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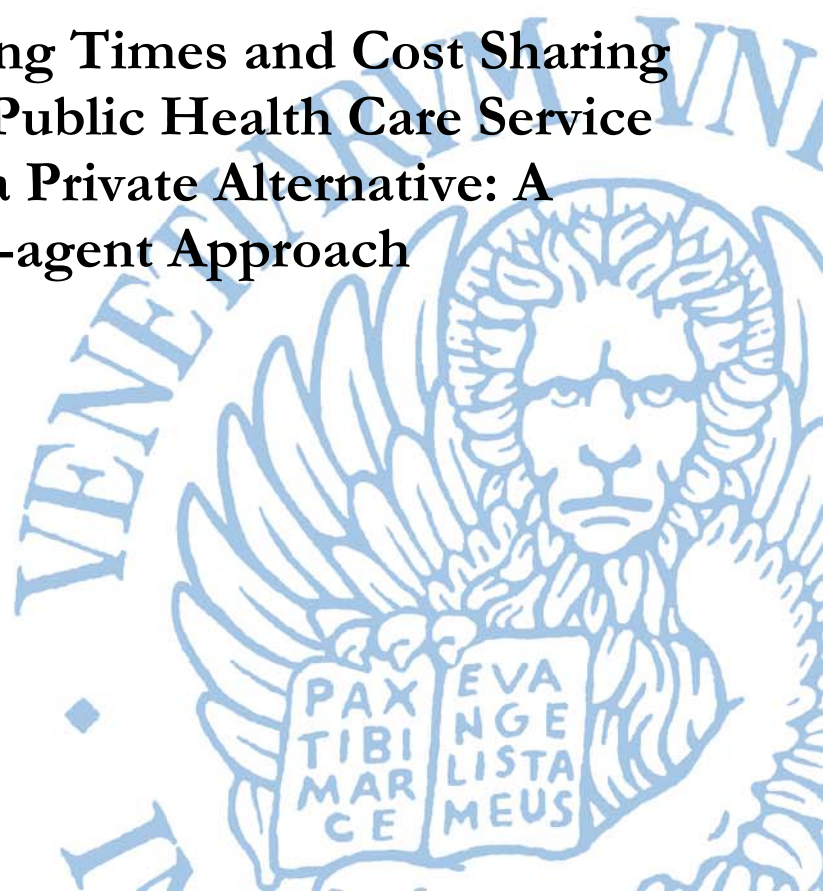
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# Working Paper

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**Waiting Times and Cost Sharing  
for a Public Health Care Service  
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Multi-agent Approach**

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# Waiting Times and Cost Sharing for a Public Health Care Service with a Private Alternative: A Multi-agent Approach

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## Abstract

Cost sharing represent a well-established tool for the control of health care demand in many Oecd countries, even though it is used with caution, and in combination with other instruments, in order to avoid potential negative impacts on access to essential health care services. Waiting lists and waiting times represent an alternative (and implicit) way to control demand in public health care systems, even though rationing by waiting may be an inferior solution to cost-sharing in terms of welfare.

This paper focuses on the use of waiting times, cost-sharing, and other tools (in particular, priority and appropriateness criteria) in order to control demand for a public outpatient health service in presence of a fully paid out-of-pocket private alternative. We develop an agent-based model where heterogeneous agents maximise their individual utility based on income and health status. On this basis, we develop some computational experiments based on micro-simulations that offer some useful insights for health care policy. In particular, we show that: i) the presence of a private alternative to public treatment can improve social welfare and health equity in a NHS, when public supply is constrained by a fixed budget and longer waiting times than the private one; ii) using prioritisation of waiting lists without any copayment to control the demand for public treatment may produce high performances in terms of social welfare, health equality and policy efficiency; iii) applying a moderate copayment rate as a tool to control public demand could determine the same policy efficiency of using only priority lists, if the copayment revenues are used to fund the public provision.

**KeyWords:** health care demand; private provision; waiting times; cost-sharing; equity, agent-based model.

**JEL Codes:** I14, I18, C63

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# 1. Introduction<sup>1</sup>

The increase in health care expenditure is mostly determined both by demographic and technological factors, essentially population ageing and the extension of the options of care allowed by scientific advance; though the growing of expenditure is also connected to economic factors, such as the increase in per capita income. In last years, the set of health care services with price-elastic demand and with many therapeutic substitutes has greatly grown. Whether these services are not given a price, health care system will be exposed to a risk of excess demand, which can be particularly high due to the presence of supply induced demand typical of health care market. Since the 80's, many health care systems adopted several measures either on the supply side or on demand side, in order to control both autonomous and induced excess consumption of health care services. Sometime these policies affected the degree of equity in the access to health care.

On the supply side, control instruments change following a dynamic learning process in order to increase the effectiveness of controlling expenditure. It is likely that incentives to producers' efficiency become more important than traditional measures such as expenditure ceilings and budget constraints. Moreover, the definition of the precise range of covered services (e.g., basic levels of health care insured by a National Health Service) will become increasingly important, in order to control a demand which tends to grow far beyond the boundaries of evidence-based medicine (EBM). In a same way, private health care insurances will tend to segment supplied coverages, with considerable premium variations.

On the demand side, control tools can be either direct or indirect and both can be used at aggregated level or at micro-level (i.e. at local health unit or health care professional's level). Direct tools aim at controlling the demand autonomously expressed by patients, which is not (or not completely) influenced by health care professionals. Indirect tools affect health care professionals but, on the same time, they indirectly aim at steering and selecting demand according to appropriateness and priority criteria.

Cost-sharing and rationing by waiting times are the most frequently used instruments for direct control of health care demand within public health care systems even though they may determine negative effects in terms of equity and allocative efficiency. Besides these traditional instruments of economic and real rationing, there are other important policy tools for controlling health care demand: direct tools such as health education and indirect tools such as the incentives for general practitioners, the adoption of appropriateness criteria

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according to EBM), and prioritising waiting lists.

In this paper we use an agent-based model (ABM) to analyse the impact of two direct tools (rationing through waiting times and cost-sharing) and two indirect tools (appropriateness and priority criteria) to control the demand for a public outpatient service provided by a National Health Service in presence of a fully paid out-of-pocket private alternative. In particular, we develop a ABM model where heterogeneous agents maximise their individual utility based on income, health level, and other individual characteristics such as risk aversion and the relative preference for health with respect to income. We also analyse the implications, in terms of efficiency and equity, of adopting different sets of policy tools in order to control the demand for the public outpatient service.

Multi-agent models have been applied increasingly in economic and organisational research and they have been also used to analyse health care organisations (e.g. see Moreno-Nealon, 2003; Vermeulen et al., 2007; Daknou et al., 2008; Laskowsky et al. 2009). ABM approach allows to explore several issues that are difficult to deal with in analytical models, such as repeated and dynamic interaction among heterogeneous decision-making agents and between the agents and their environment (Wooldridge, 2002).<sup>2</sup> Therefore, this approach seems particularly well suited to model waiting times of heterogeneous patients to access public health care services characterised by capacity constraints and private alternatives. However, while a considerable focus of the literature has been on system-level performance dynamics, quantified in terms of patient safety, economic indicators, staff workload and patients' flows, relatively little work exists in applying ABM to health care policy.

Our model investigate the impact of individual agents' characteristics and interaction between agents and health care providers (the NHS and private services) in a dynamic framework characterised by different tools to control the demand for the public service. On this basis, we develop some computational experiments based on micro-simulations that offer some useful insights for health care policy. In particular, we show that: i) the presence of a private alternative to public treatment can improve social welfare and health equity in a NHS, when public supply is constrained by a fixed budget and longer waiting times than the private one; ii) using prioritisation of waiting lists without any copayment to control the demand for public

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<sup>2</sup> The application of ABM in economic and organisational research has lead to the development of Agent-based Computational Economics (ACE), i.e. the computational study of economic processes modeled as dynamic systems of interacting agents who do not necessarily possess perfect rationality and information (Tesfatsion and Judd, 2006). Differently from standard economic models, ACE models focus on dynamic processes and local interactions among economic agents rather than equilibria. In contrast to the models of conventional simulation (e.g. system dynamics), in which participants are modeled in an aggregated way (top-down), in ACE models agents are treated individually (bottom-up approach) and this requires a detailed specifications of structural conditions, institutional arrangements, and behavioral hypotheses.

treatment may produce high performances in terms of social welfare, health equality and policy efficiency; iii) applying a moderate copayment rate as a tool to control public demand could determine the same policy efficiency of using only priority lists, if the copayment revenues are used to fund the public provision.

The plan of the paper is the following. Section 2 provides a general analysis of the main direct and indirect tools for controlling health care demand in an NHS and focus, in particular, on the efficiency and equity implications of using waiting times to ration demand. In section 3, we present a multi-agent based model of demand for an outpatient health service provided by the NHS, and which is characterised by waiting times and cost-sharing arrangements in presence of a fully paid out-of-pocket private alternative. In section 4 we develop a particular specification of the model, based on several reasonable assumptions about the values to assign to the relevant variables, and provide some preliminary results of the effects of different simulations in terms of social welfare and equity. Lastly, section 5 reports some conclusions.

## **2. Demand control within a NHS: the issue of waiting times**

Many public health care systems adopt several (and heterogeneous) measures on the demand side to control both autonomous and induced excess consumption of health care. The control of demand should aim to increase the effectiveness and appropriateness of the provided care, even though in many cases it is simply intended as a way to ration and limit expenditure.

Table 1 reports the whole set of the main direct and indirect policy tools for the control of health care demand within a NHS. Direct tools aim at controlling the demand autonomously expressed by consumers, which is not (completely) influenced by physicians, while indirect tools can be used to control the demand mainly driven by health care professionals. The latter types of tools affect directly health care professionals but, on the same time, they indirectly aim at steering and selecting demand according to appropriateness and priority criteria.

Cost-sharing and implicit rationing by waiting times are the most used (and analysed) instruments for the direct control of health care demand within public health care systems. Both instruments directly influence the demand variables and allow to control ex post moral hazard. Another traditional way to control demand is “real rationing”, i.e. the definition of quantitative limits to the access to public health care services.

**Table 1 - Tools for demand control within a NHS**

Direct tools	Indirect tools
<p><b>a) Cost-sharing</b></p> <ul style="list-style-type: none"> <li>• Coinsurance or Copayment</li> </ul> <p><b>b) Rationing:</b></p> <ul style="list-style-type: none"> <li>• Waiting times (implicit rationing, ineffective control...)</li> <li>• Quantitative limits to the access to public health care services</li> </ul> <p><b>c) Health care education</b></p> <ul style="list-style-type: none"> <li>• Social marketing for health promotion</li> <li>• Promotion of patient's compliance and patient's empowerment to improve correct self-medication</li> </ul>	<p><b>d) Steering and selecting demand:</b></p> <ul style="list-style-type: none"> <li>• Empowerment and incentive for General Practitioners as gatekeepers</li> <li>• Appropriateness criteria (EBM): Clinical guidelines; Diagnostic and therapeutic paths</li> <li>• Prioritising waiting lists (priority classes and indicators)</li> </ul>

The use of price (cost-sharing) as economic tool for limiting excess demand (moral hazard) is quite frequent in public health care systems. Cost-sharing can take on a number of forms (and these are often combined): deductible (an all-inclusive amount – either per case or per year - entirely paid by the patient before insurance cover begins); co-insurance (the percentage of the expenditure, beyond the deductible, which the patient must pay); copayment (the amount paid by the patient for a health service which is independent of the total cost of the service).

Cost-sharing can be constrained by the degree of demand inelasticity and by its potential negative impact on access to health care services by particular categories of patients, with negative implications in term of health outcomes and equity.<sup>3</sup> Usually, copayment or co-insurance schemes are not well accepted owing to their regressivity and (according to some analysts) to their negative impact on preventive care, which could increase health care costs in the future (Rebba, 2009). Nevertheless, in many OECD countries cost-sharing represents a well-established tool for the control of health care demand, even though it is used with caution, and in combination with other instruments, in order to avoid potential negative impacts on access to essential healthcare services.<sup>4</sup>

<sup>3</sup> Empirical analysis has shown that it is quite difficult to use cost-sharing in order to reduce only the consumption of health care treatments with a low “productivity” in terms of gained health. A proper use of copayments should attempt to minimise the risk of an indiscriminate reduction of health care consumption, avoiding to affect essential and appropriate care. On this point, the new approach of “value-based cost sharing” (Pauly e Blavin, 2008) seems to provide useful directions, pointing out that optimal cost-sharing should be designed considering not only the price elasticity of demand but also the cost-effectiveness of different treatments.

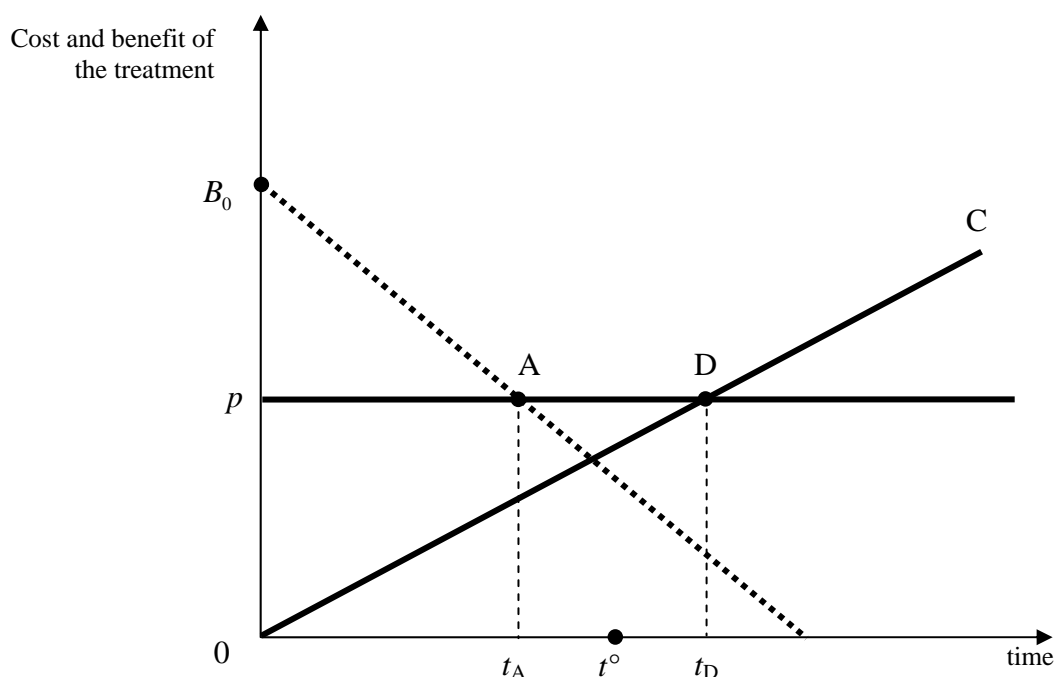
<sup>4</sup> In order to mitigate negative income effects, maximum ceilings in annual amount of cost- sharing can ensure that patients do not face “excessive” expenses during the year, thereby reducing uncertainty and risk.

