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Modeling the political choice of public health insurance

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This article aimed to study the choice that people have to make between two health insurance systems in a monopolistic scheme. The first health insurance system proposes a uniform contribution level and the second one proposes a contribution level that is proportional to the probability of getting sick. The individuals differ (or are distinguished) by their number in a group, the net income, the contribution level, the probability of getting sick, and health cost. Two kinds of voting models using the welfare function are used; a direct vote that involves a size effect and a probabilistic vote that involves a bias in favor of one system. The results, according to theoretical models, indicate that a uniform contribution level is adopted by high-risk individuals and also if wealth and illness are strongly negatively correlated. However, when wealth and illness are not correlated or are poorly correlated, a contribution proportional to the probability of getting sick is adopted. These results were explained by the fact that the loss of wellbeing for low-income and sick people is more important.

KEYWORDS

health insurance, welfare function, utility, direct voting model, probabilistic voting model

1. Introduction

In this article, the choice that people have to make between two health insurance systems has been studied: a uniform contribution level and a contribution level proportional to the probability of getting sick. In many health insurance systems, people have public insurance and (or) subscribe to private insurance with a premium depending on the frequency of visits to the physician. Thus, people can be led to make a choice according to their needs: pay a fixed contribution to cover health care or pay more/less according to their probability of getting sick. Indeed, we are unfortunately not equal in health, that is, there are people who need more health care in contrast to others. Therefore, according to needs, health coverage may differ between individuals.

In this article, we aimed to investigate the preference between two health insurance systems in a monopolistic scheme. The first health insurance system proposes a uniform contribution level, and the second one proposes a contribution proportional to the probability of getting sick. More precisely, we determined which system is preferred by people who differ by their number in a group, the probability of getting sick, the contribution level, the net income, and health cost. Two kinds of votes are used: a direct vote which involves the size effect of a group and a system wins with more than 50% of votes and a probabilistic vote that involves a bias in favor of one system (there is an additional hazard and people vote for various other reasons). Bias is a null random variable, thus there is no preferred system in this case.

In a situation where people have no choice, some people may realize that they are placed at a disadvantage by having to pay more for insurance than for the care they received, or in some cases, the health insurance is unaffordable for many people in the low-income population, where household budgets are small. Thus, in this article, a reflection is made on a compromising system that could satisfy a large majority of people in a democracy.

Various authors have investigated the influence of institutional factors on health [1–7]. Models have been developed to explain why individuals are in favor of a public health insurance such as redistribution from high-income to low-income individuals [8–13]. According to van de Ven and van Vliet [14], health medical consumption and income have a significant impact on the choice of a health insurance system. For Rossignol [15], in a representative or a direct democracy, with altruistic agents, social insurance was adoptable, especially for treatments with the best value for money, while according to Zweifel et al. [16], a public health supply is preferred under exclusive and non-exclusive regimes by voters.

Taking these contributions into account, this article focused on the preference of people between a uniform contribution level and a contribution level proportional to the probability of getting sick in a monopolistic scheme. Moreover, in Switzerland, individuals voted two times and rejected a single health insurance fund. This article is organized as follows. Section 2 presents the models. Sections 3 and 4 analyze the choice of a health insurance system. The conclusion is presented in the last section.

2. The model

2.1. Welfare functions

We considered a democracy with n individuals distributed in k homogeneous groups $G1, G2, \ldots, Gk$. The proportion of individuals α_j in Gj is $\alpha_j = nj/n$.

People have an income Y_j and they can be healthy or sick. The probability p of getting sick depends on the individuals. The risk pj in the population is distributed in [0; 1] according to the cumulative distribution function $F(p)$.

Individuals spend a part of Y_j on health care. τj is the contribution level for health insurance in Gj. τj is constant or depends on the probability of getting sick according to the company. H is the cost of health care and Hj the reimbursement of care.

The net income RNj of a healthy individual is the difference between the income and the contribution level. This contribution level is fixed or proportional to the probability of getting sick.

$$RNj = Y_j - \tau j.Y_j \quad (1)$$

When the agent is sick, RNj becomes the difference between the income, the reimbursement of health care and the contribution level, and the cost of health care.

$$RNj = Y_j - \tau j.Y_j - H + Hj \quad (2)$$

U is the wellbeing function of the agent. The expected wellbeing is (1) + (2)

$$EUj = (1 - p_j)\, U\,(Y_j\, \tau j.Y_j) + p_j\, U\,(Y_j - \tau j.Y_j - H + Hj) \quad (3)$$

The expected wellbeing is the sum of the wellbeing in healthy and sick cases.

