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

Costin Oarda,
CSS Insurance

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IAA AAI ASTIN Non-Life Insurance

About the speaker

Costin Oarda

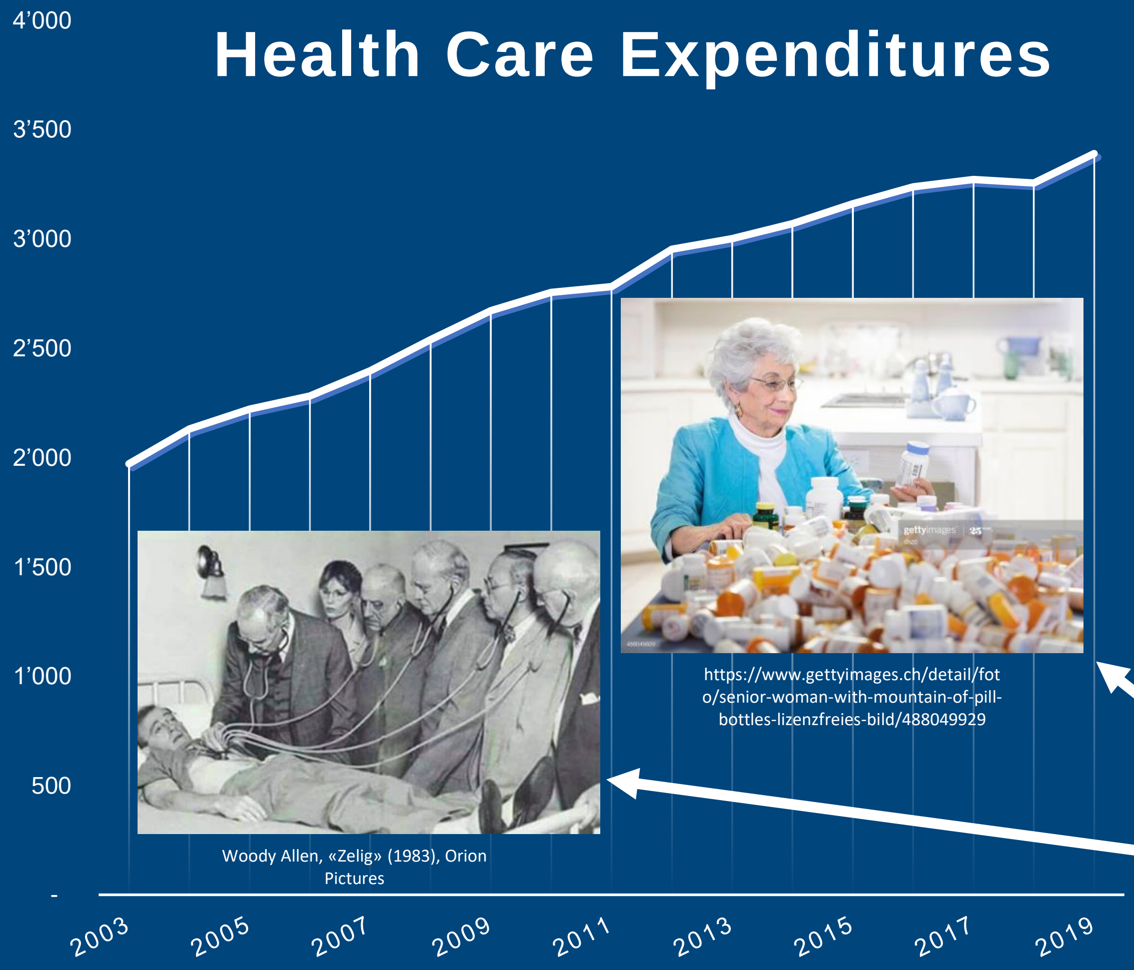
- Qualified Actuary of the French and Swiss Associations of Actuaries (IA & SAA)
- Reserving Actuary, CSS Insurance
- Research on Moral Hazard Problem (Health Insurance)