Waiting times induce the elimination (or reduction) of public health care demand, not only by patients capable to turn to private health care services, but also by low income patients who forgo health care because waiting would determine a too high opportunity cost of time and/or a decay in their health level (Lindsay and Feigenbaum, 1984; Martin and Smith, 1999; Cullis et al., 2000; Rebba, 2009). Under this perspective, also waiting times produce regressive effects. Moreover, in public health care systems, using waiting times as a rationing mechanism in substitution of cost-sharing, may be an inferior solution in terms of equity and allocative efficiency. In fact, using waiting times (rather than cost-sharing) as the unique tool to control the demand for public health care, on the one hand, can restrain an appropriate demand for public treatments even though it expresses a real need (likewise using cost-sharing without any exemption), while on the other hand it provides a strong incentive to opt for alternative private treatments which are less (not) accessible to less wealthy people. These effects are illustrated in Figure 1 which represents a situation where only waiting times are used to control the demand for a completely free public health service in presence of a fully paid out-of-pocket private alternative which can be purchased at price  $P$ . Considering only the opportunity cost of waiting time  $C$  (the sum of income losses due to work stoppage before accessing the service, other costs born to access the service, and anxiety costs)<sup>5</sup>, a patient would choose to enter in the waiting list for the free public treatment only if the waiting time were lower than  $t_D$ . But waiting too much can also reduce the benefit rising from the public treatment because of a decay in the patient's health level: the money value of the health benefit of the treatment, starting from  $B_0$ , decreases with time and falls below the price  $P$  of the alternative private treatment when the waiting time is higher than  $t_A$ . If the waiting time for the public treatment were  $t^\circ$  (where  $t_A < t^\circ < t_D$ ), the patient could immediately choose the fully paid private alternative even though her/his opportunity cost of time were lower than  $P$  at time  $t^\circ$ . It follows that people with lower ability to pay could not access the private alternative and would be constrained either to wait in the public list or to forgo the treatment with a negative impact on their health status, i.e., with negative effects in terms of equity and allocative efficiency.

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<sup>5</sup> For empirical analyses of opportunity costs, see Acton (1975) and Propper (1995); the latter also analyse anxiety costs.

**Figure 1 - Choice between a public treatment and a private alternative**



Besides traditional instruments of economic and real rationing, such as cost sharing and waiting times, there are other important direct tools for controlling health care demand which have been rather neglected by economic analysis. Among these tools one should consider better citizens' information and health education, which can affect the variables inducing health care consumption (Muraro and Rebba, 2004) and can be promoted following two main strategies:

- health prevention and modification of risky lifestyle through social marketing for public health (Siegel and Doner, 1998; Kotler et al., 2002) or “libertarian paternalism” policies (Le Grand, 2008; Le Grand and Srivastava 2009; Muraro and Rebba, 2010)<sup>6</sup>;
- promoting patient's compliance and patient's empowerment within the relationship with health care services and professionals, through a correct use of self-diagnosis and of self-medication (Sindall, 2001).

The policies adopted to pursue both strategies can determine relevant effects both on

<sup>6</sup> Many developed countries have implemented innovative health marketing tools in order to promote safe lifestyles and reduce risk factors related to cardiovascular, neoplastic and respiratory diseases. The implementation of social marketing techniques to primary and secondary health prevention aims at providing incentives to voluntary giving up of unhealthy behaviours in order to increase individual and social welfare (control of ex ante moral hazard). While promoting prevention and correct lifestyles, one must also consider individual incentives and costs which are linked to the change of particular behaviours; moreover, the effectiveness of health marketing policies strongly depends on cooperation between health care agencies and other institutional players such as education and local authorities.



allocative efficiency and on equity of access to health care. In particular, the empowerment of demand depends both on a more widespread information about health care and on socio-cultural changes which partly modify the agency relationship between patients and physicians with a stronger role of patients, especially in their relationships with general practitioners.<sup>7</sup>

Finally, as regards indirect control tools, particular policies can regulate and steer health care demand, reducing moral hazard and increasing appropriateness:

- the empowerment of primary care services, providing the right incentives to general practitioners (contractual agreements between local health authorities and practitioners; cooperative agreements and networks of practitioners; empowerment of social and health care community districts);
- the definition and implementation of appropriateness criteria according to EBM, in particular diagnostic and therapeutic paths and guidelines;
- the definition of priority criteria for managing waiting lists of inpatient and outpatient services; prioritisation aims at regulating access to health care services according to clinical severity, emergency, or to other relevant variables, through either priority classes (homogeneous waiting groups) or priority indicators (Mullen, 2003; Mariotti, 1999, 2006; Mariotti et al., 2008).

The policy tools for indirect control of health care demand can be used for regulating the consumption induced by health care producers. These tools have become increasingly important as complement of direct policy tools. In fact, in many cases the derived demand of health care is influenced by the provider (in first place the doctor) who affects consumer's preferences.

Health economists have not developed yet a systematic analysis of the complete set of direct and indirect policy tools for the control of health care demand (reported in Table 1), and of their effects in terms of efficiency and equity. Only some recent contributions (Farnworth, 2003; Gravelle and Siciliani, 2008; Siciliani, 2008; Felder, 2008) have considered the welfare

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<sup>7</sup> The empowerment of demand does not encompass all citizens and socio-demographic classes: asymmetry of information drawbacks in the patient-physician relationship are still important for elderly, low education and low income people (generally with lower ability to pay and higher information costs) and they should be reduced increasing the equity of access to health care services. Several studies have shown that a substantial improvement in general health status can be obtained by reducing existing inequalities in income, education, and access to information and new technologies, with a reduction of both the burden of disease among the more deprived groups and the overall health care needs (Marmot and Wilkinson, 1999; McIntyre and Mooney, 2007). Moreover, the conditions of access to health care have a very strong impact on the health inequalities between social groups: more deprived classes are less able to gain benefits from health care services (lower choice ability, lower probability to follow the right care path; lower ability to comply to preventive programs, more difficulties in the interaction with health care professionals, lower capacity to access to more innovative forms of care) (Kakwani et al., 1997; Van Doorslaer et al., 2004).

and equity implications of the combined choice of cost-sharing and waiting times when private health care services, alternative to public NHS services, are available.

In the following section 3, we develop a multi-agent model to analyse the use of two direct tools (implicit rationing through waiting times and cost-sharing) and two indirect tools (appropriateness criteria and prioritisation of waiting lists) to control the demand for a public out-patient service in presence of a fully paid out-of-pocket private alternative. We ask whether it would be desirable, from a societal point of view, to use both cost-sharing and waiting times in combination with other instruments (exemptions from copayment, priority classes or indicators, and appropriateness criteria), in order to reduce the typical negative effects on equity and efficiency of the two traditional direct tools of demand-control.

### **3. The model**

We develop an agent-based model where heterogeneous agents maximise their individual utility based on income, the level of health, and other individual characteristics (risk aversion and the relative preference for health with respect to income). The agents' utility is influenced by the access to an outpatient treatment which produces a health benefit and which can be obtained either from the NHS (free of charge or with a copayment  $T$ ) or from a private provider (at full price). The fully paid private treatment is assumed to determine a higher individual expected benefit than the public treatment (owing to the full choice of professionals). Anyway, the access to private treatment is faster for two reasons: since a part of demand for private treatment is restrained by the payment of the full price  $p$  (while the public treatment is either free or charge or requires a copayment  $T < p$ ); since we assume that private supply can satisfy a larger share of potential demand than public supply (the latter is constrained by the fixed NHS budget). It follows that in the public sector a longer waiting list will arise, with longer waiting times than in the private sector.

This particular framework allows us to investigate the impact of individual agents' characteristics and interaction between agents and health care providers (the NHS and private services) within a dynamic framework characterised by different tools to control the demand for the public treatment (specifically, rationing by waiting times, cost-sharing, appropriateness and priority criteria). On this basis, we develop some computational experiments based on micro-simulations that allow to analyse the efficiency and equity effects of different scenarios and offer some useful insights for health care policy .

### 3.1 Characteristics of individual agents

#### *Individual utility function*

We consider  $N$  heterogeneous individuals. Each individual  $i$  has an utility function:

$$[1] \quad U_i = U(y_i, H_i, \theta_i)$$

that depends on the yearly monetary income  $y_i$ , the yearly stock of health  $H_i$ , and a vector of  $K$  individual characteristics  $\theta_i = \{\theta_{1i}, \dots, \theta_{ki}, \dots, \theta_{Ki}\}$ . We assume that  $0 \leq y_i \leq +\infty$  and  $0 \leq H_i \leq 1$ .

The functional form of the utility function is derived by means of the following four assumptions.

*Assumption 1* – positive marginal utility of income and health:

$$[2] \quad \frac{\partial U}{\partial y_i} = U_y > 0 \text{ and } \frac{\partial U}{\partial H_i} = U_H > 0$$

*Assumption 2* – strict concavity:

$$[3] \quad \frac{\partial U_y}{\partial y_i} = U_{yy} < 0, \quad \frac{\partial U_H}{\partial H_i} = U_{HH} < 0 \text{ and } U_{yy}U_{HH} - U_{yH}^2 > 0$$

*Assumption 3* – minimum level of utility when  $y_i = 0$  e  $H_i = 0$ :

$$[4] \quad U_{\min} = U(0, 0, \theta_i)$$

*Assumption 4* – minimum level of utility when  $y_i = 0$  or  $H_i = 0$ :

$$[5] \quad U_{\min} = U(y_i, 0, \theta_i) = U(0, H_i, \theta_i) = U(0, 0, \theta_i)$$

A specification that satisfies all previous assumptions is:

$$[6] \quad U(y_i, H_i, \theta_i) = f(y_i, \theta_i)g(H_i, \theta_i)$$

with  $f_y > 0, f_{yy} < 0$ ,  $g_H > 0, g_{HH} < 0$  and  $U(0, 0, \theta_i) = f(0, \theta_i)g(0, \theta_i)$ .

In particular we assume:

$$[7] \quad U_i = \frac{1}{1 - \rho_i} [y_i H_i^{\varepsilon_i}]^{1 - \rho_i}$$

where  $\theta_i = \{\rho_i, \varepsilon_i\}$ ,  $f(y_i, \theta_i) = \frac{1}{1 - \rho_i} y_i^{1 - \rho_i}$  e  $g(H_i, \theta_i) = H_i^{\varepsilon_i(1 - \rho_i)}$ .

$\rho_i > 0$  is the relative risk aversion parameter and  $\varepsilon_i > 0$  represents the relative intensity of individual preference about health with respect to net income.

With this Cobb-Douglas-type utility function, strict concavity requires  $1 - \rho_i < 1$ ,  $\varepsilon_i(1 - \rho_i) < 1$  and  $(1 + \varepsilon_i)(1 - \rho_i) < 1$ .

Parameters  $\rho_i$  and  $\varepsilon_i$  are chosen by each individual, so utility functions are different across individuals, and are random numbers drawn from a uniform distribution in the range  $[\rho_{\min}, \rho_{\max}]$  and  $[\varepsilon_{\min}, \varepsilon_{\max}]$ .

Furthermore, we assume that individuals consider a limited time horizon  $\bar{t}$  for their utility maximization (they are not completely rational). In particular, we assume  $\bar{t}=365$  days, then agents consider both income and health as referred to one year.

### *Stock of health and benefit from the treatment*

At a given time  $t_0$ , the  $i$ -th agent has a health status  $H_i^0$ , that she/he needs to improve (or not worsen) by receiving an outpatient treatment (e.g. an ambulatory service, a specialist visit, or a diagnostic treatment) with a potential benefit  $\beta_i$  measured as an increase of the health status. The health benefit can be different depending on whether the treatment is provided by a public service (without any possibility of choice of the desired health care professional) or by a private one (with full choice of the desired professional). In particular we assume that, owing to the possibility of free choice of the desired professional, the effectiveness of the private service, measured by the parameter  $\eta$ , is 100%, while if the treatment is provided by a public service the benefit the effectiveness is lower: i.e.  $0 < \eta < 1$ . So the expected benefit  $\tilde{\beta}_i$  depends on the chosen provider and is defined:

$$[8] \quad \tilde{\beta}_i = \begin{cases} \beta_i & \text{in the private service} \\ \eta\beta_i & \text{in the public service} \end{cases}$$

Then, we assume that  $i$ 's health decreases at an individual rate of decay  $\delta_i$  per period (similarly to Lindsay-Feigenbaum, 1984), while, after the treatment, the agent can enjoy a constant level of health for the rest of the year. Therefore, if the treatment is obtained at time  $\tau$  (i.e. after  $\tau$  days), the individual stock of health at day  $t$  is:

$$[9] \quad h_i(t) = \begin{cases} H_i^0(1-\delta_i)^t & \text{if } t \leq \tau \\ (H_i^0 + \tilde{\beta}_i)(1-\delta_i)^t & \text{if } t > \tau \end{cases}$$

The yearly stock of health is measured as the average value of all her/his daily health levels.

