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Genetic Health Risks: The Case for Universal Public Health Insurance

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Abstract

This paper examines the role of the public sector in providing genetic insurance and health care when health risks are genetically determined at conception. We characterize the ex ante efficient outcome (where individuals are placed behind the veil of ignorance), and demonstrate that this outcome cannot be achieved by private health insurance markets or by a government which cannot commit to a once-and-for-all transfer policy. In contrast, the desired outcome can be attained through public provision of universal health (genetic) insurance and of genetic testing, coupled with a public pension scheme.

Key words: Public health insurance; Genetic insurance; Genetic testing; *Ex ante* efficiency; Time inconsistent policy

JEL Classification: H51; I18; G22

1 Introduction

This paper is motivated by an interest in genetic testing in particular and health insurance in general. Genetic testing is already widespread: hundreds of genetic disorders can be detected through pre-natal screening, and in most industrialized countries programs are in place for the universal testing of newborns for a number of genetic and metabolic diseases (Hanley, 2005). In countries with publicly-funded health care systems, the growth in the panoply of available genetic tests has been accompanied by a corresponding growth in concern regarding the cost of testing and of treatment, and of the potential cost burden this may represent for the health care system (Miller *et al.*, 2002; Hoy *et al.*, 2003). This discussion is often embedded in a broader reflection on the appropriate role of the public sector in the provision of health care. In countries with predominantly private health care systems – notably, the United States – the question of genetic testing is intimately tied to concerns over the privacy of information and the pricing (availability) of health insurance.

What incentives do individuals face to undergo costly genetic testing when it may reveal a predisposition to conditions that would increase the cost of private insurance? According to Tabarrok (1994) the only way to ensure that individiuals purchase private genetic insurance – to insure against the increased premiums associated with being 'infirm' – is by government mandate. The first contribution of this paper is to develop a theoretical model that examines private incentives to purchase genetic insurance and undergo preventative treatments. We are able to show that when individuals are born identical (and subsequently are revealed to be healthy or infirm), individuals may voluntarily purchase genetic insurance and engage in preventative care, even when the information from the testing is fully available, abstracting from the complications arising from moral hazard or adverse selection. The problem, of course, is more complex when individuals are heterogeneous from birth.. Even still, some individuals may voluntarily purchase genetic insurance and undertake beneficial preventative measures – but, in the absence of some sort of intervention, the outcome in this case is not ex-ante efficient.

Below, we characterize the *ex ante* efficient outcome, and show that competitive private insurance companies will not offer individuals health insurance on the terms required to attain this outcome. This is because, as Doherty and Thristle (1996) point out, in an environment where differences in individual's genetic risks are publicly known, one can acquire insurance against the risk that a certain disease predisposition will translate into an actual disease, but it is impossible to insure against having the "wrong" parents with defective genes. As hinted by Cutler (2002) and Cutler and Zeckhauser (2000), in this sort of economic environment the *ex ante* efficient outcome cannot be attained unless individuals can purchase antenatal insurance - before they know who their parents are - an option that is not of any practical interest.

Our model allows us to highlight the factors which cause individual decisions to deviate from the ex-ante efficient outcome. We then wonder if public policy could re-align incentives so as to restore the ex-ante efficient outcome. The second contribution of the paper is the setting out of conditions under which an ex-ante efficient would arise whenever individuals are heterogeneous, once again abstracting from the issues surrounding information asymmetry. One policy tool is publicly-provided health care (or, equivalently, publicly-provided health insurance): we are able to offer another reason for considering public provision which completely ignores the typical reliance upon information asymmetries. However, publicly-privided health care on its own is not enough to generate the ex-ante efficient solution. For universal public health insurance to be optimal, it must be the case that government policy is time-inconsistent, therefore precluding it from implementing a redistributive policy of this kind: the lesson drawn from models such as those developed by Bruce and Waldman (1991), Coate (1995), and Glazer and Niskamen (1992) is that when a social-welfare-maximizing government cannot commit to denying assistance to individuals who have not purchased adequate protection for themselves, then a cash transfer policy is time inconsistent and welfare reducing as compared to the provision of universal public health insurance. Typically, infirm (or high-risk) individuals have an incentive to not purchase insurance, since a greater degree of neediness in the disaster state will increase the transfer which they receive. Strikingly, we show that, even if the government were to choose the transfer policy required to implement the *ex ante* efficient outcome, and even if infirm (or high-risk) individuals purchase full genetic and health insurance, the equilibrium is not efficient. This is because all individuals - healthy and infirm strategically adjust their savings to minimize their tax burden. In contrast, public provision of health care (and genetic testing), coupled with publicly provided pensions which discourage the government from redistributing in period two, make it possible to implement the desired outcome as an equilibrium.

The paper is organised as follows. Section 2 describes the *ex ante* efficient outcome - when individuals are behind the veil of ignorance. Here we also examine whether individuals undertake genetic testing when it is socially optimal. Section 3 shows that this outcome could be implemented by a Benthamite government which can commit to a once-and-for-all redistributive policy, but is not attainable if the government cannot resist redistributing wealth from rich to poor in the second period. In contrast, the *ex ante* efficient outcome is attained when genetic testing, health care and pensions to finance consumptions in period two are publicly provided. Section 4 provides a discussion and concludes.

2 Efficient Outcomes with Genetically Determined Health Risks

Consider a two-period economy in which individuals are born either healthy or infirm. Regardless of their risk type, all individuals are healthy in period 1 and during this period they can learn their type by undergoing a genetic test, at a cost c.[1] Otherwise, risk types are publicly - and costlessly - revealed at the beginning of period two. In period two, infirm-type individuals face two states of nature: "good" and "disaster". The probability that an infirm-type individual experiences ill health is π. In the disaster state he/she becomes ill and incurs loss L , which may be interpreted as the cost of medical treatment. In contrast, healthy-type individuals remain healthy in period two.

We assume that, at birth, all individuals are equally likely to turn out to be infirm, and that this probability is equal to γ, $0 < \gamma < 1$. An individual who undergoes a genetic test and learns that he or she is infirm can, in period one, undertake preventive medical treatment, at fixed cost M. Individuals who undertake preventive medical treatment reduce the risk of the disaster state to $\pi - \alpha$. The results of the genetic test are public information.

Individual utility, U, depends on consumption, C, in each period and, for simplicity, we assume that there is no discounting of future consumption. Consequently, $U = U(C_1)+U(C_2)$. In period one, all individuals have income y, and they finance consumption in period two by savings in period one. We assume that there exists a competitive insurance market. In period one, before undergoing genetic testing, individuals can purchase genetic insurance G at actuarially-fair premium γ. In period two, health care insurance coverage

Z against loss L is sold to infirm-type individuals who did not undergo genetic testing at price π per unit of coverage and to those who have undergone genetic testing and preventive medical treatment, at price $\pi - \alpha$ per unit of coverage.

The timeline of events is as:

Period 1

Born identical——Genetic (premium) Insurance Decision——Genetic Testing (Infirm/healthy type revealed) and Prevention Decision——Savings determined

Period 2

Infirm/Healthy types revealed by Nature——Health Insurance Decision——Nature determines whether an infirm individual falls sick

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It is assumed here that the value of prevention measures is higher when they are undertaken in period one. Otherwise it is less costly to wait until the beginning of period two when infirm-healthy types are revealed and then, undertake preventive measures. A number of diseases and health conditions can benefit from early preventive measures: an early detection (at birth) and dietary restrictions prevents severe brain damage in individuals with Phenylketonuria (PKU) and the early treatment of cystic fibrosis can prevent the onset of the disease and improve the person's quality of life.

The *ex ante* utility of an individual who undertakes testing and preventive measures is

$$\begin{aligned} EU &= \gamma[U\left(y-c-M-s_I+(1-\gamma)G\right) \\ &\quad +(\pi-\alpha)U\left(s_I-L+(1-\pi+\alpha)Z\right) \\ &\quad +(1-\pi+\alpha)U\left(s_I-(\pi-\alpha)Z\right)] \\ &\quad +(1-\gamma)\left[U\left(y-c-\gamma G-s_H\right)+U(s_H)\right], \end{aligned} \tag{1}$$

where s_I and s_H are period-one savings by individuals whom genetic testing reveals that they are infirm-type and healthy-type, respectively.

