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Separating selection and incentive effects in health insurance

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**Keywords : Health insurance, demand for health care,
moral hazard, adverse selection, full maximum likelihood
estimation**

SEPARATING SELECTION AND INCENTIVE EFFECTS IN HEALTH INSURANCE

Lucien Gardiol Pierre-Yves Geoffard
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Abstract

This paper provides an analysis of the health insurance and health care consumption. A structural microeconomic model of joint demand for health insurance and health care is developed and estimated using full maximum likelihood method using Swiss insurance claims data for over 60 000 adult individuals. The estimation strategy relies on the institutional features of the Swiss system, in which each individual chooses among the same menu of contracts, ranked by the size of their deductible.

The empirical analysis shows strong and robust evidence of selection effects. Nevertheless, once selection effects are controlled for, an important incentive effect (“ex-post moral hazard”) remains. A decrease in the co-payment rate from 100% to 10% increases the marginal demand for health care by about 90% and from 100% to 0% by about 150%. The correlation between insurance coverage and health care expenditures may be decomposed into the two effects: 75% may be attributed to selection, and 25 % to incentive effects.

KEYWORDS: Health insurance, demand for health care, moral hazard, adverse selection, full maximum likelihood estimation

1 Introduction

Standard insurance theory predicts that expenditures and coverage should be positively correlated, for two main reasons. First, individuals who expect high health care costs may choose a more generous coverage (*selection effect*)². Second, a more extensive coverage may increase health costs (*incentive effect*), either through an increase in the probability to experience sickness (ex ante moral hazard) or through an increase in expenditures in a given health state (ex post moral hazard).

Even if these two explanations revert the causality relationship between costs and coverage, they are quite difficult to separate empirically, especially on cross sectional data (see, e.g., Chiappori and Salanié (2000)). However, the selection versus incentive effects puzzle can be solved in different ways. The Rand Health Insurance Experiment (RHIE) in 1974 conducted a randomised experiment to estimate how demand responds to changes in price of

¹We thank CSS and Konstantin Beck for providing data and many insights, Ramses Abul Naga, Pierre-André Chiappori, Alberto Holly, Pravin Trivedi, Stefan Felder, and Martin Schellhorn for discussions and suggestions, seminar and conference participants at Toronto (CHERA: 9th Canadian Conference on Health Economics), Taipei (National Taiwan University), Paris (Fifth European Congress in Health Economics, and CEPR Public Policy Symposium), São Paulo (LAMES), Lund (Eleventh European Workshop on Econometrics and Health Economics), and Venice (CES-ifo Summer Institute). Financial support from the Swiss National Fund for Scientific Research (PNR 45) is gratefully acknowledged. Remaining errors are ours.

²We limit the term of *adverse* selection to the situation in which insurance firms compete in contracts and attempt to selectively attract good risks; this is possible only if there is a selection effect in the sense defined above, but market regulation in Switzerland prevents adverse selection as far as basic health insurance is concerned.

health care (Newhouse and The Insurance Experiment Group (1996), Manning et al. (1998)). Some natural experiments were also exploited (Chiappori et al (1998), Eichner (1998)). Finally many studies estimate simultaneously the demand for insurance and the demand for health care to identify both effects (Cameron et al (1988), Dowd (1991), Holly et al (1998), Cardon and Hendel (2001), Schellhorn, (2001), Werblow and Felder (2003)). To address this issue, the present paper develops a structural microeconomic model of joint demand for health insurance and health care, and estimate the model on Swiss data by the full maximum likelihood method.

Since the RHIE gives, in a very robust way, estimation of incentive effects, most of the recent studies take these results as a reference and concentrate on showing evidence of selection effects (Cutler and Zeckhauser (2000)). Cutler and Reber (1998) show some descriptive evidence of selection effects through the “Harvard death spiral”; Cameron et al. (1988) find that socio-demographic and some health variables explain the choice of insurance but do not test for the effect of unobservable variables. However, Dowd et al. (1991), Cardon and Hendel (2001) and Jones et al. (2002) test for selection effects through unobservable variables and find no significant evidence. If the intuition and the descriptive statistics seems to plead in favor of selection effects, robust empirical evidence is difficult to find. This difficulty may stem from the diversity of health insurance plans on many various dimensions. Coverage of ambulatory care, hospital care, or drugs costs, may substantially differ from one plan to an other, and this often makes it impossible to rank contracts in terms of extent of coverage.

In Switzerland, mandatory health insurance plan differs only from one

variable (deductible) between people. This gives a perfect field of investigation for selection and incentive effects. Moreover, a growing evidence of selection issue emerges from Swiss data (Schellhorn (2001), Werblow and Felder (2003), Lehmann and Zweifel (2005)). Gardiol, Geoffard and Grandchamp (2005) also shows that both effects are present in Switzerland.

The main finding of the paper is that even though selection effects are very important, incentive effects are also present, and far from being negligible: a decrease in the co-payment rate from 100% to 10% increases the marginal demand for health care by 88%; a decrease from 100% to 0% increases marginal demand by 150%. In a short way, we estimate that selection effects explain about three quarters of the observed correlation between insurance coverage and health care expenditures, with the remaining quarter explained by incentive effects.

Section 2 presents the Swiss health insurance system and our data. Section 3 develop a structural microeconomic model of joint demand for health insurance and health care. A parametric version of this model is estimated in section 4. We conclude in section 5.

2 The Swiss health insurance system

2.1 Overall description

The Swiss health insurance system offers interesting features that can be used to test for the presence of asymmetric information. Even if it seems reasonable that, in any system, each individual selects the best contract given his/her preferences and information, selection occurs only when this

information is hidden to the insurer, or when it is observed but cannot be used for risk selection or contract pricing. This latter case corresponds to the Swiss health insurance system.

In Switzerland, health insurance is a two-tier system. Since 1996, according to the federal Law on Health Insurance (LAMal), all individuals must subscribe to one among several sickness funds. Each fund covers outpatient expenditures (a bundle of health goods and services defined by law), and half of inpatient expenditures, the other half being covered by the State.

All insurance contracts include: a deductible on yearly expenditures, a co-payment rate of 10% once the deductible level has been reached (and a fixed daily contribution of SFr 10 in case of hospitalisation), and a cap on yearly payments equal to SFr 600 (approximately 400 euros) in addition to the deductible. Private non-for profit insurance firms offer a menu of such contracts, that differ in terms of deductibles and premiums. Since 1998, deductibles can be equal to SFr 230, 400, 600, 1 200, or 1 500³. Premiums vary across insurance funds, but are identical for all risk groups, for a given deductible. In particular, no price discrimination based upon age, gender, or health condition, is allowed. A risk adjustment scheme between insurance funds reduces the incentives to select risks. Moreover, the range of premium reductions for individuals who choose a higher deductible rather than the basic one of SFr 230 is also limited by law; the explicit motivation of such a regulation was to implement some redistribution between risk groups,

³Since the 1st January 2004, the cap on yearly payments is equal to SFr 700 and the lower deductible is equal to SFr 300 rather than SFr 230. At current exchange rates, 1 SFr is approximately equivalent to 0.65 euros, or 0.83 US dollars.

since it was assumed that high risks individuals would rather opt for small deductibles.

In short, the law introduced mandatory deductibles and co-payments to address moral hazard issues, imposed uniform premiums and risk adjustment to address selection issues, and regulated premium reductions to implement some form of redistribution explicitly based on self selection. Finally, redistribution to some specific groups (low income) take the form of premium subsidies directly paid by each State (*Canton*).

