Moral Hazard in Supplementary Health Insurance: Modelling the Behaviour of the Insured and the Optimal Contract

INSTITUT DES ACTUAIRES
SECTIONS VIRTUAL COLLOQUIUM 2020

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CSS Insurance

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About the speaker

SECTIONS VIRTUAL COLLOQUIUM 2020

Costin Oarda

- Actuary IA (Institut des Actuaires)
- Reserving actuary

CSS Insurance

- Market leader in health insurance in Switzerland
- 1.8 million policyholders (31.12.2019)
- 6.5 billions in premiums earned (2019)

1. Introduction

1. Introduction
Moral Hazard in Health Insurance

Insurer

Information asymmetry

Contract Theory

Adverse Selection

Characteristics of the insured

Behaviour of the insured

Level of risk

Challenges

Moral Hazard

Health Insurance

Effort

Behavioural model

Expected profit

Risk exposure

Free riders

Fraud

Optimal Contract Resolution Algorithm

Profitability

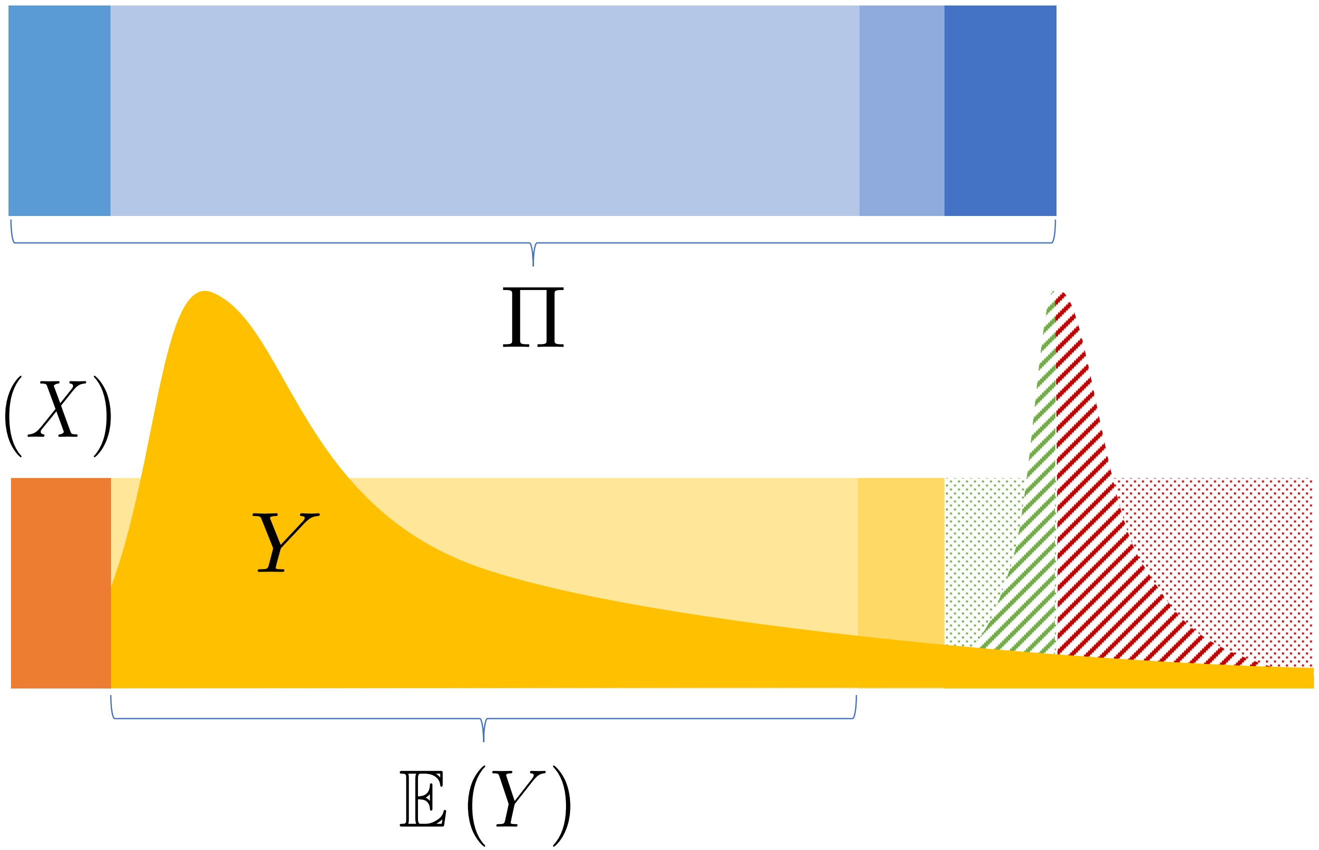
Incentive structure

Attractive products

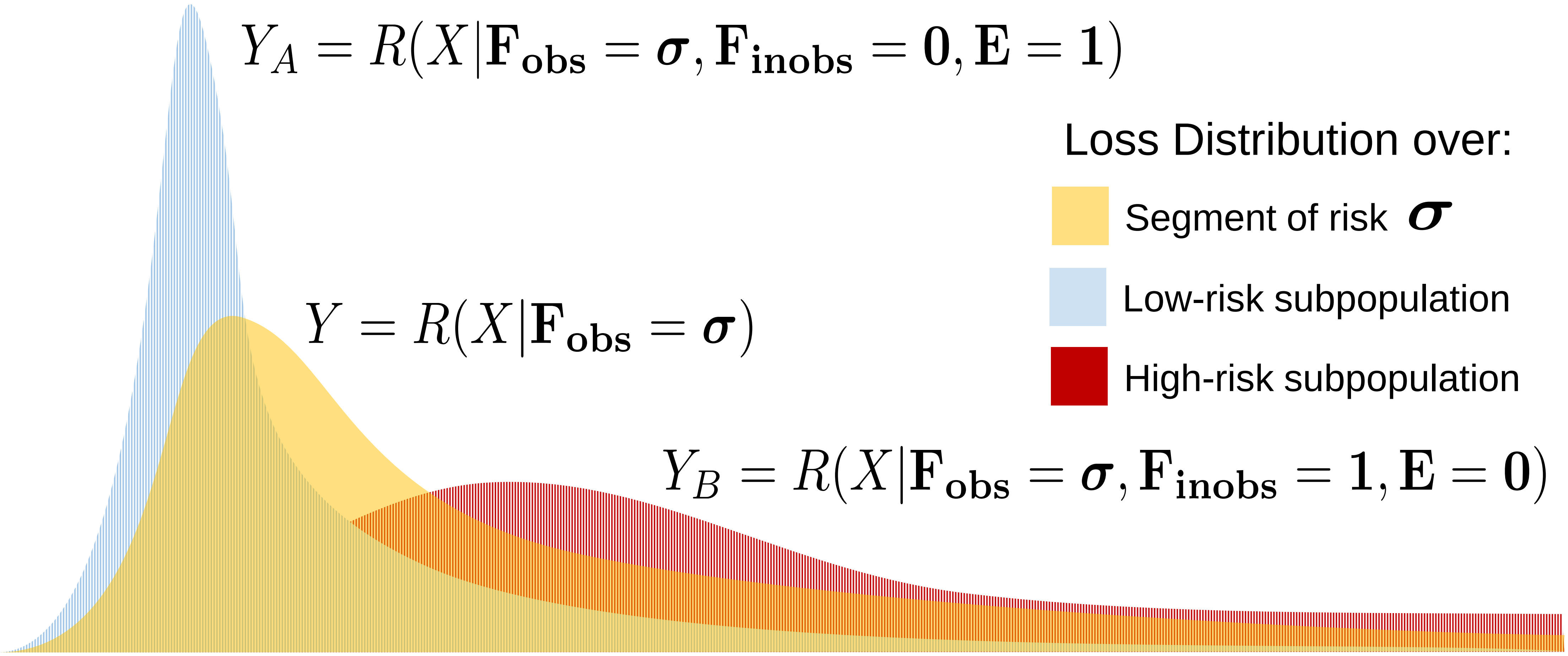
1. Introduction
Insurance Contract, a Risk Transfer

Insurance contract (Π, R) for the risk transfer $X|\mathbf{F}_{\text{obs}}, \mathbf{F}_{\text{inobs}}, \mathbf{E}$

- **Insured's liability**
  - Premium Π
- **Insurer's liability**
  - Administrative costs
  - Aggregate claim $Y = R(X)$
    - Pure premium $\mathbb{E}(Y)$
    - Cost of Capital
  - Insurer's Profit
  - Insurer's Deficit



1. Introduction
Impact of Contract Design on Loss Distribution



1. Introduction
Dealing with the Moral Hazard Problem

The Research Problem

- Is it possible to model the behaviour of an insured linked to a complementary health insurance portfolio by quantifying his level of effort to reduce his risk exposure during the life of the contract?

- If so, how can we model the optimal contract in the presence of moral hazard?

2. Methods

2. Methods
Some Notations and Concepts

- Contracts $(\Pi, R_{\Lambda,\Psi})$ are with reimbursement functions $R_{\Lambda,\Psi}$ with two parameters
  - Coverage Ceiling Λ
  - Deductible Ψ
- Output x (of risk X) is a signal from effort $\mathbf{e}$ to limit the risk
- Wealth $W_{\Pi,R_{\Lambda,\Psi}}(x)$
- Utility of wealth $u\left(W_{\Pi,R_{\Lambda,\Psi}}(x)\right)$
- Cost of effort $c\left(\mathbf{e}\right)$

2. Methods

