of de la Croix and Michel (1999). Specifically, offspring are given a frame of reference of health capital, i.e., a norm n_t, against which they evaluate their old age health capital, h_{t+1}. Let $n_t = \epsilon h_t$, with $\epsilon > 0$ and we suppose $\partial U_t/\partial \epsilon < 0$.

Agents take all decisions at adulthood. Adult agents allocate their exogenous income w_t among consumption, unhealthy activities, and health investments m_t as medical care and physical activity. The corresponding budget constraint is

$$w_t = c_t + v_t + m_t. \tag{1}$$

When elderly, individuals might suffer from a NCD with a probability π_t, and this depends on their health capital, as specified below. Specifically, we consider that $U_t(\cdot)$ is a strictly increasing function of c_t, v_t, and h_{t+1}, but decreasing in π_t and n_t.[4] In particular, we can consider the following function in order to get closed-form solutions:

$$U_t(c_t, v_t, h_{t+1}, \pi_t, n_t) = \ln c_t + \lambda \ln v_t + (1-\pi_t)\gamma \ln(h_{t+1} - n_t) + \pi_t \gamma (1-\phi) \ln(h_{t+1} - n_t), \tag{2}$$

where $\lambda > 0$ represents the weight that agents give to unhealthy activities, and $\gamma > 0$ stands for their concern about future health capital. The disutility of suffering from a NCD is captured by $\phi \in [0, 1]$ and is caused by the morbidity of a disease and time loss due to treatment, which reduces the utility driven from health capital.[5] Finally, we note the effects of social norms: specifically, that the logarithmic specification implicitly imposes the restriction that $h_{t+1} > n_t = \epsilon h_t$, i.e., agents enjoy a higher health capital

[4] We also assume that $\partial^2 U_t(\cdot)/\partial c_t^2$, $\partial^2 U_t(\cdot)/\partial v_t^2$, $\partial^2 U_t(\cdot)/\partial h_{t+1}^2$ are strictly negative, and $\lim_{c_t \to 0} \partial U_t(\cdot)/\partial c_t$, $\lim_{v_t \to 0} \partial U_t(\cdot)/\partial v_t$, $\lim_{h_{t+1} \to 0} \partial U_t(\cdot)/\partial h_{t+1} = +\infty$.

[5] Note that we allow for the two extreme cases: mortal disease ($\phi = 1$), and negligible morbidity ($\phi = 0$).

than the previous cohort. Also, for $\epsilon \to 0$, the model reduces to a model with no social norms, where agents fully enjoy the health capital accumulated when old. This case is informative as a benchmark.

We start by assuming, simplistically, that the probability of suffering from a NCD is a decreasing function of an agent's health capital at adulthood, i.e., $\pi_t = \pi(h_t)$, such that $\partial\pi(h_t)/\partial h_t < 0$, $\lim_{h_t \to 0} \pi(h_t) = \pi_H$ and $\lim_{h_t \to \infty} \pi(h_t) = \pi_L$, with $0 < \pi_L < \pi_H < 1$. Assuming $\pi_t = \pi(h_t)$ means to neglect that agents' actions have an impact on their own probability of developing a NCD. This is of course not consistent with the literature on sin and unhealthy goods consumption that demonstrates the role of one's consumption on one's potential development of a NCD. Nonetheless, it allows us to focus firstly on the role of social norms on the intergenerational transmission mechanism, since we assume that adults' consumption choices solely affect their offspring' inherited health capital (h_t). Even in this extreme case, there is a role for corrective taxation. We then analyze in Section 4 the broader setup where we assume $\pi_t = \pi(h_{t+1})$, i.e., individuals' consumption additionally affects their own probability of developing an NCD.

As in Grossman (1972, 2000), our model assumes that health capital accumulates over time. In particular, we consider the following law of motion:

$$h_{t+1} = (1-\delta)h_t + \sigma m_t - \alpha v_t, \tag{3}$$

where $0 < \delta < 1$ and $\sigma, \alpha > 0$.

Health capital in old age, h_{t+1}, is a function of the inherited health capital h_t, accounting for the depreciation rate δ. Yet, agents may modify their health capital through health investments and unhealthy activities during adulthood. Thus, h_{t+1}, increases with health investments (m_t) where σ captures their effectiveness, and reduces with unhealthy consumption (v_t), where α captures their harmfulness. Therefore adulthood choices, v_t and m_t, modify their offspring' inherited health capital, as well as their offspring' inherited health capital norm. This assumption is consistent with recent research on epigenetics suggesting precisely that the risk factors of NCDs may affect the health capital of following generations (see for example Alm et al., 2017, on the grand parents' intergenerational transmission of health capital due to diet choices, and Barrès, 2016 for a dissemination article on epigenetics).

The parameter δ captures the depreciation of health capital from adulthood to old age (Grossman, 1972, 2000). It accounts for ageing and encompasses all exogenous factors that may decrease health capital during adulthood. offspring inherit the fraction of health capital not depreciated by the end of their parents' adulthood. With such modelling, we aim to illustrate that individuals make consumption choices that increase or decrease their body mass index (BMI), which is a proxy for health capital. The health capital they then have at adulthood is transmitted towards their own offspring. They grow old in the following period and may develop diabetes, cardiovascular diseases, or various types of cancers, given their BMI. Because NCDs only occur at old age, we model the utility loss they impose through the parameter ϕ, which implies a reduction of the expected utility of health capital when old, as implied by the two last terms in (2).

As a result, the intergenerational transmission of NCDs occurs through three different channels. First, adulthood choices have a direct impact on their offspring' inherited health capital. Second, adulthood choices also affect their offspring' probability of developing a NCD in their old age. These two first mechanisms were already present in Goulão and Pérez-Barahona (2014). Third, by affecting their own old age health capital, parental choices then in turn affect their offspring' inherited norms in relation to health capital.

3 The decentralized economy

The consumption problem reduces to maximizing (2) subject to (1) and (3). Combining the FOCs gives

$$\frac{\partial U_t}{\partial v_t} = \frac{\partial U_t}{\partial c_t} + \alpha \frac{\partial U_t}{\partial h_{t+1}}. \tag{4}$$

Since $\pi = \pi(h_t)$ and h_t is taken as given we can characterize the following closed form solutions for the specific utility function (2):

$$c_t = \frac{\sigma w_t + (1-\delta-\epsilon)h_t}{\sigma[\lambda + 1 + \gamma(1-\phi\pi_t)]}, \tag{5}$$

$$v_t = \frac{\lambda[\sigma w_t + (1-\delta-\epsilon)h_t]}{(\sigma+\alpha)[\lambda + 1 + \gamma(1-\phi\pi_t)]}, \tag{6}$$

$$m_t = \frac{\sigma[\gamma(\sigma+\alpha)(1-\phi\pi_t) + \lambda\alpha]w_t - (1-\delta-\epsilon)[(\lambda+1)\sigma+\alpha]h_t}{\sigma(\sigma+\alpha)[\lambda + 1 + \gamma(1-\phi\pi_t)]}. \tag{7}$$

A sufficient condition for c_t, $v_t > 0$, is that $\epsilon \leq 1-\delta$, i.e., social norms are not too strong. Strong social norms imply high level of health capital, and the only way to increase health capital is to increase health investment m_t (see Eq. 3). However m_t is increased at the cost of pushing down general and unhealthy consumptions, otherwise the budget constraint (1) is not respected. Thus, $\epsilon \leq 1-\delta$ ensures c_t, $v_t > 0$ and, in this case, $m_t > 0$ is guaranteed considering that agents' income is high enough (see Eq. 7). For the sake of presentation, we assume $\epsilon \leq 1-\delta$ and that w_t is sufficiently large to satisfy positivity. Appendix A considers the case of strong social norms.