Note that since all individuals are identical and no externalities are present from genetic testing, the individual's choice is a socially optimal one. To determine whether individuals would voluntarily choose to undergo genetic testing and preventive measures if it is socially optimal for them to do so, we can compare utility when everyone who is revealed to be infirm chooses to undergo genetic testing and preventive care, with the individual's utility when no one undergoes testing. Straightforward calculations (left for appendix A) demonstrate that all individuals will purchase full health insurance, $\widehat{Z} = L$ and full genetic insurance, $\widehat{G} = M + (\pi - \alpha)L$ (if testing and prevention are chosen) and $\widehat{G} = \pi L$ (if no testing is chosen), in order to perfectly smooth consumption paths over their life-cycle. The genetic insurance is effectively protecting them against the subsequent revelation that they are infirm and will therefore need to purchase health care insurance. Comparing the individual per-period consumption for the scenario where all consumers undergo genetic testing (left-hand side of (2)) with that where they do not test in period one (right-hand side of (2)), we find that agents choose to test if and only if it is socially efficient for them to do so, i.e.,

$$\frac{y - c - \gamma\left[M + (\pi - \alpha)L\right]}{2} > \frac{y - \gamma\pi L}{2} \tag{2}$$

$$\begin{aligned} -c - \gamma\left[M - \alpha L\right] &> 0 \\ \gamma\alpha L &> c + \gamma M, \end{aligned} \tag{3}$$

which simply means that the expected increase in consumption due to the reduced likelihood of loss exceeds the cost of undergoing testing and the expected cost of preventive health care. This result can be contrasted with that of Tabarrok (1994), who suggests that individuals would need to be compelled to purchase genetic insurance before undergoing testing. Here, where all individuals are *a priori* identical, no such regulation need be implemented: if it is desirable for individuals to seek testing, they will do so paying privately the cost of testing and of preventive measures and purchasing full genetic insurance on the private market.

Moreover, it should be noted that in this extremely simple setting there are no issues - à la Tabarrok (1994) or Polborn *et al.* (2006) - with respect to a wish to suppress information regarding the results of the genetic test on the part of the consumer. In period two, the only individuals who purchase health insurance are of the infirm type, and therefore even if insurance companies cannot observe the agents' types, from the fact that an individual seeks to purchase health insurance in period two, the insurer can infer that this person is of the infirm type. In contrast, it is clearly important to the consumer that the purchase of preventive medical care can be observed by the insurance company, so that period two health care premiums will be adjusted accordingly.

But of course, as observed by Doherty and Thistle (1996), it is not really plausible to suppose that all individuals face the same risk of becoming infirm. In practice, even though individuals may not know for sure whether they are the healthy or infirm type, there is often information (typically observable and verifiable) about the healthiness of their parents (and grandparents) which means that all agents do not in fact face the same risk of being infirm in period two. Therefore consider a simple generalization of our genetic testing model in which agents may be at either high ($\overline{\gamma}$) or low ($\underline{\gamma}$) risk of becoming infirm in period two. The proportion λ of the population is high-risk, and proportion $(1-\lambda)$ is low risk. As above, we assume that genetic testing and preventive medical treatment can be taken in period one at private costs. We also assume that the fact that an individual has undertaken preventive medical treatment is observable, and the fact that they are infirm- or healthy-type is costlessly revealed at the beginning of period two. For simplicity, we assume that all infirm-type individuals who have not undertaken preventive medical treatment in period one face the same probability π of experiencing the disaster state in period two.

When individuals are born heterogeneous, their decisions with respect of undergoing genetic testing may differ. From (3), testing will be undertaken if:

$$\alpha L > \frac{c}{\gamma_i} + M,$$

where $\gamma_i = \left\{\overline{\gamma}, \underline{\gamma}\right\}$, observe that if the above inequality holds for low-risk type $\underline{\gamma}$, it will hold for the high-risk type $\overline{\gamma}$, but the reverse is not true. This means that it may be beneficial for high-risk individuals to undertake testing, but it is not necessarily true for low-risk ones. Since there are no externalities from testing, individual optimal choice coincides with that of society. The following remark summarizes our findings regarding socially desirable genetic testing and insurance.

Remark 1 *In a private insurance market irrespective of whether individuals are a priori identical or differ in the risk of becoming infirm, no regulation mandating genetic insurance purchases is required: individuals will seek socially desirable genetic testing, pay privately the cost of testing and of preventive measures, and prior to testing - purchase full genetic insurance.*

However, this private market solution is not *ex ante* efficient – i.e., it does not coincide with the outcome that all individuals would choose behind the veil of ignorance (i.e., before they learned their risk type, $\overline{\gamma}$ or $\underline{\gamma}$) given that they were able to purchase insurance at actuarially-fair rates. It is straightforward to show (the results are available upon request) that individuals behind the veil of ignorance would want to purchase insurance to protect themselves against the risk of being born in a high-risk category and facing a higher-than-average insurance premium. Indeed, all individuals, identical under the veil of ignorance, would choose a socially desirable testing and health/genetic insurance so that consumptions were equalized over their life time. Recall that we have assumed that the risk-class to which each agent belongs is observable, thus it is possible for competitive private insurers to offer premium insurance to each risk type, i.e. $G_{\overline{\gamma}}, G_{\underline{\gamma}}$. In contrast, it is not possible for them to sell insurance against being a $\overline{\gamma}$-risk individual rather than a $\underline{\gamma}$-risk person. What this means is that in the competitive insurance market high-risk individuals pay higher premiums for genetic insurance than do low-risk individuals, and therefore experience lower life-time utility than do low-risk individuals. Therefore, the *ex ante* efficient outcome - in which lifetime utility is independent of type - is not achieved. In an environment where types are costlessly observable, it is not possible for individuals to insure against being born the high-risk type, as suggested by Cutler (2002), Cutler and Zeckhauser (2000), and Tabarrok (1994).

3 Cash Transfers and In Kind Provision

Given that the competitive private market cannot replicate the *ex ante* efficient outcome, one might wonder whether appropriately designed public policy might alleviate this problem. One possible strategy would be for the government to provide a cash transfer to high-risk individuals - financed by a tax on low-risk citizens - which would enable them to cover the higher expenses they incur in purchasing genetic insurance as compared to the expenditures of low-risk individuals; however, whether or not this policy is effective clearly depends upon high-risk agents taking out full insurance. In this section, we examine this problem.

We assume that in period one, once an individual is born and type is revealed, the government can redistribute from low-risk to high–risk individuals a cash transfer T. Individuals can subsequently undergo genetic testing at cost c, enabling them to learn their type (infirm or healthy), and then undertake appropriate preventive treatment at cost M if infirm. They then decide upon savings once type is revealed (whether savings are type-sensitive or not does not change the main results of the paper). At the beginning of period two, before the bad state strikes the proportion π of infirm-type individuals, every infirm person decides upon the amount of health insurance coverage, Z.

When the government can commit to a once-and-for-all income transfer T from low-risk to high-risk individuals at the beginning of period one, both groups of individuals purchase a full genetic insurance coverage (at rates that reflect their risk type) to smooth their consumptions between the "infirm" and the "healthy" states. Also, infirm-type individuals purchase full health insurance coverage, thus smoothing their consumption between the disaster and non-disaster states.[2] Moreover, in this setting, it is straightforward to show that a government which maximizes a Benthamite social welfare function will implement a system of income transfers which replicates the *ex ante* Pareto efficient outcome described in the previous section.

However, as stressed by the literature on time consistency (e.g., Boadway, 1997), what is not self-evident is whether a government which seeks to maximize social welfare can credibly claim to be committed to a 'once-and-for-all' transfer policy. To this end, it is useful to examine what happens if infirm-type individuals choose to underinsure ($Z < L$) and the government is able to provide "disaster relief", τ, to those who fell sick without adequate insurance coverage. The timeline of events presented in this section is thus:

Period 1

Born high- (prob. $\overline{\gamma}$) or low-risk (prob.$\underline{\gamma}$)——Government redistributes T from low- to high-risk individuals——Genetic Insurance Decision——Genetic Testing (Infirm/healthy type revealed) and Prevention Decision——Savings determined

Period 2

Infirm/Healthy types revealed by Nature——Health Insurance Decision——Nature determines who from infirm types falls sick——Government redistributes from sick to non-sick

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The standard result for the Benthamite government's redistribution can be expressed as equalizing consumption in period two across all citizens (see Appendix B). Anticipating that disaster relief will be provided in the case

[2] See similar results under commitment in Bruce and Waldman 1991 and Coate 1995.

of underinsurance, a representative high-risk infirm individual solves the following problem

$$\max_{Z} EU_I = \begin{array}{c}(\pi-\alpha)U(s_I - L + (1-\pi+\alpha)Z + \widetilde{\tau}) \\ +(1-\pi+\alpha)U(s_I - (\pi-\alpha)Z + \widetilde{\tau}^I),\end{array}$$

where $\widetilde{\tau}, \widetilde{\tau}^I$ are the solutions to the optimisation problem in (21)-(22). Consequently,

$$\begin{aligned}\frac{\partial EU_I}{\partial Z} &= (\pi-\alpha)U'(s_I - L + (1-\pi+\alpha)Z + \widetilde{\tau})\left((1-\pi+\alpha) + \frac{d\widetilde{\tau}}{dZ}\right) \\ &\quad -(1-\pi+\alpha)U'(s_I - (\pi-\alpha)Z + \widetilde{\tau}^I)\left((\pi-\alpha) - \frac{d\widetilde{\tau}^I}{dZ}\right).\end{aligned}$$