Expected Utility of the Insurer and the Insured

- Insurer's expected profit V

$$V_{\Pi,R_{\Lambda,\Psi}}(\mathbf{e}) = \Pi - \mathbb{E}\left(R_{\Lambda,\Psi}(X) \middle| \mathbf{E} = \mathbf{e}\right)$$

- Insured's expected utility U

$$U_{f_{X|\mathbf{E}},\Pi,R_{\Lambda,\Psi}}(\mathbf{e}) = U^{\text{Wealth}}_{f_{X|\mathbf{E}},\Pi,R_{\Lambda,\Psi}}(\mathbf{e}) - c(\mathbf{e})$$

Where the expected utility of wealth is defined by

$$U^{\text{Wealth}}_{f_{X|\mathbf{E}},\Pi,R_{\Lambda,\Psi}}(\mathbf{e}) = \int_{\mathbb{R}_-} u\left(W_{\Pi,R_{\Lambda,\Psi}}(x)\right) f_{X|\mathbf{E}}(x|\mathbf{e})\, dx$$

2. Methods
Optimal Contract Model

- Optimal Contract Model under moral hazard

$$\max_{(\Pi,\Lambda,\Psi,\mathbf{e}_{\mathrm{CPI}})\in(\mathbb{R}_+)^3\times[0,1]^J} V_{\Pi,\Lambda,\Psi}(\mathbf{e}_{\mathrm{CPI}})$$

$$\text{subject to} \quad \begin{cases} \mathbf{e}_{\mathrm{CPI}} = \underset{\mathbf{e}\in[0,1]^J}{\operatorname{argmax}} \; U_{\Pi,\Lambda,\Psi}(\mathbf{e}) \\ U_{\Pi,\Lambda,\Psi}(\mathbf{e}_{\mathrm{CPI}}) \geq \underline{U} \end{cases}$$

- Problem solving contracts $(\Pi_*, R_{\Lambda_*,\Psi_*})$ are the optimal contracts

2. Methods
Behavioural Model

Construction of Effort Indicators

- Data Mining
- Segmentation
- Generalized Linear Mixed Model
  - Frequency
  - Intensity
- Transformation of the negative of the residual into the standard uniform distribution $E \backsim \mathcal{U}(0;1)$

2. Methods
Optimal Contract Resolution Algorithm

- Preparation
  - Design the theoretical model and modelling framework
  - Implement in an appropriate software
    - Behavioural Model
    - Optimal Contract Resolution Algorithm
  - Estimating parametric copulas of $(X, \mathbf{E})$ and the conditional density $f_{X|\mathbf{E}}$
- Initialization
  - Calibrate the utility function (risk aversion)
  - Calibrate the cost of effort (participation and incentive constraints)
- Resolution

3. Results

3. Results
A Concrete Initial Contract: Is It Optimal?

- Insured $i = 4627$ is:
  - a 33-year-old woman living in the Paris area
  - with a standard insurance scheme (no chronic illness or maternity)
- This insured signed an initial contract covering the “medical consultations and visits” benefit with the following parameters :
  - annual premium Π_0 : €32
  - annual coverage ceiling Λ_0 : €117
  - annual deductible Ψ_0: €49