From (7)-(5) we can observe that, all other things being equal, first, income (w_t) increases both consumption and unhealthy consumption but it also raises health investment. Second, for a given probability of NCDs, greater inherited health conditions (h_t)

make health investments less valuable. Therefore health investment decrease while general and unhealthy consumption increase. Third, a greater probability of suffering from a NCD, a greater disutility of NCD (ϕ), or a lower concern about future health capital (γ), all decrease old age expected utility. Consequently, general and unhealthy consumption increase and health investments decrease. Finally, stronger inherited norms in relation to health capital increase health investments and therefore lowers general and unhealthy consumption.

3.1 Dynamics

Given the initial health conditions $h_0 > 0$, the dynamics of the economy is completely characterized by the evolution of health capital, as described by (3). By substituting (5)-(7) into (3), we get the corresponding transition function:

$$h_{t+1} = \frac{\epsilon(1+\lambda)h_t + \gamma(1-\phi\pi(h_t))[(1-\delta)h_t + \sigma w_t]}{1+\lambda+\gamma(1-\phi\pi(h_t))} \equiv \varphi(h_t). \tag{8}$$

Note that $\varphi(h_t) > 0$ for all the values of the parameters assumed. Moreover, the stronger the social norm (ϵ) the greater the health capital when old, which is transmitted to their offspring (h_{t+1}).

We specify the function $\pi(h_t)$ in order to get further analytical results. In particular, consistent with the hypothesis on $\pi(h_t)$, we assume

$$\pi(h_t) = \begin{cases} \pi_H & \text{if} \quad h_t < h^c, \\ \pi_L & \text{if} \quad h_t \geq h^c. \end{cases} \tag{9}$$

The above step function assumes two possible probabilities of developing a NCD, depending on the health capital level. Considering a step function is obviously a simplification of reality but nonetheless it captures the main features of much of the medical literature on NCDs. Take, for example, the BMI cut off points proposed by WHO (1995). These cut off points (h^c in our step function) have been defined to reflect the risks of NCDs (π_L and π_H in the step function) to which the general population is exposed based on the simple BMI measure (weight in kilograms divided by height in meters squared, kg/m^2). Indeed, BMI threshold levels are a stylized representation of a complex reality but precisely due to their simplicity they can be used worldwide as guidelines and alerts in the prevention and treatment of NCDs.[6] In general, the medical literature is based on threshold levels above which it is assumed that the probability of diseases suddenly increases.

[6] A complex reality sometimes calls for reformulation. In 2004, the WHO proposed different BMI thresholds to the Asian population because the medical literature suggested that the Asian population faced the risks of NCDs at lower BMI levels than the European population, see WHO (2004).

Taking (9), the corresponding transition function is then given by:

$$\varphi(h_t) = \begin{cases} \frac{(1+\lambda)h_t}{(1+\lambda)+\gamma(1-\phi\pi_H)}\epsilon + \frac{\gamma(1-\phi\pi_H)[(1-\delta)h_t+\sigma w_t]}{(1+\lambda)+\gamma(1-\phi\pi_H)} \equiv \varphi_{\pi_H}(h_t) & \text{if} \quad h_t < h^c, \\ \frac{(1+\lambda)h_t}{(1+\lambda)+\gamma(1-\phi\pi_L)}\epsilon + \frac{\gamma(1-\phi\pi_L)[(1-\delta)h_t+\sigma w_t]}{(1+\lambda)+\gamma(1-\phi\pi_L)} \equiv \varphi_{\pi_L}(h_t) & \text{if} \quad h_t \geq h^c. \end{cases} \quad (10)$$

We assume for simplicity that all exogenous elements of the model are constant. Therefore, neglecting technical progress and population growth, we focus on steady-state equilibria defined as fixed points of (10), i.e., $\varphi(h^*) = h^*$. Notice that this notion of long-run equilibrium requires $0 \leq \epsilon < 1$ due to (2). Individuals' frame of reference for their own health capital is thus a proportion of the health capital of the precedent cohort.

Assuming the functional form (9) we can show that the dynamics of the model admits two stable steady-states.

Proposition 1 *Let us define $h^*_{\pi_i}$ as:*

$$h^*_{\pi_i} = \frac{\gamma\sigma(1-\phi\pi_i)w}{(1-\epsilon)(1+\lambda)+\delta\gamma(1-\phi\pi_i)}, \quad (11)$$

where $0 \leq \epsilon < 1$, $i = \{H, L\}$, and $0 < h^*_{\pi_H} < h^*_{\pi_L}$. If $0 < h^*_{\pi_H} < h^c < h^*_{\pi_L}$, there exist two steady-states given by $h^*_{\pi_H}$ and $h^*_{\pi_L}$. Instead, if either $0 < h^*_{\pi_H} < h^*_{\pi_L} < h^c$ or $0 < h^c < h^*_{\pi_H} < h^*_{\pi_L}$, there is a unique steady-state given by $h^*_{\pi_H}$ and $h^*_{\pi_L}$, respectively. Moreover, all the steady-states are stable.

Proof. For an exogenous given income $w_t = w$, we get (11) by taking $h_t = h_{t+1} = h^*$ in (10). Provided that $0 \leq \epsilon < 1$, it is easy to verify that $0 < \varphi'_{\pi_i}(h_t) < 1$ for all h_t. This implies that each steady-state is strictly positive and stable. One can also check that $h^*_{\pi_H} < h^*_{\pi_L}$ since $h^*_{\pi_i}$ is a decreasing function of π_i. Moreover, as it is clear from (10), multiplicity of equilibria only happens when the cut off h^c is such that $h^*_{\pi_H} < h^c < h^*_{\pi_L}$. ■

The richer the economy, the better the long-term health conditions. Indeed, a wealthier household consumes more but also increases its investments in health. A greater effectiveness of health investments make it easier to reach a higher level of health capital; increases in the weight given to the future make relatively more important health capital in old age, leading to a higher long-term level.

The two stable steady-states are represented in Figure 1. For a high probability of NCDs (π_H), the dynamics is given by φ_{π_H} and the equilibrium level of health capital $h^*_{\pi_H}$, which is below $h^*_{\pi_L}$, the equilibrium level of capital for a low probability of NCDs (π_L). Note also that $\varphi(h_t)_{\pi_H} < \varphi(h_t)_{\pi_L}$ for all $h_t > 0$ because $\varphi(h_t)_{\pi_i}$ is a decreasing function of π_i, and that this is also true for $\varphi(0)_{\pi_i}$. Moreover $\partial\varphi'_{\pi_i}(h_t)/\partial\pi_i \leq 0$ and, therefore, $\varphi(h_t)$ is steeper for lower probabilities of disease.