It can be shown that $\frac{d\widetilde{\tau}}{dZ} = -\frac{N-1}{N}(1-(\pi-\alpha))$ and $\frac{d\widetilde{\tau}^I}{dZ} = \frac{N-1}{N}(\pi-\alpha)$ (see Appendix C). Since second period consumptions are equalized, the above first order condition is equal to zero. Thus, the expected utility of an infirm-type individual in period two is *independent* of the amount of health insurance that is purchased. This result is somewhat surprising. One might expect infirm individuals to have an incentive to systematically underinsure - thereby making themselves eligible for an enhanced government handout in the disaster state. This result is driven, however, by the fact that aggregate income is effectively certain in period two, and a Benthamite government will ultimately equalize the distribution of this aggregate income across all citizens. Consequently, infirm individuals' consumption in period two is independent of the amount of health insurance purchased in period 1. For convenience in what follows we assume that $\widetilde{Z} = 0$.

We now turn to the determination of savings at the end of period one. Observe that, if individuals have undertaken genetic testing at the beginning of period one, then uncertainty regarding their type is resolved: they know, for sure, whether they are healthy or infirm, and whether they were originally low-risk or high-risk individuals is no longer of any relevance to their savings decisions. In this case, therefore, the optimisation problem solved by a representative healthy individual is

$$\max_{s_{H_i}} U_H = U(Y_i - s_{Hi}) + U\left(s_{Hi} + \widetilde{\tau}_i^H\right),$$

where $Y_i = y - c - \overline{\gamma}G_{\overline{\gamma}i} + T_i$ if the individual is of high-risk, or $Y_i = y - c - \underline{\gamma}G_{\underline{\gamma}i} + T_i$ if the individual is of low-risk; T_i designates the tax levied by the government in period 1, and $\widetilde{\tau}_i^H$ - which is the solution to the government period-two redistribution problem (described in Appendix B) and depends on the savings decisions of all individuals in period one - denotes the period two transfer (which, in the case of healthy individuals, will in fact be a tax). Similarly, if the individual i is infirm, applying the condition that second period consumptions are equalized, the level of their period-one savings, s_{Ii}, can be found by solving

$$\max_{s_{Ii}} U_I = U(Y_i - s_{Ii}) + U\left(s_{Ii} - L + \widetilde{\tau}_i\right)$$

where $Y_i = y - c - M + (1 - \overline{\gamma})G_{\overline{\gamma}i} + T_{\overline{\gamma}}$ if the individual is of high-risk, and $Y_i = y - c - M + (1 - \underline{\gamma})G_{\underline{\gamma}i} + T_{\underline{\gamma}}$ if the individual is of low risk. At an optimum, it must therefore be true that

$$\frac{dU_H}{ds_{Hi}} = -U'(Y_i - s_{Hi}) + U'\left(s_{Hi} + \widetilde{\tau}_i^H\right)\left[1 + \frac{d\widetilde{\tau}_i^H}{ds_{Hi}}\right] = 0, \tag{4}$$

$$\frac{dU_I}{ds_{Ii}} = -U'(Y_i - s_{Ii}) + U'\left(s_{Ii} - L + \widetilde{\tau}_i\right)\left[1 + \frac{d\widetilde{\tau}_i}{ds_{Ii}}\right] = 0. \tag{5}$$

We define $\widetilde{s}_{Hi}, \widetilde{s}_{Ii}$ as the solution to (4) and (5) respectively. Next, we can show that $\frac{d\widetilde{\tau}_i}{ds_{Ii}} = \frac{d\widetilde{\tau}_i^H}{ds_{Hi}} = -\frac{N-1}{N}$ (see Appendix D). Therefore we obtain that

$$\frac{U'(Y_i - \widetilde{s}_{Hi})}{U'\left(\widetilde{s}_{Hi} - \widetilde{\tau}_i\right)} = \frac{U'(Y_i - \widetilde{s}_{Ii})}{U'\left(\widetilde{s}_{Ii} - \widetilde{\tau}_i\right)} = \frac{1}{N},\ \forall i \tag{6}$$

Since consumption is equalized in period two, equation (6) also implies that all individuals must achieve the same consumption levels in period one.

Observe from (6) that there is only imperfect consumption smoothing, which implies that the *ex ante* outcome is not attained: this is because both healthy and infirm individuals overconsume in period one, in order to reduce the burden of redistributive taxation in period two. Moreover, the inefficiency clearly becomes more acute as the size of the population increases: individuals effectively consume their entire endowment during period one, leaving themselves in relative penury in period two.

We now consider the decision problem of a high-risk individual with respect to the purchase of genetic (premium) insurance. By analogy with the result on health insurance purchases, one can expect and, indeed, show (see Appendix E) that the expected utility is independent of the amount of genetic insurance purchased. Thus, it is optimal to purchase no genetic insurance, i.e. $\widetilde{G}_{\overline{\gamma}} = \widetilde{G}_{\underline{\gamma}}$. But will they undergo genetic testing? Not necessarily, as set out in the following proposition.

Proposition 2 *When government redistributive policy is time-inconsistent, individuals may choose not to undergo genetic testing although it is socially desirable for them to do so.*

Proof. It is socially desirable for a high-risk individual to undergo genetic testing as long as the reduction in the expected loss due to illness in period two is at least as high as the cost of testing and preventive medical care, i.e.,

$$\gamma_i \alpha L \geqslant c + \gamma_i M, \ \gamma_i = \left\{ \overline{\gamma}, \underline{\gamma} \right\}. \tag{7}$$

The net *socia*l benefit of a single agent undergoing genetic testing and preventive medical treatment is equal to the expected increase in aggregate income available for the government to redistribute in period two (left-hand-side of (7)) less the expected cost of testing and preventive treatment (right-hand-side of (7)). When government redistributive policy is time-inconsistent the increase in aggregate income is shared equally among all N individuals. Thus, a high-risk individual undergoes genetic testing if and only if

$$\frac{\gamma_i \alpha L}{N} \geqslant c + \gamma_i M. \tag{8}$$

This means that individuals will not undergo genetic testing although it is socially desirable for them to do so if

$$\gamma_i \alpha L \geqslant c + \gamma_i M \geqslant \frac{\gamma_i \alpha L}{N}. \tag{9}$$

It is straightforward to check that, since $\overline{\gamma} > \underline{\gamma}$, if (8) is satisfied for low-risk individuals, then it is also satisfied for high-risk persons. More interestingly, however, the reverse is not true, and therefore it is possible that high-risk individuals choose to undergo testing (and preventive treatment), whereas low-risk individuals do not, although it would be socially desirable for all of them to do so. ■

We turn now to the optimal first-period tax/transfer policy of the government. Our results (See Appendix F) demonstrate rather intriguingly that the expected social welfare is independent of the first-period government transfer. Intuitively, it seems plausible to predict that the optimal policy for the government would be to choose a zero transfer policy in period one or, if a positive level of transfer were optimal, to anticipate that this transfer would be chosen strategically to influence the savings decisions of healthy- and infirm-type individuals. It is slightly startling to discover that, even when the government is not able to resist offering disaster assistance at the end of period two, the level of social welfare is in fact independent of the government's first-period redistributive policy. In particular, it is consistent with optimal policy to choose the same redistributive transfer policy as would be selected in the full commitment case, even though infirm individuals may rationally choose to forego health insurance, and will therefore require — and be offered — disaster relief. Even more startling is that even if the government chooses the first-best level of cash transfer, and infirm-type individuals choose to fully insure, the *ex ante* optimum will still not be achieved (see equation (6)).

The equilibrium path deviates from that required to achieve the *ex ante* optimum because the tax burden associated with the government's redistributive program is sensitive to changes in period-one savings. Even if the government provides the *ex ante* optimal transfer at the beginning of period one, even if individuals choose to take out genetic insurance, to undertake genetic testing and preventive medical treatment, and even if all infirm individuals choose to fully insure, the equilibrium will still not be *ex ante* efficient because agents' strategic behaviour leads to the distortion of their savings decision. Observe, in particular, that if $\frac{d\widetilde{\tau}_H}{ds_H}, \frac{d\widetilde{\tau}_I}{ds_I} = 0$, then equations (4) and (5) show that there will be full consumption-smoothing between the first and second periods, just as is required for the implementation of the *ex ante* efficient outcome. One way of dampening incentives to undersave and underinsure is to provide services in-kind. This fact underlies our next proposition.