The budget constraint (BC) of the health insurance company, if we assume that it is actuarial, is:

$$\text{Company receipts}: \sum\nolimits_{j=1}^{k} \mathrm{N_j \tau j Y_j} \quad (4)$$

The receipts are the share of income spent on health care:

$$\text{Company expenditures}: \sum\nolimits_{j=1}^{k} \mathrm{N_j H_j p_j} \quad (5)$$

The expenditures are the reimbursement of health care:

$$BC: (4) = (5) \Longrightarrow \sum\nolimits_{j=1}^{k} N_j \tau j Y_j = \sum\nolimits_{j=1}^{k} N_j H_j p_j \quad (6)$$

2.2. The redistribution effects

θj measures the redistribution effects; θj is the difference between the reimbursement from the health insurance and the contribution level to health insurance.

For any agent and company and in all cases

$$\theta_j = p_j\, Hj - \tau j\, Y_j \quad (7)$$

If θ_j *is* > 0, the agent receives more than it pays.

Equation (6) implies that the total redistribution is null.

Therefore,

$$\sum N_j\, \theta_j = 0$$

(see Proof in Appendix 1).

θ_j can be decomposed into horizontal θ_j^H and vertical θ_j^V redistribution, such as $\theta_j = \theta_j^H + \theta_j^V$:

$$\theta_j^H = p_j\, Hj - \frac{1}{N} \sum\nolimits_l N_l p_l H_l \quad (8)$$

The agent receives horizontal redistribution if the level of reimbursement is higher than the average.

$$\theta_j^V = \frac{1}{N} \sum\nolimits_l N_l \tau_l Y_l - \tau j\, Y_j \quad (9)$$

The agent receives vertical redistribution if the contribution level is less than the average.

$$\sum\nolimits_l N_l P_l H_l = \sum\nolimits_l N_l \tau_l Y_l \textit{by the BC}$$

2.3. Health insurance systems

C1: Uniform contribution level

C1 reimburses the entire health care with a contribution level uniform for all.

$\overline{Y}$ is the average income and $\overline{p}$ is the average probability of getting sick. Therefore,

$$\tau = \frac{H\,\overline{p}}{\overline{Y}} \quad (10)$$

The contribution level increases when the cost of health care or the probability of getting sick increases. However, when the income increases, the contribution level decreases.

(see Proof in Appendix 1).

For C1:

$$\theta_j = H.\bar{p}\,(\frac{p_j}{\bar{p}} - \frac{Y_j}{\bar{Y}}) \text{ and } \theta_j > 0 \Longleftrightarrow \frac{p_j}{\bar{p}} > \frac{Y_j}{\bar{Y}} \tag{11}$$

$$\theta_j^H = H(p_j - \bar{p}) \text{ and } \theta_j^H > 0 \Longleftrightarrow p_j > \bar{p} \tag{12}$$

$$\theta_j^V = \frac{H\overline{P}}{\overline{Y}}(\overline{Y} - Y_j) \text{ and } \theta_j^V > 0 \Longleftrightarrow Y_j < \overline{Y} \tag{13}$$

With C1, individuals benefit from horizontal redistribution if the level of risk is higher and from vertical redistribution if the income of people is lower than the average.

(see Proof in Appendix 1).

C2: Contribution level proportional to the probability of getting sick

C2 reimburses all health care with a contribution level proportional to the probability of getting sick.

We have

$$Hj = H$$

$$\tau j = P_j\,\delta, \delta > 0$$

Thus,

$$\delta = \frac{H\overline{P}}{\sum \frac{Nj\ p_j\ Yj}{N}} \tag{14}$$

$$\tau j = p_j \delta = p_j \frac{H\bar{p}}{\frac{\sum N_l p_l Y_l}{N}}. \tag{15}$$

The contribution level increases when the risk increases (see Proof in Appendix 1).