In an economy starting with poor health conditions, i.e., $h_0 < h^c$, agents strongly discount their old age because the probability of developing NCDs would be high. Then, they substitute health investments with consumption (including unhealthy activities), which leads to a long-run equilibrium $h^*_{\pi_H}$ characterized by a low level of health capital and a high probability of NCDs. This is in stark contrast to an economy such that $h_0 \geq h^c$. The lower discount of old age induces agents to invest more in health and, therefore, the economy ends up in a healthier situation $h^*_{\pi_L}$ and with a low probability of NCDs. Taking $w_t = w$, $h_t = h^*_{\pi_i}$ and $\pi_t = \pi_i$ in (5)-(7) for $i = \{H, L\}$, we get the corresponding steady-state equilibrium values for c, v, and m denoted by $c^*_{\pi_i}$, $v^*_{\pi_i}$ and $m^*_{\pi_i}$, respectively.

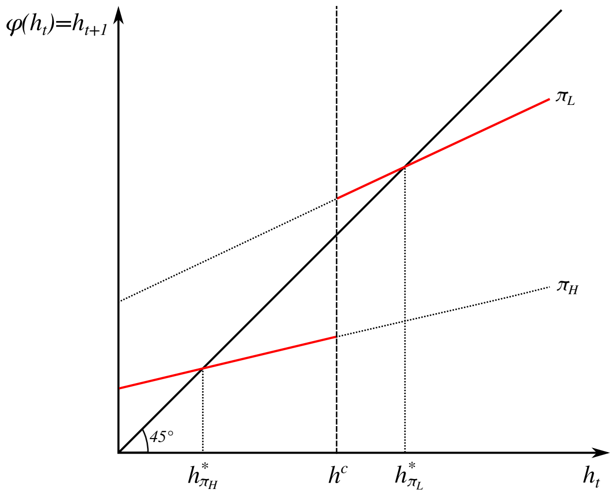


Figure 1: The two stable steady-states. The "low steady-state", in which a low level of health capital is associated with a high probability of NCDs; and the "high steady-state", in which a high level of health capital is associated with a low probability of NCDs.

3.2 Long-run equilibrium and social norms interventions

Having characterized the dynamics of the economy, we can now focus on the role of social norms on the long-run equilibria as illustrated in Figure 2.[7] As observed above, the stronger the social norm the greater the health capital when old, which is subsequently transmitted to their offspring, i.e., $\partial h_{t+1}/\partial \epsilon > 0$, see (8). This translates into a higher steady-state value of health capital, $\partial h^*_{\pi_i}/\partial \epsilon > 0$. Graphically, the slope of the transition function increases with the strength of the norm $(\partial \varphi'_{\pi_i}(h_t)/\partial \epsilon > 0)$. Interestingly, this effect is greater for higher probabilities of developing a disease, $\partial(\partial h^*_{\pi_i}/\partial \epsilon)/\partial \pi_i > 0$. In

[7]Note that all the results of this section and the following parts of the article are also valid for the case of strong social norms. See Appendix A.

Figure 2, this implies a steeper rotation for high levels of probability of NCDs, which results in a higher increase of the steady-state value of health capital for higher probabilities of NCDs. Intergenerational social norms encourage individuals to invest more in health. In terms of long-term health status, the norm counterbalances the reduced value for old age induced by a high probability of NCDs. The asymmetry of the effect comes from the fact that individuals with a low probability of disease value their old age more. A smaller discount already induces significant levels of long-term health capital, even in the absence of any norm. Therefore, the relative change due to the norm of their long-run health status would be smaller.

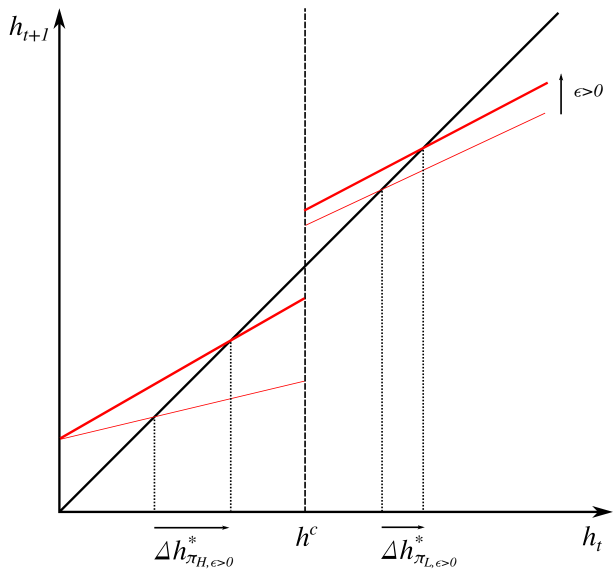


Figure 2: Social norms are more effective for economies in the health trap

An important implication of the effect of the social norm on the equilibrium is that social norms could be used as policy instruments. The literature on "social norms interventions" focus on the change in the pattern of behavior of the reference group, taking as immutable the social ties and social process upon which the social norm is built (see the Introduction). In our model, this would be illustrated as a shock on the health capital of the previous cohort (h_t), achieved with an increase in an exogenous parameter; σ for instance. This would mean a higher impact of health investments in the accumulation of health capital. Shocks in other parameters such as a higher income (w) or a decrease in the weight that agents give to unhealthy activities λ would generate similar effects, see (11). Additionally, a positive shock in the social norm ϵ would also have a positive effect on the accumulation of health capital in the long term.

Suppose a policy maker can indeed change the strength of the norm ϵ. We do not enter into a discussion of how such a process would be achieved but focus on the analysis of its implications. Figure 3 below shows how social norms can induce the economy to escape the health capital trap. Consider a sufficiently high level of ϵ that would make the

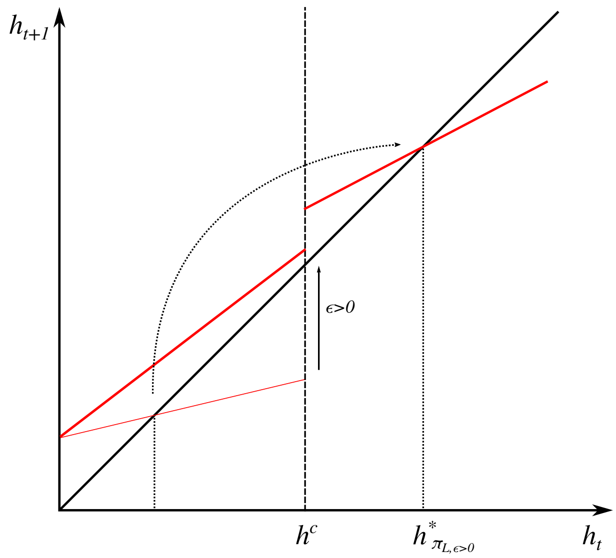


Figure 3: Social norms can be used to escape the health trap.

steady-state value of h always to the right of h^c, see (10). In this case, even an economy starting with a low health capital could achieve the high-health-capital-low-probability-of-disease steady-state if social norms are strong enough. We summarize this outcome in the following proposition.