In addition to this mandatory health insurance, individuals may also subscribe to a supplementary insurance, that covers additional goods and services considered to be “comfort” services, such as a single hospital room, coverage of alternative medicine, etc. The supplementary insurance contract may be subscribed at a different insurance firm than the mandatory one, even though not many individuals use this option.

A particularly interesting feature of the Swiss system is that, as far as “basic” insurance is concerned, the menu of contracts offered to each individual is the same for every individual. This is an important element. Put simply, theory predicts a selection effect⁴: each individual chooses the best contract, and empirical estimation needs to compare the preferred contract with other alternatives, which determine the opportunity cost (Cardon and Hendel (2001)).

A first question we may ask is why different individuals choose different

⁴Since insurance funds cannot compete in contracts, there is *no* adverse selection *stricto sensu* in Switzerland. However, individuals may self select themselves into the most adapted contracts, given their private information.

levels of deductible. The main reason seems to be related to health status: different expectations about future expenditures may lead high risk individuals to self-select among plans with more extensive coverage (i.e., lower deductible). Other reasons may play a role as stickiness, differences in risk aversion, time preference or cash constraints (the premium being paid in advance), but the data does not contain the information needed to analyse these points.

2.2 Data

We use administrative data provided by CSS, one of the largest private (non for profit) insurance firms in Switzerland. For each adult individual covered, we observe the amount of yearly health care expenditures as known by CSS, for individuals living in the Canton de Vaud, the Swiss State that includes the city of Lausanne. The data set contains information on 62 415 individuals, and covers four years (1997 to 2000) which represent 199 019 observations.

It is important to stress out that individuals need to address all health care bills to the insurer if they want to be reimbursed; in some cases (inpatient care, and prescription drugs) the insurer first pays the bill, and then charges the amount due (deductible, co-payment, daily contribution to hospital housing costs) to the insured. Therefore, the bill may be received by the insurer, even before the deductible level has been reached and the individual has an incentive to report an expenditure. This administrative data can reasonably be assumed to be highly reliable (at least above the deductible level) in the sense that they include most actual health care expenditures (and all inpatient care expenditures) for the given population. An other benefit of

such data is the number of observations: exhaustive health care expenditures for more than 60 000 individuals followed up for four years is certainly highly valuable information.

Unfortunately, this administrative data provides few variables (with respect to survey data), and this strongly conditions the econometric analysis. Specifically, the following variables are available in our data set:

- Gender
- Birthyear
- Annual total health costs per insured (outpatient, inpatient and drugs) for 1997 to 2000
- Deductible for 1997 to 2000

Our sample may not be representative of the Swiss population, or even of the population of the Canton de Vaud. However, concentrating on a specific geographic area may reduce unobserved heterogeneity and increase robustness of results. The descriptive statistics of our work data set are presented in Table 1.

2.2.1 Data preparation and descriptive statistics

The original data set contains 62 415 individuals. In order to focus only on our specific problem and to consider yearly observations of each individual as independent, we exclude all observed sources of exogenous heterogeneity. We restrict the empirical analysis to a sub-sample composed of the following individuals:

- men (in our data, we cannot identify pregnancy costs, fully covered by insurance funds)
- who stayed at CSS from Jan 1, 1997 until Dec 31, 2000 (this excludes people who died or switched to another insurance fund)
- who kept the same deductible level during the whole period (only 13% of our sample changed their deductible at least once during the four years)
- older than 25 (children and younger adults face a different menu of contracts)
- who did not receive a premium subsidy. Individuals eligible to the subsidy receive from the State a fixed percentage of the premium (eligibility condition, and subsidy rate, are based upon income; the subsidy can cover up to 100 % of the premium), and hence have a stronger incentive to opt for a low deductible.
- not eligible to disability pension benefits in any of the four years (eligibility is based on severe health conditions, and a specific public insurance fund covers health care expenses).

The final data set contains 7 885 individuals observed between 1997 and 2000 (which means 31 540 observations). Table 1 presents the population descriptive statistics of our work data set.

Notice that the proportion of agents with no health expenditures dramatically increases with the deductible level. At the opposite, the proportion of high health expenditures decreases strongly with the deductible level. This

Table 1: Descriptive statistics of health expenditures across deductible

Deductible	230	400	600	1 200	1 500	all
	Number of observations					
Age 26-35	929	556	1 081	467	649	3 682
Age 36-45	1 781	870	1 903	869	902	6 325
Age 46-55	2 861	1 202	2 058	803	609	7 533
Age 56-65	2 719	1 069	1 625	490	319	6 222
Age 66-75	2 423	883	963	292	144	4 705
Age 76-85	1 594	439	383	140	45	2 601
Age >85	325	65	35	39	8	472
<i>N</i> =	12 632	5 084	8 048	3 100	2 676	31 540
	Annual Health Expenditures					
Mean	3 474.6	2 648.3	1 872.5	1 327.5	614.1	2 478.9
<i>Std. Deviation</i>	6 512.9	4 814.9	3 767.7	4 150.4	2 430.5	5 240.3
Mean if participation	4 127.0	3 239.7	2 667.7	2 703.9	1 682.0	3 408.3
[0]	16%	18%	30%	51%	63%	27%
]0; 1 500]	33%	37%	37%	28%	27%	33%
]1 500; 7 500]	40%	37%	28%	17%	8%	32%
]7 500]	11%	8%	5%	4%	2%	8%

table shows a positive correlation between insurance coverage and health expenditure. As said in the introduction, such a positive correlation may be due to incentive effects, to selection effects, or to both. The rest of the paper provides a way to separate these two effects.

2.2.2 Death and the deductible

A first direct evidence of self-selection behavior is given by the analysis of individuals who died during the four year period (Gardiol et al. (2005)). Table 2 shows that the mortality rate dramatically decreases with the deductible level⁵. Since insurance coverage certainly does not increase the incentive to die, this provides a strong evidence of selection effects: individuals with a higher probability to die select lower deductibles, which may reveal that they rationally expect very large health care expenditures at the end of their life.

Table 2: Mortality rate per class of age and deductible (in per thousand)

Class of age	[21-50]	[51-64]
Deductible 230	9.8	38.1
Deductible 400	3.6	22.3
Deductible 600 and more	3.1	16.3

We also performed a logit estimation in order to control for gender, and non linear effects of age (age, age², and age³ were included in the regressors).

⁵We group the three highest deductible level since the number of observations is too low to compute a reliable mortality rate.

Figure 1: Probability to die per age for men

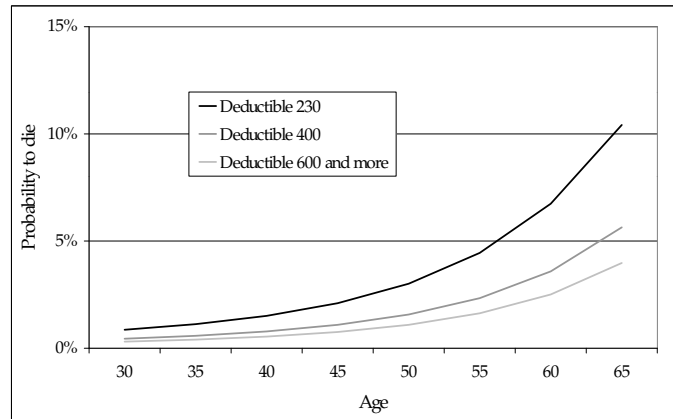


Figure 1 shows the average estimated probability to die for men between 21 and 64 years old. The differentiated level of probability to die across deductible level shows the presence of a selection effect.

Such strong evidence of selection effects induces us to develop a structural model in order to estimate simultaneously incentive and selection effects.