Assuming that the treatment occurs at time  $\tau$  (with  $0 < \tau < \bar{t}$ )<sup>8</sup>, the yearly stock of health can be defined as:

$$\begin{aligned}
 [10] \quad H_i(\tau) &= \frac{\sum_{t=1}^{\tau} h_i(t)}{\bar{t}} = \frac{1}{\bar{t}} \left[ \sum_{t=1}^{\tau} H_i^0 (1 - \delta_i)^t + \sum_{t=\tau+1}^{\bar{t}} (H_i^0 + \tilde{\beta}_i) (1 - \delta_i)^t \right] = \\
 &= \frac{1}{\bar{t}} H_i^0 \frac{1 - (1 - \delta_i)^{\tau}}{\delta_i} + \left( 1 - \frac{\tau}{\bar{t}} \right) (H_i^0 + \tilde{\beta}_i) (1 - \delta_i)^{\tau}
 \end{aligned}$$

The yearly stock of health  $H_i(\tau)$  is represented by the grey area in Figure 2.

To model the decay of health we assume that, without treatment, health decreases with time, reaching its minimum level  $H_{\min}$  at time  $t_i^H$ :

$$[11] \quad t_i^H = t_{\min} + (t_{\max} - t_{\min}) \left( \frac{H_i^0 - H_{\min}}{H_{\max} - H_{\min}} \right)^d$$

where  $d$  is a parameter common for all individuals. The value of  $t_i^H$  depends directly on the initial stock of health  $H_i^0$ , so if the stock is very low,  $H_i^0 \rightarrow H_{\min}$ , then  $t_i^H \rightarrow t_{\min}$ , i.e. the stock of health decreases to  $H_{\min}$  in a very short time. On the other hand, if health is very good,  $H_i^0 \rightarrow H_{\max}$ , the minimum stock of health is reached close to the maximum time  $t_i^H \rightarrow t_{\max}$ .

Once  $t_i^H$  is computed from the initial stock of health  $H_i^0$ , it is possible to derive the individual rate of decay  $\delta_i$ :

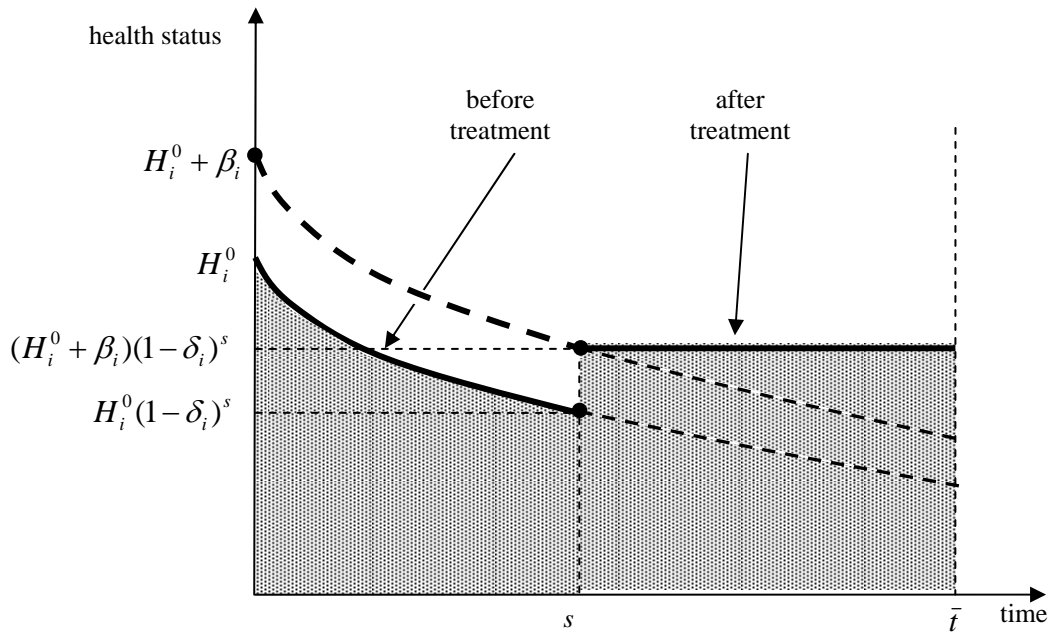
$$[12] \quad \delta_i = 1 - \left( \frac{H_{\min}}{H_i^0} \right)^{1/t_i^H}$$

Figure 3 shows the resulting decay of the health status when  $d = 2$ , for some initial level of  $H_i^0$ . The stock of health and the potential benefit are individual specific and are random numbers drawn from a uniform distribution in the range  $[H_{\min}, H_{\max}]$  and  $[\beta_{\min}, \beta_{\max}]$ .

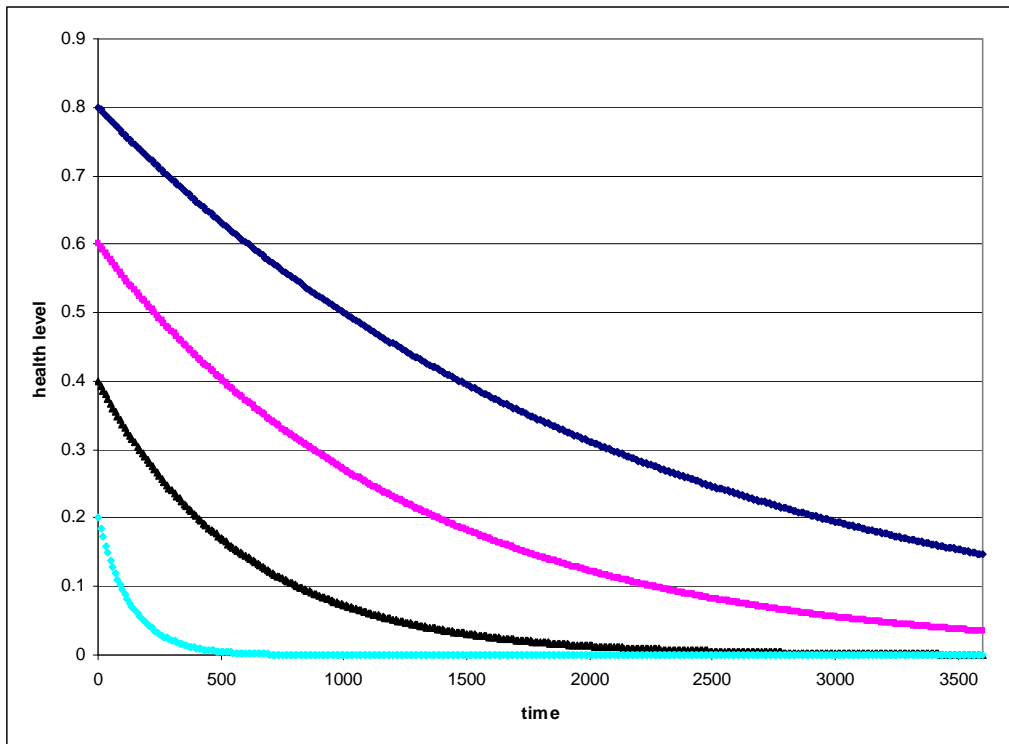
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<sup>8</sup> In other terms, we assume that the treatment occurs within one year.

**Figure 2 - Time profile of the stock of health**



**Figure 3 - Decay of health level for  $d=2$**



Notes:  $H_{\min}=0.1$ ,  $H_{\max}=1$ ,  $t_{\min}=3$  days,  $t_{\max}=7300$  days

### *Income*

The  $i$ -th agent is endowed with a positive yearly income  $y_i^0$  and is characterised by an employment status,  $S_i$ , defined as:

- 1 - self-employed
- 2 - employee
- 3 - without occupation (unemployed, retired, ...).

The individual employment status is randomly drawn from a distribution in which each status has a frequency  $q_j$ ,  $j=1,2,3$ , with  $q_1 + q_2 + q_3 = 1$ .

Yearly income is a random number drawn from a log-normal distribution specific to the employment status. If the  $i$ -th individual has an employment status  $S_i$ , then her/his income is drawn from a lognormal distribution with mean  $\mu(S_i)$  and standard deviation  $\sigma(S_i)$ :

$$[13] \quad y_i \sim \text{lognormal}(\mu(S_i), \sigma(S_i))$$

### *Opportunity costs*

The opportunity cost of waiting time per day,  $c_i$ , depends on individual employment status and is defined as a fraction  $\bar{c}(S_i)$  of the income earned in a day:

$$[14] \quad c_i = \bar{c}(S_i) y_i^0 / 365$$

Each agent bears an opportunity cost of time when waiting for the treatment for a time longer than  $t_i^L$ . After time  $t_i^L$  the level of health decreases below a threshold  $H_L$  leaving her/him unable to perform usual activities and causing a loss of individual income. The value of  $t_i^L$  is computed given the initial health status  $H_i^0$  and the threshold  $H_L$ :

$$[15] \quad t_i^L = t_{\min} + (t_{\max} - t_{\min}) \left( \frac{H_i^0 - H_L}{H_{\max} - H_{\min}} \right)^d$$

So, if the treatment is obtained at time  $\tau$ , the net yearly income of the  $i$ -th agent after the treatment is:

$$[16] \quad y_i(\tau) = \begin{cases} y_i^0 & \text{if } \tau \leq t_i^L \\ y_i^0 - c_i(\tau - t_i^L) & \text{if } \tau > t_i^L \end{cases}$$

Moreover, income decreases if the treatment is provided by the private sector at a price  $p$ , or if the public sector charges a copayment  $T_i$ , variable according to individual characteristics (i.e. chronic conditions or income level)<sup>9</sup>.

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<sup>9</sup> The specific characteristics of the copayment will be better clarified in section 3.2.

In those cases income is:

$$[17] \quad y_i(\tau, p) = \begin{cases} y_i^0 - p & \text{if } \tau \leq t_i^L \\ y_i^0 - c_i(\tau - t_i^L) - p & \text{if } \tau > t_i^L \end{cases}$$

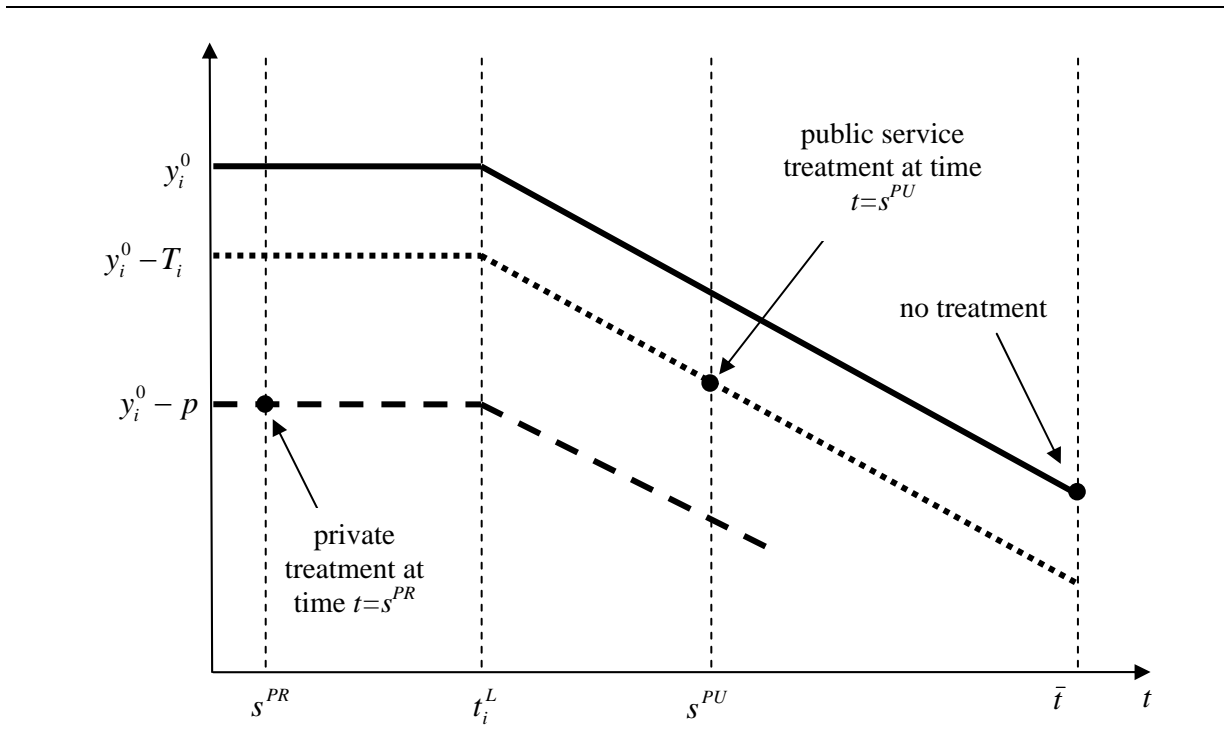
$$[18] \quad y_i(\tau, T_i) = \begin{cases} y_i^0 - T_i & \text{if } \tau \leq t_i^L \\ y_i^0 - c_i(\tau - t_i^L) - T_i & \text{if } \tau > t_i^L \end{cases}$$

If the agent forgoes the treatment, her/his income decreases only because of opportunity costs, if  $t_i^L < \bar{t}$ :

$$[19] \quad y_i(\bar{t}, 0) = \begin{cases} y_i^0 & \text{if } \bar{t} \leq t_i^L \\ y_i^0 - c_i(\bar{t} - t_i^L) & \text{if } \bar{t} > t_i^L \end{cases}$$

The time profile of net income for the three different situations (public, private, and no treatment) is shown in Figure 4.