For C2:

$$\theta_j = p_j\, H\,(1 - Y_j \frac{\bar{p}}{\frac{\sum N_l p_l Y_l}{N}}) \text{ and}$$
$$\theta_j > 0 \Longleftrightarrow \bar{p} Y_j < \frac{\sum N_l\, p_l\, Y_l}{N} \tag{16}$$

$$\theta_j^H = H\,(p_j \bar{p}) \text{ and}$$
$$\theta_j^H > 0 \Leftrightarrow p_j > \bar{p} \tag{17}$$

$$\theta_j^V = \delta(\frac{\sum_l N_l P_l Y_l}{N} - p_j Y_j) \tag{18}$$

With C2, people benefit from horizontal redistribution if the level of risk is higher and from vertical redistribution if the health cost is lower (see Proof in Appendix 1).

2.4. Choice of a health insurance system

2.4.1. Direct vote

$$\text{The expected utility is: } \mathrm{EUj} = \mathrm{E}\,(\mathrm{U}(\mathrm{RN_J})) \tag{19}$$

U is an increasing and concave function.

A voter in Gj prefers C1 if:

$$EUj\,(C1) > EUj\,(C2) \tag{20}$$

C1 is preferred with more than 50% of the votes

Therefore, C1 is preferred if

$$\sum_{EU_j\,(C_1) > EU_j\,(C_2)} \alpha_j > 0,50 \tag{21}$$

2.4.2. Probabilistic vote

Hypothesis 1

βi is the bias in Gj in favor of C2. βi is independently distributed between groups and uniform in $[-\frac{1}{2w}, +\frac{1}{2w}]$, w is the degree of homogeneity [17, 18].

Hypothesis 2

Company maximizes the probability of winning.

$$\text{The expected utility is } \mathrm{EUj} = \mathrm{E}\,(\mathrm{U}(\mathrm{RN_J})) \tag{22}$$

U is an increasing and concave function.

C1 is preferred if

$$EUj\ (C1) > EUj\ (C2) + \beta_i. \tag{23}$$

3. Choice of the health insurance system by the direct voting model

$$\text{C1 is preferred if EUj (C1)} > \text{EUj (C2)}$$

$$EUj\ (C1) = \left(1\ \ p_j\right)\ U\left(Y_j\ \ \tau Y_j\right) + p_j U\left(Y_j\, \tau Y_j - H + H_j\right)$$

$$= U\ \left(Y_j - \tau Y_j\right),\ H_j = H$$

and

$$EUj\ (C2) = (1\ \ p_j)\ U(Y_j\, \delta p_j Y_j) + p_j\ U(Y_j\, \delta p_j Y_j - H + H_j)$$

$$= U\ \left(Y_j - \delta p_j Y_j\right),\ H_j = H$$

Thus,

$$EUj\,(C1) > EUj\,(C2) \Longleftrightarrow U\ \left(Y_j\,(1 - \tau\right) > U\,(Y_j\,(1 - \delta\, p_j).$$

Therefore,

$$EUj\,(C1) > EUj\,(C2) \Longleftrightarrow (1 - \tau) > \left(1 - \delta p_j\right)$$

$$EUj\,(C1) > EUj\,(C2) \Longleftrightarrow \tau < \delta p_j \text{ with } \delta p_j = \tau_j$$

$$EUj\;(C1) > EUj\;(C2) \Longleftrightarrow \frac{H\overline{P}}{\overline{Y}} < p_j \frac{H\overline{p}}{\frac{\sum N_l p_l Y_l}{N}}$$

C1 is preferred if it is allowed to have a lower contribution level. Finally, we obtain the following proposal:

Proposition 1

$$EU_J\,(X) > EUj\,(Y) \Longleftrightarrow \frac{1}{N}\sum_l N_l P_l Y_l < p_j\,\overline{Y}$$

$$\overline{PY} = \frac{1}{N}\sum N_l P_l Y_l$$

$$\Longleftrightarrow p_j > \frac{\overline{PY}}{\overline{Y}} \tag{24}$$

C1 is preferred if the risk level pj is higher. Indeed, with C2, high-risk individuals pay more.

In case where $p_1 < p_2 < \ldots < p_k$, we propose Proposition 2.