3 Structural model

This section presents a structural microeconomic model of joint demand for health insurance and health care, adapted to the Swiss institutional features. The parametric version of this model is estimated in the next section. To keep the analysis as tractable as possible, we assume a one period model with two stages. In the first stage, the agent observes some private information

and chooses her insurance contract among the offered menu. In the second stage, an uncertain health state is realised, and the agent consumes health care and other goods.

3.1 Setup

3.1.1 Information

We assume that ex ante, the agent has some private information θ about her future health. Ex post, her health state h is drawn from a distribution conditional on θ , denoted by $\mu(\cdot|\theta)$. A large value of θ indicates good health, in the sense that $\mu(\cdot|\theta')$ stochastically dominates $\mu(\cdot|\theta)$ at the first order when θ' is larger than θ . An example is $h = \theta + \varepsilon$, where ε is drawn from a distribution independent of θ . Health state h is observed by the agent, but not by the insurer.

3.1.2 Preferences

Once the health state is known to the agent, she chooses to allocate her wealth between health care consumption (which monetary cost is determined by the insurance contract) and other consumption goods. We denote by $y \in \mathbb{R}^+$ the total amount of health care used by the individual, and by $c \in \mathbb{R}^+$ a composite consumption good. The marginal rate of substitution between health care must be affected by health, and a simple way to model this assumption is to assume that preferences are represented by the following Cobb-Douglas utility function:

$$u(c, y, h) = b(h) + \alpha(h) \ln(c) + (1 - \alpha(h)) \ln(y),$$

with: $\alpha(h) \in [0, 1]$, monotonically increasing with h from 0 to 1, and $b(h)$ increasing with h . The marginal rate of substitution between health care and consumption is equal to $((1 - \alpha(h))/\alpha(h)) (c/y)$, and hence for any (c, y) it decreases with h from $+\infty$ to 0. Bad health (small h , α close to 0) induces a large *MRS* for health care.

3.1.3 Budget set

We take the consumption good c as a numeraire, and denote by p the full monetary unit cost of health care. Hence, if the individual was not insured, she would pay py . Notice that, given that half of hospital expenditures are paid by the State, the insured cost py represents the full cost of ambulatory care and half of inpatient costs.

An insurance contract is characterized by a deductible D , a co-payment rate τ , and a cap on expenditures that we denote by $D + \tau K$. As said above, in Switzerland contracts differ by their deductible level D , but the co-payment rate is identical across contracts ($\tau = 10\%$), as well as the maximal amount of annual out-of-pocket health expenditure beyond the deductible (equal to SFr 600, which corresponds to $K = 6000$). We denote the insurance premium by $P(D)$. Insurance contracts only cover monetary costs, and therefore the total monetary co-payment is given by: $\min\{py, D + \tau(py - D), D + \tau K\}$.

The consumption of health care also induces non monetary costs, for example travel and time costs. In practice, such costs may be related to the opportunity cost of time and to the distance to the point of service. However, our data does not contain information on those variables. In order to keep the model as simple as possible, we assume that non monetary unit costs are

proportional to monetary prices: $k = ap$. We assume that these costs are not covered by health insurance and are added to the cost of care. The total treatment cost for the patient equals the sum of the out of pocket payment and the non monetary costs.

The available income is denoted by W_0 . At the time of consumption, the agent has paid the premium $P(D)$, thus the available income is $W = W_0 - P(D)$. We can now characterise the budget set at the time of health care consumption. In fact, since the marginal cost of care decreases with the quantity consumed, the budget set is not convex. However, it is the union of three budget sets $B(W, t)$, each one corresponding to a co-payment rate $t \in \{0, \tau, 1\}$: $B(W, t) = \{(c, y) | c + p(t + a)y \leq W(t)\}$, with:

- $W(1) = W$
- $W(\tau) = W - D(1 - \tau)$,
- $W(0) = W - D - \tau K$.

In the first case, the total cost is $c + p(a + 1)y$, and the marginal monetary cost of health care is p . In the second range, the total cost is $c + pay + \tau(py - D) + D$ and the marginal monetary cost of y is τp . In the third range, the agent consumes above the cap; the marginal monetary cost of health care is zero, and the total cost of (c, y) is $c + pay + D + \tau K$. In short, the first case corresponds to a large marginal cost and a small fixed cost, and the latter case to a small marginal cost and a large fixed cost.

Keeler, Newhouse, and Phelps (1977) address the issue of a marginal price which decreases with the quantity consumed. They build a theoretical model in which a consumer takes a sequence of decisions; at each time t ,

the consumer computes her marginal cost, which under rational expectations depends on the expected distribution of annual expenditure, conditional on the information at time t (in particular, on past expenditures so far). Unfortunately, our data does not contain information on the timing of health care consumption within a given year. Hence we adopt a perfect foresight assumption: on January 1, the consumer learns h , her health condition for the whole coming year, and decides the total amount of care she will consume in that year.

3.1.4 Choice

The timing of the decision problem is the following:

1. Stage 1: The agent privately observes θ . She chooses her deductible level D among the given menu:

$$\max_D E[v(W_0 - P(D), \tilde{h}, D)|\theta]. \quad (1)$$

2. Stage 2: The health state h is revealed, and the agent consumes (c, y) :

$$v(W_0 - P(D), h, D) = \max_{(c,y) \in B(W_0 - P(D), t)} u(c, y, h). \quad (2)$$

In this setup, the existence of a selection effect is due to the fact that a larger value of θ (a better expected health) will lead to the choice of a larger deductible D (a lower coverage), as Proposition 2 below will show. Thus observing a larger value of D (a lower coverage) reveals a larger value of θ (a better expected health); since the distribution of $(h|\theta)$ increases with θ , Bayes' law implies that $(h|D)$ increases with D .

3.2 Stage 2: incentive effect

We solve this model by backward induction, and start with the choice of health care expenditure, given a contract D .

The following proposition characterises the solution to problem (2).

Proposition 1 *Assume $W > D(1+a) + K(\tau+a)$. There exist two functions $h^1(D)$ and $h^2(D)$, both decreasing with D , with $h^2 \geq h^1$, and two scalars λ_0 and λ_τ with $\lambda_0 > \lambda_\tau > 1$, such that the solution to problem (2) is given by:*

- *If $h > h^2(D)$, then health care consumption is below the deductible: $t^* = 1$, and $y(W, h, D) = Y(W, h)$;*
- *If $h \in [h^1(D); h^2(D)]$, then health care consumption is between the deductible and the cap: $t^* = \tau$, and $y(W, h, D) = \lambda_\tau Y(W, h)$;*
- *If $h < h^1(D)$, then health care consumption exceeds the cap: $t^* = 0$, and $y(W, h, D) = \lambda_0 Y(W, h)$,*

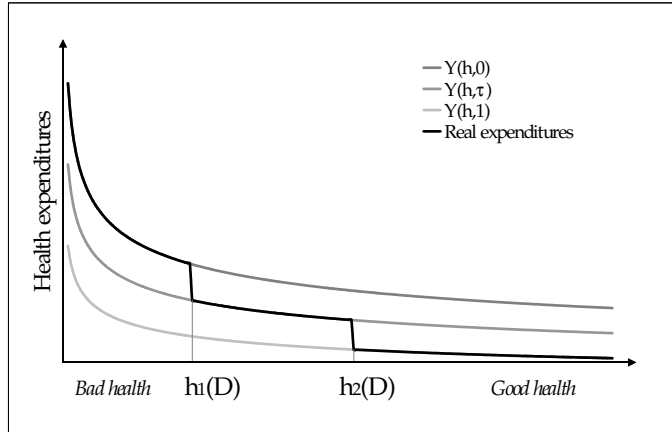
where $Y(W, h)$ is given by: $Y(W, h) = \frac{(1-\alpha(h))W}{p(1+a)}$.