CSS Insurance

- Market leader in health insurance in Switzerland
- 1.6 million policyholders (31.12.2020)
- 6.5 billions in premiums earned (2020)

1. Introduction

1. Introduction
Moral Hazard in Health Insurance



https://www.gettyimages.ch/detail/foto/senior-woman-with-mountain-of-pill-bottles-lizenzfreies-bild/488049929

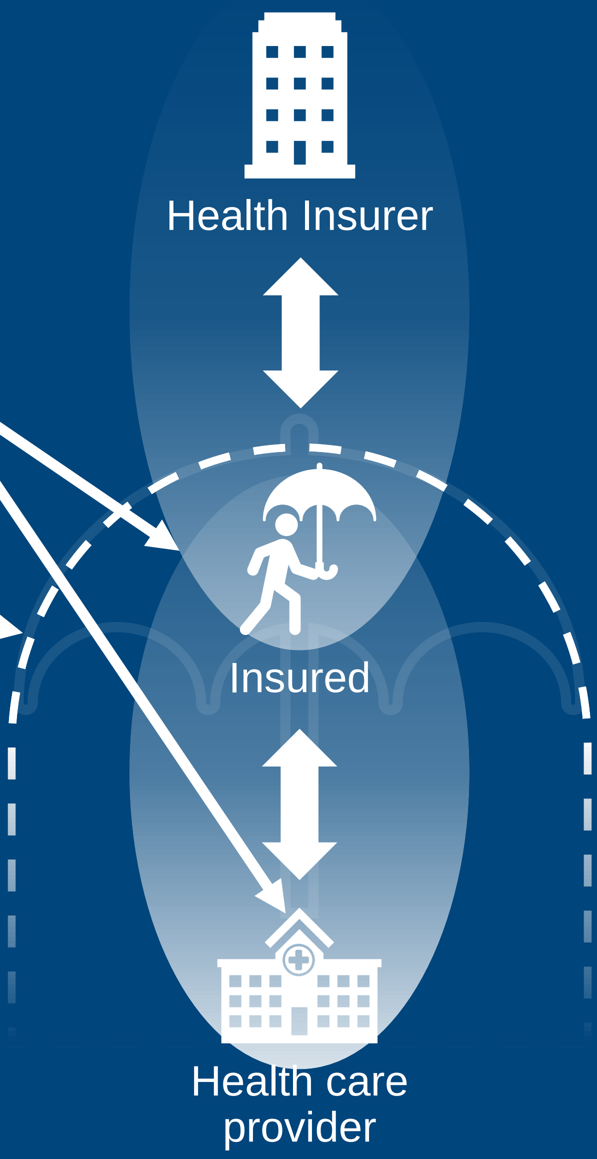
Woody Allen, «Zelig» (1983), Orion Pictures

Moral Hazard Problem

1. Information asymmetry

2. Inefficient incentives in the health system

3. Non-self-responsible behaviour / inefficiency



1. Introduction
Moral Hazard in Health Insurance

Moral Hazard: a solution?