Proposition 3 *The ex ante efficient outcome can be implemented by a Benthamite government which provides health care to sick individuals and public pension of* $\frac{1}{2}\left(y - c - (M + (\pi - \alpha)L)(\underline{\gamma} + \lambda(\overline{\gamma} - \underline{\gamma})\right)$ *to all individuals in period two, and finances the provision of these services as well as of socially desirable genetic testing and preventive measures by imposing an equal per capita tax,* $T^* = \frac{1}{2}\left(y + c + (M + (\pi - \alpha)L)(\underline{\gamma} + \lambda(\overline{\gamma} - \underline{\gamma})\right)$ *in period one.*

Proof. Since the government provides medical care and covers expenses of the genetic test and preventive measures, individuals do not face any expenses related to health care, and losses (L) of sick individuals are covered fully. Given a tax T^*, individual i's consumption in period one is $\frac{1}{2}$ $\big(y - c - (M + (\pi - \alpha)L)(\underline{\gamma} + \lambda(\overline{\gamma} - \underline{\gamma})\big) - s_i$, where s_i is private saving. Observe that consumptions in period two can be financed by public pensions and private saving, s_i. We can demonstrate that $s_i = 0, .\forall i \in [1, N]$. Individual i solves

$$\max_{s_i} U_i = U(y - T^* - s_i) + U(T^* - c - (M + (\pi - \alpha)L)(\underline{\gamma} + \lambda(\overline{\gamma} - \underline{\gamma}) + s_i),$$

subject to

$$T^* = \frac{1}{2}\left(y + c + (M + (\pi - \alpha)L)(\underline{\gamma} + \lambda(\overline{\gamma} - \underline{\gamma})\right).$$

The first order condition yields at the optimum

$$U'(y - T^* - s_i) = U'(T^* - c - (M + (\pi - \alpha)L)(\underline{\gamma} + \lambda(\overline{\gamma} - \underline{\gamma}) + s_i).$$

Thus, $s_i^* = 0$. ■

Note that the problem stemming from time-inconsistency of government policy demonstrated here is not specific to a Benthamite government. Any social welfare function which takes account of the welfare of the disadvantaged would result in a similar conclusion. While the problem of a time inconsistent government policy leading to individuals choosing non-optimal savings has been well-studied in the literature, what we want to emphasize here is that when the government is time-inconsistent its policies in period one intended to help those who are born unlucky, may trigger an avalanch of undesirable effects: suboptimal insurance coverage, a suboptimal level of genetic testing and preventive care, and undersaving.

Similar to Bruce and Waldman (1991) and Coate (1995), the problem of time-consistent government policy is resolved by implementing an appropriate program which undertakes in-kind redistribution. What is important to observe is that a public health insurance program alone is not sufficient to obtain the ex ante efficient outcome, since individuals are still motivated to overconsume in period one, anticipating a bail-out in period two. Offering a public pension alone does not lead to the ex ante efficient outcome either, since multiple health-risk individuals will not be able to insure against their type on a private competitive market. Furthermore, socially desirable genetic testing and preventive care may not be undertaken. A combination of two expenditure programs is necessary to deal with this problem. Notice, however, that the solution in Proposition 3 does not require that the government use any information about individual's type which is interesting given that it is often the inability of the government to observe an individual's type that prevents tax policy from reaching an optimal outcome (Mirrlees, 1971; Diamond and Mirrlees, 1971; Stiglitz, 1982; Boadway et al., 1996).

Another consideration in the solution above is that the costs of genetic testing and preventive measures have to be included in the package of universally insured services. Indeed, in a publicly-financed health care system, private individuals do not internalize fully the costs of NOT undergoing preventive measures – for instance, increased health insurance premiums, i.e., π versus $\pi - \alpha$, or the increased risk of falling ill and facing loss L. These costs are shared equally among all citizens. To align social and private incentives, a public health care system has to provide strong incentives for individuals to reduce the risk of falling ill.

4 Public Policy Options and Concluding Remarks

This paper examines *ex ante* efficiency and its importance for health insurance markets. The analysis of section 3 shows that in settings in which individuals have information about either their health status, or about the likelihood that they will turn out to have a poor health status, a competitive insurance industry will not be able to offer insurance products (including genetic insurance) which implement the *ex ante* efficient outcome. In the absence of corrective public policy, individuals who are born infirm, or who are born knowing that they are at higher risk of becoming infirm, are born unlucky: through no fault of their own, they will experience lower life-time utility than individuals who are born healthy, or who are born knowing that they have a greater likelihood of being healthy. Only when individuals are born ignorant of their health status, but with an identical risk of becoming healthy or infirm, is it possible for markets to provide consumers with insurance products that enable them to achieve the same lifetime utility level as they would obtain if they could purchase insurance behind the veil of ignorance.

Is there any way to achieve the *ex ante* efficient outcome in an economy with multiple risk types? As discussed in section 3, the first-best outcome cannot be obtained by providing high-risk individuals with compensatory cash transfers, even if the government were able to costlessly verify to which risk class individuals belonged. However, somewhat surprisingly, this is not because high-risk and/or infirm-type individuals fail to fully insure themselves, but because the savings decision is distorted: knowing that the government will not be able to resist the temptation of providing disaster assistance, both high-risk and low-risk individuals overconsume in period one. Moreover, since the government cannot prevent itself from implementing a redistributive tax and transfer policy at the end of the second period, private and social incentives for genetic testing and prevention do not coinside, which may lead to too low level of prevention leaving individuals with the high-than-neccessary risk of falling ill.

At least one mechanism can solve the problem of the time inconsistency of government redistributive policy when it cannot commit to a once-and-for-all transfer. That mechanism — widely adopted in many industrialized economies —has two parts. The first element is public universal health insurance, i.e., a publicly funded comprehensive health insurance system, that covers the costs of genetic testing and of preventive medical care for individuals who are identified as being at high-risk of becoming infirm, and also covers the loss associated with the disaster state for infirm-type individuals who subsequently fall ill. The costs of providing universal health care are appropriately covered by imposing an equal per capita tax on all citizens in each period. The second element is a public pension provided in period two and financed by a tax in period one. In effect, the *ex ante* optimal outcome can be attained through a combination of in-kind provision of services to sick individuals as well as a public pension for everyone in period two and a uniform tax on all citizens in period one (when incomes are equal).

Strikingly, the *ex ante* optimal outcome cannot be achieved solely through mandatory insurance. Recall that, along the equilibrium path, individuals may choose to purchase genetic insurance, as well as disaster insurance. The reason that the equilibrium outcome is not the desired outcome is not due to problems with the purchase of insurance, but to inadequate savings: a policy which makes the purchase of genetic or disaster insurance mandatory does not influence the savings decision, and hence does not influence the equilibrium outcome. Mandatory insurance - which covers genetic testing and preventive treatment as well as providing disaster insurance - will prove effective only if coupled with a disincentive on the government part to redistribute wealth in period two. This can be achieved through a publicly provided pension. This paper makes it clear that as in the real world, the decisions with regard to different social programs are interconnected.

Another lesson to be drawn from the results in this paper is that the failure of income tax systems in many countries to differentiate individual tax burdens on the basis of what appear to be observable differences between taxpayers - e.g., health status- is, in fact, desirable. Governments can use expenditure policy to redistribute resources between those who are healthy and those who are infirm, but by restricting the public sector's capacity to redistribute income through the tax system, this mitigates the distortion of other decisions - in our case, the savings decision - thus achieving a higher overall level of welfare.

Notes

1. Later this assumption is relaxed to allow for observable health risk heterogeneity since birth.

2. We assume here that purchase of genetic insurance is socially optimal.

3. The assumption that individuals purchase no insurance merely simplifies the exposition but does not alter the results.