PROOF: See Appendix.

The intuition of this proposition is straightforward. First, given D , the co-payment rate is determined by the realisation of h . The co-payment rate at the optimal consumption level depends on health h : good health lowers health care consumption and therefore increases t .

When h decreases but remains in the same range with respect to h^1 and h^2 , demand for health care smoothly increases: the marginal cost of health care is not changed, but the marginal rate of substitution between health

Figure 2: Demand for health care per co-payment rate



care and consumption increases. However, at the margin $h = h^2$, when h decreases from $h^2 + \varepsilon$ to $h^2 - \varepsilon$, the marginal monetary cost of health care drops from 1 to τ : this price effect is a pure *ex post* “moral hazard” incentive effect, which leads to a discontinuous increase in y by a factor $\lambda_\tau > 1$ (and a discontinuous decrease in c). The same holds at the other margin, for $h = h^1$.

This proposition states that (ex post) demand can be written as a “natural demand” $Y(W, h)$, that would correspond to the demand for health care if no monetary costs were insured, multiplied by a factor λ , which is a function of the co-payment rate.

Figure 2 shows the demand for health care as a function of h , for a given value of D . Under no coverage (i.e. a co-payment rate of 100%), health care demand would be equal to $Y(W, h) \equiv \bar{y}(W, h, 1)$, the demand under a monetary price of $1.p$, for any value of h . However, for values of

h smaller than $h^1(D)$, total health care consumption is above the cap, so that the co-payment rate is 0%, and the demand increases from $\bar{y}(W, h, 1)$ to $\bar{y}(W, h, 0) = \lambda_0 Y(W, h)$. Notice that a change in D does not change the “natural demand” $Y(W, h)$, but it affects the threshold values $h^1(D)$ and $h^2(D)$: an increasing deductible induces a shift to the left of these values, therefore reducing demand for *some* realizations of h .

The threshold values depend on the deductible, and are directly determined by the function $\alpha(\cdot)$. Hence, if preferences differ across individuals in the sense that this function $\alpha(\cdot)$ is different, this will imply that the threshold values h^1 and h^2 depend on the individual. A larger value of α induces a lower marginal rate of substitution for health care, and smaller threshold values.

3.3 Stage 1: selection effect

We can now turn to Stage 1, and characterise the choice of deductible. The optimal deductible is the solution to the problem:

$$\max_{D \in \{230, 400, 600, 1200, 1500\}} E[v(W_0 - P(D), \tilde{h}, D) | \theta]. \quad (3)$$

Private information θ about the distribution of future health h affects the trade off between different values of D , as the following proposition shows.

Proposition 2 *Assume $W > D + \tau K$. The marginal change of expected utility due to a marginal increase in D is given by:*

$$\frac{\partial E[v | \theta]}{\partial D} = C_0 + C_1 P(h \leq h^1(D) | \theta) + C_2 P(h \geq h^2(D) | t),$$

where C_i depend on (W, D, τ, K) , with $C_1 < 0$, $C_2 > 0$, $C_0 + C_1 < 0 < C_0 + C_2$.

Hence, the optimal value of D , solution to problem (3), increases with θ .

PROOF: See Appendix.

First, notice that if the distribution of health is very favorable, such that for any D , $P(h > h^2(D)) = 1$, then we have that $\partial E[v|\theta]/\partial D = C_0 + C_2 > 0$: it is always optimal to have D as large as possible; similarly, when $P(h < h^1(D)) = 1$ for any D (very bad expected health), then $\partial E[v|\theta]/\partial D = C_0 + C_1 < 0$, and the best D is the lowest. Now, for $\theta' > \theta$, we know that $\mu(\cdot|\theta')$, the distribution of h conditional on θ' , dominates at the first order $\mu(\cdot|\theta)$. This implies in particular that $P(h < h_1|\theta') < P(h < h_1|\theta)$, and $P(h > h_2|\theta') > P(h > h_2|\theta)$. Since $C_1 < 0$ and $C_2 > 0$, this implies that for any D , $\partial E[v|\theta]/\partial D$ increases with θ . In short, when θ is larger, the marginal net benefit of increasing D is also larger. This implies that the larger θ , the larger the optimal value deductible D^* .

All other things equal, a smaller θ increases the probability to be below the cap ($h < h^1$) or above the deductible ($h < h^2$). Therefore it increases the expected marginal effect of the deductible on out-of-pocket expenditures. When the agent faces the trade off between a premium reduction ($P'(D) < 0$) and increased out-of-pocket expenditures, a higher θ indicates that contracts with larger deductible levels will be preferable.

Notice that the same holds under some heterogeneity in preferences, as represented by differing functions $\alpha(\cdot)$. What matters is that people who expect a small marginal rate of substitution for health care, whether this is due to good health or a low α , will opt for a larger deductible level.

3.4 Specification

Proposition 2 implies that the set of all possible values of θ can be split into intervals $[\theta^i, \theta^{i+1}]$ (some of these intervals may be actually empty) such that $D^i \in \{230, 400, 600, 1200, 1500\}$ is preferred if and only if $\theta \in [\theta^i, \theta^{i+1}]$. Therefore, observing a deductible level D^i makes it possible to infer that $\theta \in [\theta^i, \theta^{i+1}]$.

Notice however that some individuals did not behave according to equation (1). In the years considered (1997 to 2000), premiums displayed a very odd pattern: some contracts were dominated, in the sense that they led to a total payment on health care (insurance premium and out-of-pocket health expenditure $P(D) + C(y; D)$) higher than another contract under *any* realization of y . Figure 3 shows the total payment on health care for the whole range of health care expenditures, for the five contracts under consideration, in year 1999 (the other years show similar patterns). We can easily see that it was *never* optimal to buy a contract with a deductible of 230 Sfr, since the deductible of 600 or 1 500 Sfr led to a lower total expenditure in *any* situation. However, for individuals who expect a high demand, the difference is very small (Sfr 100 or Sfr 7 per year, respectively), and the computation may be difficult to perform. Hence, we replace the insurance coverage choice equation (1) with a logit choice model (Luce and Raiffa (1957), McFadden (1974)):

Denote by $X_i(\theta) = E[v(W_0 - P(D_i), \tilde{h}, D_i) | \theta]$. We assume that the probability that the agent chooses the deductible D_i is given by:

$$P(D^* = D_i|\theta) = \pi_i(\theta) \equiv \frac{\omega_i X_i^{-\rho}(\theta)}{\sum_j \omega_j X_j^{-\rho}(\theta)},$$

where ρ may be interpreted as the “degree” of rationality; with $\rho = 0$, choice is done at random, without any consideration to relative costs and benefits of alternative choices; with $\rho = +\infty$, choice is perfectly rational in the sense that $\pi_i = 1$ for the largest X_i , and 0 for all other values.

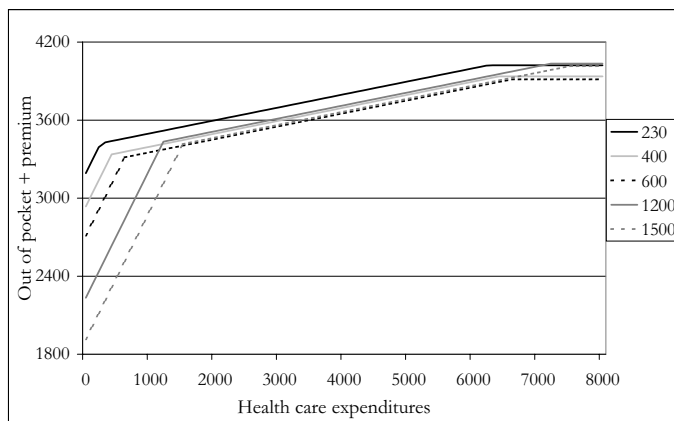
The weights ω_i represent psychological biases that may favor some values of D . In particular, ω_{230} may be considered as larger than the other weights, since the deductible 230 is labeled as “basic” while the others are labeled as “option”. Moreover, the deductible 230 corresponds to the historical one, and inertia may lead people to keep their deductible at this level.