3. Results
Health Care Consumption

- During one insurance year, insured $i = 4627$ visits the physician on dates $t \in \{t_1, t_2, t_3, t_4\}$, and we have on an annual basis:
  - an annual health care expenditure HCE: €127
  - an annual reimbursement from the Social Security R_{SS}: €24
  - an annual output x : €-103
  - an annual deductible Ψ_0: €49
  - an annual coverage ceiling Λ_0: €117
  - an annual reimbursement by the complementary health insurance $R_{\Lambda,\Psi}(x)$: €54

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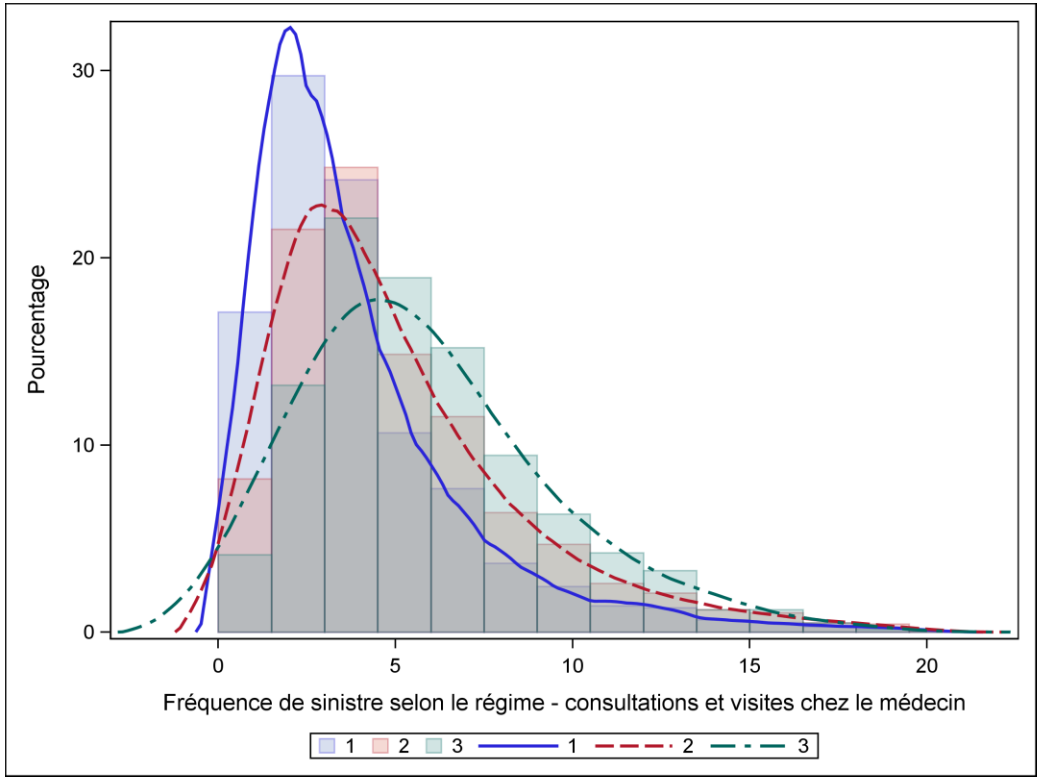
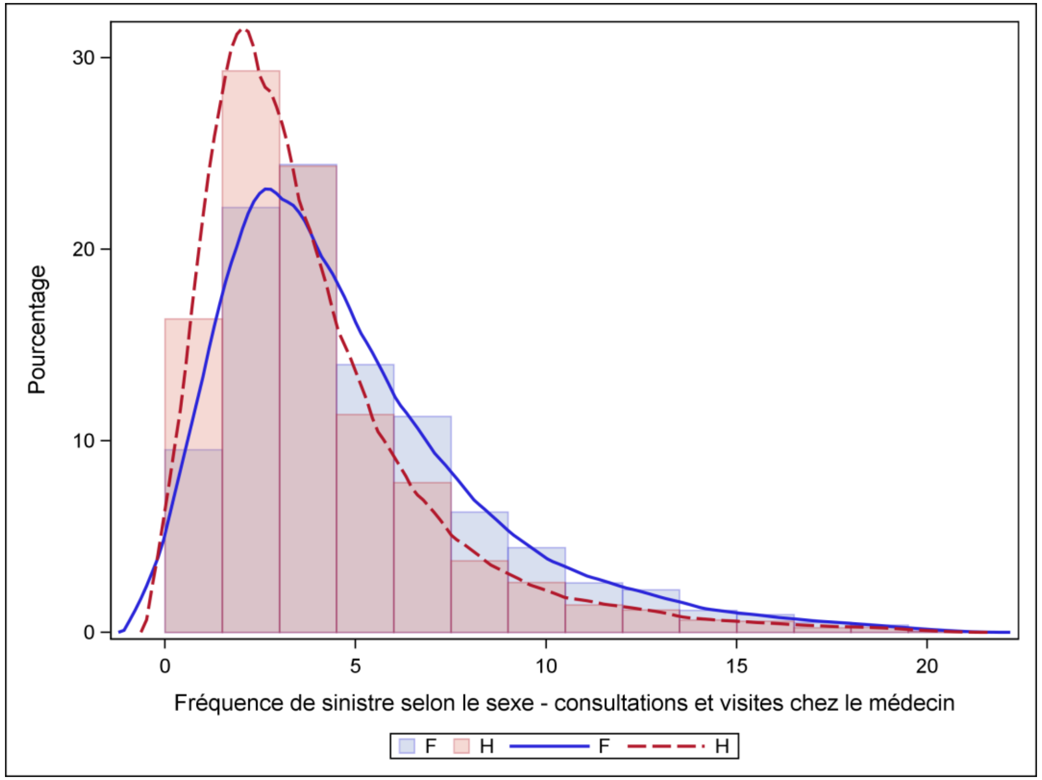
3. Results
Claim Frequency by Risk Factors