Proposition 2

There is an integer r, $1 < r < k$ *with* $p_1 < \ldots < p_r < \frac{\overline{PY}}{\overline{Y}} < p_{r+1} < \ldots < p_k$*, such as:*

Groups G1, G2,…, Gr prefer C2 *and Groups Gr+1, …, Gk* prefer C1.

Either $cov\,(p,\;Y)$ the covariance between wealth and disease such as:

$$cov\,(p,\;Y) = \overline{PY} - \overline{PY}$$

$$= \overline{Y}\,(\frac{\overline{PY}}{\overline{Y}} - \overline{P}) \tag{25}$$

If wealth and illness are not correlated, $\frac{\overline{PY}}{\overline{Y}} = \overline{P}$.

If wealth and illness are negatively correlated, which is empirically the most realistic case, we have $\frac{\overline{PY}}{\overline{Y}} < \overline{P}$.

Thus, C1 is preferred if more than 50% of individuals are as follows:

$$p_j > \frac{\overline{PY}}{\overline{Y}} \text{ so } P_{median} > \frac{\overline{PY}}{\overline{Y}} \tag{26}$$

$$p_j > \hat{P} \Longrightarrow P_{median} > \hat{P} \tag{27}$$

It is considered that $P_{median} < \overline{P}$ (a minority of people are frequently ill).

Proposition 3

If wealth and illness are not correlated or poorly correlated, then P_{median} *is* $< \frac{\overline{PY}}{\overline{Y}}$; thus, there is a majority for C2.

If wealth and illness are strongly negatively correlated, then P_{median} *is* $> \frac{\overline{PY}}{\overline{Y}}$; thus, there is a majority for C1.

4. Choice of the health system by the probabilistic voting model

For C1 and C2, $Hj = H$, thus

$$EUj\;(C1) = U\left(Y_j - \tau\,.Y_j\right)$$

$$EUj\,(C2) = U\,(Y_j - \tau_J.Y_j)$$

C1 is preferred if

$$\beta\, i < U\,(Y_j - \tau\,.Y_j) - U\,(Y_j - \tau_J.Y_j).$$

With the hypothesis of βi[1] independently distributed among groups and uniform in $[-\frac{1}{2w}, +\frac{1}{2w}]$, the share of voters supporting C1 is

$$P(\beta_i < U\,(Y_j - \tau\,.Y_j) - U\,(Y_j - \tau_J.Y_j))$$

$$= w\,[U\,(Y_j - \tau\,.Y_j) - U\,(Y_j - \tau_J.Y_j)\;(-\frac{1}{2w})]$$

$$= 1/2 + w[U\,(Y_j - \tau\,.Y_j) - U\,(Y_j - \tau_J.Y_j)] \tag{28}$$

The share of voters supporting C1 is $\frac{1}{2} + \sum_j \alpha_j\; w[U\,(Y_j - \tau\,.Y_j) - U\,(Y_j - \tau_J.Y_j)]$

Note:

$$D(C1, C2) = \sum \alpha_j\, w\,[U\,(Y_j - \tau\,.Y_j) - U\,(Y_j - \tau_J.Y_j)]$$

C1 is preferred if $D\;(X,\;Y)$ *is* > 0

If we replace τ and τ_j by

$$\tau = \frac{H\,.\,\overline{p}}{\overline{Y}} \text{ et } \tau_J = p_j\, H \frac{\sum\; N_l\, p_l}{\sum_j\; N_l pl\; Y_l}$$

$$D(C1, C2) = \sum \alpha_j [U\,(Y_j - \frac{H\,.\,\overline{p}}{\overline{Y}}\,Y_j) - U\,(Y_j - p_j\, H \frac{\sum\; N_l\, p_l}{\sum_j\; N_l pl\; Y_l}\,Y_j)]$$

$$= \sum \alpha_j [U\,(Y_j - \frac{H\,.\,\overline{p}}{\overline{Y}}\,Y_j) - U\,(Y_j - p_j \frac{H\overline{P}}{\sum \frac{N_l pl\; Y_l}{N}}\,Y_j)]. \tag{29}$$

The agents are not averse to risk

In this case, the utility function is linear, therefore, we propose another proposition (Proposition 4).