Proposition 2 *Let us assume $h^c < \frac{w\sigma}{\delta}$. There is a strength level of the norm $\epsilon^c \in (0,1)$ such that $h^*_{\pi_H}(\epsilon) \geq h^c$ for $\epsilon \geq \epsilon^c$. Moreover, $h^*_{\pi_L}$ would be the only long-run equilibrium of the economy.*

Proof. Considering $\pi_i = \pi_H$ in (11), one can find that $h^*_{\pi_H}(\epsilon) \geq h^c$ iff $\frac{\gamma(1-\phi\pi_H)(w\sigma-\delta h^c)}{h^c(1+\lambda)} \geq (1-\epsilon)$. Solving this condition, we identify the critical value

$$\epsilon^c \equiv 1 - \frac{\gamma(1-\phi\pi_H)(w\sigma - \delta h^c)}{h^c(1+\lambda)}. \tag{12}$$

Notice that ϵ^c should be lower than 1 because $\epsilon \in (0,1)$. This is only possible if $h^c < \frac{w\sigma}{\delta}$. Finally, the low steady-state disappears when $h^*_{\pi_H}(\epsilon) \geq h^c$: as in Figure 2, the transition function (10) associated to π_H crosses the 45°-line after h^c and, therefore, the economy ends up in $h^*_{\pi_L}$ for all $h_0 > 0$. ■

As is clear from Proposition 2, the threshold value of health capital h^c, as defined in the step function (9), is determinant to avoid the low-health-capital-high-probability-of-disease steady-state. We have not been precise about what influences h^c. We believe it clearly depends on biology, obviously, but also on the quality of medical technology and health care available, and captures the ability of national health systems to reduce premature mortality and morbidity due to NCDs. As examples, consider the prescription of drugs to prevent heart attacks and strokes, early screening of some types of cancers, and vaccinations against human papillomavirus. In fact, premature deaths due to NCDs occur mainly in low-and-middle income countries (82%) and the WHO highlights national health systems responses as key instruments in reducing these deaths (see WHO, 2014; in particular, Annex 1). In our model, this translates to having two different economies: a low-middle-income economy with a high h^c below which probabilities of disease are higher, and a high-income one in which an appropriate health care system, allows for a lower level of h^c.

Figure 4 illustrates the effect of improvements in medical technology on escaping the health capital trap. Appropriate health care and medical technology reduce the level of health capital below which individuals may develop a NCD with high probability from h_0^c to h_1^c. Consequently, the economy may escape more readily from the health capital trap.

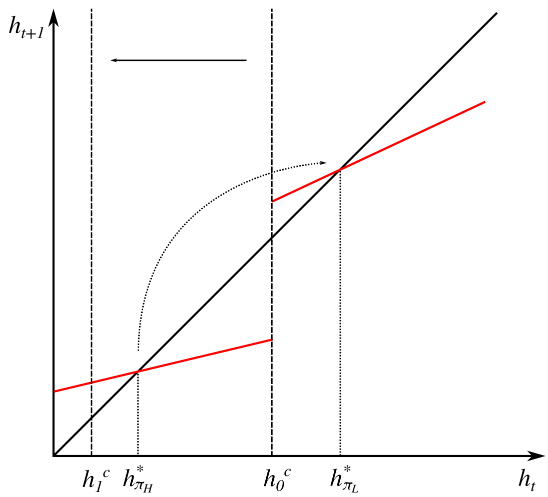


Figure 4: Improvement in medicine effectiveness ($\downarrow h^c$) can be used to escape the health capital trap.

A subsequent effect is that social norms do not need to be as strong to escape the health capital trap with improvements in health technology and care. Taking (12) it can be checked that $\partial \epsilon^c / \partial h^c > 0$. That is, a decrease in h^c due to improvements in health technology lower the critical level of the social norm needed to escape the health capital trap.[8,9]

The critical level ϵ^c needed to escape the health capital trap is also decreasing in income (w), in the effectiveness of health investments (σ) and in the weight given to the future (γ). All the three parameters have a positive impact on the trajectory of health capital (see Section 3.1), and therefore a lower level of ϵ^c is sufficient to escape the health capital trap. Conversely, increases in the high probability of NCDs (π_H), in the depreciation of health capital (δ), in the morbidity of the disease (ϕ), and in the relative utility of unhealthy eating (λ), all lead to increases in the minimum level of the social norm needed to escape the health capital trap. The effect is just the reverse, as all parameters lead to a decrease in the trajectory of health capital to the left of h^c and therefore a higher level of the critical social norm is needed to escape the health capital trap. Both higher levels of a high probability of disease and of morbidity lower the utility of health capital in old age: if the depreciation of health capital increases, lower levels of health capital will be attained at old age for the same investments, while increases in the relative utility of unhealthy eating make it more costly to invest in medical technology.

4 Welfare analysis

As observed before, households do not take into account the effect of their decisions on the welfare of future generations. They disregard, in particular, how their choices affect the probability of suffering from a NCDs of subsequent cohorts. We show in this section, that this results in suboptimal levels of health investments, as well as excessively high consumption and modifiable risk factors, and on an over-prevalence of NCDs (suboptimal levels of health capital) and suboptimal welfare level.

We commence the welfare analysis by describing the social optimum in a generalized version of the framework introduced in Section 2. This allows us to identify the different mechanisms behind the intergenerational externality stressing the role played by social

[8]This effect is not exclusive to NCDs. Consider the current COVID-19 crisis and take the social norm to be social interactions among individuals. In 2020, and in the absence of medical technology to deal with the virus, nations worldwide were forced to impose an extreme level of the "social norm" and impose lockdown to minimize social interactions. Though a careful analysis is still required in due course, countries in which screening was available and infected individuals were identified have not (to the best of our knowledge) imposed lockdowns, even though strict rules of social interaction were imposed, such as the use of masks or minimum physical distancing among individuals.

[9]Note also in Proposition 2 that the condition $h^c < \frac{w\sigma}{\delta}$ is required because in our model ϵ is bounded by 1 (otherwise, ϵ^c would be greater than 1). An interpretation for this condition is that there is a social norm that makes the economy avoid the health trap if medical technology (or health systems) are good enough, and thus, if h^c is low enough.

norms. Then, we will consider sin taxes as a policy to re-establish social optimality and remark on how the negative effect of the externality is attenuated under the presence of social norms on health capital. This requires an investigation as to what extent strengthening social norms can lessen the pressure for high taxes, and ultimately opens the discussion about the optimal level of social norms.

4.1 Social optimum *vs.* decentralized solution

Let us first study the social optimum by considering a full-fledged forward-looking social planner, who maximizes a social welfare function that includes the utility of all generations. We also generalize the setup considered in the previous sections, assuming that adult consumption affects one own probability of NCDs. This assumption corresponds more to reality where NCDs are mainly evidenced after 40 years old and also depend on adulthood eating choices. In the previous sections, we have neglected this important effect to focus entirely on the intergenerational externality and on the role of social norms. We now add a layer of complexity and assume $\pi = \pi(h_{t+1})$, with $\partial\pi(h_{t+1})/\partial h_{t+1} < 0$, $\lim_{h_{t+1}\to 0} \pi(h_{t+1}) = \pi_H$ and $\lim_{h_{t+1}\to\infty} \pi(h_{t+1}) = \pi_L$, with $0 < \pi_L < \pi_H < 1$.