**Figure 4 - Income time profile**



#### *Anxiety while waiting for the treatment*

If the treatment is not delivered timely, the utility of the agent decreases because of anxiety costs (Propper, 1995). Differently from Propper (1995), we model anxiety by discounting utility at a compound rate  $a_i$  for each period.



Anxiety disappears when the individual obtains the treatment, so if the treatment is obtained at time  $\tau$  the level of utility is:

$$[20] \quad U_i = \frac{1}{(1+a_i)^\tau} U(y_i(\tau), H_i(\tau), \theta_i)$$

We assume furthermore that the individual is not anxious if she/he decides to forgo the treatment. The anxiety parameter  $a_i$  is a random number drawn from a uniform distribution in the range  $[a_{\min}, a_{\max}]$ .

#### *Utility maximisation*

Agents face a problem of maximisation because they can choose among three possible situations:

a) *treatment provided by the public service* at time  $\tau^{PU}$  :

$$[21] \quad U_i^{PU} = \frac{1}{(1+a_i)^{\tau_{PU}}} U(y_i(\tau_{PU}, T_i), H_i(\tau_{PU}), \theta_i)$$

b) *treatment provided by the private service* at time  $\tau_{PR}$  :

$$[22] \quad U_i^{PR} = \frac{1}{(1+a_i)^{\tau_{PR}}} U(y_i(\tau_{PR}, p), H_i(\tau_{PR}), \theta_i)$$

c) *no treatment*: there are neither benefits nor costs for the treatment and utility is not discounted for anxiety. So, if the individual chooses to not demand the treatment, health and income are evaluated at time  $\bar{t}$  :

$$[23] \quad U_i^N = U(y_i(\bar{t}, 0), H_i(\bar{t}), \theta_i)$$

The maximum level of utility that can be reached by the agent is then:

$$[24] \quad U_i = \max[U_i^{PU}, U_i^{PR}, U_i^N]$$

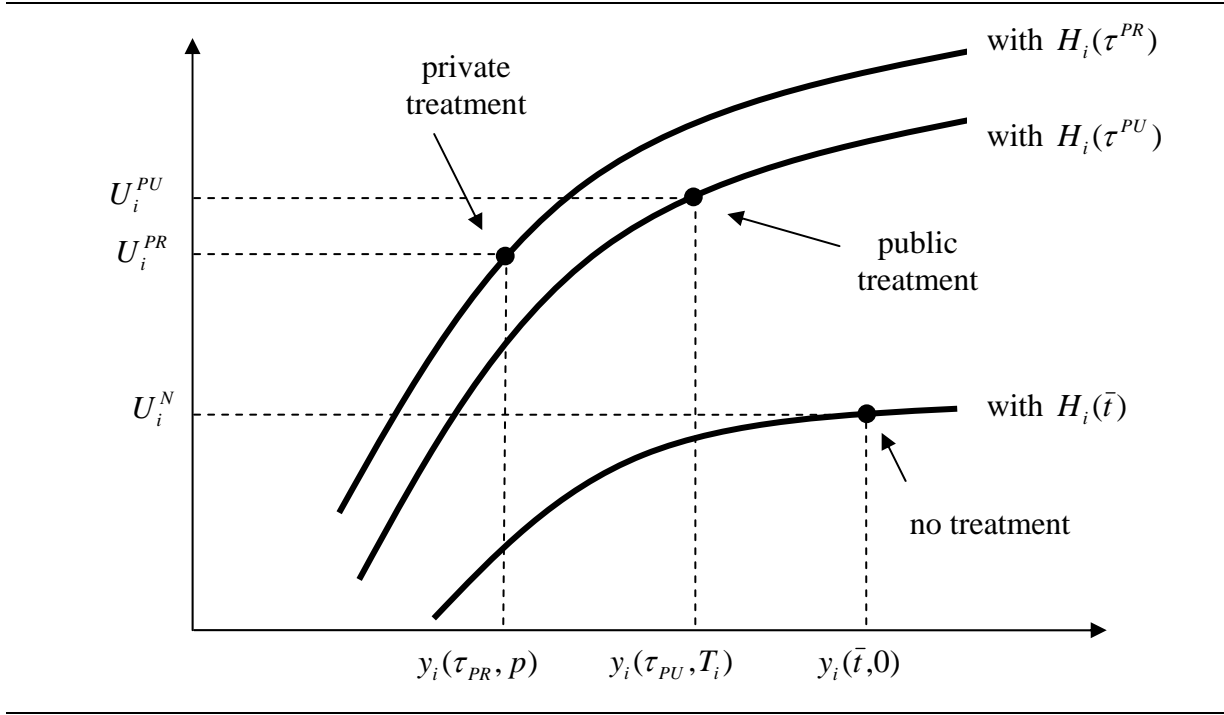
If the maximum level of utility is  $U_i^{PU}$ , the individual best action is to wait for time  $\tau_{PU}$  in order to receive the treatment from the public service paying a copayment  $T_i$ . This situation is depicted in Figure 5a.

If the maximum level of utility is  $U_i^{PR}$ , the individual best action is to ask for the treatment provided by the private sector, at time  $\tau_{PR}$  and at price  $p$ . This situation can be seen in Figure 5b.

If the maximum level of utility is  $U_i^N$ , the individual best action is to renounce to the treatment, as in the private sector the treatment is too costly and in the public sector the

waiting time is too long (owing to budget constraints in the NHS). This situation is represented in Figure 5c.

**Figure 5a - The best action is public treatment**



**Figure 5b - The best action is private treatment**

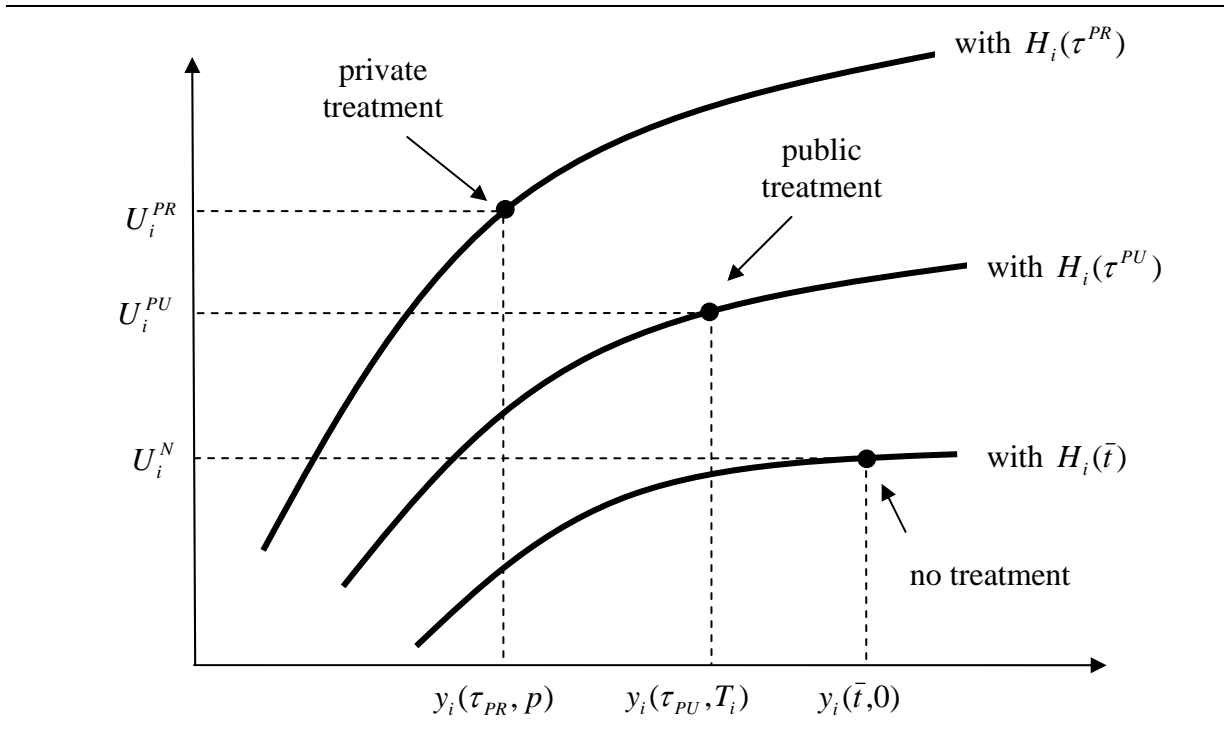
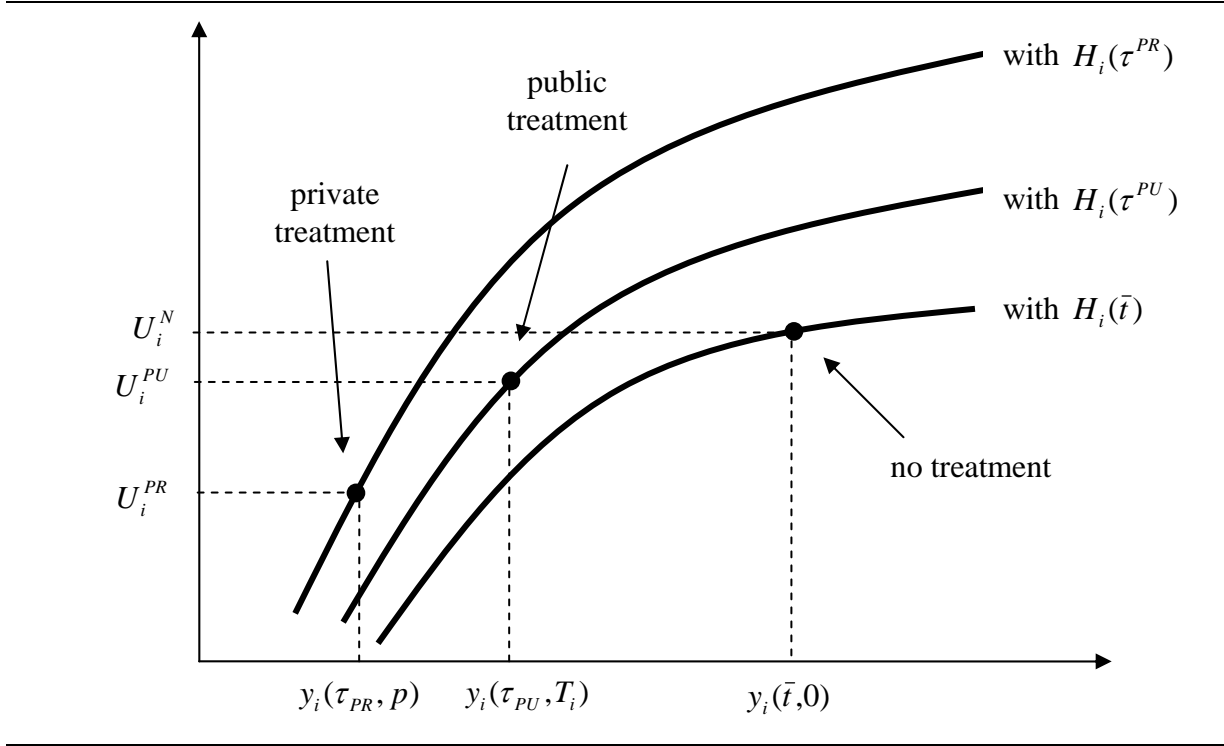


Figure 5c - The best action is no treatment



### 3.2 The institutional framework

As seen above, we assume that the treatment is provided by the private sector at price  $p$  or by the public sector without charges or with a copayment  $T$ , defined as a share of the full price  $p$ . In both private and public sector the treatment can be provided immediately only if the number of treatments asked is lower than the maximum number of treatments that can be provided in each period. If the maximum number of treatments that can be provided is not sufficient to satisfy all the demanded treatments, then a waiting list will arise.

The public sector can deal with the excess demand in several ways. We consider three control tools of demand for the public treatment: copayment, prioritization (priority classes) and appropriateness criteria.

#### *Copayment*

The agents' access to the public service waiting list can be influenced by the introduction of a copayment. The copayment to pay to access the public treatment is defined as a rate  $T$  of the price  $p$  of the private alternative treatment. Such a copayment can discourage some individuals to join the list, mainly the poorest, thereby determining a reduction of waiting list and waiting time for the public treatment. Moreover, the copayment determines a stronger

financial impact on the agents with a lower stock of health who could derive relatively higher benefits from the treatment. These regressive distributional effects of the copayment can be reduced if two kinds of exemption are introduced:

a) exemption for low income:

$$[25] \quad T_i = \begin{cases} 0 & \text{if } y_i \leq y_L \\ T & \text{if } y_i > y_L \end{cases}$$

where  $y_L$  is the income threshold (a sort of poverty line) below which no copayment must be paid.

b) exemption for chronic conditions and high benefit from the treatment<sup>10</sup>:

$$[26] \quad T_i = \begin{cases} 0 & \text{if } \beta_i \geq \beta_p \text{ and } H_i \leq H_p \\ T & \text{otherwise} \end{cases}$$

where  $H_p$  is the low health threshold and  $\beta_p$  is the high benefit threshold.