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Appendix A

Consider a two-stage problem of an individual who decides to purcahse genetic insurance and undergo genetic testing. By backward induction, first, solve

$$\begin{aligned} \max_{Z}\ & (\pi-\alpha)U\left(s_I - L + (1-\pi+\alpha)Z\right) \\ & +(1-\pi+\alpha)U\left(s_I - (\pi-\alpha)Z\right), \end{aligned} \tag{10}$$

to yield $\widehat{Z} = L$. Second, given $\widehat{Z} = L$, solve

$$\max_{s_I} U\left(y - c - M - s_I + (1-\gamma)G\right) \tag{11}$$

$$+(\pi-\alpha)U\left(s_I - L + (1-\pi+\alpha)\widehat{Z}\right) \tag{12}$$

$$+(1-\pi+\alpha)U\left(s_I - (\pi-\alpha)\widehat{Z}\right),$$

to yield

$$\widehat{s}_I = \frac{1}{2}\left(y - c - M + (1-\gamma)G + (\pi-\alpha)L\right), \tag{13}$$

and

$$\max_{s_H} U\left(y - c - \gamma G - s_H\right) + U(s_H), \tag{14}$$

to yield

$$\widehat{s}_H = \frac{1}{2}\left(y - c - \gamma G\right). \tag{15}$$

Finally, given (13) and (15) solve

$$\begin{aligned} \max_{G} EU \;=\; & \gamma[U\left(y - c - M - \widehat{s}_I + (1-\gamma)G\right) \\ & +U\left(\widehat{s}_I - (\pi-\alpha)L\right)] \\ & +(1-\gamma)\left[U\left(y - c - \gamma G - \widehat{s}_H\right) + U(\widehat{s}_H)\right]. \end{aligned}$$

The first order condition at the optimum yields

$$G = M + \widehat{s}_I - \widehat{s}_H,$$

thus,

$$\widehat{G} = M + (\pi - \alpha)L,$$

$$\widehat{s}_I = \frac{y - c - \gamma\left[M + (\pi - \alpha)L\right]}{2} + (\pi - \alpha)L,$$

and

$$\widehat{s}_H = \frac{y - c - \gamma\left[M + (\pi - \alpha)L\right]}{2}.$$

Note that the lifetime utility of infirm-type and healthy-type individuals are identical at

$$\widehat{U}_I = \widehat{U}_H = 2U\left(\frac{y - c - \gamma[M + (\pi - \alpha)L]}{2}\right).$$

Now, consider a two-stage problem of an individual who opts out from genetic testing. By backward induction, first, solve

$$\begin{aligned} &\max_{Z}\ \pi U\left(s + G - L + (1 - \pi)Z\right) \\ &+(1 - \pi)U\left(s + G - \pi Z\right), \end{aligned} \tag{16}$$

which yields $\widehat{\widehat{Z}} = L$. Second, given that $\widehat{\widehat{Z}} = L$ solve

$$\begin{aligned} \max_{s,G} EU &= U\left(y - \gamma G - s\right) \\ &\quad +\gamma U\left(s + G - \pi L\right) + (1 - \gamma)U(s). \end{aligned} \tag{17}$$

The first order conditions at the optimum are

$$\frac{\partial EU}{\partial G} = -U'\left(y - \gamma G - s\right) + U'\left(s + G - \pi L\right) = 0,$$

$$\begin{aligned} \frac{\partial EU}{\partial s} &= -U'\left(y - \gamma G - s\right) + \gamma U'\left(s + G - \pi L\right) \\ &\quad +(1 - \gamma)U'(s) = 0 \end{aligned}$$

$$G(1+\gamma) = y - 2s + \pi L. \tag{18}$$

Since genetic insurance protects against realization of the 'infirm' state it must be true that consumption in the 'healthy' and the 'infirm' states are equalized, i.e.,

$$U'(s + G - \pi L) = U'(s). \tag{19}$$

Substituting (18) into (19) yields

$$\widehat{\widehat{s}} = \frac{y - \gamma\pi L}{2}. \tag{20}$$

Subsequently, given (20) equation (18) yields

$$\widehat{\widehat{G}} = \pi L.$$

Thus, the utility of a representative individual who does not undertake genetic testing is

$$\widehat{\widehat{U}} = 2U\left(\frac{y - \gamma\pi L}{2}\right).$$

Appendix B: opt tau

If infirm-type individuals choose to take out insurance a suboptimal level of health insurance, i.e., $Z < L$, then in period two after the disaster occurs and proportion $\pi - \alpha$ of them have experienced the disaster state, the government chooses "disaster" transfer τ_i by solving the problem

$$
\begin{aligned}
\max_{\tau_i} W_d = & \sum_{i=1}^{\lambda\overline{\gamma}(\pi-\alpha)N} U(s_{\overline{\gamma}Ii} + (1-\pi+\alpha)Z_i - L + \tau_{\overline{\gamma}i}) \\
& + \sum_{i=\lambda\overline{\gamma}(\pi-\alpha)N+1}^{\lambda\overline{\gamma}N} U\left(s_{\overline{\gamma}Ii} - (\pi-\alpha)Z_i + \tau_{\overline{\gamma}i}^{I}\right) \\
& + \sum_{i=\lambda\overline{\gamma}N+1}^{\lambda N} U\left(s_{\overline{\gamma}Hi} + \tau_{\overline{\gamma}i}^{H}\right) \\
& + \sum_{i=\lambda N+1}^{(\lambda+(1-\lambda)\underline{\gamma}(\pi-\alpha))N} U\left(s_{\underline{\gamma}Ii} - L + (1-\pi+\alpha)Z_i + \tau_{\underline{\gamma}i}\right) \\
& + \sum_{i=(\lambda+(1-\lambda)\underline{\gamma}(\pi-\alpha))N+1}^{(\lambda+(1-\lambda)\underline{\gamma})N} U\left(s_{\underline{\gamma}Ii} - (\pi-\alpha)Z_i + \tau_{\underline{\gamma}i}^{I}\right) \\
& + \sum_{i=(\lambda+(1-\lambda)\underline{\gamma})N+1}^{N} U\left(s_{\underline{\gamma}Hi} + \tau_{\underline{\gamma}i}^{H}\right),
\end{aligned} \tag{21}
$$

subject to the government's budget constraint

$$
\sum_{i=1}^{N} \tau_i = 0, \tag{22}
$$

where τ_i is the disaster assistance provided to infirm individuals who fall ill or a tax imposed on infirm-type individuals who do not fall ill or on healthy type individuals. Individuals are ordered from $i = 1$ to N according to their type:

If $i \leq \lambda\overline{\gamma}(\pi-\alpha)N$, then individual i is of high-risk, infirm and sick in period two.

If $\lambda\overline{\gamma}(\pi-\alpha)N+1 \leq i \leq \lambda\overline{\gamma}N$, then individual i is of high-risk, infirm and non-sick in period two.

If $\lambda\overline{\gamma}N + 1 \leq i \leq \lambda N$, then individual i is of high-risk and healthy in period two.

If $\lambda N + 1 \leq i \leq (\lambda + (1-\lambda)\underline{\gamma}(\pi-\alpha))N$, then individual i is of low-risk, infirm and sick in period two.

If $(\lambda + (1-\lambda)\underline{\gamma}(\pi - \alpha))N + 1 \leq i \leq (\lambda + (1-\lambda)\underline{\gamma})N$, then individual i is of low-risk, infirm and non-sick in period two.

If $(\lambda + (1-\lambda)\underline{\gamma})N + 1 \leq i \leq N$, then individual is of low-risk and healthy in period two.

The first order condition with respect to τ_i is

$$\frac{\partial W_d}{\partial \tau_i} = U_i'(\bullet) + \mu = 0, \quad \forall \ \tau_i, \tag{23}$$

where μ is the shadow price of the budget constraint. This condition requires that consumption in period two is equalized for all citizens.

Appendix C: tau and Z

Fully differentiating (23) and (22) (which determine optimal disaster relief in Appendix B) with respect to Z_i and $\tau_i, \forall i \in [1, N]$ yields

$$\begin{pmatrix} U'' & 0 & ... & 0 & 0 & 1 \\ 0 & U'' & 0 & ... & 0 & 1 \\ ... & ... & ... & ... & ... & ... \\ 0 & 0 & ... & 0 & U'' & 1 \\ 1 & 1 & 1 & 1 & 1 & 0 \end{pmatrix} \begin{pmatrix} d\widetilde{\tau}_1 \\ d\widetilde{\tau}_2 \\ ... \\ d\widetilde{\tau}_N \\ d\mu \end{pmatrix}$$

$$= \begin{pmatrix} K_i U'' & 0 & ... & 0 & 0 \\ 0 & K_i U'' & 0 & ... & 0 \\ ... & ... & ... & ... & ... \\ 0 & 0 & ... & 0 & K_i U'' \\ 0 & 0 & 0 & 0 & 0 \end{pmatrix} \begin{pmatrix} dZ_1 \\ dZ_2 \\ ... \\ dZ_{N\left(\lambda\overline{\gamma}+(1-\lambda)\underline{\gamma}\right)} \end{pmatrix},$$

where $K_i = -1 + (\pi - \alpha) \ \forall i \in [1, \lambda\overline{\gamma}(\pi-\alpha)N]$ or $\forall i \in [\lambda N + 1, \left(\lambda + (1-\lambda)\underline{\gamma}\right)(\pi - \alpha)N]$ and $K_i = (\pi - \alpha) \ \forall i \in [\lambda\overline{\gamma}\,(\pi-\alpha)\,N + 1, \lambda\overline{\gamma}N] \ \forall i \in [\left(\lambda + (1-\lambda)\underline{\gamma}(\pi - \alpha)\right)N]$.Note that because second period utilities are equalized the index i in U_{J} can be suppressed.