The full-fledged forward-looking social planner seeks to maximize the social welfare function $\beta^{-1}U_{-1} + \sum_{t=0}^{\infty} \beta^t U_t\left(c_t, v_t, n_t, h_{t+1}, \pi_t\right)$ subject to (1), (3), and $c_t, v_t, m_t, h_t > 0$, where w_t and h_0 (initial condition) are given, and $\beta \in (0, 1)$ represents the inter-temporal discount rate. For this problem the Lagrangian is

$$\mathcal{L} = \beta^{-1}U_{-1} + \sum_{t=0}^{\infty} \beta^t \left[U_t\left(c_t, v_t, n_t, h_{t+1}, \pi_t\right) + \xi_{t+1}\Omega_t\right], \tag{13}$$

where $\Omega_t \equiv (1-\delta)h_t + \sigma w_t - (\sigma+\alpha)v_t - \sigma c_t - h_{t+1}$ and $\xi_{t+1} > 0$ is the Lagrangian multiplier (shadow price of health capital). Combining the FOCs ($\partial\mathcal{L}/\partial c_t = 0$, $\partial\mathcal{L}/\partial v_t = 0$ and $\partial\mathcal{L}/\partial h_{t+1} = 0$), the social optimum is characterized by the expression

$$\frac{\partial U_t}{\partial v_t} = \frac{\partial U_t}{\partial c_t} + \alpha\left(\frac{\partial U_t}{\partial h_{t+1}} + \frac{\partial U_t}{\partial \pi_t}\frac{\partial \pi_t}{\partial h_{t+1}}\right) + \alpha\beta\left[\xi_{t+2}(1-\delta) + \frac{\partial U_{t+1}}{\partial n_{t+1}}\frac{\partial n_{t+1}}{\partial h_{t+1}}\right]. \tag{14}$$

We can then compare this condition with the one corresponding to the decentralized solution, where each individual maximizes the utility $U_t(c_t, v_t, n_t, h_{t+1}, \pi_t)$ subject to (1), (3), and $c_t, v_t, m_t, h_t > 0$, and w_t and h_0 (initial condition) are given. Combining the FOCs on c_t, v_t and h_{t+1} give us

$$\frac{\partial U_t}{\partial v_t} = \frac{\partial U_t}{\partial c_t} + \alpha\left(\frac{\partial U_t}{\partial h_{t+1}} + \frac{\partial U_t}{\partial \pi_t}\frac{\partial \pi_t}{\partial h_{t+1}}\right), \tag{15}$$

which describes the decentralized solution.[10] The decentralized solution is not socially optimal since equations (14) and (15) are different. These conditions differ in the last term

[10] For the particular case where adult consumption does not affect probability of NCDs ($\pi_t = \pi(h_t)$)

of (14) that clearly demonstrates the different sources of the intergenerational externality not considered by individuals. They do not account for the direct effect of health capital transmission on future generations, as captured by $\xi_{t+2}(1-\delta)$. Furthermore, they do not consider the indirect effect of the inherited health capital imposed by the social norm, $\frac{\partial U_{t+1}}{\partial n_{t+1}}\frac{\partial n_{t+1}}{\partial h_{t+1}}$. Indeed, if both effects vanish ($i.e.$, $\delta \to 1$, and $\epsilon \to 0$ implying $\partial n_{t+1}/\partial h_{t+1} = 0$) the externality disappears resulting in the equality of (14) and (15).

4.2 Taxes

Since individuals do not take into account the social transmission of NCDs we can set taxes on unhealthy activities in order to reestablish social optimality. Let us consider the decentralized problem with a tax (τ_t) on unhealthy consumption. The resulting tax revenue ais used to subsidize (s_t) healthy activities m_t (see, for instance, Goulão and Pérez-Barahona, 2014; and Cremer *et al.*, 2012).

Individuals maximize $U_t(c_t, v_t, n_t, h_{t+1}, \pi_t)$ subject to (3) and the modified budget constraint

$$w = c_t + (1 - s_t)m_t + (1 + \tau_t)v_t, \tag{16}$$

taking s_t and τ_t as given. Finally, at the equilibrium, $s_t m_t = \tau_t v_t$ for all $t \geq 0$. The corresponding FOCs yield

$$\frac{\partial U_t}{\partial v_t} = \frac{\partial U_t}{\partial c_t} + \left(\sigma\frac{\tau_t}{1-s_t} + \alpha\right)\left(\frac{\partial U_t}{\partial h_{t+1}} + \frac{\partial U_t}{\partial \pi_t}\frac{\partial \pi_t}{\partial h_{t+1}}\right). \tag{17}$$

Equating this expression to the social optimum condition (14), we get the optimal trajectory for this policy as stated in the following proposition:

Proposition 3 *The optimal tax policy is characterized by*

$$\frac{\tau_t}{1-s_t} = \frac{\alpha\beta}{\sigma}\frac{\xi_{t+2}(1-\delta) + \frac{\partial U_{t+1}}{\partial n_{t+1}}\frac{\partial n_{t+1}}{\partial h_{t+1}}}{\frac{\partial U_t}{\partial h_{t+1}} + \frac{\partial U_t}{\partial \pi_t}\frac{\partial \pi_t}{\partial h_{t+1}}}. \tag{18}$$

Taxes allow the recovery of optimality, forcing households to internalize how their individual choices affect future generations' welfare.

This result contrasts to Kalamov and Runkel (2020) because in their setting a uniform tax is only second best. The authors have focused on the taxation problem when unhealthy consumption in childhood creates habits and affects marginal utility of consumption of the unhealthy good in adulthood. Conversely, the consumption of unhealthy goods in adulthood has no effect on the future consumption of offspring. Therefore, a

the term $\frac{\partial U_t}{\partial \pi_t}\frac{\partial \pi_t}{\partial h_{t+1}}$ disappears in (14) and (15) because by assumption $\partial \pi_t/\partial h_{t+1} = 0$. In this case the analogous of (15) is (4), as already stated in Section 3.

uniform tax on unhealthy consumption cannot be first best because unhealthy goods consumption has different externalities depending on the period of life in which consumption occurs.

It is interesting to observe that, all other things being equal, $\partial\tau_t/\partial\epsilon < 0$, meaning that a stronger social norm (ϵ) is associated with a lower level of optimal tax. This is an implication of assuming the functional utility form in (2), which makes the social norm have a disutility effect. In particular, specifying the social norm as $n_t = \epsilon h_t$, then $\frac{\partial U_{t+1}}{\partial n_{t+1}}\frac{\partial n_{t+1}}{\partial h_{t+1}} = -\epsilon$. Note also that in the absence of transmission mechanisms ($\delta \to 1$ and $\partial n_{t+1}/\partial h_{t+1} = 0$) the proposition directly shows that $\tau_t = 0$ and, since at the equilibrium $s_t m_t = \tau_t v_t$, $s_t = 0$ as well.

4.3 Golden rule

To further explore the role of social norms on the tax level, we focus on the golden rule problem defined in Chichilnisky *et al.* (1995). As in Mariani *et al.* (2010), the golden rule allocation can be considered as a constrained social optimum in which the planner maximizes the aggregate surplus at the steady-state. We can see it as the problem faced by a "myopic" social planner, who treats all generations symmetrically (as if they were all already at the steady-state) and ignores the transition process. The main advantage of this constrained social optimum is the greater analytical tractability of the problem. Additionally, by assuming further the step function (9), we can get a closed-form expression for the tax policy and the effect of the norm.[11] This will allow us to tease out the key mechanisms regarding social welfare.