#### *Prioritisation of waiting lists*

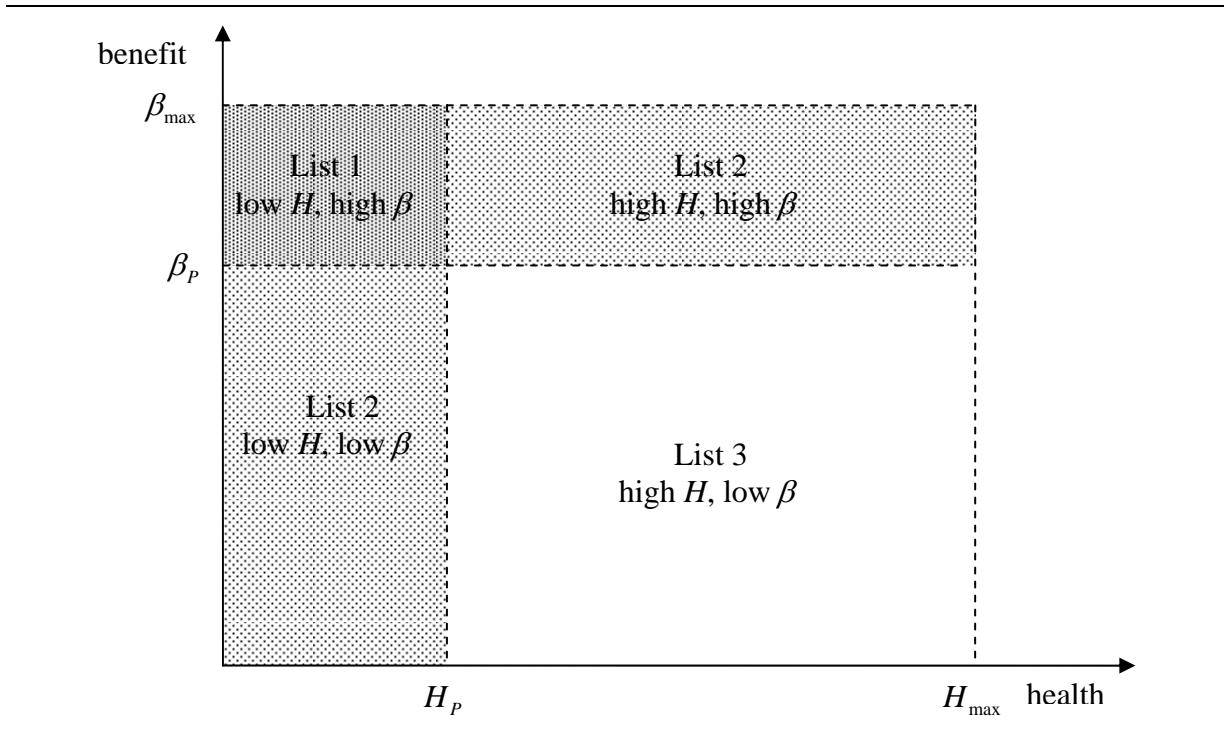
Our model considers also a prioritisation scheme modelled as a multiple list system, in which lists (classes) are ordered in decreasing level of priority and the number of potential treatments are assigned in order to assure lower waiting time to higher priority lists. The individual levels of health and of benefit from the treatment determine the priority and the list in which the individual is assigned to. We assume that the NHS providing the public treatment defines three priority lists, as shown in Table 2 and in Figure 6.

**Table 2 - Prioritisation with a multiple list system**

	Health	Benefit
List 1: high priority <i>low health – high benefit</i>	$H_i^0 \leq H_p$	$\beta_i \geq \beta_p$
List 2: average priority <i>low health (and low benefit)</i> <i>high benefit (and high health)</i>	$H_i^0 \leq H_p$ $H_i^0 > H_p$	$\beta_i < \beta_p$ $\beta_i \geq \beta_p$
List 3: low priority <i>high health – low benefit</i>	$H_i^0 > H_p$	$\beta_i < \beta_p$

<sup>10</sup> This second type of exemption recalls the so called “value-based cost sharing”, i.e., medical care that is seen to provide a higher marginal benefit to the patient should have lower coinsurance rates than medical care with lower marginal benefits. Pauly and Blavin (2008) have shown that value-based cost sharing can be justified only under asymmetric information (e.g. when patients may decide to forgo preventive care because they do not realize its long-term health benefits) and that anyway coinsurance rates must be designed to balance the twin goals of risk sharing (considering the marginal benefit of the treatment) and averting moral hazard.

**Figure 6 - Prioritisation with a multiple list system**



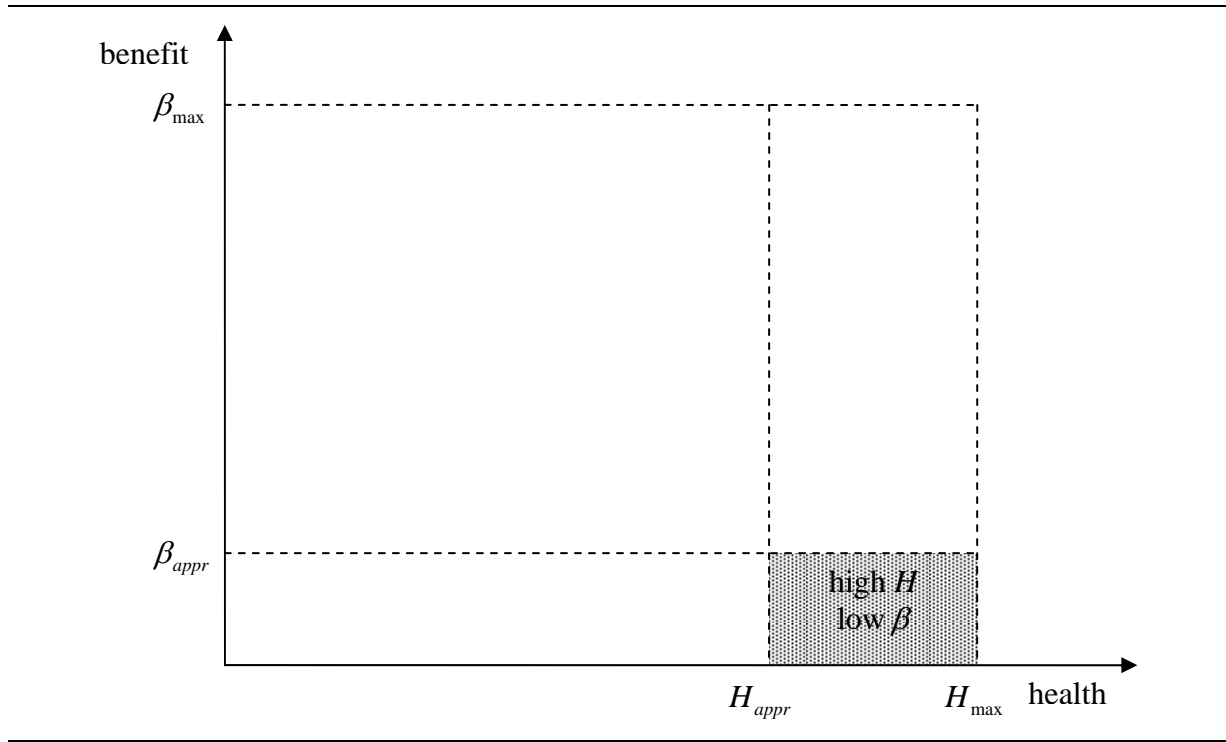
### *Appropriateness*

We also hypothesise that the NHS adopts appropriateness criteria with an explicit rationing of patients characterised by lower health care needs, based on EBM considerations. In other terms, the public treatment is refused in case of inappropriate demand, defined as a condition with both a high level of health ( $H_i^0 > H_{appr}$ ) and a very low expected benefit from the treatment ( $\beta_i < \beta_{appr}$ ), as shown in Table 3 and Figure 7.

**Table 3 - Appropriateness criteria**

	Health and benefit
Appropriate demand	$H_i^0 \leq H_{appr}$ or $\beta_i \geq \beta_{appr}$
Inappropriate demand	$H_i^0 > H_{appr}$ and $\beta_i < \beta_{appr}$

**Figure 7 - Appropriateness criteria**

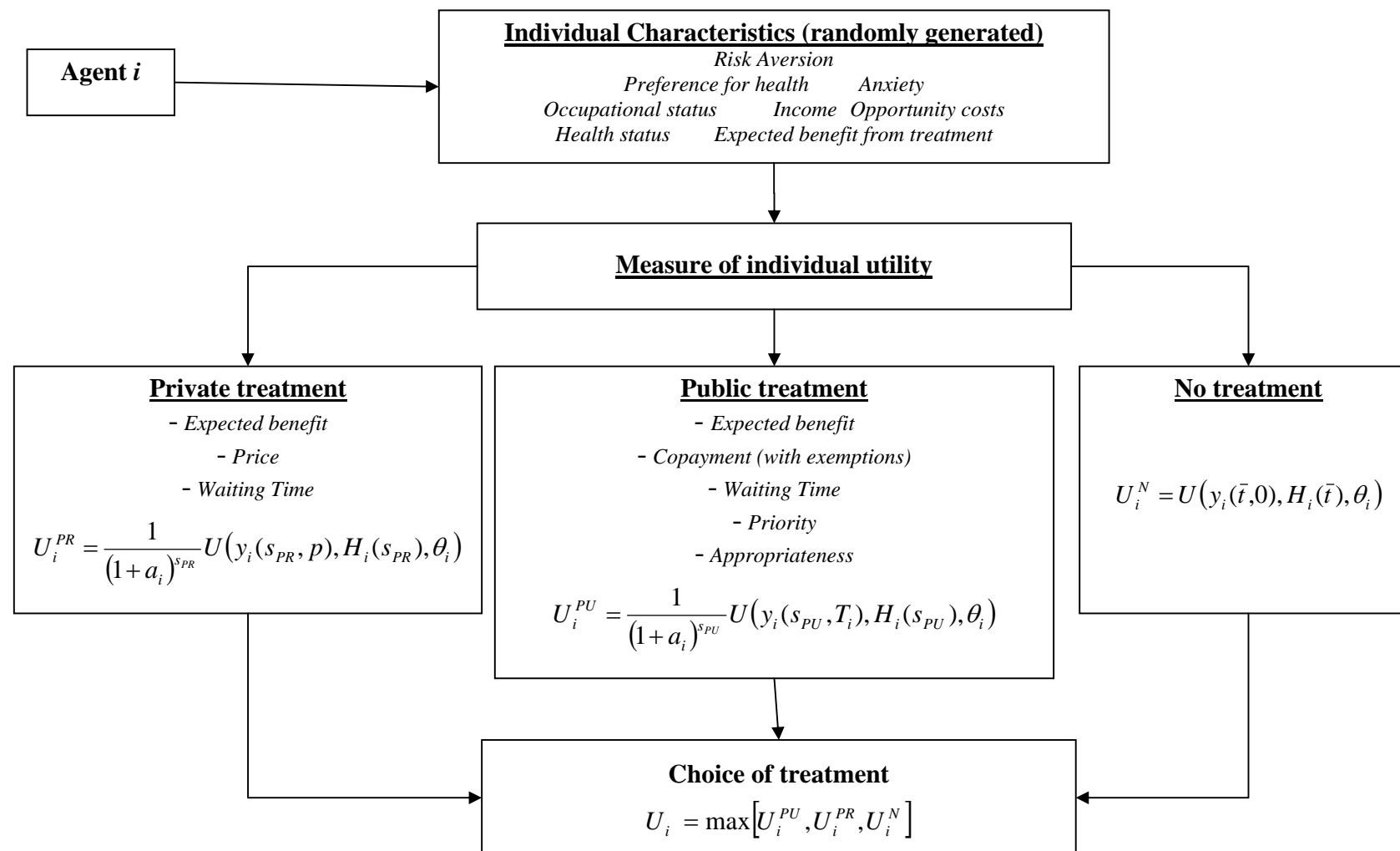


Considering the previous framework, each agent  $i$ , according to her/his individual characteristics (health status, income, risk aversion, preference for health, expected benefit from the treatment, occupational status, opportunity costs, and anxiety), which are randomly generated in the model, will choose between three different alternatives (public, private, and no treatment) in order to maximise her/his utility. The whole process of individual agents' choice, based on the variables and parameters previously defined, is represented in Figure 8.

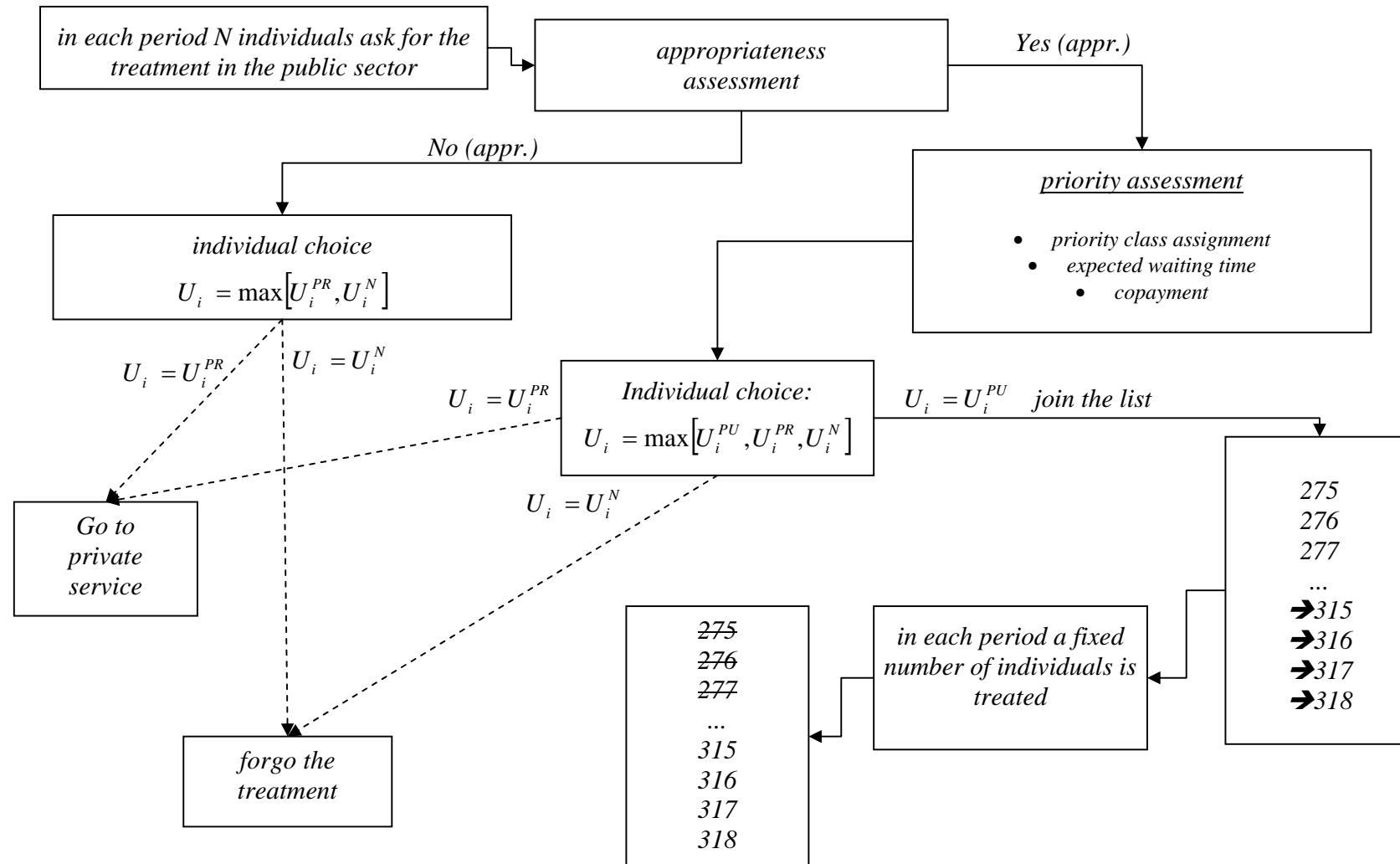
Figure 9 illustrates the dynamics of the model when all the tools for the control of the demand for the public treatment ( appropriateness criteria, prioritisation lists, copayment and rationing by waiting times) are considered.