With this limited rationality setting the main conclusion from the structural model remains unchanged: Individuals in *good* health (a higher θ), have a larger probability to choose a larger D so that observing a larger value of D (a lower coverage) reveals a higher *expected* value of θ (a better health)

Rather than specifying the assumption on the distribution on θ , and the distribution of $Y(W, h)$ conditional on θ , we specify the distribution of demand in the following way. Firstly, since we do not observe income W in the data, we model the demand $Y(h) \equiv E(Y(\tilde{W}, h))$, where the expectation is taken over W . Secondly, we assume that each individual behave as if she has a natural expenditures level, $Y(h)$, distributed according to a log-normal distribution, with parameters $(\mu_\theta, \sigma_\theta)$. The deductible choice is related to the level of θ , so that $(D|\theta) \succeq (D|\theta') \Leftrightarrow \theta > \theta'$. Using Bayes' law, this relation may be inverted, so that $(\theta|D) \succeq (\theta|D') \Leftrightarrow D > D'$.

Therefore we model this by stating that the natural expenditures level, Y ,

Figure 3: Out of pocket and premium per deductible (SFr)



conditional on the deductible level, is distributed according to a log-normal distribution with parameters (μ_D, σ_D) . Formally, this distribution is the convolution of $(Y(h)|\theta)$ with the distribution of θ , taken over all individuals who choose D^i .

Under these specifications, we can now easily reformulate selection and incentive effects:

- if μ_D and σ_D differ across deductible levels, there is a selection effect;
- if $\lambda_t > 1$ for $t \in \{\tau, 0\}$, there is an incentive effect.

4 Testing for Selection and Incentive effects

The structural model implies gaps near the two trim points h^1 and h^2 . However actual data do not follow this pattern. This may be explained by two facts. First the insured are not perfectly informed ex ante about the amounts involved to cure their disease, and reimbursement claims may be transmitted to the insurer after a variable delay. Second, there is more than one realisation h in a given year, and there may be several episodes of care in a given year. In that case, it is not clear which marginal cost of care may determine demand of care during each episode: under perfect foresight, the marginal co-payment rate given the whole annual expenditure should be applied to each episode; under strict myopia, it should be the marginal co-payment rate determined by previous claims in the same year. This would smooth the annual demand function.

Accordingly, we assume that the estimated demand stems from myopic agents, i.e. that agents face a monetary price determined by their current level of spending. Under this assumption, we have that $\lambda = 1$ before they reach their deductible level, then λ_τ up to the cap, and λ_0 after the cap level is reached.

The observed consumption level Z is equal to λY , where Y may be interpreted as the consumption level that would prevail in the case of a co-payment of 100%. Since $Y = Z/\lambda$, the three different zones for positive expenditures may be represented as:

$$Z \leq D \Rightarrow Y = Z$$

$$\begin{aligned}
 D \leq Z \leq D + K &\Rightarrow Y = D + \frac{(Z - D)}{\lambda_\tau} \\
 Z \geq D + K &\Rightarrow Y = D + \frac{K}{\lambda_\tau} + \frac{(Z - D - K)}{\lambda_0}
 \end{aligned}$$

Notice that the three zones are delimited only by the observable variable Z . Therefore, knowing Z , λ_τ , λ_0 we may compute the level of “natural” health care demand Y .

4.1 Estimation method

The model is estimated through the maximization of the log-likelihood function. We estimate simultaneously λ_τ , λ_0 , μ_D and σ_D in a two-step model, setting p_D as the probability of positive health expenditures. In a first step, we estimate the probability of participation, p_D , through a maximum likelihood procedure. In a second step, we consider only positive expenditures and estimate the following three parts log-likelihood function:

$$\begin{aligned}
 \mathcal{L}(\lambda_\tau, \lambda_0, \beta, \gamma) &= \ln \left[\prod_{Z_i < D_i} \left[\frac{D_i - Z_i}{D_i} \right] \phi \left(\frac{\ln(D_i) - \mu_i}{\sigma_i} \right) + \left[\frac{Z_i}{D_i} \right] \frac{1}{Z_i} \varphi \left(\frac{\ln(Z_i) - \mu_i}{\sigma_i} \right) \right] \\
 &+ \ln \left[\prod_{D_i \leq Z_i < D_i + K} \frac{1}{\lambda_\tau D_i + (Z_i - D_i)} \varphi \left(\frac{\ln(D_i + \frac{(Z_i - D_i)}{\lambda_\tau}) - \mu_i}{\sigma_i} \right) \right] \\
 &+ \ln \left[\prod_{Z_i \geq D_i + K} \frac{1}{\lambda_0 D_i + (\frac{\lambda_0}{\lambda_\tau})K + (Z_i - K - D_i)} \varphi \left(\frac{\ln(D_i + \frac{K}{\lambda_\tau} + \frac{(Z_i - K - D_i)}{\lambda_0}) - \mu_i}{\sigma_i} \right) \right]
 \end{aligned}$$

where

$$K = 6\,000$$

$$\mu_i = X_i' \beta$$

$$\sigma_i = X_i' \gamma$$

When the observed health expenditures are under the deductible level, the possibility of under-reporting exists since agents have less incentives to claim reimbursement; under-reporting may even take the extreme form of no reporting at all. However, as said above, this problem only concerns outpatient care without any prescribed drugs, and hence may be of limited importance. Nevertheless, observing no claim in a given year, which occurs with a probability $(1 - p)$, may reveal that the agent is in very good health, or has no incentive to report claims because she is below the deductible. Since we have no way to distinguish these effects in p , we make two modeling assumptions. First, we allow p_D to vary with the deductible level for every model estimated. Second, the likelihood function weights observations below the deductible in the following manner: if $Z_i < D_i$ is observed, a weight $[(D_i - Z_i)/D_i]$ is given to the assumption that the actual expenditure merely lies between zero and the deductible level, which occurs with probability $[(D_i - Z_i)/D_i] \phi\left(\frac{\ln(D_i) - \mu_i}{\sigma_i}\right)$, and a weight $[Z_i/D_i]$ is given to the assumption that Z_i is indeed the actual expenditure, which occurs with probability $1/Z_i \varphi\left(\frac{\ln(Z_i) - \mu_i}{\sigma_i}\right)$. The relative weight attributed to the second assumption increases with the observed value Z .

4.2 Results

The model is estimated in two steps.

4.2.1 Estimation of the first step

The results of the first step are given in table 3, in which p gives the probability of having positive health expenditures during the year.

Table 3: Estimation of the first step

p_D	Coefficient
constant	0.5694 (0.0078)
D400	0.0094 (0.0053)
D600	-0.0889 (0.0063)
D1200	-0.2996 (0.0097)
D1500	-0.4037 (0.0101)
age	0.0044 (0.0001)
log likelihood	-16 015

Note: Standard errors in parentheses

As expected, the probability of having positive health expenditures decreases strongly for higher deductible levels. As mentioned above, this effect can capture selection and under-reporting effects. Not surprisingly the probability of participation increase with age. All coefficients are highly significant, except the coefficient of D400 which is positive but not significant at a 95 % confidence level.

4.2.2 Estimation of the second step

Our identification strategy allows to nest four models by imposing constraints in the following way, as described in table 4:

Benchmark We assume that there are no selection effects, and no incentive effects: $\lambda_\tau = \lambda_0 = 1$ and for all D , $\mu_D = \mu$, $\sigma_D = \sigma$.