In solving the golden rule problem the social planner maximizes $U(c, v, n(h), h, \pi(h))$, subject to (1) and (3) at the steady-state, and $c, v, m, h > 0$. The Lagrangian for this problem is

$$\mathcal{L} = U(c, v, n, h, \pi) + \xi \left[\frac{\sigma}{\delta}(w - c) - \frac{\alpha + \sigma}{\delta} v - h\right], \tag{19}$$

where $\xi > 0$ is the Lagrangian multiplier and w is given. From the FOCs ($\partial\mathcal{L}/\partial c = 0$, $\partial\mathcal{L}/\partial v = 0$ and $\partial\mathcal{L}/\partial h = 0$), the golden rule allocation is characterized by

$$\frac{\partial U}{\partial v} = \frac{\partial U}{\partial c} + \frac{\alpha}{\delta}\left(\frac{\partial U}{\partial h} + \frac{\partial U}{\partial \pi}\frac{\partial \pi}{\partial h} + \frac{\partial U}{\partial n}\frac{\partial n}{\partial h}\right). \tag{20}$$

By contrasting this expression with the decentralized condition (15) at the steady-state we can see that they differ in $\frac{\partial U}{\partial n}\frac{\partial n}{\partial h}$ and δ. As before, individual choices are not socially optimal because households neglect both direct and indirect effects of health

[11]Note that at the steady-state it is indifferent to assume that $\pi \equiv \pi(h_t)$ or alternatively $\pi \equiv \pi(h_{t+1})$ follow the step function (9).

capital transmission. If $\delta \to 1$ and $\partial n/\partial h = 0$ the decentralized solution would coincide with the golden rule since the externality vanishes.

Proceeding as in section 4.2 we identify the optimal (golden) policy by equating condition (17) at the steady-state with (20):

$$\frac{\tau}{1-s} = \frac{\alpha}{\sigma\delta}\left[(1-\delta) + \frac{\frac{\partial U}{\partial n}\frac{\partial n}{\partial h}}{\frac{\partial U}{\partial h} + \frac{\partial U}{\partial \pi}\frac{\partial \pi}{\partial h}}\right]. \tag{21}$$

As expected, without externality ($\delta \to 1$ and $\partial n/\partial h = 0$) taxes/subsidies would not be required and, therefore, $\tau = 0$ and $s = 0$. We can follow the functional forms of Section 3 and investigate the corresponding closed-form solutions.

Proposition 4 *Provided $\pi(h_{t+1})$ defined as the step function (9), the optimal sin tax verifies*

$$\frac{\tau}{1-s} = \frac{\alpha}{\sigma\delta}\left[(1-\delta) - \epsilon\right]. \tag{22}$$

Proof. At the steady-state, the probability π of suffering from a NCD is either π_H or π_L provided the step function (9). Then, taking the corresponding FOCs and $\partial\pi/\partial h = 0$, it is easy to see that the optimal policy $\frac{\tau}{1-s}$ verifies (21) without the term $\frac{\partial U}{\partial \pi}\frac{\partial \pi}{\partial h}$. Moreover, for the utility function (2), $\frac{\partial U}{\partial h} = \frac{1}{h-n}$ and $\frac{\partial U}{\partial n}\frac{\partial n}{\partial h} = -\frac{\epsilon}{h-n}$ because the norm is defined as $n = \epsilon h$. Finally (22) is obtained by rearranging terms. ■

Proposition 4 clearly shows that the strength of the norm (ϵ) decreases the tax. In addition, the closed-form (22) allows us to identify further mechanisms behind this effect. We can see that the reduction of the tax will be greater the stronger the harm of unhealthy activities (α) and the weaker the effectiveness of health maintenance activities (σ). In contrast, a low transmission of health capital between generations (*i.e.*, high δ) reduces the effect because the externality would be moderate. Indeed, we recover the generalized result that there is no need for corrective taxation in the extreme situation of no transmission of health capital and the non-existence of social norm ($\delta \to 1$ and $\epsilon = 0$).

In order to better understand how stronger social norms lessen taxes, let us examine the golden rule allocation values. Considering the assumptions in Proposition 4, we can compute the golden rule allocation values from the FOCs of the constrained social planner.

Proposition 5 *When the probability of NCDs is given by the step function in (9), the* *golden rule allocation is characterized by*

$$h^g_{\pi_i} = \frac{\gamma\sigma(1-\pi_i\phi)w}{\delta[(1+\lambda)+\gamma(1-\phi\pi_i)]}, \tag{23}$$

$$c^g_{\pi_i} = \frac{w}{(1+\lambda)+\gamma(1-\phi\pi_i)}, \tag{24}$$

$$v^g_{\pi_i} = \frac{\lambda\sigma w}{(\alpha+\sigma)[(1+\lambda)+\gamma(1-\phi\pi_i)]}, \tag{25}$$

$$m^g_{\pi_i} = \frac{[\lambda\alpha+(\alpha+\sigma)\gamma(1-\phi\pi_i)]w}{(\alpha+\sigma)[(1+\lambda)+\gamma(1-\phi\pi_i)]}, \tag{26}$$

with $i = \{H, L\}$.

Note that the golden rule allocation is independent of the social norm. Since the golden rule is maximizing welfare at the steady-state (constant health capital), whatever the level of the social norm, health capital is kept constant. This effect is well captured by the functional forms assumed, in particular (2). We can compare the golden rule allocation with the decentralized solution. If there are no social norms ($\epsilon = 0$), it can be shown that $h^g_{\pi_i} > h^*_{\pi_i}$, $c^g_{\pi_i} < c^*_{\pi_i}$, $v^g_{\pi_i} < v^*_{\pi_i}$, $m^g_{\pi_i} > m^*_{\pi_i}$. Individuals invest too little in health and therefore, health capital is too low with excessive levels of consumption. As shown in Section 3, social norms ($\epsilon > 0$) induce households to invest more in health ($\partial m^*_{\pi_i}/\partial\epsilon > 0$), leading to higher levels of health capital ($\partial h^*_{\pi_i}/\partial\epsilon > 0$) and less consumption ($\partial c^*_{\pi_i}/\partial\epsilon < 0$ and $\partial v^*_{\pi_i}/\partial\epsilon < 0$). Then, as with a social norm, individual choices get closer to the optimal (golden rule) allocation, and it only requires a lower level of corrective tax to make individuals internalize the intergenerational externality.[12]

Thus far, our analysis has shown that social norms can significantly modify the welfare implications of the social transmission of NCDs. This is particularly evident when one considers public policies to correct the associated intergenerational externality. As shown above, the strength of social norms lessens the levels of taxes required to decentralize the optimal policy. It follows naturally to query whether an appropriate implementation of social norms can be used as an alternative to taxes. In the next section we will illustrate this point by focusing on the long-run equilibrium.

4.4 Optimal health capital norm

We consider a planner who, instead of using taxes, searches for the strength of the norm that maximizes social welfare at the steady-state. We are thus considering the golden

[12] Proposition 3 also underlines that a strong norm, $\epsilon > 1-\delta$, would induce an excessive level of health investments, resulting in too much health capital and suboptimal levels of consumption. In this case the tax would be negative, playing the role of a subsidy.

rule problem in which the instrument variable is the level of the social norm instead of the tax level. Let it be the optimal health capital norm under the golden rule problem. In our model, the strength level of the norm is assumed to be constant; thus, focusing on the level of the norm at the steady-state is a natural step in the analysis. For the sake of simplicity, we assume that the planner can directly set the social norm but abstract from the technology that enables its implementation.