Using Cramer's rule, we observe that for infirm individuals who fall sick, i.e. $\forall i \in [1, \lambda\overline{\gamma}(\pi - \alpha)N]$ or $\forall i \in [\lambda N + 1, \left(\lambda + (1-\lambda)\underline{\gamma}(\pi-\alpha)\right)N]$,

$$\frac{d\widetilde{\tau}_i}{dZ_i} = \frac{1 - (\pi-\alpha)\,(N-1)\,(U'')^{N-1}}{-N\,(U'')^{N-1}} = -\frac{N-1}{N}(1 - (\pi - \alpha));$$

and that for infirm individuals who do not fall sick, i.e. $\forall i \in [\lambda\overline{\gamma}(\pi - \alpha)N+1,\ \lambda\overline{\gamma}N]$ or $\forall i \in [\left(\lambda + (1-\lambda)\underline{\gamma}(\pi-\alpha)\right)N+1,\ \left(\lambda+(1-\lambda)\underline{\gamma}\right)N]$,

$$\frac{d\widetilde{\tau}_i}{dZ_i} = \frac{-(\pi-\alpha)\,(N-1)\,(U'')^{N-1}}{-N\,(U'')^{N-1}} = \frac{N-1}{N}(\pi-\alpha).$$

Appendix D

Fully differentiating (23) and (22) (which describe the optimal level of disaster relief in Appendix B) with respect to s_i and $\tau_i, \forall i \in [1, N]$ yields

$$\begin{pmatrix} U'' & 0 & ... & 0 & 0 & 1 \\ 0 & U'' & 0 & ... & 0 & 1 \\ ... & ... & ... & ... & ... & ... \\ 0 & 0 & ... & 0 & U'' & 1 \\ 1 & 1 & 1 & 1 & 1 & 0 \end{pmatrix} \begin{pmatrix} d\widetilde{\tau}_1 \\ d\widetilde{\tau}_2 \\ ... \\ d\widetilde{\tau}_N \\ d\mu \end{pmatrix}$$

$$= \begin{pmatrix} -U'' & 0 & ... & 0 & 0 \\ 0 & -U'' & 0 & ... & 0 \\ ... & ... & ... & ... & ... \\ 0 & 0 & ... & 0 & -U'' \\ 0 & 0 & 0 & 0 & 0 \end{pmatrix} \begin{pmatrix} ds_1 \\ ds_2 \\ ... \\ ds_N \end{pmatrix}.$$

Note that because second period utilities are equalized the index i in U_J can be suppressed. Using Cramer's rule, we note that

$$\frac{d\widetilde{\tau}_i}{ds_i} = \frac{(N-1)\,(U'')^{N-1}}{-N(U'')^{N-1}} = -\frac{(N-1)}{N}.$$

Similarly,

$$\frac{d\widetilde{\tau}_i}{ds_j} = \frac{-\,(U'')^{N-1}}{-N(U'')^{N-1}} = \frac{1}{N},\ \forall i \neq j.$$

Appendix E: PROOF that EU is independent of G

A representative high-risk individual solves

$$\max_{G_{\overline{\gamma}i}} U_i = \begin{array}{c} \overline{\gamma}\left[\begin{array}{c} U\left(y-c-M+(1-\overline{\gamma})G_{\overline{\gamma}i}+T_{\overline{\gamma}i}-\widetilde{s}_{\overline{\gamma}Ii}\right)+ \\ U(\widetilde{s}_{\overline{\gamma}I}-L+\widetilde{\tau}_i) \end{array}\right] \\ +(1-\overline{\gamma})\left[U\left(y-c-\overline{\gamma}G_{\overline{\gamma}i}+T_{\overline{\gamma}i}-\widetilde{s}_{\overline{\gamma}Hi}\right)+U(\widetilde{s}_{\overline{\gamma}Hi}+\widetilde{\tau}_{Hi})\right] \end{array}.$$

The first order condition yields

$$\frac{\partial U_i}{\partial G_{\overline{\gamma}i}} = \overline{\gamma}\left(1-\overline{\gamma}-\frac{d\widetilde{s}_{\overline{\gamma}Ii}}{dG_{\overline{\gamma i}}}\right)U'(y-c-M+(1-\overline{\gamma})G_{\overline{\gamma}i}+T_{\overline{\gamma}i}-\widetilde{s}_{\overline{\gamma}Ii})$$
$$+\overline{\gamma}U'(\widetilde{s}_{\overline{\gamma}Ii}-L+\widetilde{\tau}_i)\left(1+\frac{d\widetilde{\tau}_i}{d\widetilde{s}_{\overline{\gamma}Ii}}\right)\frac{d\widetilde{s}_{\overline{\gamma}Ii}}{dG_{\overline{\gamma}i}}$$
$$+\overline{\gamma}U'(\widetilde{s}_{\overline{\gamma}Ii}-L+\widetilde{\tau}_i)\sum_{j\neq i}\frac{d\widetilde{\tau}_i}{d\widetilde{s}_j}\frac{d\widetilde{s}_j}{dG_{\overline{\gamma}i}}$$
$$-(1-\overline{\gamma})\left(\overline{\gamma}+\frac{d\widetilde{s}_{\overline{\gamma}Hi}}{dG_{\overline{\gamma}i}}\right)U'(y-c-\overline{\gamma}G_{\overline{\gamma}}+T_{\overline{\gamma}i}-\widetilde{s}_{\overline{\gamma}Hi})$$
$$+(1-\overline{\gamma})U'(\widetilde{s}_{\overline{\gamma}Hi}+\widetilde{\tau}_{Hi})\left(1+\frac{d\widetilde{\tau}_i^H}{d\widetilde{s}_{\overline{\gamma}Hi}}\right)\frac{d\widetilde{s}_{\overline{\gamma}Ii}}{dG_{\overline{\gamma}i}}$$
$$+(1-\overline{\gamma})U'(\widetilde{s}_{\overline{\gamma}Hi}+\widetilde{\tau}_{Hi})\sum_{j\neq i}\frac{d\widetilde{\tau}_i^H}{d\widetilde{s}_j}\frac{d\widetilde{s}_j}{dG_{\overline{\gamma}i}}.$$

The application of the first-order conditions (4) and (5) (the Envelope Theorem) to the above yields

$$\begin{aligned}\frac{\partial U_i}{\partial G_{\overline{\gamma}i}} &= \overline{\gamma}\left(1-\overline{\gamma}\right)U'(I1)+\overline{\gamma}U'(I2)\sum_{j\neq i}\frac{d\widetilde{\tau}_i}{d\widetilde{s}_j}\frac{d\widetilde{s}_j}{dG_{\overline{\gamma}i}} \\ &\quad -\left(1-\overline{\gamma}\right)\overline{\gamma}U'(H1)+(1-\overline{\gamma})U'(H2)\sum_{j\neq i}\frac{d\widetilde{\tau}_i^H}{d\widetilde{s}_j}\frac{d\widetilde{s}_j}{dG_{\overline{\gamma}i}},\end{aligned}$$

where $I1, I2$ $(H1, H2)$ denote the consumption of an infirm (healthy) individual in periods one and two, respectively. The application of the conditions that second period consumptions are equalized and (6) to the above yields

$$\frac{\partial U_i}{\partial G_{\overline{\gamma}i}} = U'(I2)\left(\overline{\gamma}\sum_{j\neq i}\frac{d\widetilde{\tau}_i}{d\widetilde{s}_j}\frac{d\widetilde{s}_j}{dG_{\overline{\gamma}i}}+(1-\overline{\gamma})\sum_{j\neq i}\frac{d\widetilde{\tau}_i^H}{d\widetilde{s}_j}\frac{d\widetilde{s}_j}{dG_{\overline{\gamma}i}}\right). \tag{24}$$

One can demonstrate that $\frac{d\widetilde{s}_j}{dG_{\overline{\gamma}i}} = 0$ for $j \neq i$. Fully differentiating (4) and (5) with respect to s_i and G_i yields

$$\begin{pmatrix} U''_{11}+\frac{1}{N}U''_{21} & 0 & ... & 0 & 0 \\ 0 & U''_{12}+\frac{1}{N}U''_{22} & 0 & ... & 0 \\ ... & ... & ... & ... & ... \\ 0 & 0 & ... & 0 & U''_{1N}+\frac{1}{N}U''_{2N} \end{pmatrix}\begin{pmatrix} d\widetilde{s}_1 \\ d\widetilde{s}_2 \\ ... \\ d\widetilde{s}_N \end{pmatrix}$$

$$= \begin{pmatrix} (1-\gamma_i)U''_{11} & 0 & ... & 0 & 0 \\ 0 & (1-\gamma_i)U''_{12} & 0 & ... & 0 \\ ... & ... & ... & ... & ... \\ 0 & 0 & ... & 0 & (1-\gamma_i)U''_{1N} \end{pmatrix} \begin{pmatrix} dG_1 \\ dG_2 \\ ... \\ dG_N \end{pmatrix},$$

where $\gamma_i \in \{\overline{\gamma}, \underline{\gamma}\}$. Applying Cramer's rule, we obtain that $\frac{d\widetilde{s}_i}{dG_j} = 0$. Applying this result to (24) yields that $\frac{\partial U_i}{\partial G_{\overline{\gamma}i}} = 0$.This implies that expected utility is independent of $G_{\overline{\gamma}i}$.