Incentive only We assume no selection effects (for all D , $\mu_D = \mu$ and $\sigma_D = \sigma$). All differences in average consumption are due to incentive effects. In short, the λ parameters will capture all the correlation between insurance coverage and expenditures that is not captured by the p_D .

Selection only This setting assumes away incentive effects ($\lambda_\tau = \lambda_0 = 1$). Individuals do select the deductible according to their expected level of demand, but demand is not affected by the deductible level.

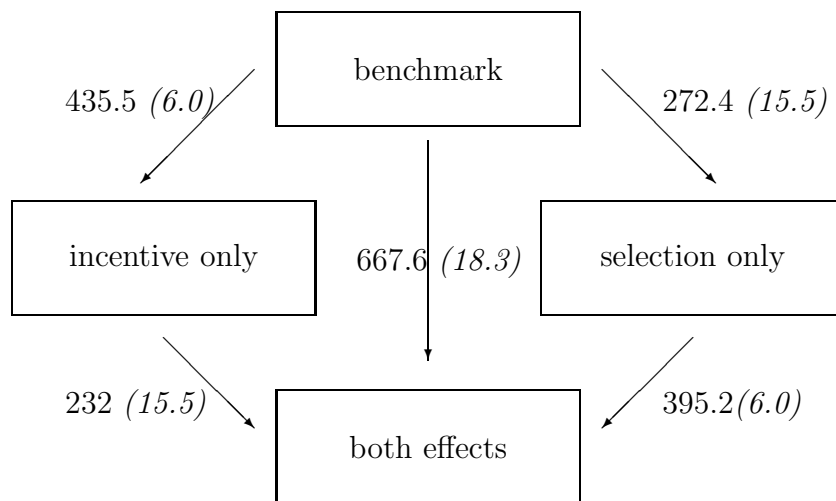
Both effects This setting assumes that the correlation between insurance coverage and expenditures may be due to both selection and incentive effects. This is the unconstrained estimation.

Table 4: Constrained and unconstrained second step estimations

<i>Variable</i>		<i>Benchmark</i>	<i>Incentive</i>	<i>Selection</i>	<i>Both effects</i>
log-likelihood		-179 971	-179 753	-179 835	-179 637
λ_τ			1.6565		1.8783 (0.0167)
λ_0			2.0947		2.4964 (0.0211)
μ_D	constant	5.3923	5.4547	5.5576	5.4635 (0.0304)
	D400			-0.0661	0.0195 (0.0185)
	D600			-0.1709	0.0356 (0.0194)
	D1200			-0.2584	0.1567 (0.0365)
	D1500			-0.6914	-0.0522 (0.0653)
	age	0.0344	0.0281	0.0330	0.0265 (0.0006)
	σ_D^2	constant	1.5261	1.2329	1.5960
D400				-0.1006	-0.1323 (0.0136)
D600				-0.1146	-0.1894 (0.0131)
D1200				-0.0338	-0.1774 (0.0262)
D1500				0.1106	-0.0930 (0.0489)
age		-0.0056	-0.0035	-0.0060	-0.0036 (0.0004)

Note: Standard errors in parentheses

Figure 4: Likelihood ratio tests (*critical value*)



Both “selection only” and “incentive only” models are significantly better than the benchmark ($L - ratios$ of 272.4 and 435.5 respectively). Moreover, the “both effects” unconstrained model is significantly better than the “incentive only” and the “selection only” model ($L - ratios$ of 395.2 and 232 respectively). Hence, incentive effects are present and significant even after controlling for self-selection effects. Figure 4 gives the details of the test with the critical value at a confidence level of 95%. All tests are highly significant. We conclude that our sample provides evidence of both selection and incentive effects.

Given the results of the tests, we concentrate hereafter on the unconstrained model “Both effects”. As Table 4 shows, incentive effects imply that when the deductible level is reached, individuals marginally consume about 88% more than what they would consume under a full marginal mon-

etary cost. Once the cap level is reached, the marginal consumption is 2.5 times the amount without insurance. Since the confidence interval at a 5% level for the coefficient of λ_τ is [1.7627; 1.9937] we conclude that λ_τ is significantly different from one. Similarly, the confidence interval for the coefficient of λ_0 is [2.2396; 2.7536], meaning that λ_0 is significantly different from one and from λ_τ ⁶.

As expected, the global effect of age is increasing wether health expenditures decrease with the level of deductible (see next section for more details).

4.2.3 Joining the two steps together

In order to show the effect of age and deductible on health expenditures, table 5 displays the expected health expenditures⁷ by deductible and age with respect to $\mu_D, \sigma_D, p_D, \lambda_\tau$ and λ_0 .

As expected, we see that for a given class of age, health care expenditures decrease with the level of deductible. Moreover, health care expenditures increase dramatically with age for any of the deductible level.

⁶Due to the non linearity of the likelihood function, we performed 100 Monte-Carlo simulations of our complete model, and obtained mean values for the λ s of 1.9213 and 2.5820, with respective standard error of 0.0717 and 0.1493. This convinces us that we do not face a strong small sample bias and that we may rely on the asymptotic values for our tests.

⁷Since the model estimates the log of the expenditure, we need to apply retransformation methods to obtain the expected value of the expenditure (Duan (1983), Mullahy (1998) and Manning (1998)). However, since we also assume that the “natural demand” Y , conditional on observable, follows a lognormal distribution of parameters (μ_D, σ_D) , the expected value of the corresponding residual is directly given by $e^{(\sigma_D^2)/2}$. For our purpose, the precision of this estimate is sufficient.

Table 5: Expected health expenditures

At age	30	40	50	60	70	80	90
Deductible 230	1 250	1 714	2 342	3 192	4 340	5 891	7 985
Deductible 400	1 009	1 403	1 945	2 688	3 703	5 090	6 984
Deductible 600	762	1 079	1 525	2 146	3 009	4 205	5 858
Deductible 1 200	511	751	1 097	1 597	2 314	3 337	4 788
Deductible 1 500	319	480	716	1 058	1 554	2 269	3 296

Figure 5: Observed (O) and expected (E) health expenditures for three deductibles

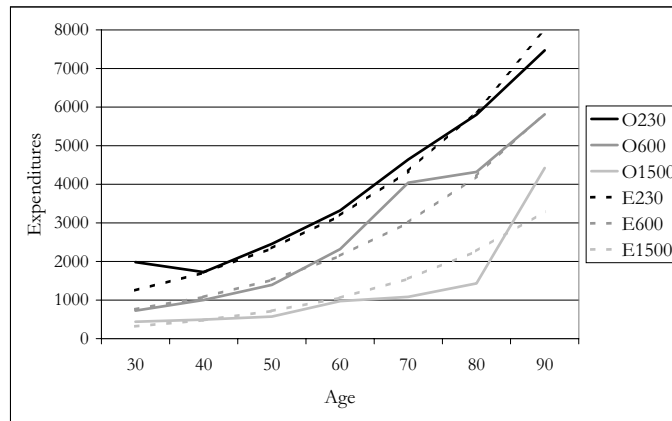


Figure 5 compares, for three deductible levels, the mean observed expenditure level per age group with the estimated expected spending for a representative individual of this age group. The estimation fits very well the data, except at older age, which may be explained by the very small number of observations in these groups.