Proposition 4

If individuals are not averse to risk,

$$D(C1, C2) = 0 \tag{30}$$

1 βi *is a random uniform law variable on* $[-\frac{1}{2W}, \frac{1}{2W}]$*, so density f with :* $f(x) = w$ *if* $x \in [-\frac{1}{2W}, \frac{1}{2W}]$ and $f(x) = 0$ *if* $x \notin [-\frac{1}{2W}, \frac{1}{2W}]$.

There is no collective preference for C1 or C2 (see Proof in Appendix 1).

However, in health care insurance, this case is unrealistic as people are averse to risk.

The agents are averse to risk

The utility function is concave.

C1 wins if $D(C1, C2)$ is > 0

$$\text{Thus, } \sum \alpha_j \left[U\left(Y_j - \frac{H \cdot \bar{p}}{\bar{Y}} Y_j\right) > \sum \alpha_j \left[U\left(Y_j - p_j \frac{H\overline{P}}{\sum \frac{N_l p l\ Y_l}{N}} Y_j\right)\right]\right.$$

Since $\alpha_j = Nj/N$ (utilitarian criterion)

Therefore,

$$D(C1, C2) = \sum Nj/N \left[U\left(Y_j - \frac{H \cdot \bar{p}}{\bar{Y}} Y_j\right) - \sum Nj/N\left[U\left(Y_j - p_j \frac{H\overline{P}}{\sum \frac{N_l p l\ Y_l}{N}} Y_j\right)\right]\right. \quad (31)$$

Utility function

As people are averse to risk, the utility function must be increasing (first positive derivative) and concave (second negative derivative).

We assume that the utility function is logarithmic

$$U(x) = ln(x)$$

$$U'(x) = \frac{1}{x} > 0 \ et\ U''(x) = -\frac{1}{x^2} < 0$$

$$For\ U(x) = ln(x)$$

$$D(C1, C2) = \sum \frac{N_j}{N} \left[ln\left(Yj - \frac{H \cdot \bar{p}}{\bar{Y}} Yj\right) - ln\left(Yj - \frac{H \cdot \bar{p}}{\overline{PY}} p_J Yj\right)\right] \quad (32)$$

(see Proof Appendix 1).

Proposition 5

When the agents are averse to risk with $U(x) = ln(x)$, C1 wins if the correlation between wealth and illness is negative or null, and $D(C1, C2)$ *is* > 0.

C1 is preferred if the probability of getting sick is independent of the wealth criterion. Therefore, C1 is preferred if the poor are significantly sicker or the rich are less sick.

5. Discussion and implications for health policies

In this article, individuals living in a democracy were distributed into homogeneous groups, and were distinguished by their number in a group, the probability of getting sick, the contribution level, the net income, and health care cost. These variables are in line with the literature. Indeed, according to Wynand, healthcare consumption and income are determinants in the choice of health insurance, while it has been shown that the contribution level changed the health-seeking behavior [19]. Even, according to Mhere [20], household income, age, family size, and chronic illnesses are predictors of the choice behind a health insurance system.

People choose health insurance systems in a monopolistic scheme. The first health insurance system proposes a uniform contribution level, while the second health insurance system proposes a contribution proportional to the probability of getting sick. Two kinds of votes are used: a direct vote that involves a size effect and a company wins with more than 50% of votes and a probabilistic vote that involves a bias in favor of one company since there is an additional hazard and the agents vote for the other reason. Bias is a null random variable, thus there is no preferred system in this case.

In a direct vote, we found that a uniform contribution level is adopted if the level of risk is higher and if wealth and illness are negatively correlated. Indeed, in this case, high-risk individuals can benefit from the uniform contribution level without experiencing the increase in premium. Therefore, with the choice of contribution proportional to the probability of getting sick, high-risk individuals pay more. In a probabilistic vote, we found that a uniform contribution level is adopted if income and the probability of getting sick vary inversely; the poor are sicker or the rich are healthy. These results can be explained by the fact that the loss of wellbeing for low-income and sick people is more impactful.

Health insurance is unaffordable for many in the low-income population, where household budgets are small and even the most basic needs compete. Therefore, the choice of contribution proportional to the probability of getting sick could be unpopular among these people, especially if their risk level is high.