Claim Frequency By Insurance Scheme

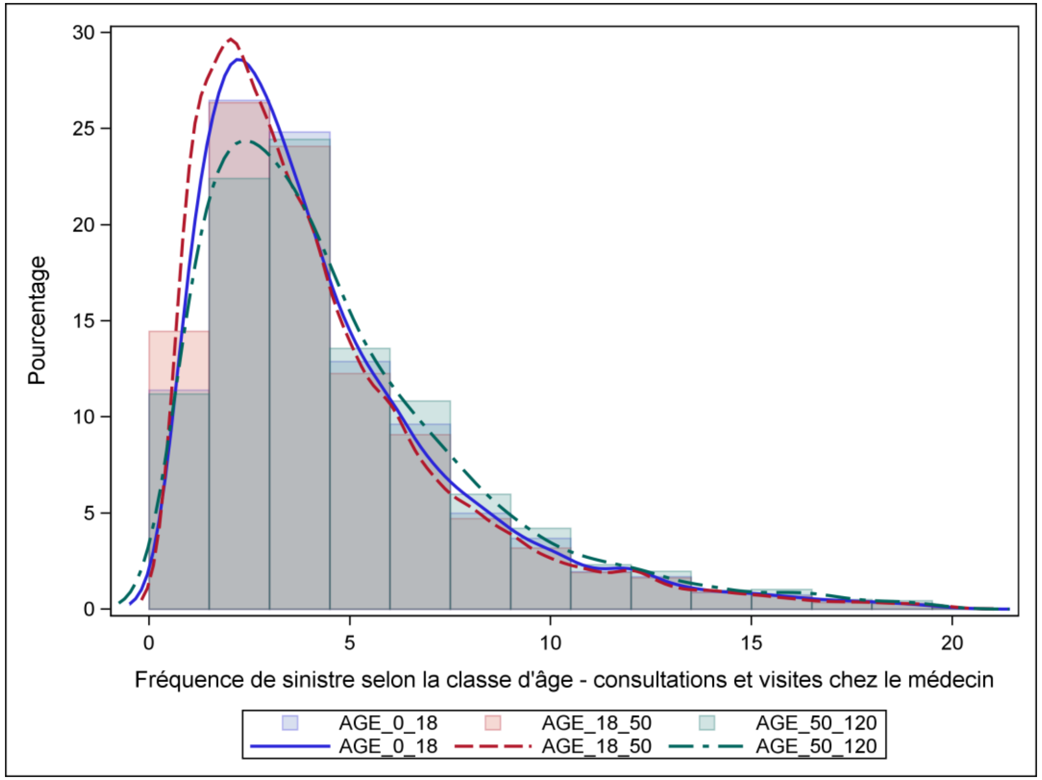


Claim Frequency By Gender

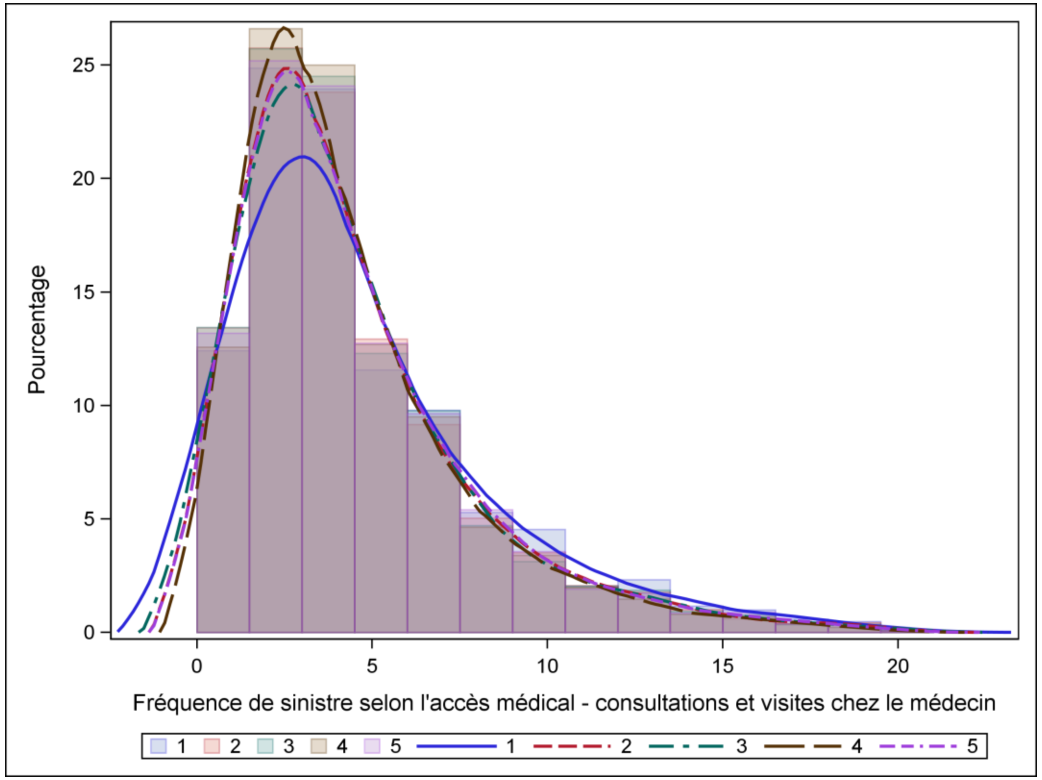


3. Results
Claim Frequency by Risk Factors

Claim Frequency
By Age Class

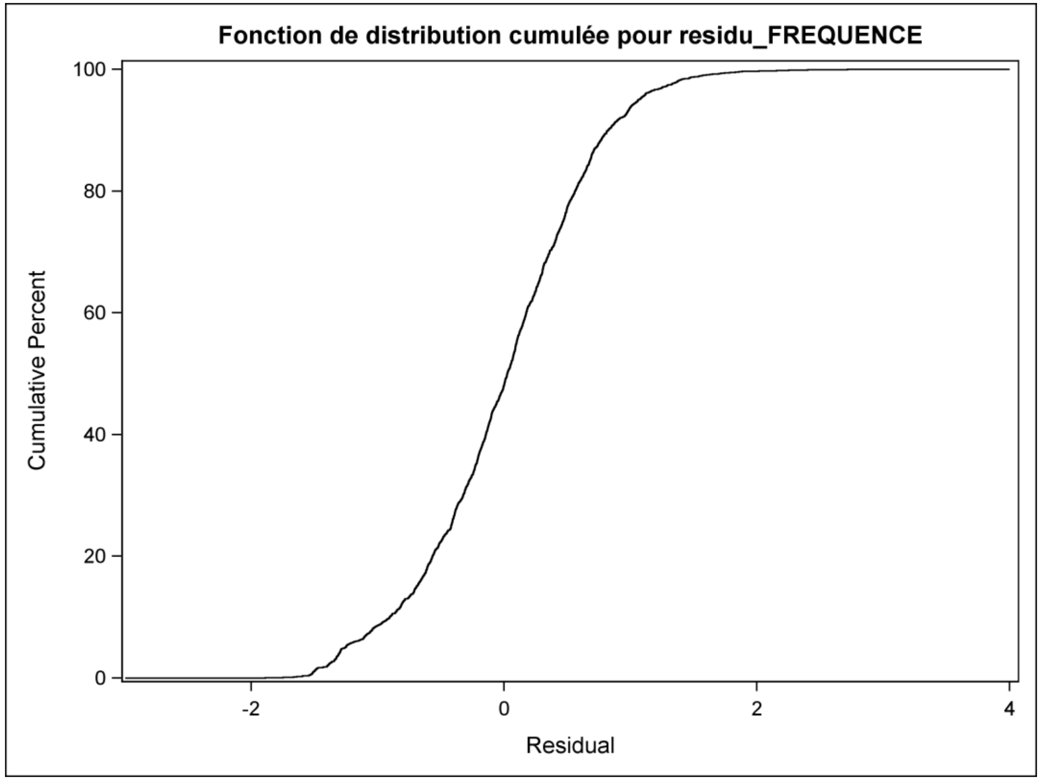


Claim Frequency
By Medical Acess



3. Results
Behavioural Model (Frequency)

Residual Distribution (Frequency Model) over the Insured Segment



Construction of the Effort Indicator in Frequency

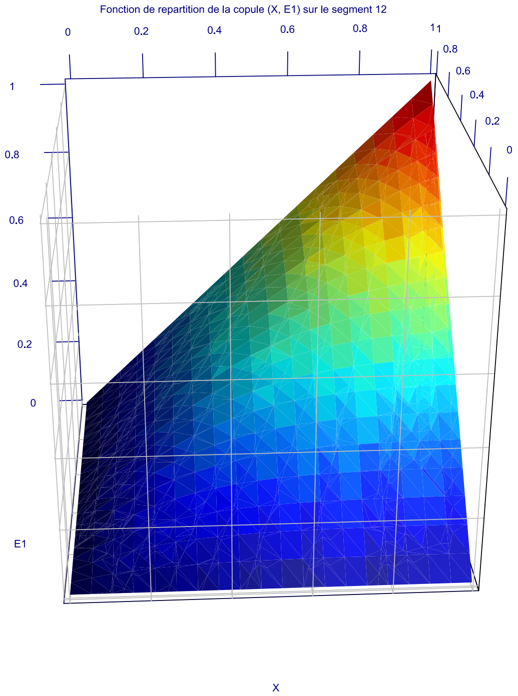