In each period  $N$  agents with all individual characteristics are randomly generated. A fixed number of these agents can be treated in the public sector. First, each individual who needs health care asks for the public treatment provided by the NHS. The NHS assesses the appropriateness of agent's demand. If the individual demand is considered inappropriate, the agent can choose (to maximise her/his utility) either to ask for the private treatment or to renounce.

**Figure 8 - The agent's choice**



**Figure 9 - Model dynamics**





If the demand is assessed to be appropriate, the individual is assigned to one of the three waiting lists according to her/his health status and expected health benefit from treatment; the maximum waiting time for public treatment is precisely defined for list 1 (high priority) and list 2 (average priority) while if the agent is assigned to the list 3 (low priority) her/his expected waiting time is calculated dividing the current number of agents waiting in list 3 by the daily number of treatments for patients in list 3 (if the daily number of treated individuals in lists 1 and 2 were not sufficient to guarantee them the defined maximum waiting times, this number would be increased with a corresponding reduction of the daily number of treatments provided to patients in list 3). In this case, the individual can choose between three different alternatives (public, private, and no treatment) in order to maximise her/his utility, considering expected waiting time and copayment for public treatment, the price of private alternative, and all the other relevant variables.

### 3.3 Social welfare

In order to evaluate from a societal point of view the effects of different tools used to control the demand for public treatment in terms of efficiency and equity, now we define: a social evaluation function of individual welfare, a social welfare function and a policy efficiency index.

#### *Social evaluation function of individual welfare and equivalent income*

As we have seen above, each agent makes her/his own choice (private, public, or no treatment) considering a personalised utility function that depends upon her/his specific characteristics. In order to make a comparison of the utility levels associated to individual choices, we need only to assume ordinality and non comparability across individuals. If we want to obtain a measure of social evaluation, instead, we need to assume cardinal and comparable utility levels.

To this aim, first of all we assume that the collectivity has a *social evaluation function of individual welfare*  $v(y_i, H_i)$  that allows to evaluate socially the level of individual welfare by means of a unique function. We assume that the *social evaluation of individual welfare* has the functional form of the individual utility function, but uses fixed social parameters  $\bar{\rho}$  and  $\bar{\varepsilon}$  set at the median value of the distribution of individual parameters:

$$[27] \quad v_i = v(y_i, H_i) = \frac{1}{(1 - \bar{\rho})} \left( y_i H_i^{\bar{\varepsilon}} \right)^{1 - \bar{\rho}}$$

The anxiety parameter, associated to the wait for treatment, is also set at the median value of the

distribution of individual parameters.

From the social evaluation function  $v(y_i, H_i)$  it is possible to derive a money metric measure of individual welfare by defining an *equivalent income*,  $y_i^e$ , that represents the monetary income that gives rise to the same level of individual welfare when health is set at a reference level  $H_R$ :

$$[28] \quad v_i = v(y_i, H_i) = v(y_i^e, H_R)$$

If we set  $H_R=1$ , from  $v_i = \frac{1}{(1-\bar{\rho})} (y_i^e H_i^{\bar{\varepsilon}})^{1-\bar{\rho}}$  the  $i$ -th agent's equivalent income is:

$$[29] \quad y_i^e = [v_i(1-\bar{\rho})]^{1/(1-\bar{\rho})}$$

It is also possible to define a sort of equivalence scale of health by treating the health level as an individual characteristics that influences the individual welfare for a given level of income. The equivalence scale  $\lambda_i$  is defined as:

$$[30] \quad \lambda_i = \frac{y_i}{y_i^e}$$

From the above definitions:

$$[31] \quad \lambda_i = \frac{y_i}{y_i^e} = \frac{y_i}{\left[ \frac{1}{(1-\bar{\rho})} (y_i H_i^{\bar{\varepsilon}})^{1-\bar{\rho}} (1-\bar{\rho}) \right]^{1/(1-\bar{\rho})}} = \frac{1}{H_i^{\bar{\varepsilon}}} = H_i^{-\bar{\varepsilon}}$$

Therefore, the equivalent income is also equal to:

$$[32] \quad y_i^e = \frac{y_i}{\lambda_i} = y_i H_i^{\bar{\varepsilon}}$$

If, for instance,  $H_i=0.5$  and  $\bar{\varepsilon}=0.5$ , the equivalent income is  $y_i^e = y_i 0.5^{1/2} = 0.7071 y_i$ . This means that an individual with income  $y_i$  and  $H_i=0.5$  is as well off as another individual with the 70.71% of  $y_i$  and with  $H_i=1$ .

### *Social welfare*

The aggregate level of welfare can be obtained with a social welfare function based on social evaluation of individual welfare, with the usual properties.

We use the simple utilitarian social welfare function:

$$[33] \quad W = \sum_{i=1}^N v_i = \sum_{i=1}^N v(y_i, H_i)$$

In order to obtain a monetary measure of the social welfare, we use the equally distributed

equivalent income  $y^{EDE}$  with a reference level of health  $H_R$  :

$$[34] \quad W = \sum_{i=1}^N v(y^{EDE}, H_R)$$

Considering the social evaluation function [27] and setting  $H_R=1$ , the equally distributed equivalent income is defined as:

$$[35] \quad y^{EDE} = [W(1 - \bar{\rho})]^{1/(1-\bar{\rho})}$$

#### *Policy efficiency index*

We define a policy efficiency index by comparing the actual social welfare reached in a particular institutional setting (simulation) with the maximum potential social welfare:

$$[36] \quad E = \frac{W - W_0}{W_{\max} - W_0}$$

where  $W$  is the actual welfare reached in the simulation,  $W_{\max}$  is the value of social welfare when all individuals receive the health benefit  $\beta_i$  from the treatment immediately and without costs and  $W_0$  is the value of social welfare when nobody is treated within one year.

By construction, the policy efficiency index ranges from 0 to 1.

## **4. Results of different simulations of the model**

### **4.1 Values of parameters and simulations**

Now we present different simulations of the agent-based model described in previous section and analyse the related effects in order to obtain some aggregate indicators of the relative performance of the policy instruments that could be used to control the demand for the public outpatient treatment.

To this aim, firstly we need to assign specific, and reasonable, values to all the different parameters. All the chosen values are reported in Table 4.

Table 5 summarises the mix of institutional choices of the different simulations performed.

First of all, to produce some benchmark results, we simulate an institutional framework in which there are only private service providers (simulation 01). Then we simulate a situation where the outpatient treatment is provided only by the NHS (simulation 02).

**Table 4 – Values of parameters used in the simulations**

<i>Parameter</i>	<i>Value</i>
Number of agents	100
Number of periods	1000
Relative risk aversion (uniform distribution): range $\rho_{\min}, \rho_{\max}$	0.0, 1.0
Preference for health (uniform distribution): range $\varepsilon_{\min}, \varepsilon_{\max}$	0.0, 1.0
Initial stock of health (uniform distribution): range $H_{\min}, H_{\max}$	0.1, $1 - \beta_{\max}$
Benefit from treatment (uniform distribution): range $\beta_{\min}, \beta_{\max}$	0, 0.1
Quality parameter for public treatment: $\eta$	0.75
Decay exponent: $d$	2.0
Time horizon for utility maximization: $\bar{t}$	365 days
Time to reach the minimum level of health: $t_{\min}, t_{\max}$	3, 7300days
Anxiety parameter (uniform distribution): range $a_{\min}, a_{\max}$	0.00001, 0.0001
Employment status (frequency) <sup>(*)</sup> : $q_1, q_2, q_3$	0.07, 0.29, 0.64
Average yearly income by employment status <sup>(*)</sup> : $\bar{y}(S_i)$	20100, 17300, 13900 €
Standard deviation of yearly income by employment status <sup>(*)</sup> : $\sigma(S_i)$	1.869, 1.700, 1.894
Poverty line <sup>(*)</sup> : $y_L$ (50% of mean income of the overall distribution)	7660 €/year
Opportunity costs by employment status: $\bar{c}(S_i)$	0.50, 0.10, 0.00
Price of private treatment $p$	200 €
Copayment for public treatment: $T$	0.25 $p$
Potential daily demand satisfaction rate by public service	30%
Potential daily demand satisfaction rate by private service	100%
Priority lists List 1: <i>low health – high benefit</i> List 2: <i>low health and low benefit–high benefit and high health</i> List 3: <i>high health – low benefit</i>	Max. waiting time by priority list List 1: 3 days, List 2: 10 days List 3: no limit
Priority thresholds	$H_p = 0.2$ $\beta_p = 0.9 \beta_{\max}$
Appropriateness thresholds	$\beta_{app} = 0.03$ $H_{appr} = 0.7$

Note: <sup>(\*)</sup> The values are drawn from the Bank of Italy Survey on Household Income and Wealth - 2008

Simulations from A to E represent five extensions of simulation 02 (only public provision). Simulations from A to D are obtained combining different policy tools for the control of demand for the public treatment:

- copayment without exemptions;
- copayment with exemptions (low income, low health)
- priority classes;
- appropriateness criteria.

Simulation *E* considers the simultaneous use of all those instruments of demand control .

Finally, simulations from *F* to *M* repeat previous simulations from *A* to *E* considering the coexistence of private and public provision of the outpatient treatment.

**Table 5 –Simulations**

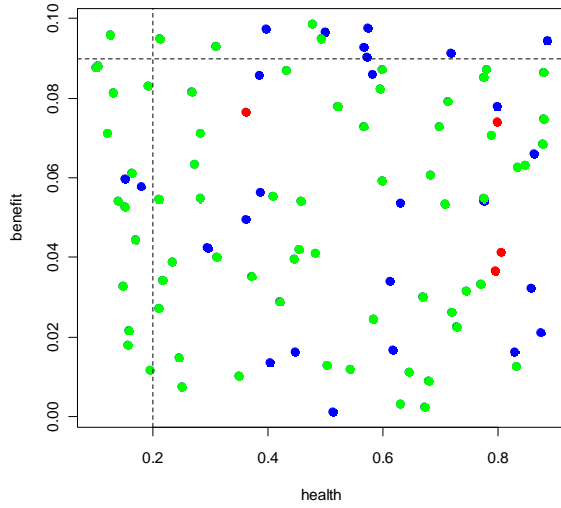
	<i>Simulation</i>	<i>Private sector</i>	<i>Public sector (30%)</i>	<i>Copayment</i>		<i>Priority classes (pr)</i>	<i>Appropriateness (appr)</i>
				<i>Copayment (t)</i>	<i>Health/ income exemption (yH)</i>		
01	01-priv	X	-	-	-	-	-
02	02-pub	-	X	-	-	-	-
A	A-pub-t	-	X	X	-	-	-
B	B-pub-tyH	-	X	X	X	-	-
C	C-pub-pr	-	X	-	-	X	-
D	D-pub-appr	-	X	-	-	-	X
E	E-pub-tyH-pr-appr	-	X	X	X	X	X
F	F-pp	X	X	-	-	-	-
G	G-pp-t	X	X	X	-	-	-
H	H-pp-tyH	X	X	X	X	-	-
I	I-pp-pr	X	X	-	-	X	-
L	L-pp-appr	X	X	-	-	-	X
M	M-pp-tyH-pr-appr	X	X	X	X	X	X

*Note: pp = private & public services*

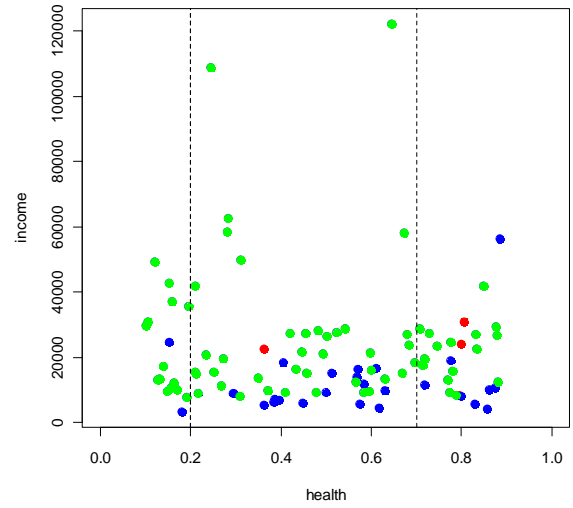
As an example of how the model works, Figures 10 and 11 show the individual choice (between public and private) and the dynamics of the agent-based model with simulation *I* (coexistence of public and private provision, and use of priority lists as the unique tool to control demand by the public provider). Figure 10 (a) shows that, within the framework of simulation *I*, the public treatment is mostly chosen by individuals with both high health level and high benefit, while some individuals assigned to the list 3 (low priority) decide to renounce to treatment. Figure 10 (b) shows that public treatment is generally chosen by low income individuals, whatever their level of health. Figure 11 (a) shows the average waiting time for each priority list, with the average waiting time for list 3 (low priority) converging around 40 days in the long run. Figure 11 (b) shows how individuals choose between private and public provision in the long run.