In many countries, the health insurance systems are weakened by a continuous increase in healthcare spending due to varied reasons such as the demographic factor, technological progress in treatments, and the coverage that depends on the political factor [15]. This last point has been discussed in this article with a reflection on the choice of two health coverage systems. These results emphasize that a risk/income duality is to be considered in any health coverage policy. Thus, any project that is drawn up to reform the health system must be preceded by a thorough reflection of the correlation between wealth and illness in the population.

According to the correlation, the willingness to pay for health insurance is not the same between individuals of various income and risk levels. Based on this observation, the government could consider locally or for a category of the population (high-risk, low-income, for example) an insurance with a price-controlled offer owing to a fixed rate, a prohibition on price increases by the insurer, the same level of coverage at the same cost, and the development of generic use for low-income and high-risk or specific packages of care with no incidence on quality.

This study is the first to use the welfare function and theoretical models to explain the choice that people have to make between two health insurance schemes. It can be useful to serve as the foundation for conducting empirical research. However, it would be interesting to introduce other conditions in the said models, such as partial reimbursement, or other factors, such as age, education level, or the level of democracy. Even, empirical studies would be interesting to confirm these results.

In conclusion, a uniform contribution level system is adopted if wealth and illness are negatively correlated. These results suggest that politicians need to adapt their formulation of health insurance by targeting locally the level of correlation between wealth and disease in the population through some of the avenues outlined earlier.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

The author confirms being the sole contributor of this work and has approved it for publication.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Appendix 1

Proofs

Proof 1:

$$\theta_j = pj\,Hj - \tau j\,Yj$$
$$\sum N_j\, j = \sum N_j\, p_j\, H_j\ \sum N_j\, \tau j\, Y_j$$
$$= (5) - (4)$$
$$= 0\,(BC)$$
$$So: \sum N_j\, \theta_j = 0$$

Proof 2:

$$Hj = H$$
$$\tau j = \tau$$
$$\text{CB become}: \tau \sum_j \text{NjY}_j = \text{H} \sum \text{Njp}_j$$
$$\tau = H.\frac{\sum Njp_j}{\sum_j Nj\,Y_j} = \frac{H\,\frac{\sum N_j p_j}{N}}{\frac{\sum_j Nj\,Y_j}{N}}$$

Proof 3:

$$\theta_j = p_j\,Hj - \tau j\,Y_j = pj\,H - \frac{H\overline{p}}{\overline{Y}}\,Y_j = H.\overline{p}\,(\frac{p_j}{\overline{p}} - \frac{Y_j}{\overline{Y}})$$
$$\theta_j > 0 \iff \frac{p_j}{\overline{p}} > \frac{Y_j}{\overline{Y}}$$
$$\theta_j^H = p_j\,H - H\,\frac{\sum_l N_l p_l}{N} = H\,(p_j - \overline{p})$$
$$\theta_j^V = \frac{\sum_l N_l \tau\, Y_l}{N}\,\tau\, Y_j = \tau\,(\overline{Y} - Y_j) = \frac{H\overline{P}}{\overline{Y}}\,(\overline{Y} - Y_j)$$

Proof 4:

$$(6) \to : \sum_j Nj\tau j\,Y_j = \sum NjHj\,p_j$$

Thus:

$$\delta \sum_j Njp_j\,Y_j = \sum NjH\,p_j \ \text{ and } \delta = \frac{\text{H}\sum \text{Nj}\,\text{p}_\text{j}}{\sum \text{Njpj Yj}} = \frac{\text{H}\sum \frac{\text{Nj pj}}{\text{N}}}{\sum \frac{\text{Nj pj Yj}}{\text{N}}}$$

Proof 5:

$$\theta_j = p_j\,Hj\ \tau j\,Y_j = p_j\,H - pj\,\frac{H\sum N_l\,p_l}{\sum_l N_l pl\,Y_l}\,Y_j =$$
$$p_j\,H\,(1 - \frac{Yj\sum N_l\,p_l}{\sum_l N_l pl\,Y_l})$$
$$\theta_j > 0 \iff \sum_l N_l p_l\,Y_l > (\sum_l N_l p_l)\,Y_j$$
$$\theta_j > 0 \iff Y_j < \frac{\sum N_l\,p_l\,Y_l}{\sum_l N_l pl}$$
$$\theta_j^H = pj\,Hj - \frac{\sum_l N_l p_l H_l}{N} = pj\,H - H\,\frac{\sum_l N_l p_l}{N}$$
$$\theta_j^V = \frac{\sum_l N_l \tau_l Y_l}{N}\,\tau j\,Yj = \delta\,\frac{\sum_l N_l P_l Y_l}{N} - Pj\delta Yj$$