Now that we have a well specified model including both effects, we are able to assess the main question: How much of the observed difference in expenditures between the deductible levels is due to self-selection and how much to incentives? For each deductible level D , we compute the expected spending if they were attributed a SFr 1 500 deductible level using the estimated values of the λ , holding the distribution parameters (p_D, μ_D, σ_D) constant. Table 6 gives the observed health expenditures per deductible and the part of the difference with deductible 1 500 due to incentive and selection effects. For example, the 230 group spend in average SFr 3 474. With a deductible of 1 500, they would have spent SFr 2 777 rather than SFr 614 for “true” deductible 1 500. That is, 76% of the observed difference of SFr 2 860 may be attributed to self-selection.

The values for the other deductible levels are of the same order of magnitude (see table 6), so that we may state that the differences in spending are roughly due for 1/4 to incentive effects and 3/4 due to self-selection effects.

4.3 Normality test

Our empirical model imposes a Log-normality assumption on the underlying health care “natural” demand. We computed the individual natural consumption Y with the mean of the λ s, which we then normalise with the

Table 6: Part of the observed difference in expenditures due to selection and incentive effect

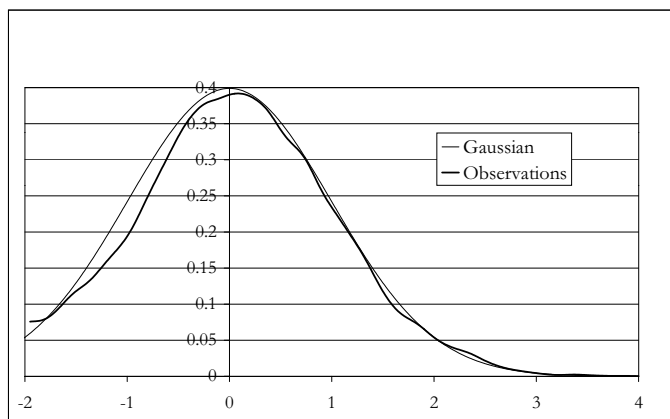
<i>Deductible</i>	<i>230</i>	<i>400</i>	<i>600</i>	<i>1 200</i>	<i>1 500</i>
Observed expenditures	3 474	2 648	1 872	1 327	614
Difference with deductible 1 500	2 860	2 034	1 258	713	0
<i>Decomposition</i>					
Incentive effect	697	521	306	62	
Selection effect	2 163	1 513	952	651	

individual μ_D and σ_D : $Y_i^{(n)} = (\ln(Y_i) - \mu_D)/\sigma_D$ for an individual with deductible D . The Log-normality assumption only affects positive observations, and hence the estimated participation probabilities p_D are not taken into account. The model assumptions moreover states that the observations under the deductible level are underestimated due to under-reporting. It is unfortunately impossible to correct these values and perform a formal normality test. Therefore we rely on the empirical distribution of the estimated Y values. Figure 6 indicates that the Log-normality assumption is not violated in a way that would bias our results.

For the observations above the deductible level (right-hand side⁸), both curves are very close. The density is slightly lower than expected for observed values in the interval between SFr 100 and the deductible, and higher for observed values below SFr 100. This may reveal some under-reporting, which

⁸Given the normalisation procedure, the mode corresponds to a natural expenditure equal to μ_D .

Figure 6: Normality test



is taken into account in our estimating procedure.

4.4 Robustness of the approach

Up to now, all the presented estimations were done on a specific data set (men in the *Vaud* Canton). We repeated the estimation on the four available samples (women in *Vaud*, men and women in *Geneva* Canton). Table 7 presents the λ and the expected health expenditures per deductible in the four samples. As expected, women spend more in health care than men and the level of health expenditures in *Geneva* is on average higher than in *Vaud*. In terms of selection effects, the difference of expected expenditures between the deductible levels are of the same magnitude for all estimations. And in terms of incentive effects, we can see that the λ_τ and the λ_0 are very close from one estimation to the other. This allows us to argue that our approach

can be more generally applied than for one specific population and that the estimated λ ($\lambda_\tau \simeq 1.9, \lambda_0 \simeq 2.5$) may be extended at least to other regions in Switzerland.

Table 7: Estimations for Men and Women in *Vaud* and *Geneva* (at age 40)

	Vaud		Geneva	
	Men	Women	Men	Women
λ_τ	1.878	1.899	1.961	2.055
λ_0	2.496	2.388	2.525	2.163
Deductible 230	1 714	2 539	2 423	3 260
Deductible 400	1 403	2 273	2 019	3 024
Deductible 600	1 079	1 799	1 667	2 272
Deductible 1 200	751	1 270	1 340	1 853
Deductible 1 500	480	970	605	1 249

5 Conclusion

To the nagging problem “adverse selection *versus* moral hazard”, we propose a typical Swiss solution: “selection *and* incentive effects”.

From a general model where individuals have a private information on their health status and preferences for health care, and self select a health insurance plan, we derive the implications for the swiss setting. Switzerland is an ideal playground for this topic: the basic insurance is mandatory, the benefit package and co-payment rate are identical across sickness funds, so

that the swiss agents have only two questions to answer: Which level of deductible do I choose, and how much do I consume. The model then sums up to two sets of parameters: first, (μ_D, σ_D) capture private information inferred from the selected deductible level (D); second, $(\lambda_\tau, \lambda_0)$ capture the incentive effects. All parameters were simultaneously estimated through a non linear maximum likelihood.

We find a very strong selection effect. Once self-selection is controlled for, there are still important incentive effects. We estimate that when the co-payment rate decreases from 100% (no coverage) to 10%, individuals increase their marginal consumption by about 90%. When the monetary costs are fully covered, the marginal consumption increases by an additional factor of about 1/3. In short, when the co-payment rate decreases from 10% to 0% (full insurance), marginal consumption is roughly multiplied by a factor of 2.5.

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6 Appendix

6.1 Proof of Proposition 1

Our main problem is that, since the co-payment rate decreases with the quantity of health care consumed, the budget set is not convex. Hence, we define the pseudo indirect utility function over each linear part of the budget set:

$$\bar{v}(W, h, t) \equiv \max_{c, y \in B(t)} u(c, y, h), \quad (4)$$

where (c, y) belongs to the budget set $B(t)$ corresponding to the co-payment value t : $B(t) = \{(c, y) | c + p(t + a)y \leq W(t)\}$, with $W(1) = W$, $W(\tau) = W - D(1 - \tau)$, and $W(0) = W - D - \tau K$. The indirect utility function v is the maximum of the three following values:

$$v(W, h, D) = \max\{\bar{v}(W, h, 1); \bar{v}(W, h, \tau); \bar{v}(W, h, 0)\}.$$

With u given by $u(c, y, h) = b(h) + \alpha(h) \ln(c) + (1 - \alpha(h)) \ln(y)$, with: $\alpha(h) \in [0, 1]$, monotonically increasing with h from 0 to 1, and $b(h)$ increasing with h , the solution to problem (4) is given by:

$$\bar{c}(W, h, t) = W(t)\alpha(h) ; \bar{y}(W, h, t) = \frac{W(t)}{p(a + t)}(1 - \alpha(h)).$$

Setting $V(h) = b(h) + \alpha(h) \ln(\alpha(h)) + (1 - \alpha(h)) \ln(1 - \alpha(h))$, the indirect pseudo-utility \bar{v} is given by:

$$\bar{v}(W, h, t) = V(h) + (\alpha(h) - 1) \ln(p(t + a)) + \ln(W(t)).$$

We have

$$v(W, h, D) = V(h) - (1 - \alpha(h)) \ln(p) + \max_t \{\phi(\alpha(h), t)\},$$

where $\phi(\alpha, t) \equiv (\alpha - 1) \ln(t + a) + \ln(W(t))$. We have that $\bar{v}(W, h, t) \geq \bar{v}(W, h, t')$ if $\phi(\alpha(h), t) \geq \phi(\alpha(h), t')$.