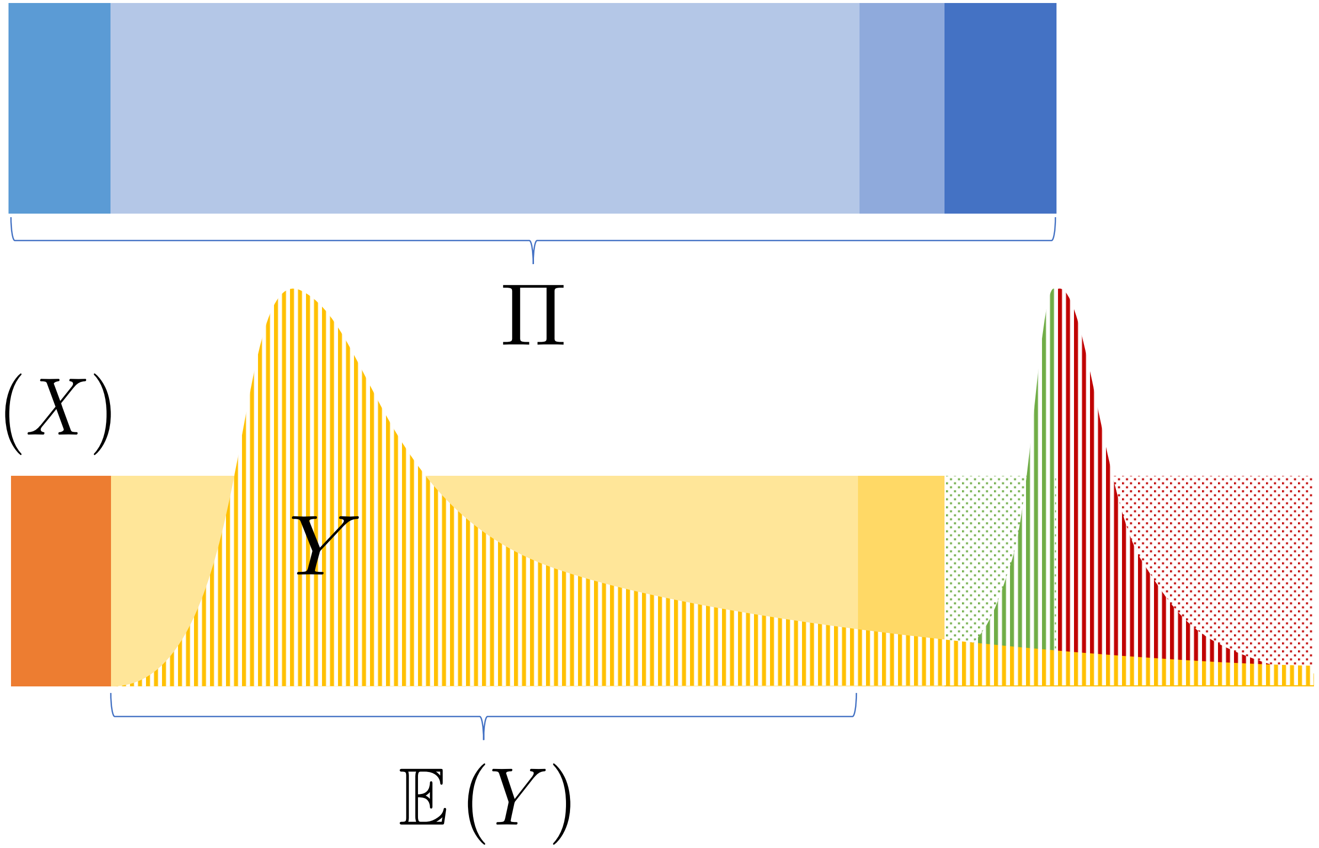
Behavioural Model

Optimal Contract Resolution Algorithm

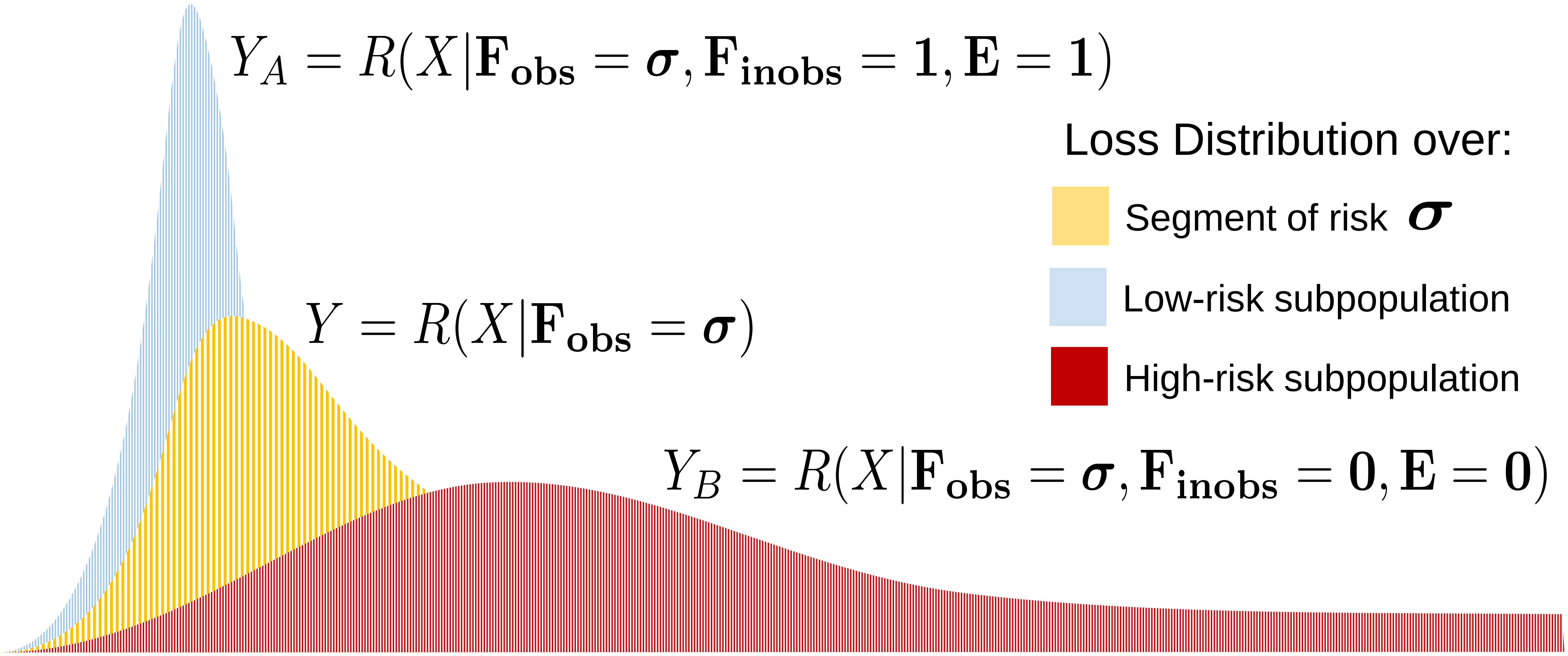
1. Introduction
Insurance Contract, a Risk Transfer

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 $c(\mathbf{e})$

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

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

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

- 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 $E \backsim \mathcal{U}(0;1)$