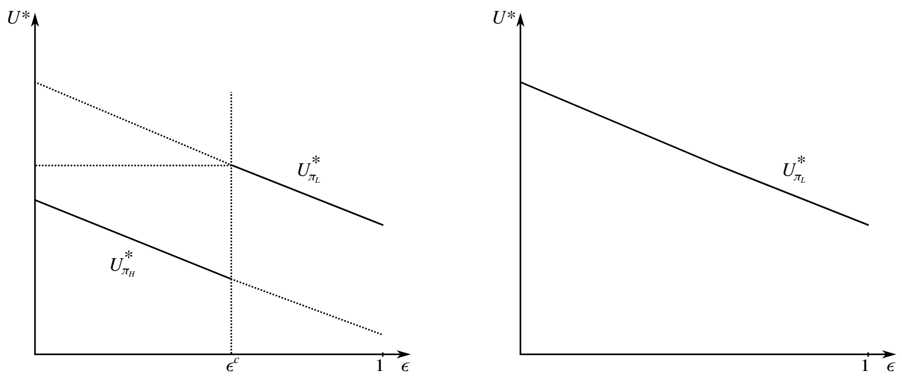
Before proceeding with the analysis, it is useful to consider at the level of the norm that would have been *the most preferred* by the individual at the steady-state. This is obviously a conceptual construction that we use as benchmark. In reality, in our model individuals live for two periods, and if they make part of the cohorts alive at the steady-state, they take the norm as given. Using $n_t = \epsilon h_t$ in (2), the individual utility at the steady-state becomes:

$$U^*_{\pi_i} = \ln c^*_{\pi_i} + \lambda \ln v^*_{\pi_i} + (1 - \phi\pi_i)\gamma \ln((1 - \epsilon)h^*_{\pi_i}), \tag{27}$$

with $i = \{H, L\}$, and $c^*_{\pi_i}$, $v^*_{\pi_i}$ denoting individuals' choices' steady-state values. Provided (11) and the individual choices (5)-(7), we can see that ϵ has two opposite effects on the individual steady-state utility (27). On the one hand, $\partial U^*_{\pi_i}/\partial\epsilon < 0$ since $\partial c^*_{\pi_i}/\partial\epsilon < 0$ and $\partial v^*_{\pi_i}/\partial\epsilon < 0$. This effect is a direct consequence of the disutility of deviating from the norm. It states that the strength of the norm reduces long-run utility for a π_i given. Therefore, $\epsilon = 0$ would maximize individual utility if only this effect would be accounted for.

However, the strength of the norm may affect π_i through health capital accumulation. Indeed, a strong enough norm may allow an economy in the first step of (9), $\pi_i = \pi_H$, to sufficiently increase health capital and achieve the step π_L. In other words, if an economy is in a health trap, then a sufficient increase of the social norm allows the economy to escape the health trap, as illustrated previously in Figure 3. However, escaping the health trap is not a guarantee of achieving a higher utility. It is necessary that $U^*_{\pi_L} > U^*_{\pi_H}$ at h^c, so that the most preferred level of the social norm is positive. We illustrate these two possibilities in Figure 5.

Suppose the economy is in the health trap ($\pi_i = \pi_H$). Figure 5(a) shows that departing from $\epsilon = 0$ and increasing ϵ has the initial effect of reducing $U^*_{\pi_H}$ due to the disutility effect of the norm. Nevertheless, when the strength of the norm equals the critical value ϵ^c identified in Proposition 2, the economy escapes the trap and the long-run welfare becomes $U^*_{\pi_L} > U^*_{\pi_H}$. Since $U^*_{\pi_L}$ also diminishes with ϵ, the preferred level of the norm would be $\epsilon^* = \epsilon^c$. Figure 5(b) represents the scenario where the economy is in the high-health-capital-low-probability-of-disease steady-state when $\epsilon = 0$. For this case, setting a norm would be suboptimal and, therefore, $\epsilon^* = 0$. In summary, at the steady-state,



(a) Direct effect is strong enough (b) Indirect effect is strong enough

Figure 5: Most preferred social health norm

individuals would prefer to "get rid" of the social norm because it acts as a constraint to individuals' choices, unless ϵ^c allows them to achieve a higher steady-state and a higher level of utility.

Returning to the golden rule problem we proceed by analyzing the level of the social norm that decentralizes the golden rule allocation defined by (23)-(26). As noted previously the golden rule allocation is not affected by the level of social norms as individuals' behaviors are. The solution for the decentralization of the golden rule allocation passes by equating condition (17) at the steady-state, with taxes set at zero, with (20) and solving for ϵ. This basically results in (22), with taxes set at zero. Therefore, the level of social norm that offsets the intergenerational externality emerging from health capital transmission is $1-\delta$, i.e., the share of health capital transmitted to the following generation.

Notwithstanding that $1-\delta$ decentralizes the golden rule allocation, note that (23)-(26) is conditional on the level of π_i. Consider one economy in the health capital trap and in which $U^*_{\pi_L} > U^*_{\pi_H}$ at ϵ^c; that is, individuals would be better off at the high steady-state equilibrium at ϵ^c. Two situations may occur: either $\epsilon^c < 1-\delta$ or $\epsilon^c \geq 1-\delta$. In the former case, implementing the golden rule with $\epsilon^g = 1-\delta$ makes individuals bear a level of health norm higher than they would have wished. In the latter case, $\epsilon^g = \epsilon^c$. That is, the social planner would force the economy to escape the health capital trap. As a result, the economy would escape the low steady-state and achieve a higher welfare at the high steady-state (see Figure 5 a). At the same time, ϵ^c would also be *the most preferred* level of the social norm. In a sense, both the planner's intentions and individual preferences would have been aligned.

The intuition behind this result is related to the effect of the health norms on the transmission of NCDs and, in particular, on the level of health capital in the long term.

The probability of suffering from a NCD is higher when the economy is in a health trap. If the probability of NCD reduces welfare at the steady-state sufficiently, from a long term perspective it is optimal to implement $\epsilon^c > 1-\delta$. Indeed, as shown before, health capital at the steady-state is increasing with the social norm (see Figure 2). As a consequence, the probability of a NCD would diminish, augmenting long-run welfare. It is necessary to ensure that $\partial U^*_{\pi_i}/\partial \pi_i < 0$, though. Taking the individual choices at the steady-state and $\partial h^*_{\pi_i}/\partial \pi_i < 0$, one can identify the necessary and sufficient condition for this to hold. Proposition 6 summarizes these results.