- Generalized Linear Mixed Model
- Transformation of the negative of the residual into the standard uniform distribution $E \backsim \mathcal{U}(0;1)$
- Effort indicator for $i = 4627$:

$$e_1^i = 0.42$$

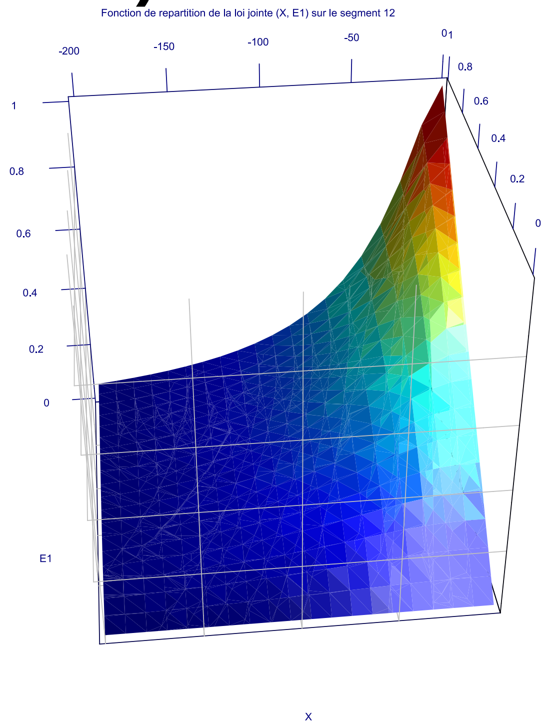
3. Results

Parametric Copula Estimation

Cumulative Distribution Function of the Copula (X, E1) (Segment 12)

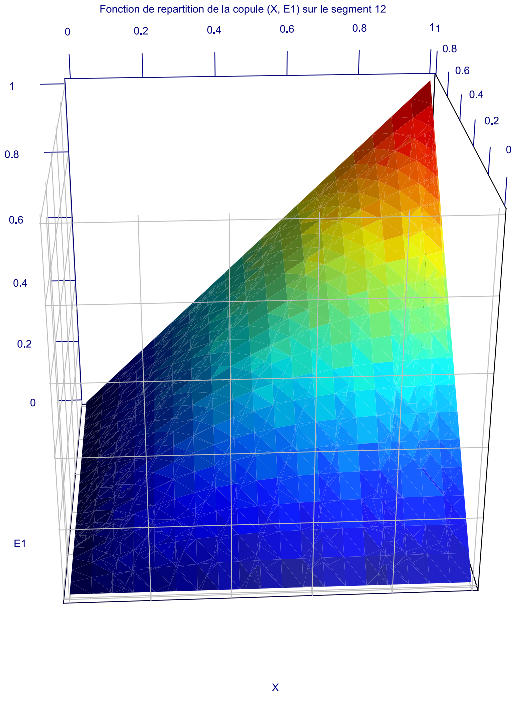


Cumulative Distribution Function of the Joined Distribution (X, E1) (Segment 12)