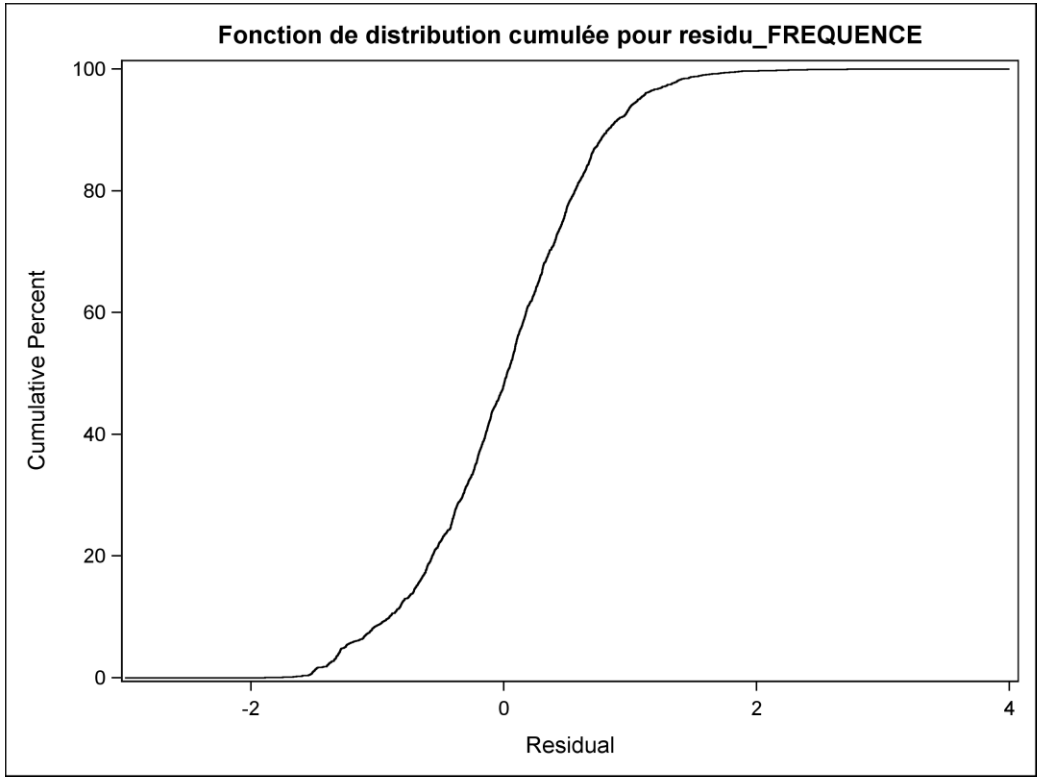
2. Methods
Optimal Contract Resolution Algorithm

- Preparation
  - Design the theoretical model and modelling framework
  - Implement in SAS & R
    - 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
Behavioural Model (Frequency)

Residual Distribution (Frequency Model) over the Insured Segment



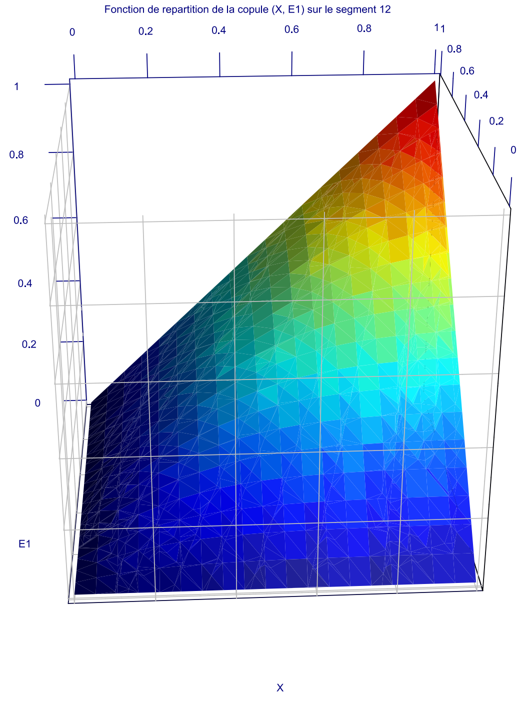
Construction of the Effort Indicator in Frequency

- 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 $i = 4627$:

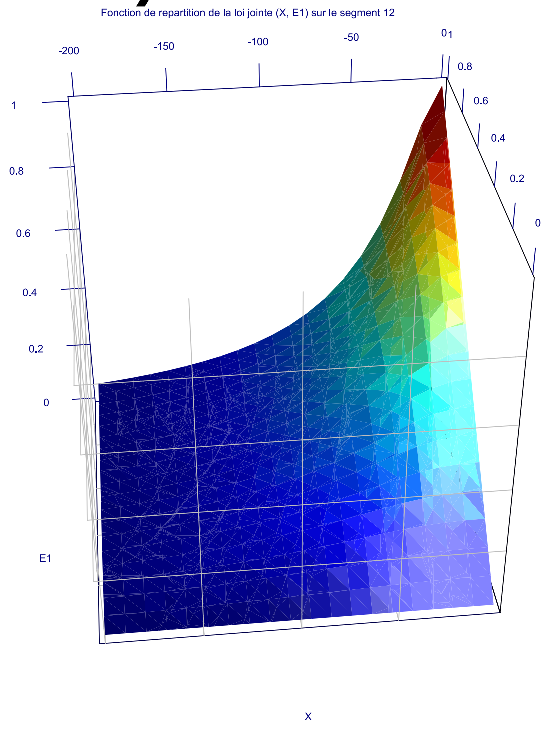
$$e = 0.42$$

3. Results
Parametric Copula Estimation

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

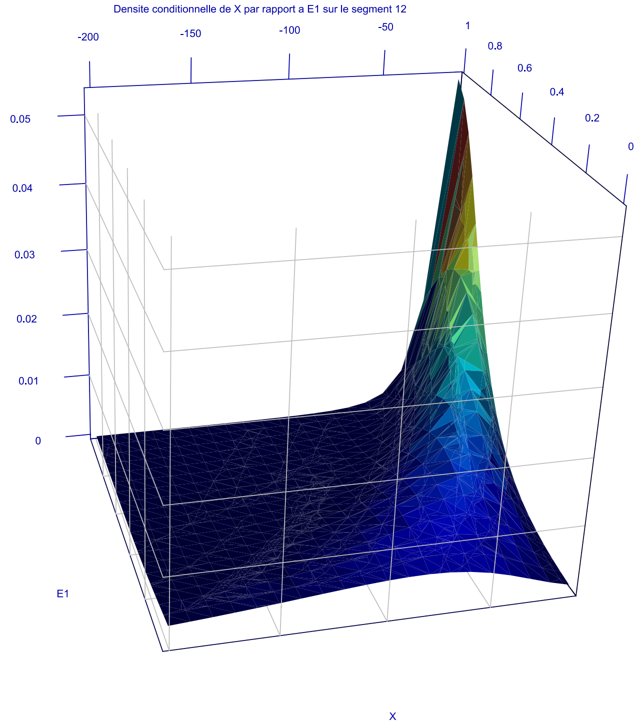


Cumulative Distribution Function of the Joined Distribution (X, E1) (Segment 12)