Proposition 6 *The golden rule allocation (23)-(26) is decentralized with $\epsilon^g = 1-\delta$, for π_i with $i = \{H, L\}$. Moreover, if the economy is in the low-health-capital-high-probability-steady-state, the social norm $\epsilon^c \geq \epsilon^g = 1-\delta$ allows the economy to achieve the high-health-capital-low-probability-steady-state, provided that $\partial U^*_{\pi_i}/\partial \pi_i < 0$.*

Proof. Provided the functional forms of Section 3, the golden rule allocation is independent of the level of ϵ (see (23)-(26)). Equating condition (17) at the steady-state, with taxes set at zero, with (20) and solving for ϵ we get $1-\delta$, which is the value that decentralizes the golden rule allocation (23)-(26). Note that $\partial U^*_{\pi_i}/\partial \pi_i < 0$ iff the probability of suffering from a NCD has a strong enough effect on the long term health capital for all $\epsilon \in (0,1)$. From (11), we can see that the effect of the probability of suffering from a NCD on $h^*_{\pi_i}$ is negative; *i.e.*, $\partial h^*_{\pi_i}/\partial \pi_i < 0$. Then, considering (5)-(7) at the steady-state, it is possible to show that $\partial U^*_{\pi_i}/\partial \pi_i < 0$ iff $|\partial h^*_{\pi_i}/\partial \pi_i| > \psi_{\pi_i}$, where ψ_{π_i} is defined as

$$\psi_{\pi_i} \equiv \gamma\phi \left\{ \frac{(\sigma+\lambda)[(1-\delta)-\epsilon]}{[(1-\delta)-\epsilon]h^*_{\pi_i} + \sigma w} + \frac{\gamma(1-\phi\pi_i)}{h^*_{\pi_i}} \right\}^{-1} \left\{ \frac{\sigma+\delta}{[(1+\lambda)+\gamma(1-\phi\pi_i)]} - \ln((1-\epsilon)h^*_{\pi_i}) \right\}. \tag{28}$$

■

A greater probability of suffering from a NCD induces individuals to discount more in the future. This has two opposite effects on the long term welfare $U^*_{\pi_i}$ since $U^*_{\pi_i}(\overset{+}{c^*_{\pi_i}}, \overset{+}{v^*_{\pi_i}}, \overset{+}{h^*_{\pi_i}}, \overset{-}{\pi_i})$. On the one hand, $c^*_{\pi_i}$ and $v^*_{\pi_i}$ increase, raising $U^*_{\pi_i}$. However, on the other hand, it reduces $U^*_{\pi_i}$ because π_i is higher and, moreover, $h^*_{\pi_i}$ reduces. As observed in the proof of Proposition 6, the overall impact is negative (*i.e.*, $\partial U^*_{\pi_i}/\partial \pi_i < 0$) iff the latter effect is stronger than the former one. This condition is the equivalent of saying that the reduction of the long term level of health capital is large enough; *i.e.*, $|\partial h^*_{\pi_i}/\partial \pi_i| > \psi_{\pi_i}$.

Note that this would be the case (sufficient condition) if health capital plays an important role in determining the level of long term welfare: if $h^*_{\pi_i}$ is "large", Proposition 6 holds because $\psi_{\pi_i} < 0$.[13] Moreover, the specific characteristics of the NCD can also

[13]From the definition of ψ_{π_i}, it is easy to verify that $\psi_{\pi_i} < 0$ for $h^*_{\pi_i} > \tilde{h}_{\pi_i}$ where $\tilde{h}_{\pi_i} \equiv$

reinforce the reduction of the long term level of health capital. In our model, the disability of the disease is represented by the parameter ϕ. It easy to confirm that ϕ raises $|\partial h^*_{\pi_i}/\partial \pi_i|$ because individuals would give low value to the future if the NCD involves significant disability.

5 Conclusion

The COVID-19 pandemic has led to the emergence of recent contributions in the economic modelling of epidemics. These contributions have now enriched a field that has previously been overlooked, possibly because global infectious diseases apperead to be under control (see Boucekkine et al., 2008 for a survey in the literature and Boucekkine et al., 2021 for an introduction to the articles published in the special issue on the economics of epidemics and contagious diseases published in the Journal of Mathematical Economics).

We contribute to the economic modelling of the epidemics of NCDs. Contrary to infectious diseases, NCDs do not spread due to an external pathogen. We have modelled the epidemics of NCDs by focusing on the importance of consumption choices and social norms in relation to health capital. From the individual's point of view, social norms are constraints that impose utility costs. We have shown how a planner could use them to offset negative intergenerational externalities not accounted for by the individual and, consequently, to enhance welfare.

Social norms are important instruments to consider if other possibilities, such as taxes on unhealthy goods, tend to be regressive. This is an issue often remarked on in the literature on sin/unhealthy taxes since unhealthy goods tend to be consumed disproportionally more by lower income individuals (see, among others, Allais et al. 2010; Allcott et al. 2019; and Cremer et al. 2016 for the consequences of regressivity in the political support of fat taxes). We do not assume the heterogeneity of individuals or regressivity concerns to being able to characterize the health capital dynamics and intergenerational transmission of NCDs. The regressivity of sin and unhealthy taxes is nevertheless at the core of our motivations to consider social norms as instruments.

Additionally, in our model, setting a social norm is a black box problem; the process for which we have not modelled here. Nonetheless, remaining agnostic as to how a social norm is set, we could have assumed the use of tax revenues to finance a social norm technology. Our choice, however, has been to concentrate our attention on the economic mechanisms associated with the use of the social norm as a policy instrument without imposing additional effects.

$\exp\left(\frac{\sigma+\lambda}{(1+\delta)+\gamma(1-\phi\pi_i)}\right)$.

Focusing on the steady-state utility and welfare (golden rule) enable us to avoid the analysis of the full trajectory of "optimal social" norms. It also allows us to deal with a tractable problem where the golden rule allocation is independent of the social norm, even if the planner is respecting individuals' preferences that change with a changing level of the norm. A more complex matter would have been to consider the full trajectory of social norms.

Finally, social norms on health related behaviors have considerably different impacts on the dynamics of health capital, as opposed to the social norms in health capital. This is the subject of our forthcoming work.

Appendices

A Strong social norms

We refer to $\epsilon > 1-\delta$ as strong social norms. In this case, it is easy to see that $m_t > 0$. The positivity of c_t and v_t is satisfied too, although under the assumption of a sufficiently high income $w_t \geq 1/\sigma[\epsilon - (1-\delta)]h_t$. Strong social norms induce agents to keep a high level of health conditions. Then, in contrast to the case $\epsilon \leq 1-\delta$, the individual choices show that greater inherited health conditions would increase health investment, decreasing general and unhealthy consumption.

Under strong social norms, the dynamics of h_t is also given by (8). It becomes (10) if one considers the step function (9). Proposition 1 and the corresponding interpretation of the dynamics also apply to strong social. We plot the steady-state equilibria in Figure 6. In contrast to the case $\epsilon \leq 1-\delta$ (see Figure 1), $\varphi(h_t)$ is steeper for higher probabilities of disease because with strong social norms $\partial\varphi'_{\pi_i}(h_t)/\partial\pi_i > 0$.

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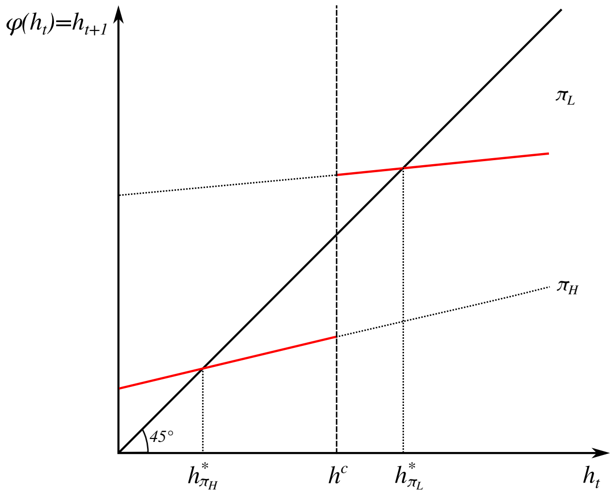

Figure 6: Strong social norms

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