Proof 6:

$$\text{C1 wins if D(C1, C2)} > 0$$
$$D(C1, C2) = \sum \alpha_j [U\,(Yj - \frac{H\,.\,\overline{p}}{\overline{Y}}\,Yj) - \sum \alpha_j [U\,(Yj - pj\,\frac{H\overline{P}}{\sum \frac{N_l pl\,Y_l}{N}}\,Yj)]$$
$$\text{The agents are not risk averse, we suppose}:$$
$$U\,(x) = x$$
$$D(C1, C2) = \sum \alpha_j\,[(Yj - \frac{H\,.\,\overline{p}}{\overline{Y}}\,Yj) - (Yj - pj\,\frac{H\overline{P}}{\sum \frac{N_l pl\,Y_l}{N}}\,Yj)]$$
$$= \sum \alpha_j\,[(-\frac{H\,.\,\overline{p}}{\overline{Y}}\,Yj) + pj\,\frac{H\overline{P}}{\sum \frac{N_l pl\,Y_l}{N}}\,Yj]$$
$$\alpha_j = Nj/N\ so:$$
$$D(C1, C2) = -\sum Nj/N\ Yj\,\frac{\overline{P}H}{\overline{Y}} + \sum \frac{\mathbf{Nj}}{\mathbf{N}}\,Yj\,pj\,\frac{H\overline{P}}{\sum \frac{N_l pl\,Y_l}{N}}$$
$$= -H\overline{P} + H\overline{P} = 0$$

Proof 7:

$$D(C1, C2) = \sum \frac{N_j}{N}\,[U\,(Yj - \frac{H\,.\,\overline{p}}{\overline{Y}}\,Yj) - U\,(Yj - \frac{H\,.\,\overline{p}}{\overline{PY}}\,pj\,Yj)]$$
$$U(x) = ln\,(x) \Rightarrow$$
$$D(C1, C2) = \sum \frac{N_j}{N}\,[\,ln\,(Yj - \frac{H\,.\,\overline{p}}{\overline{Y}}\,Yj) - ln\,(Yj - \frac{H\,.\,\overline{p}}{\overline{PY}}\,pj\,Yj)$$
$$D(C1, C2) = \sum \frac{N_j}{N}\,[\,ln\,(1 - \frac{H\,.\,\overline{p}}{\overline{Y}}) - ln\,(1 - \frac{H\,.\,\overline{p}}{\overline{PY}}\,pj)]$$
$$D(C1, C2) = ln\,\left(1 - \frac{H\,.\,\overline{p}}{\overline{Y}}\right) - \sum \frac{N_j}{N}\,ln\,(1 - \frac{H\,.\,\overline{p}}{\overline{PY}}\,pj)$$
$$\sum \frac{N_j}{N}\,ln\,(1 - \frac{H\,.\,\overline{p}}{\overline{PY}}\,pj) < \ln\,(1 - \frac{H\,.\,\overline{p}}{\overline{PY}}\,\overline{P})$$
$$\text{by concavity of ln function}$$
$$\text{And ln}\,(1 - \frac{\text{H}\,.\,\overline{\text{p}}}{\overline{\text{PY}}}\,\overline{\text{P}}) < \ln\left(1 - \frac{\text{H}\,.\,\overline{\text{p}}}{\overline{\text{Y}}}\right)$$
$$\text{because } \overline{\text{PY}} \leq \overline{\text{P}}\overline{\text{Y}} \text{ (negative or no correlation)}$$
$$\text{So}: (\text{C1}, \text{C2}) > \ln\,(1 - \frac{\text{H}\,.\,\overline{\text{p}}}{\overline{\text{Y}}}) - \ln\left(1 - \frac{\text{H}\,.\,\overline{\text{p}}}{\overline{\text{Y}}}\right) = 0.$$