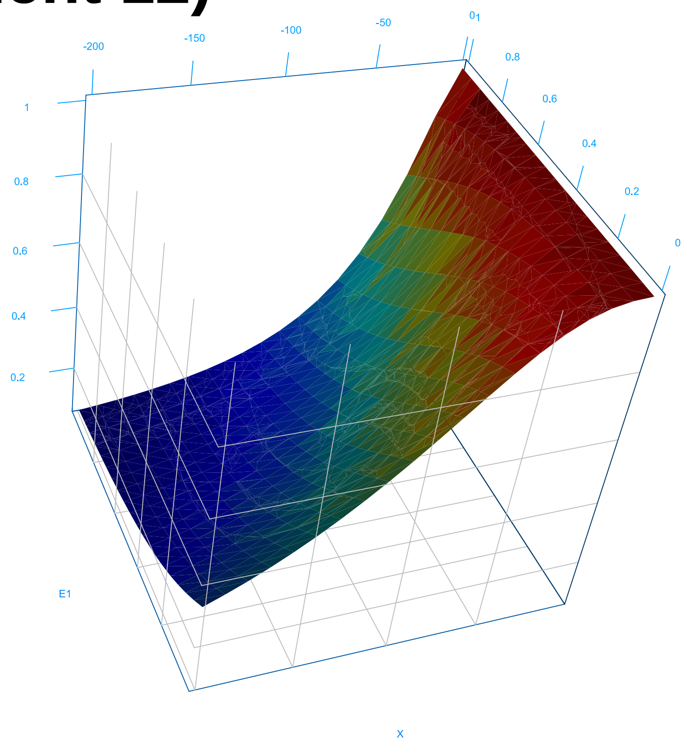


3. Results
Conditional density estimation

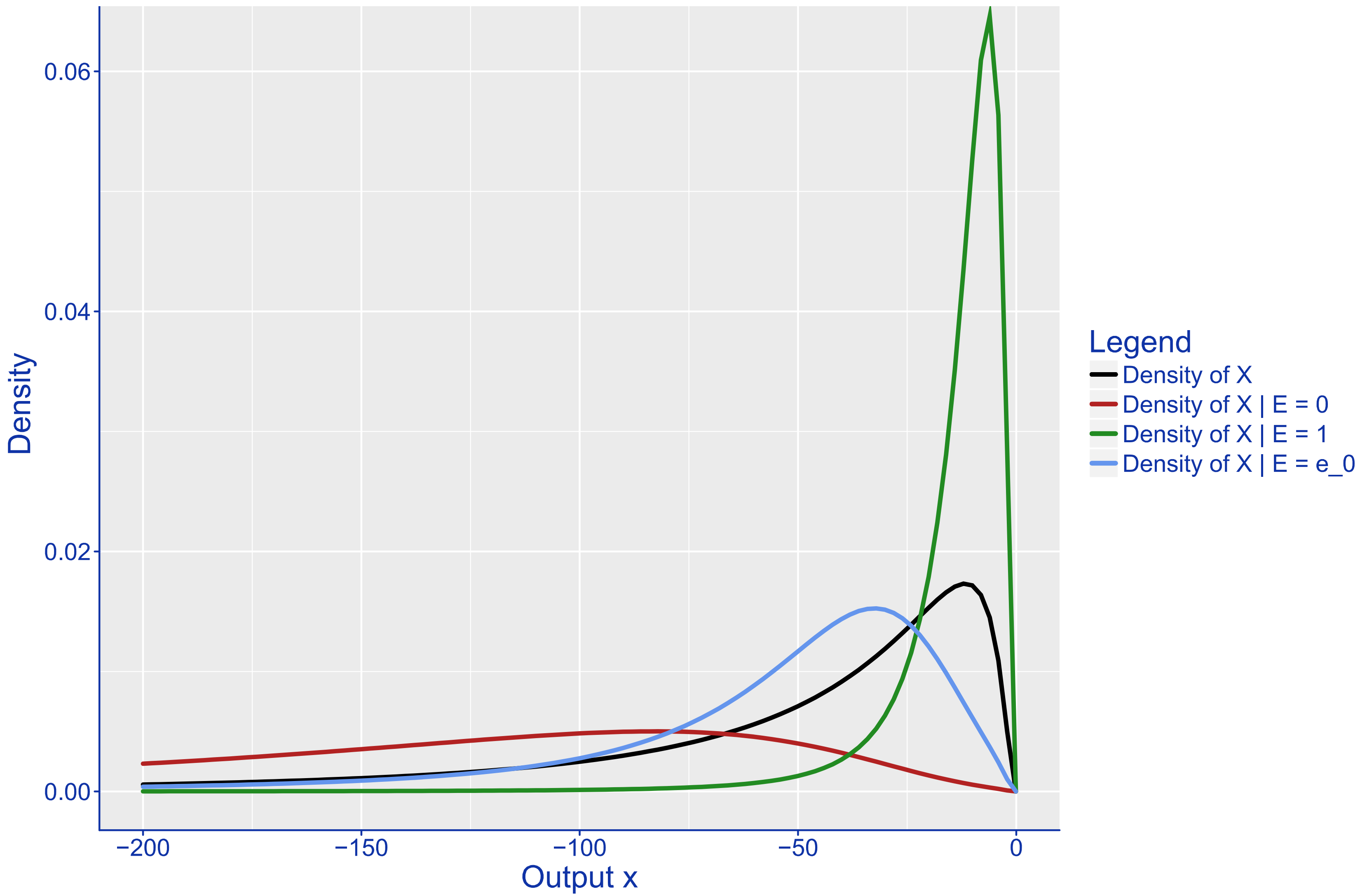
Conditional Density Function of Output X Given the Effort E1 (Segment 12)