**Figure 10 – Example of individual choice (*colour*) – Simulation I**

a) health status and potential benefit from the treatment



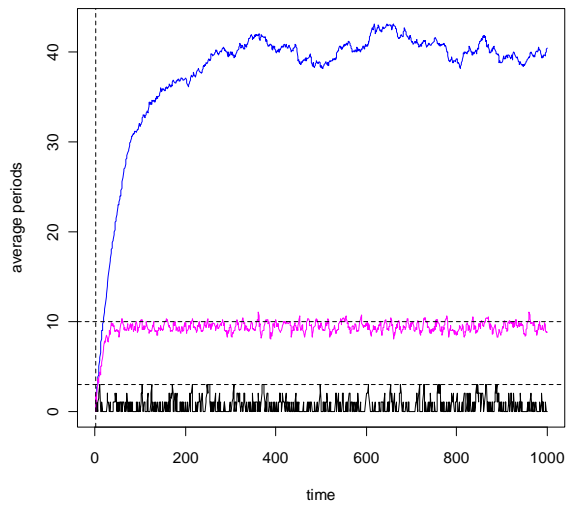
b) health status and income



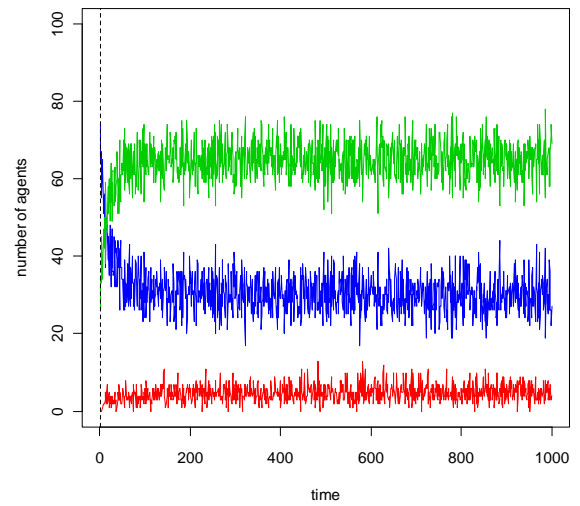
Note: *blue* = public treatment - *green* = private sector - *red* = no treatment

**Figure 11 - Example of simulation dynamics – Simulation I**

average waiting time per list of priority



individual choice per period



*black* = list 1 (high priority) – *purple* = list 2 (average)  
*blue* = list 3 (low)

*blue* = public treatment – *green* = private sector  
*red* = no treatment

## 4.2 Aggregate effects of policy simulations

We now examine the results of different simulations as concerns, in particular, waiting times, social welfare, income inequality, health inequality, and policy efficiency.

Table 6 shows the share of individual choices (between public, private, and no treatment) and the average characteristics of individuals (income, health level, and benefit from treatment) according to the chosen treatment option. The presence of a private alternative to public treatment (simulations from  $F$  to  $M$ ) strongly reduces the number of individuals who decide to forgo the treatment (in particular in simulation  $I$  when only priority lists are used as a way to control the demand for public treatment), even though those individuals who demand private treatment are (obviously) characterised by a higher average income. In all simulations but one (simulation  $G$ )<sup>11</sup>, those agents who decide to forgo the treatment are generally characterised by a lower average benefit from treatment and by a better level of health.

Table 7 reports some interesting results of different simulations also as far as efficiency and equity effects are concerned. Generally, the presence of a private alternative (simulations from  $F$  to  $M$ ) strongly reduces the length of the waiting list and the waiting times for the public treatment. Table 7 also reports, for all simulations, the measured variation of different indicators (social welfare, average income, average health, income inequality, health inequality, policy efficiency) with respect to a situation of no treatment. Public provision without a private alternative slightly reduces income inequality (measured the Atkinson index<sup>12</sup>), in particular with simulations  $B$  and  $D$ , but in general the presence of private providers increases the agents' welfare and policy efficiency: social welfare, as measured by the equally distributed equivalent income defined in [35], increases mostly either when only prioritisation of waiting lists (simulation  $I$ ) or all the demand control tools (simulation  $M$ ) are applied by public provider; the reduction in average income with respect to the “no treatment” situation is lower when a private alternative exists and it ranges from -0.7 to -0.8%, independently from the particular tools adopted to control the demand for the publicly provided treatment; similarly, the presence of a private alternative takes to the higher increase in average health level; health inequality

<sup>11</sup> Only in simulation  $G$ , the average benefit is slightly higher for the agents that forgo the treatment than for those that ask for public treatment. This depends on the rationing effect of the copayment without any exemption.

<sup>12</sup> The Atkinson index of income inequality used is:  $I = 1 - y^E / \bar{y}$ , where  $\bar{y} = \sum_{i=1}^N y_i / N$ ,  $y^E = \left[ \sum_{i=1}^N y_i^{1-\bar{\rho}} / N \right]^{\frac{1}{1-\bar{\rho}}}$  and  $\bar{\rho}$  is the social risk aversion of income from [27].

(measured the Atkinson index<sup>13</sup>) is strongly reduced with the private alternative in particular with simulation *M*.

The policy efficiency index, as defined by [36] (see also Figure 14) is very low when there is only the public provider, while it increases sharply when the private service is available. The use of a mix of direct and indirect tools (copayment corrected with exemptions, priority lists; appropriateness criteria) could increase further the efficiency of the system, by lowering waiting times and improving equity.

The increase of social welfare and policy efficiency determined by the presence of a fully paid private alternative crucially depends on the assumptions of our model. Firstly, private provision reduces waiting list length and waiting times for the public treatment since we hypothesised a capacity (budget) constraint for public provision and no (or lower) capacity constraint for the private one; it follows that, *coeteris paribus*, the existence of a private alternative reduces congestion in the demand for the public treatment hereby raising social welfare, average health, health equality, and policy efficiency. Secondly, we assumed that the private treatment may produce an higher individual expected benefit  $\beta_i$  than the public one, owing to the possibility for the agents to freely choose their preferred physician; this entails that the private treatment, even it is fully paid by demanders, generally produces better effects on agents' health and consequently on social welfare and policy efficiency. Anyway, since the assumptions we made seem quite reasonable (budget constraints and limits to the individual's choice of the health care professional are common characteristics of public health care systems) we believe that the results of our simulations can provide useful insights for health policy.

Moreover, the results of our simulations point out that, in presence of a private alternative, both using only priority lists (simulation *I*) and using all the tools to control public demand (simulation *M*), seem to produce the best performances in terms of social welfare, average health, health equality and policy efficiency. This could suggest two preliminary conclusions: first, it seems that using just prioritisation of waiting lists, without any copayment, could represent a parsimonious and effective tool to control the demand for public treatment; second, using the entire demand control toolkit (including copayments with exemptions) may take to a similar

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<sup>13</sup> The Atkinson index of health inequality used is:  $I = 1 - H^E / \bar{H}$ , where  $\bar{H} = \sum_{i=1}^N H_i / N$ ,

$H^E = \left[ \sum_{i=1}^N H_i^{1-\phi} / N \right]^{\frac{1}{1-\phi}}$  and  $\phi = 1 - \bar{\varepsilon}(1 - \bar{\rho})$  is the social risk aversion of health from [27].



result, but one must take into account that it should entail higher costs than to manage a single tool like lists' prioritisation.

**Table 6 – Simulation results: average characteristics by individual choice of service**

Simulation	01-priv	02-pub	A-pub-t	B-pub-tyH	C-pub-pr	D-pub-appr	E-pub-tyH-pr-appr
<i>Individual choice</i>							
No service	22.6%	69.8%	69.8%	69.8%	71.5%	69.9%	71.5%
Public service	0.0%	30.3%	30.2%	30.2%	28.5%	30.1%	28.5%
Private service	77.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
<i>Average income</i>							
No service	10,302	17,451	16,719	17,397	17,928	17,520	17,890
Public service	-	20,014	21,708	20,147	18,975	19,868	19,073
Private service	20,539	-	-	-	-	-	-
<i>Average health</i>							
No service	0.5494	0.5109	0.5124	0.5120	0.5508	0.5197	0.5532
Public service	-	0.4640	0.4604	0.4613	0.3610	0.4434	0.3547
Private service	0.4813	-	-	-	-	-	-
<i>Average benefit</i>							
No service	0.0477	0.0481	0.0482	0.0481	0.0447	0.0472	0.0446
Public service	-	0.0540	0.0537	0.0541	0.0629	0.0562	0.0632
Private service	0.0505	-	-	-	-	-	-
Simulation	F-pp	G-pp-t	H-pp-tyH	I-pp-prior	L-pp-appr	M-pp-tyH-pr-appr	
<i>Individual choice</i>							
No service	4.8%	17.7%	6.4%	5.2%	5.8%	7.3%	
Public service	30.1%	29.9%	30.1%	30.1%	30.2%	30.1%	
Private service	65.2%	52.4%	63.5%	64.7%	64.1%	62.6%	
<i>Average income</i>							
No service	16,379	8,847	16,430	16,233	15,208	15,289	
Public service	11,128	16,110	11,204	11,321	11,368	11,500	
Private service	21,635	22,601	21,737	21,597	21,723	21,808	
<i>Average health</i>							
No service	0.6315	0.5359	0.6273	0.6408	0.6791	0.6624	
Public service	0.5426	0.5625	0.5382	0.5175	0.5178	0.5011	
Private service	0.4657	0.4459	0.4639	0.4755	0.4704	0.4752	
<i>Average benefit</i>							
No service	0.0420	0.0478	0.0446	0.0398	0.0349	0.0380	
Public service	0.0477	0.0434	0.0467	0.0511	0.0507	0.0512	
Private service	0.0515	0.0543	0.0519	0.0501	0.0509	0.0507	

Note: see Table 5 for the description of simulations

**Table 7 – Aggregate simulations results**

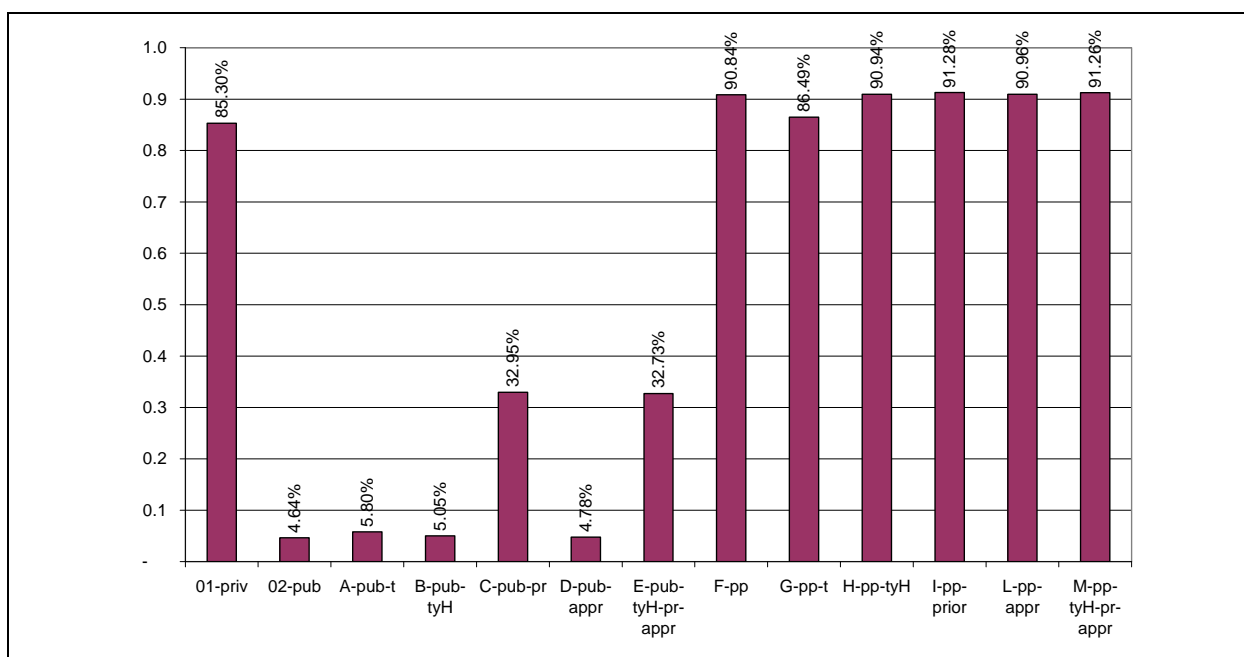
Simulation	01-priv	02-pub	A-pub-t	B-pub-tyH	C-pub-pr	D-pub-appr	E-pub-tyH-pr-appr
Lenght of the list*	-	8,014	7,422	7,813	2,966	7,858	2,982
Waiting time (days)*	-	268	248	261	327	262	319
Average income $\Delta$	-1.0%	-5.9%	-5.7%	-5.9%	-5.6%	-5.9%	-5.6%
Average health $\Delta$	25.4%	1.4%	1.8%	1.5%	8.0%	1.4%	7.9%
Income inequality $\Delta$	0.2%	-0.2%	-0.1%	-0.2%	-0.1%	-0.2%	-0.1%
Health inequality $\Delta$	0.3%	10.7%	10.6%	10.6%	2.2%	10.6%	2.3%
Social welfare $\Delta$	28.0%	1.5%	1.9%	1.7%	10.8%	1.6%	10.8%
Policy efficiency	85.3%	4.6%	5.8%	5.0%	33.0%	4.8%	32.7%
Simulation		F-pp	G-pp-t	H-pp-tyH	I-pp-prior	L-pp-appr	M-pp-tyH-pr-appr
Lenght of the list*		988	305	627	944	839	504
Waiting time (days)*		33	11	21	40	28	20
Average income $\Delta$		-0.7%	-0.8%	-0.8%	-0.7%	-0.7%	-0.8%
Average health $\Delta$		26.3%	25.7%	26.3%	26.3%	26.3%	26.3%
Income inequality $\Delta$		0.0%	0.1%	0.1%	0.0%	0.1%	0.1%
Health inequality $\Delta$		-1.1%	0.2%	-1.2%	-1.3%	-1.1%	-1.4%
Social welfare $\Delta$		29.9%	28.4%	29.9%	30.0%	29.9%	30.0%
Policy efficiency		90.8%	86.5%	90.9%	91.3%	91.0%	91.3%

Legend:  $\Delta$  = percentage change with respect to no-treatment

\* = referred to the low priority class (list 3)

Note: See Table 5 for the description of simulations

**Figure 14 – Policy efficiency index (%)**



Note: see Table 5 for the description of simulations

Anyway, these conclusions depend also on the fact that we did not consider the possibility of using the copayments' revenues to fund an increase of the potential daily demand satisfaction rate by the public service. We consider this possibility in the next section.