Appendix F: Proof of Proposition ??

Notice that the government can only observe that individuals are of low-risk or of high-risk. All other types (infirm, healthy, sick or not sick) are revealed after the first-period transfer is distributed. The optimal redistributive policy of the government in period one is found by solving

$$\begin{aligned}
\max_{T_{\overline{\gamma}},T_{\underline{\gamma}}} W \quad = \quad & \sum_{i=1}^{\lambda\overline{\gamma}(\pi-\alpha)N} \left[\begin{array}{c} U\left(y-c-M+(1-\overline{\gamma})\widetilde{G}_{\overline{\gamma}i}-\widetilde{s}_{\overline{\gamma}Ii}+T_{\overline{\gamma}}\right) \\ +U\left(\widetilde{s}_{\overline{\gamma}Ii}-L+(1-\pi+\alpha)\widetilde{Z}_{\overline{\gamma}i}+\widetilde{\tau}_{\overline{\gamma}i}\right) \end{array} \right] \\
& + \sum_{i=\lambda\overline{\gamma}(\pi-\alpha)N+1}^{\lambda\overline{\gamma}N} \left[\begin{array}{c} U\left(y-c-M+(1-\overline{\gamma})\widetilde{G}_{\overline{\gamma}i}-\widetilde{s}_{\overline{\gamma}Ii}+T_{\overline{\gamma}}\right) \\ +U\left(\widetilde{s}_{\overline{\gamma}Ii}-(\pi-\alpha)\widetilde{Z}_{i}+\widetilde{\tau}^{I}_{\overline{\gamma}i}\right) \end{array} \right] \\
& + \sum_{i=\lambda\overline{\gamma}N+1}^{\lambda N} \left[\begin{array}{c} U\left(y-c-\overline{\gamma}\widetilde{G}_{\overline{\gamma}i}-\widetilde{s}_{\overline{\gamma}Hi}+T_{\overline{\gamma}}\right) \\ +U\left(\widetilde{s}_{\overline{\gamma}Hi}+\tau^{H}_{\overline{\gamma}i}\right) \end{array} \right] \\
& + \sum_{i=\lambda N+1}^{\lambda N+(1-\lambda)\underline{\gamma}(\pi-\alpha)N} \left[\begin{array}{c} U\left(y-c-M+(1-\underline{\gamma})\widetilde{G}_{\underline{\gamma}i}-\widetilde{s}_{\underline{\gamma}Ii}+T_{\underline{\gamma}}\right) \\ +U\left(\widetilde{s}_{\underline{\gamma}Ii}-L+(1-\pi+\alpha)\widetilde{Z}_{\underline{\gamma}i}+\widetilde{\tau}_{\underline{\gamma}i}\right) \end{array} \right] \\
& + \sum_{i=(\lambda+(1-\lambda)\underline{\gamma}(\pi-\alpha))N+1}^{(\lambda+(1-\lambda)\underline{\gamma})N} \left[\begin{array}{c} U\left(y-c-M+(1-\underline{\gamma})\widetilde{G}_{\underline{\gamma}i}-\widetilde{s}_{\underline{\gamma}Ii}+T_{\underline{\gamma}}\right) \\ +U\left(\widetilde{s}_{\underline{\gamma}Ii}-(\pi-\alpha)\widetilde{Z}_{\underline{\gamma}i}+\widetilde{\tau}^{I}_{\underline{\gamma}i}\right) \end{array} \right] \\
& + \sum_{i=(\lambda+(1-\lambda)\underline{\gamma})N+1}^{N} \left[\begin{array}{c} U\left(y-c+(1-\underline{\gamma})\widetilde{G}_{\underline{\gamma}i}-\widetilde{s}_{\underline{\gamma}Hi}+T_{\underline{\gamma}}\right) \\ +U\left(\widetilde{s}_{\underline{\gamma}Hi}+\widetilde{\tau}^{H}_{\underline{\gamma}i}\right) \end{array} \right]
\end{aligned}$$

subject to

$$\lambda T_{\overline{\gamma}} + (1-\lambda)T_{\underline{\gamma}} = 0$$

where $T_{\overline{\gamma}}$ and $T_{\underline{\gamma}}$ are the first-period transfers (taxes) to a low-risk individual and high-risk individual, respectively.

Using $T_{\underline{\gamma}} = -\frac{\lambda}{1-\lambda} T_{\overline{\gamma}}$ from the budget constraint and applying the results derived above, i.e., $\widetilde{G}_{\overline{\gamma}i} = \widetilde{G}_{\underline{\gamma}i} = 0$ and $\widetilde{Z}_i = 0$, $\forall\ i \in [1, N]$, the first order condition with respect to $T_{\underline{\gamma}}$ becomes