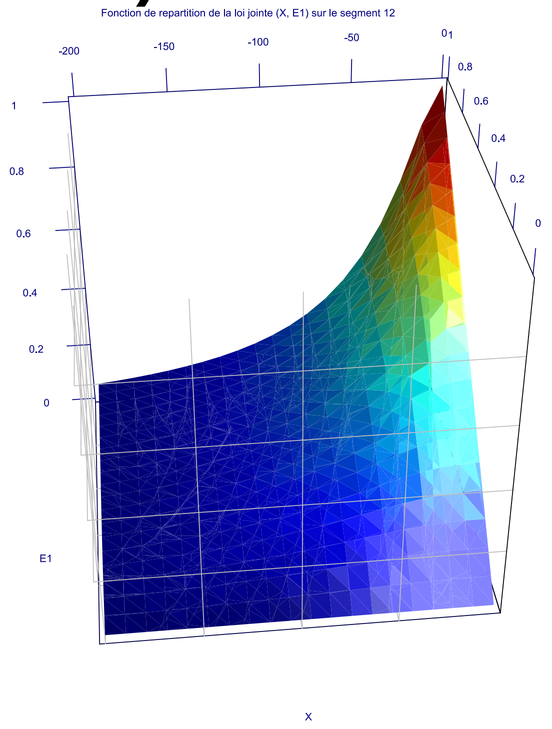


3. Results
Conditional density estimation

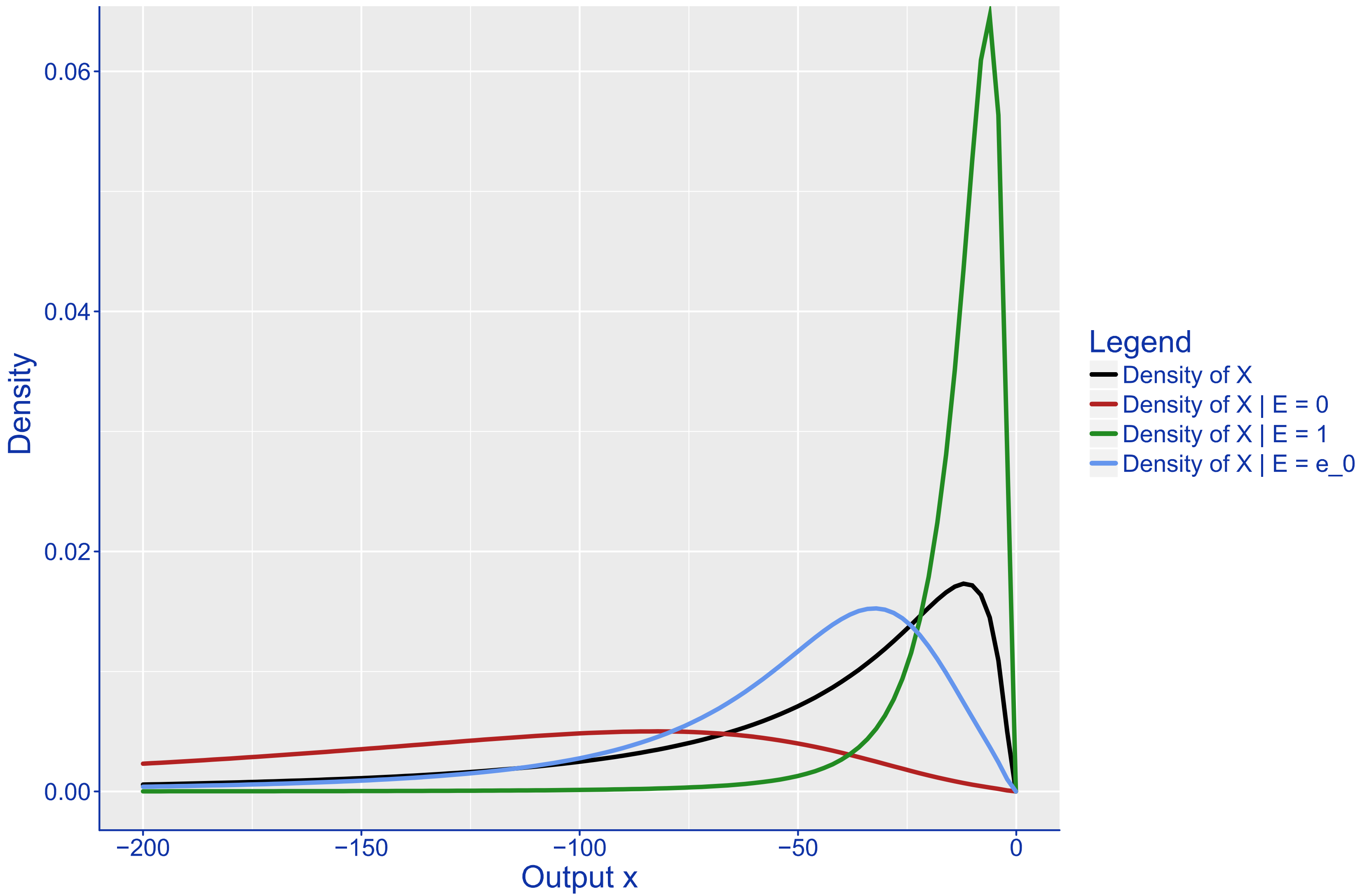
Conditional Density Function of Output X Given the Effort E1 (Segment 12)