### 4.3 Effects of a change in the copayment rate with use of revenue

We consider now only the situation with both public and private service options. There is a copayment for the public treatment with both types of exemptions alike in simulation *H* considered in previous section. Now we hypothesise that all the revenues from copayments are used to fund the public service<sup>14</sup>, and look at the effects of increasing the copayment rate from 0 to 100% of the full price of the treatment  $p$ .<sup>15</sup>

Table 8 shows the share of individual choices (between public, private, and no treatment) according to different levels of the copayment rate. The higher percentage of individuals choosing for public provision is found when the copayment rate for the public treatment is at 55% of  $p$ . This depends on the high level of the daily demand satisfaction rate (50.6%) allowed by using copayments revenues to empower the public service (see also Table 9 and Figure 15). A further increase of the copayment rate beyond 55% (e.g. at 60%) would determine a decrease in the share of agents demanding the public treatment, owing to the reduced differential between copayment and full price of private treatment.

Table 9 shows that (as expected) both the length of waiting list and waiting times for public treatment decrease with a copayment rate increase. The highest level of the policy efficiency index (91.9%) is reached with a copayment rate of 55%, and this is consistent with previous results (see also Figure 16). Therefore, using a 55% copayment with both types of exemptions provides a better result in terms of policy efficiency than using either only lists prioritisation (simulation *I* of previous section) or the entire set of tools to control the demand for public treatment (simulation *M*). Finally, it is worth noting that when the copayment revenues are used to fund the public provision, applying a moderate copayment rate of 20% - slightly lower than in the simulations of previous section - would determine the same result in terms of policy efficiency (a 91.3% index) of using only priority lists (simulation *I*) or using all the tools to

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<sup>14</sup> In each period the number of public treatment is increased by the ratio between the previous period revenue and the price  $p$ . For sake of simplicity, we do not consider here the costs of administering exemption schemes which reduce the net revenues collected for funding the public service.

<sup>15</sup> When the copayment is set to 0, the results correspond to those of simulation *F* in Table 7.

control public demand (simulation  $M$ ) when copayment was not considered a funding source for public service.

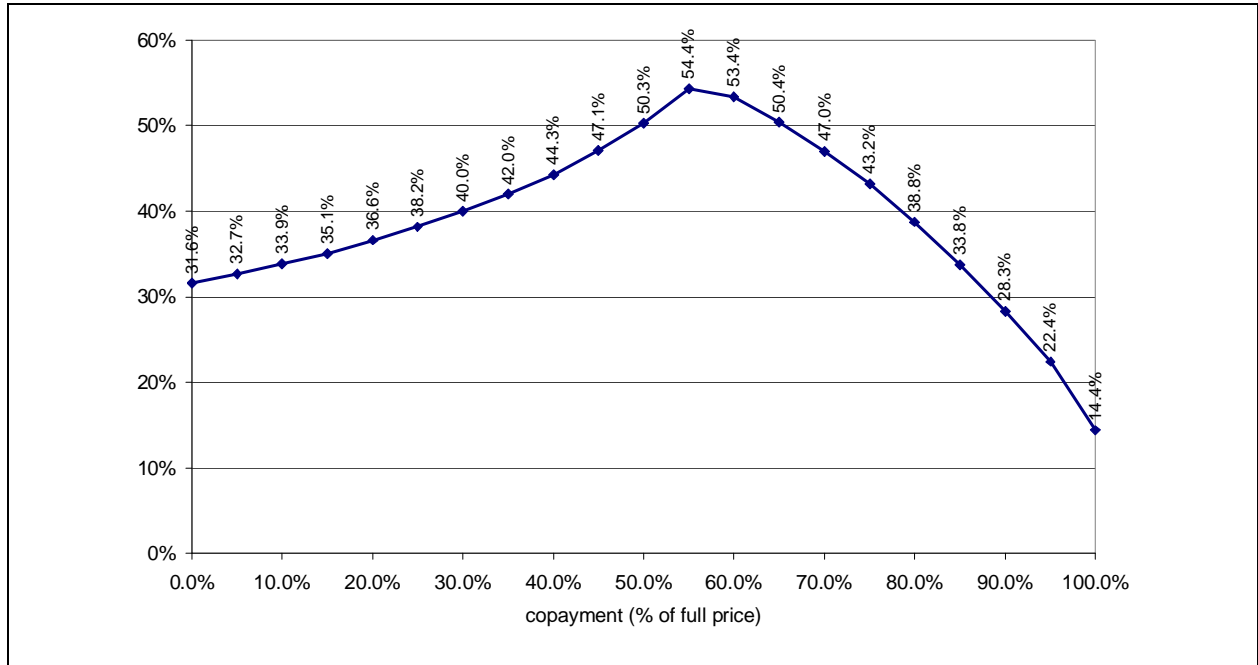
**Table 8 – Varying copayment: choice of service**

<b>Simulation</b>	<b>0</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>	<b>7</b>	<b>8</b>	<b>9</b>	<b>10</b>
Copayment: % of price	0%	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%
<i>Individual choice</i>											
No service	4.8%	5.0%	5.2%	5.4%	5.6%	5.7%	5.8%	6.1%	6.2%	6.4%	6.6%
Public service	30.1%	31.0%	32.1%	33.1%	34.5%	35.9%	37.6%	39.3%	41.3%	43.8%	46.7%
Private service	65.2%	64.0%	62.7%	61.5%	59.9%	58.4%	56.6%	54.6%	52.5%	49.8%	46.8%
<b>Simulation</b>		<b>11</b>	<b>12</b>	<b>13</b>	<b>14</b>	<b>15</b>	<b>16</b>	<b>17</b>	<b>18</b>	<b>19</b>	<b>20</b>
Copayment: % of price		55%	60%	65%	70%	75%	80%	85%	90%	95%	100%
<i>Individual choice</i>											
No service		6.8%	7.2%	7.7%	8.1%	8.5%	8.8%	9.2%	9.5%	9.7%	9.7%
Public service		50.4%	49.3%	46.4%	43.1%	39.4%	35.3%	30.6%	25.6%	20.3%	13.1%
Private service		42.8%	43.5%	46.0%	48.9%	52.1%	55.9%	60.2%	64.8%	70.1%	77.2%

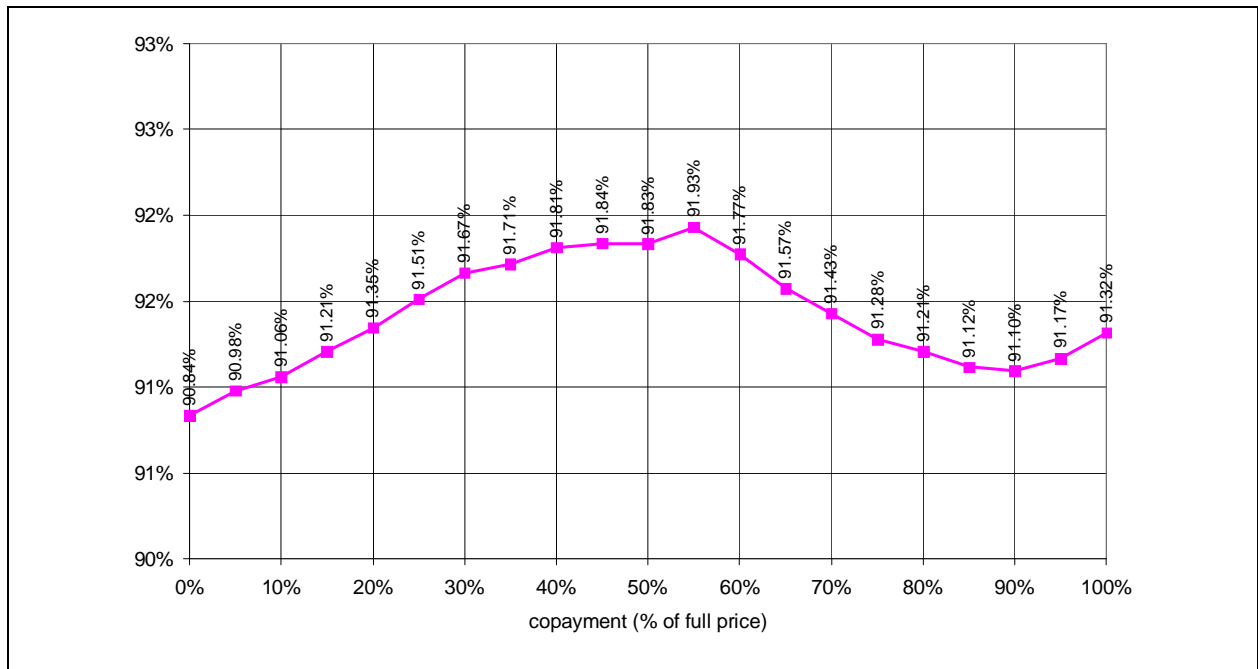
**Table 9 – Varying copayment: aggregate simulations results**

<b>Simulation</b>	<b>0</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>	<b>7</b>	<b>8</b>	<b>9</b>	<b>10</b>
Copayment: % of price	0%	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%
% public treatments	30.0%	31.0%	32.0%	33.1%	34.4%	35.9%	37.5%	39.3%	41.5%	44.0%	46.9%
Lenght of the list	988	894	800	712	622	539	453	370	293	218	144
Waiting time (days)	33	29	25	22	19	15	13	10	8	5	4
Policy efficiency	90.8%	91.0%	91.1%	91.2%	91.3%	91.5%	91.7%	91.7%	91.8%	91.8%	91.8%
<b>Simulation</b>		<b>11</b>	<b>12</b>	<b>13</b>	<b>14</b>	<b>15</b>	<b>16</b>	<b>17</b>	<b>18</b>	<b>19</b>	<b>20</b>
Copayment: % of price		55%	60%	65%	70%	75%	80%	85%	90%	95%	100%
% public treatments		50.6%	49.6%	46.6%	43.3%	39.7%	35.5%	30.8%	25.8%	20.4%	13.1%
Lenght of the list		71	52	47	43	40	35	31	26	20	13
Waiting time (days)		2	1	1	1	1	1	1	1	1	1
Policy efficiency		91.9%	91.8%	91.6%	91.4%	91.3%	91.2%	91.1%	91.1%	91.2%	91.3%

**Figure 15 –Effect of copayment increase on the demand satisfaction rate by the public service (% of potential demand)**



**Figure 16 – Effect of Copayment Increase on the Policy Efficiency Index (%)**



Summing up, funding the public service with the revenues from copayments, corrected with exemption schemes, can reduce public supply constraints thereby increasing social welfare and policy efficiency.<sup>16</sup>

## 5. Concluding remarks

In this paper we use an agent-based model to analyse the impact of two direct tools (rationing through waiting times and cost-sharing) and two indirect tools (appropriateness and priority criteria) to control the demand for a public outpatient service provided by a National Health Service in presence of a fully paid out-of-pocket private alternative. In particular, we present a model where heterogeneous agents maximise their individual utility based on income, health level, and other individual characteristics such as risk aversion and the relative preference for health with respect to income. On this basis, we develop some computational experiments based on micro-simulations providing some preliminary results potentially useful in terms of health care policy.

First, our preliminary analysis shows that the presence of a private alternative to public treatment can improve social welfare and health equity in a NHS, when public supply is constrained by a fixed budget and longer waiting times than the private one. In absence of a private alternative, agents characterised by high opportunity-costs of time and high health decay rates could decide to give up the treatment if the waiting time overcomes a critical threshold.

Second, the analysis confirms that using only waiting times as a direct tool to control the demand for a public service is less efficient and equitable in terms of health distribution than adopting one or a mix of direct and indirect tools such as: i) a copayment corrected with exemptions; ii) priority lists; iii) appropriateness criteria. In particular, using only the second tool, i.e. prioritisation of waiting lists without any copayment, may produce high performances in terms of social welfare, health equality and policy efficiency; therefore it could represent a parsimonious and effective tool to control the demand for public treatment.

Finally, funding the public service with the revenues from copayments, corrected with exemption schemes, can reduce public supply constraints, thereby increasing social welfare and policy

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<sup>16</sup> These effects could be reinforced if the private alternative is provided “intramoenia” (i.e. “inside the walls of public hospitals”) with a part of private revenues allocated to fund the public facility, as in Italy. In this case, however, the condition of perfect separation between public and private provision processes must be fulfilled as pointed out by Iversen (1997).

efficiency. In this case, applying a moderate copayment rate as a tool to control public demand could determine the same result, in terms of policy efficiency, of using only priority lists.

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