First step: $\phi_\alpha(\alpha, t) = \ln(t + a)$, hence $\phi_\alpha(\alpha, 1) > \phi_\alpha(\alpha, \tau) > \phi_\alpha(\alpha, 0)$. Second step: $\phi(1, t) = \ln(W(t))$ implies $\phi(1, 0) < \phi(1, \tau) < \phi(1, 1)$. Third step: under the assumption $W > D(1+a) + K(a+\tau)$, we have that $\phi(0, 0) > \phi(0, \tau) > \phi(0, 1)$.

Hence there exist one value $\hat{\alpha}$ such that $\phi(\hat{\alpha}, 0) = \phi(\hat{\alpha}, 1)$; for $\alpha \leq \hat{\alpha}$, $\phi(\alpha, 0) \geq \phi(\alpha, 1)$ (and the converse for $\alpha \geq \hat{\alpha}$). At this value of α , we have that $\phi(\hat{\alpha}, \tau) > \phi(\hat{\alpha}, 0) = \phi(\hat{\alpha}, 1)$ if and only if :

$$\frac{\ln\left(\frac{1+a}{a}\right)}{\ln\left(\frac{1+a}{\tau+a}\right)} \leq \frac{\ln\left(1 - \frac{D+\tau K}{W}\right)}{\ln\left(1 - \frac{D(1-\tau)}{W}\right)}. \quad (5)$$

The left hand side of this expression is equivalent to $1/(1-\tau)$ when $1/a$ is small with respect to 1; the right hand side tends to $(D+\tau K)/(D(1-\tau))$ when W is large with respect to $D+\tau K$. Thus, the inequality holds when a and W are large enough. If it does not hold, we simply set $\alpha_1 = \alpha_2 = \hat{\alpha}$. If inequality (5) holds, there exist two values α_1 and α_2 , with $0 < \alpha_1 < \hat{\alpha} < \alpha_2 < 1$, such that $\max_t \{\phi(\alpha, t)\}$ is: $\phi(\alpha, 0)$ for $\alpha \leq \alpha_1$; $\phi(\alpha, \tau)$ for $\alpha \in [\alpha_1, \alpha_2]$; $\phi(\alpha, 1)$ for $\alpha \geq \alpha_2$. These two values are defined by:

$$\alpha_1 \equiv 1 - \frac{\ln\left(\frac{W(\tau)}{W(0)}\right)}{\ln\left(\frac{\tau+a}{a}\right)}.$$

$$\alpha_2 \equiv 1 - \frac{\ln\left(\frac{W(1)}{W(\tau)}\right)}{\ln\left(\frac{1+a}{\tau+a}\right)}.$$

It is straightforward to check that $W(\tau)/W(0)$ and $W(1)/W(\tau)$ increase with D , and thus that both α_1 and α_2 decrease with D . Since $\alpha(h)$ is increasing with h from 0 to 1, we may translate these two values into: $h_i \equiv \alpha^{-1}(\alpha_i)$, which also decrease with D .

Denote $Y(W, h) \equiv \bar{y}(W, h, 1)$. When $h \geq h^2(W, D)$, we know that $\bar{v}(W, h, 1)$ is larger than $\bar{v}(W, h, \tau)$, which itself is larger than $\bar{v}(W, h, 0)$, and hence that $y(W, h, D) = \bar{y}(W, h, 1) = Y(W, h)$. When $h \in [h^1(W, D), h^2(W, D)]$, we have that $y(W, h, D) = \bar{y}(W, h, \tau) = \frac{W(\tau)}{p(a+\tau)}(1 - \alpha(h)) = \frac{W(\tau)(a+1)}{W(1)(a+\tau)}Y(W, h)$. Finally, for $h \leq h^1$, we have that $\bar{v}(W, h, 0) \geq \bar{v}(W, h, \tau) \geq \bar{v}(W, h, 0)$, and thus $y(W, h, D) = \bar{y}(W, h, 0) = \frac{W(0)}{pa}(1 - \alpha(h)) = \frac{W(0)(a+1)}{W(1)a}Y(W, h)$.

In summary, if we denote by:

$$\lambda_\tau \equiv \frac{W(\tau)(a+1)}{W(1)(a+\tau)}; \lambda_0 \equiv \frac{W(0)(a+1)}{W(1)a},$$

we have that:

- If $h \geq h^2(W, D)$, then $y(W, h, D) = Y(W, h)$;
- If $h \in [h^1(W, D); h^2(W, D)]$, then $y(W, h, D) = \lambda_\tau Y(W, h)$;
- If $h \leq h^1(W, D)$, then $y(W, h, D) = \lambda_0 Y(W, h)$.

For W large enough (formally, for $W > D(1+a) + (a+\tau)K$), we have that $\lambda_0 > \lambda_\tau > 1$.

Q.E.D

6.2 Proof of Proposition 2

We now need to compute $\partial E[v|\theta]/\partial D$. We have that:

$$\begin{aligned} E[v|\theta] &= E[K(h) - (1 - \alpha(h))p|\theta] \\ &+ \int_{h^1(D)}^{h^2(D)} [(\alpha(h) - 1) \ln(a) + \ln(W_0 - P(D) - D - \tau K)] \mu(h|\theta) dh \\ &+ \int_{h^1(D)}^{h^2(D)} [(\alpha(h) - 1) \ln(\tau + a) + \ln(W_0 - P(D) - D(1 - \tau))] \mu(h|\theta) dh \\ &+ \int_{h^2(D)}^{h^3(D)} [(\alpha(h) - 1) \ln(1 + a) + \ln(W_0 - P(D))] \mu(h|\theta) dh. \end{aligned}$$

Since the value of the integrand is continuous at $h^1(D)$ and $h^2(D)$, we have:

$$\begin{aligned} \frac{\partial E[v|\theta]}{\partial D} &= -\frac{P'(D) + 1}{W_0 - P(D) - D - \tau K} P(h \leq h^1(D)|\theta) \\ &- \frac{P'(D) + 1 - \tau}{W_0 - P(D) - D(1 - \tau)} P(h \in [h^1(D), h^2(D)]|\theta) \\ &- \frac{P'(D)}{W_0 - P(D)} P(h \geq h^2(D)|\theta). \end{aligned}$$

Hence, setting $\pi_1 = P(h \leq h^1(D)|\theta)$ and $\pi_2 = P(h \geq h^2(D)|\theta)$ (and shortening $W_0 - P(D)$ into W), we have:

$$\frac{\partial E[v|\theta]}{\partial D} = -\left(\frac{P'(D) + 1}{W - D - \tau K}\right) \pi_1 - \left(\frac{P'(D) + 1 - \tau}{W - D(1 - \tau)}\right) (1 - \pi_1 - \pi_2) - \left(\frac{P'(D)}{W}\right) \pi_2.$$

Define $C_0 = -\left(\frac{P'(D)+1-\tau}{W-D(1-\tau)}\right)$, $C_1 = -C_0 - \left(\frac{P'(D)+1}{W-D-\tau K}\right)$, and $C_2 = -C_0 - \left(\frac{P'(D)}{W}\right)$. Since $-1 < P'(D) < 0$, we immediately have that $C_0 + C_1 < 0 < C_0 + C_2$. We also have that $C_1 = \left(\frac{-(P'(D)+1)(K+D)-(W-D-\tau K)}{(W-D(1-\tau))(W-D-\tau K)}\right)$, which is negative as soon as $W > D + \tau K$. And, finally, $C_2 = \left(\frac{(1-\tau)(W+DP'(D))}{W(W-D(1-\tau))}\right)$, which is positive since $W > D$.

Q.E.D

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