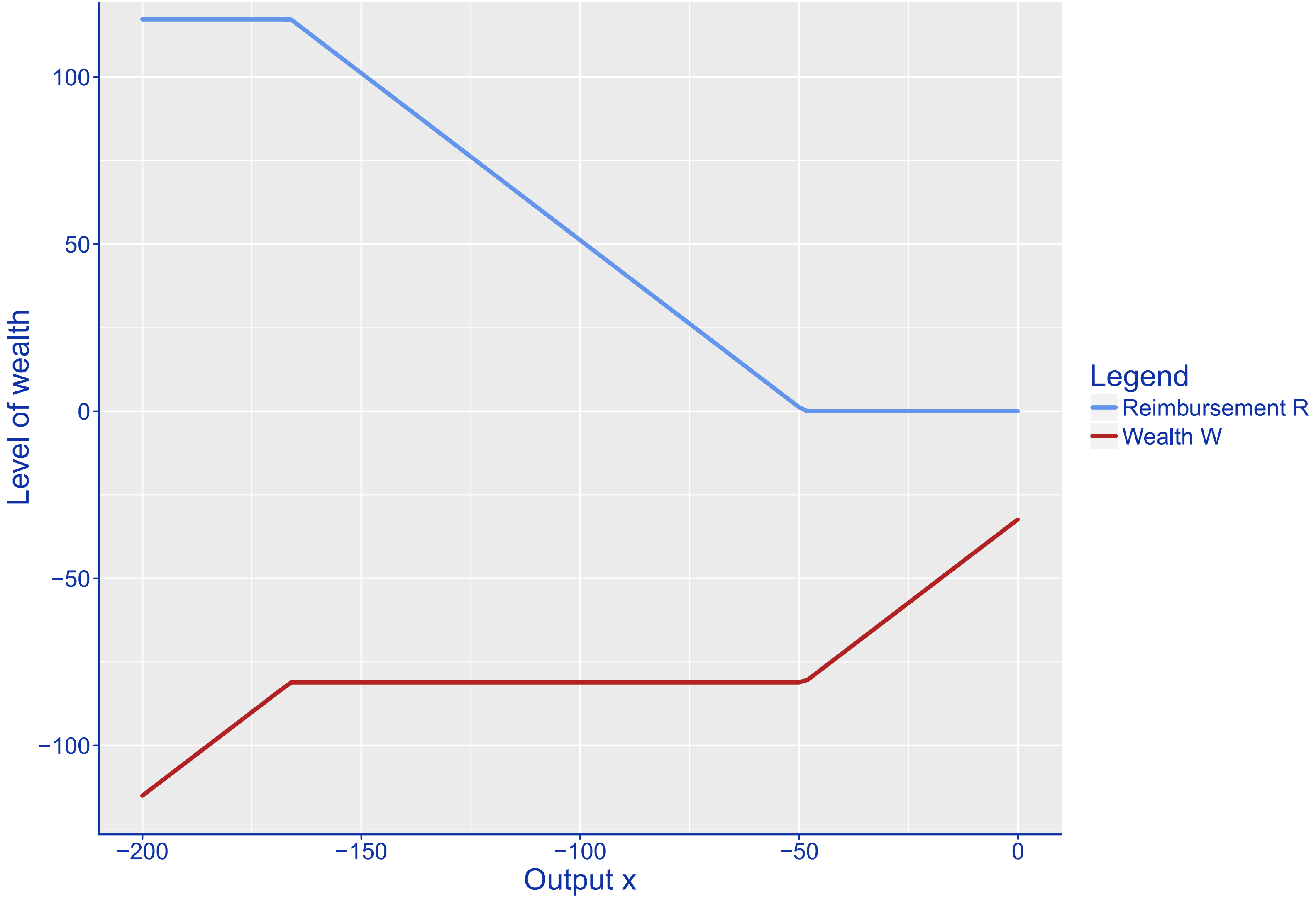
Cumulative Distribution Function of Output X Given the Effort E1 (Segment 12)



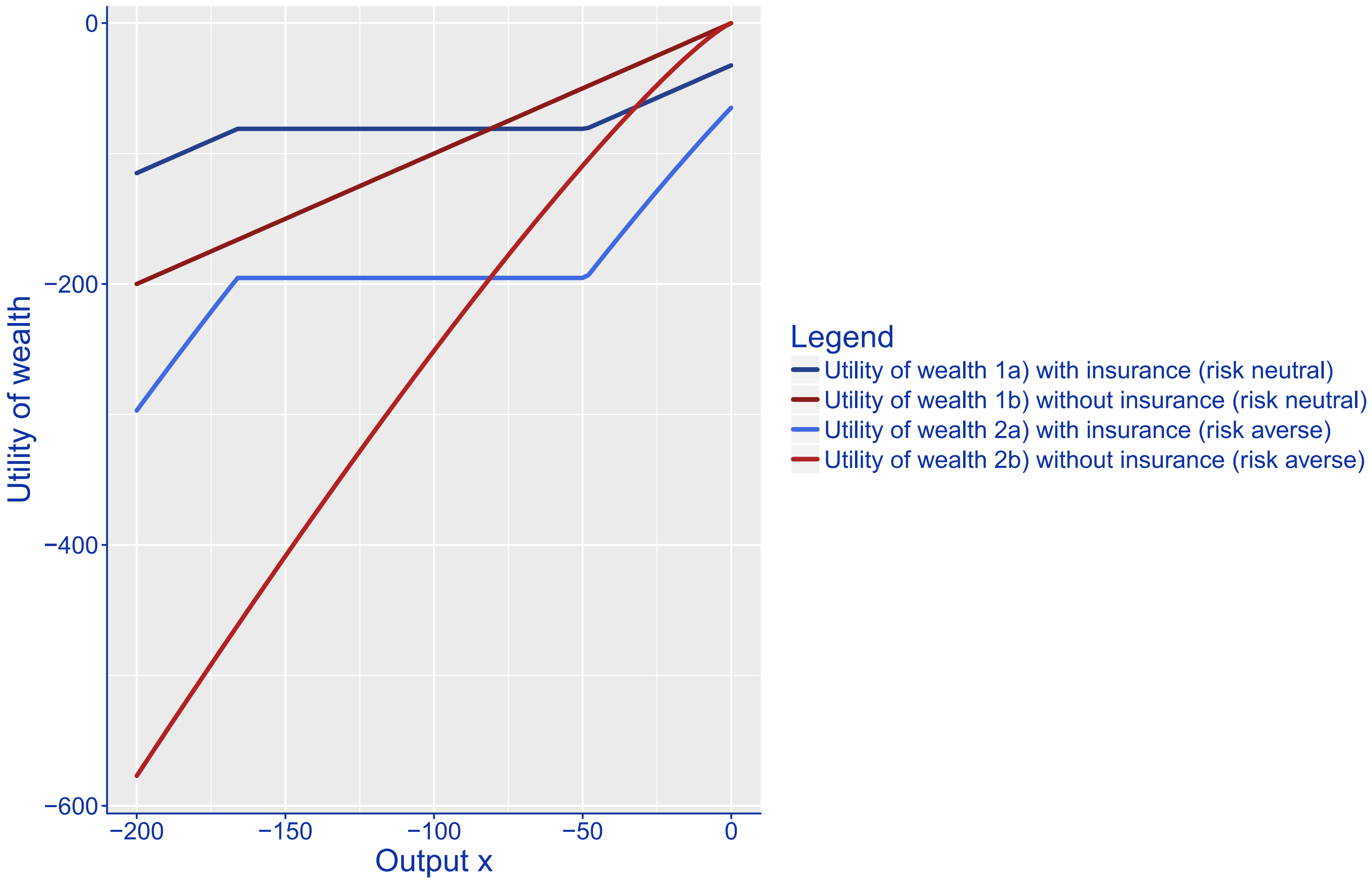
3. Results
Influence of Effort on the Distribution of Output