$$
\begin{aligned}
\frac{dW}{dT_{\overline{\gamma}}} = & \sum_{i=1}^{\lambda\overline{\gamma}(\pi-\alpha)N} \left[\begin{array}{c} U'\left(y-c-M-\widetilde{s}_{\overline{\gamma}Ii}+T_{\overline{\gamma}}\right)\left(-\frac{d\widetilde{s}_{\overline{\gamma}Ii}}{dT_{\overline{\gamma}}}+1\right) \\ +U'\left(\widetilde{s}_{\overline{\gamma}Ii}-L+\widetilde{\tau}_{\overline{\gamma}i}\right)\left(1+\frac{d\widetilde{\tau}_{\overline{\gamma}i}}{d\widetilde{s}_{\overline{\gamma}Ii}}\right)\frac{d\widetilde{s}_{\overline{\gamma}Ii}}{dT_{\overline{\gamma}}} \\ +U'\left(\widetilde{s}_{\overline{\gamma}Ii}-L+\widetilde{\tau}_{\overline{\gamma}i}\right)\sum_{j=1,j\neq i}^{N}\frac{d\widetilde{\tau}_{i}}{d\widetilde{s}_{j}}\frac{d\widetilde{s}_{j}}{dT_{\overline{\gamma}}} \end{array} \right] \\
& + \sum_{i=\lambda\overline{\gamma}(\pi-\alpha)N+1}^{\lambda\overline{\gamma}N} \left[\begin{array}{c} U'\left(y-c-M-\widetilde{s}_{\overline{\gamma}Ii}+T_{\overline{\gamma}}\right)\left(-\frac{d\widetilde{s}_{\overline{\gamma}Ii}}{dT_{\overline{\gamma}}}+1\right) \\ +U'\left(\widetilde{s}_{\overline{\gamma}Ii}+\widetilde{\tau}^{I}_{\overline{\gamma}i}\right)\left(1+\frac{d\widetilde{\tau}^{I}_{\overline{\gamma}i}}{d\widetilde{s}_{\overline{\gamma}Ii}}\right)\frac{d\widetilde{s}_{\overline{\gamma}Ii}}{dT_{\overline{\gamma}}} \\ +U'\left(\widetilde{s}_{\overline{\gamma}Ii}+\widetilde{\tau}^{I}_{\overline{\gamma}i}\right)\sum_{j=1,j\neq i}^{N}\frac{d\widetilde{\tau}^{I}_{\overline{\gamma}i}}{d\widetilde{s}_{j}}\frac{d\widetilde{s}_{j}}{dT_{\overline{\gamma}}} \end{array} \right] \\
& + \sum_{i=\lambda\overline{\gamma}N+1}^{\lambda N} \left[\begin{array}{c} U'\left(y-c-\widetilde{s}_{\overline{\gamma}Hi}+T_{\overline{\gamma}}\right)\left(-\frac{d\widetilde{s}_{\overline{\gamma}Hi}}{dT_{\overline{\gamma}}}+1\right) \\ +U'\left(\widetilde{s}_{\overline{\gamma}Hi}+\tau^{H}_{\overline{\gamma}i}\right)\left(1+\frac{d\widetilde{\tau}^{H}_{\overline{\gamma}i}}{d\widetilde{s}_{\overline{\gamma}Hi}}\right)\frac{d\widetilde{s}_{\overline{\gamma}Hi}}{dT_{\overline{\gamma}}} \\ +U'\left(\widetilde{s}_{\overline{\gamma}Hi}+\tau^{H}_{\overline{\gamma}i}\right)\sum_{j=1,j\neq i}^{N}\frac{d\widetilde{\tau}^{H}_{\overline{\gamma}i}}{d\widetilde{s}_{j}}\frac{d\widetilde{s}_{j}}{dT_{\overline{\gamma}}} \end{array} \right] \\
& + \sum_{i=\lambda N+1}^{\lambda N+(1-\lambda)\underline{\gamma}(\pi-\alpha)N} \left[\begin{array}{c} -\frac{\lambda}{1-\lambda}U'\left(y-c-M-\widetilde{s}_{\underline{\gamma}Ii}-\frac{\lambda}{1-\lambda}T_{\overline{\gamma}}\right)\left(-\frac{d\widetilde{s}_{\underline{\gamma}Ii}}{dT_{\underline{\gamma}}}+1\right) \\ -\frac{\lambda}{1-\lambda}U'\left(\widetilde{s}_{\underline{\gamma}Ii}-L+\widetilde{\tau}_{\underline{\gamma}i}\right)\left(1+\frac{d\widetilde{\tau}_{\underline{\gamma}i}}{\widetilde{s}_{\underline{\gamma}Ii}}\right)\frac{d\widetilde{s}_{\underline{\gamma}Ii}}{dT_{\underline{\gamma}}} \\ -\frac{\lambda}{1-\lambda}U'\left(\widetilde{s}_{\underline{\gamma}Ii}-L+\widetilde{\tau}_{\underline{\gamma}i}\right)\sum_{j=1,j\neq i}^{N}\frac{d\widetilde{\tau}_{\underline{\gamma}i}}{d\widetilde{s}_{j}}\frac{d\widetilde{s}_{j}}{dT_{\overline{\gamma}}} \end{array} \right] \\
& + \sum_{i=(\lambda+(1-\lambda)\underline{\gamma}(\pi-\alpha))N+1}^{(\lambda+(1-\lambda)\underline{\gamma})N} \left[\begin{array}{c} -\frac{\lambda}{1-\lambda}U'\left(y-c-M-\widetilde{s}_{\underline{\gamma}Ii}-\frac{\lambda}{1-\lambda}T_{\overline{\gamma}}\right)\left(-\frac{d\widetilde{s}_{\underline{\gamma}Ii}}{dT_{\underline{\gamma}}}+1\right) \\ -\frac{\lambda}{1-\lambda}U'\left(\widetilde{s}_{\underline{\gamma}Ii}+\widetilde{\tau}^{I}_{\underline{\gamma}i}\right)\left(1+\frac{d\widetilde{\tau}^{I}_{\underline{\gamma}i}}{\widetilde{s}_{\underline{\gamma}Ii}}\right)\frac{d\widetilde{s}_{\underline{\gamma}Ii}}{dT_{\underline{\gamma}}} \\ -\frac{\lambda}{1-\lambda}U'\left(\widetilde{s}_{\underline{\gamma}Ii}+\widetilde{\tau}^{I}_{\underline{\gamma}i}\right)\sum_{j=1,j\neq i}^{N}\frac{d\widetilde{\tau}^{I}_{\underline{\gamma}i}}{d\widetilde{s}_{j}}\frac{d\widetilde{s}_{j}}{dT_{\overline{\gamma}}} \end{array} \right] \\
& + \sum_{i=(\lambda+(1-\lambda)\underline{\gamma})N+1}^{N} \left[\begin{array}{c} -\frac{\lambda}{1-\lambda}U'\left(y-c-\widetilde{s}_{\underline{\gamma}Hi}-\frac{\lambda}{1-\lambda}T_{\overline{\gamma}}\right)\left(-\frac{d\widetilde{s}_{\underline{\gamma}Hi}}{dT_{\underline{\gamma}}}+1\right) \\ -\frac{\lambda}{1-\lambda}U'\left(\widetilde{s}_{\underline{\gamma}Hi}+\widetilde{\tau}^{H}_{\underline{\gamma}i}\right)\left(1+\frac{d\widetilde{\tau}^{H}_{\underline{\gamma}i}}{\widetilde{s}_{\underline{\gamma}Hi}}\right)\frac{d\widetilde{s}_{\underline{\gamma}Hi}}{dT_{\underline{\gamma}}} \\ -\frac{\lambda}{1-\lambda}U'\left(\widetilde{s}_{\underline{\gamma}Hi}+\widetilde{\tau}^{H}_{\underline{\gamma}i}\right)\sum_{j=1,j\neq i}^{N}\frac{d\widetilde{\tau}^{H}_{\underline{\gamma}i}}{d\widetilde{s}_{j}}\frac{d\widetilde{s}_{j}}{dT_{\overline{\gamma}}} \end{array} \right]
\end{aligned}
$$

Using the result that second period consumptions are equalized across individuals, that first period consumptions are equalized across the population, that $1+\frac{d\tilde{\tau}_{\overline{\gamma}i}}{d\tilde{s}_{\overline{\gamma}Ii}}=1+\frac{d\tilde{\tau}^{I}_{\overline{\gamma}i}}{d\tilde{s}_{\overline{\gamma}Ii}}=1+\frac{d\tau^{H}_{\overline{\gamma}i}}{d\tilde{s}_{\overline{\gamma}Hi}}=\frac{1}{N}$ $\forall i$,that $\frac{d\tilde{\tau}_i}{d\tilde{s}_j}=\frac{1}{N}$ $\forall i\neq j$, $i\in[1,N]$, $j\in[1,N]$ and that $\frac{d\tilde{s}_i}{dT_{\overline{\gamma}}}=\frac{U''(1)}{U''(1)+\frac{1}{N^2}U''(2)}$ $\forall i\in[1,N]$(where (1) and (2) denote consumptions in period one and two respectively), the first order condition can be rewritten as

$$
\begin{aligned}
\frac{dW}{dT_{\overline{\gamma}}} &= \sum_{i=1}^{\lambda N}\left[\begin{array}{c} U'(1)\left(-\frac{U''(1)}{U''(1)+\frac{1}{N^2}U''(2)}+1\right) \\ +U'(2)\,\frac{1}{N}\frac{U''(1)}{U''(1)+\frac{1}{N^2}U''(2)} \\ +U'(2)\,\frac{1}{N}\sum\limits_{j=1,j\neq i}^{N}\frac{U''(1)}{U''(1)+\frac{1}{N^2}U''(2)} \end{array}\right] \\
&\quad+\sum_{i=\lambda N+1}^{N}\left[\begin{array}{c} -\frac{\lambda}{1-\lambda}\left(-\frac{U''(1)}{U''(1)+\frac{1}{N^2}U''(2)}+1\right)U'(1) \\ -\left(\frac{\lambda}{1-\lambda}\right)U'(2)\,\frac{1}{N}\frac{U''(1)}{U''(1)+\frac{1}{N^2}U''(2)} \\ -\frac{\lambda}{1-\lambda}U'(2)\,\frac{1}{N}\sum\limits_{j=1,j\neq i}^{N}\frac{U''(1)}{U''(1)+\frac{1}{N^2}U''(2)} \end{array}\right] \\
&= \lambda N\left[\begin{array}{c} \left(-\frac{U''(1)}{U''(1)+\frac{1}{N^2}U''(2)}+1\right)U'(1) \\ +\frac{1}{N}\frac{U''(1)}{U''(1)+\frac{1}{N^2}U''(2)}U'(2) \\ +U'(2)\,\frac{1}{N}(N-1)\frac{U''(1)}{U''(1)+\frac{1}{N^2}U''(2)} \end{array}\right] \\
&\quad+(1-\lambda)\,N\left[\begin{array}{c} -\frac{\lambda}{1-\lambda}\left(-\frac{U''(1)}{U''(1)+\frac{1}{N^2}U''(2)}+1\right)U'(1) \\ -\left(\frac{\lambda}{1-\lambda}\right)\frac{1}{N}\frac{U''(1)}{U''(1)+\frac{1}{N^2}U''(2)}U'(2) \\ -\frac{\lambda}{1-\lambda}U'(2)\,\frac{1}{N}(N-1)\frac{U''(1)}{U''(1)+\frac{1}{N^2}U''(2)} \end{array}\right] \\
&= 0.
\end{aligned}
$$

Similarly it can be shown that $\frac{dW}{dT_{\underline{\gamma}}}=0$ $\forall T_{\underline{\gamma}}$. Thus, social welfare is independent of the first period redistributive policy.