3. Results
Influence of Reimbursement on Wealth

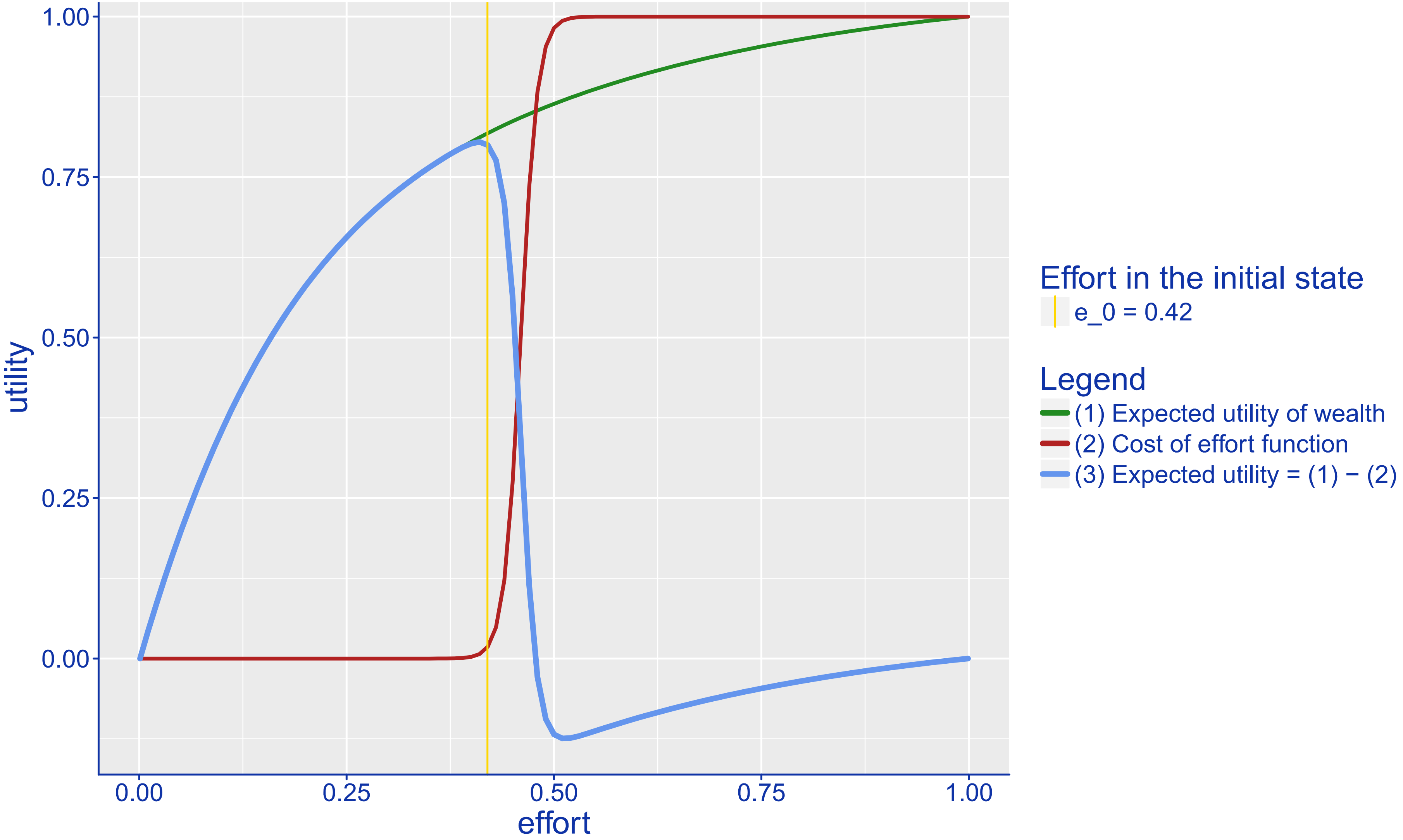


3. Results
Utility of Wealth and Risk Aversion



3. Results

Initializing the Algorithm: Calibrating the Model



3. Results
Optimal Contract Resolution Algorithm

- Initial contract of insured $i = 4627$
  - Initial characteristics $\Pi_0^i = 32, \Lambda_0^i = 117, \Psi_0^i = 49$
  - Initial effort $\mathbf{e}_{1,0}^i = 0.42$
  - Initial expected annual profit $V_{\Pi_0^i, R_{\Lambda_0^i, \Psi_0^i}}(\mathbf{e}_{1,0}^i) = 12$
- Potential premium adjustment (monopoly situation)
  - Premium adjustment $\Pi_{t_1}^i = 50, \Lambda_0^i = 117, \Psi_0^i = 49$
  - The effort decreases to $\mathbf{e}_{1,t_1}^i = 0.41$
  - The expected annual profit increases to $V_{\Pi_{t_1}^i, R_{\Lambda_0^i, \Psi_0^i}}(\mathbf{e}_{1,t_1}^i) = 29$

3. Results
Optimal Contract Resolution Algorithm

- The algorithm converged for insured $i = 4627$ and effort $j = 1$:

$$(\Pi_*^i = 67, \Lambda_*^i = 421, \Psi_*^i = 49, \mathbf{e}_{1,*}^i = 0.39)$$

- The expected annual profit increases to

$$V_{\Pi_*^i, R_{\Lambda_*^i, \Psi_*^i}}(\mathbf{e}_{1,*}^i) = 38$$

4. Conclusion

4. Conclusion

- Innovative approach
  - Operational application of Contract Theory to Health Insurance
  - Behavioural Model
  - Optimal Contract Resolution Algorithm
- Next challenges of the Optimal Contract Resolution Algorithm
  - Health Capital of the insured
  - Moral hazard of the health care provider
  - Competitive situation

Thank you for your attention

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