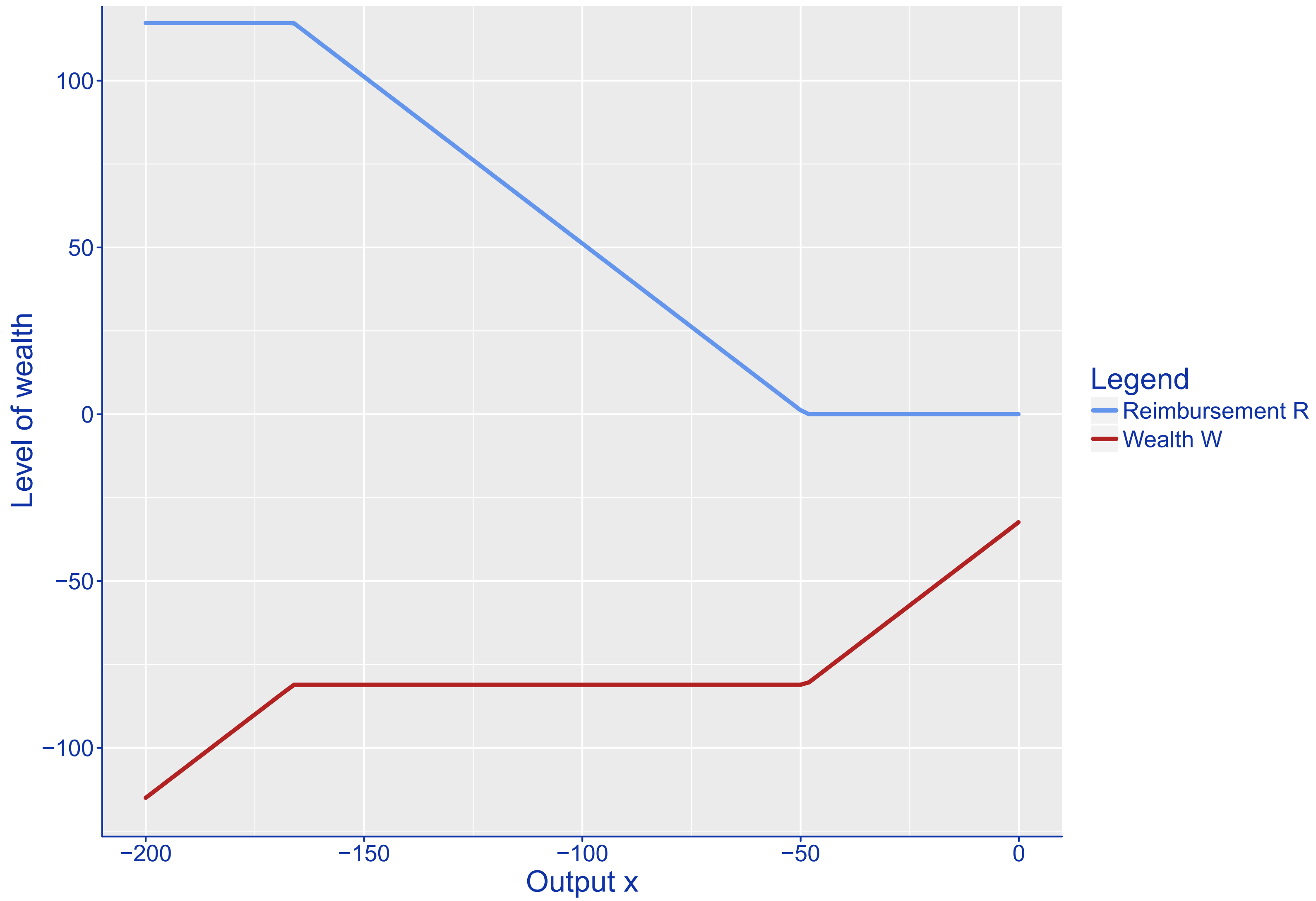
Cumulative Distribution Function of Output X Given the Effort E1 (Segment 12)



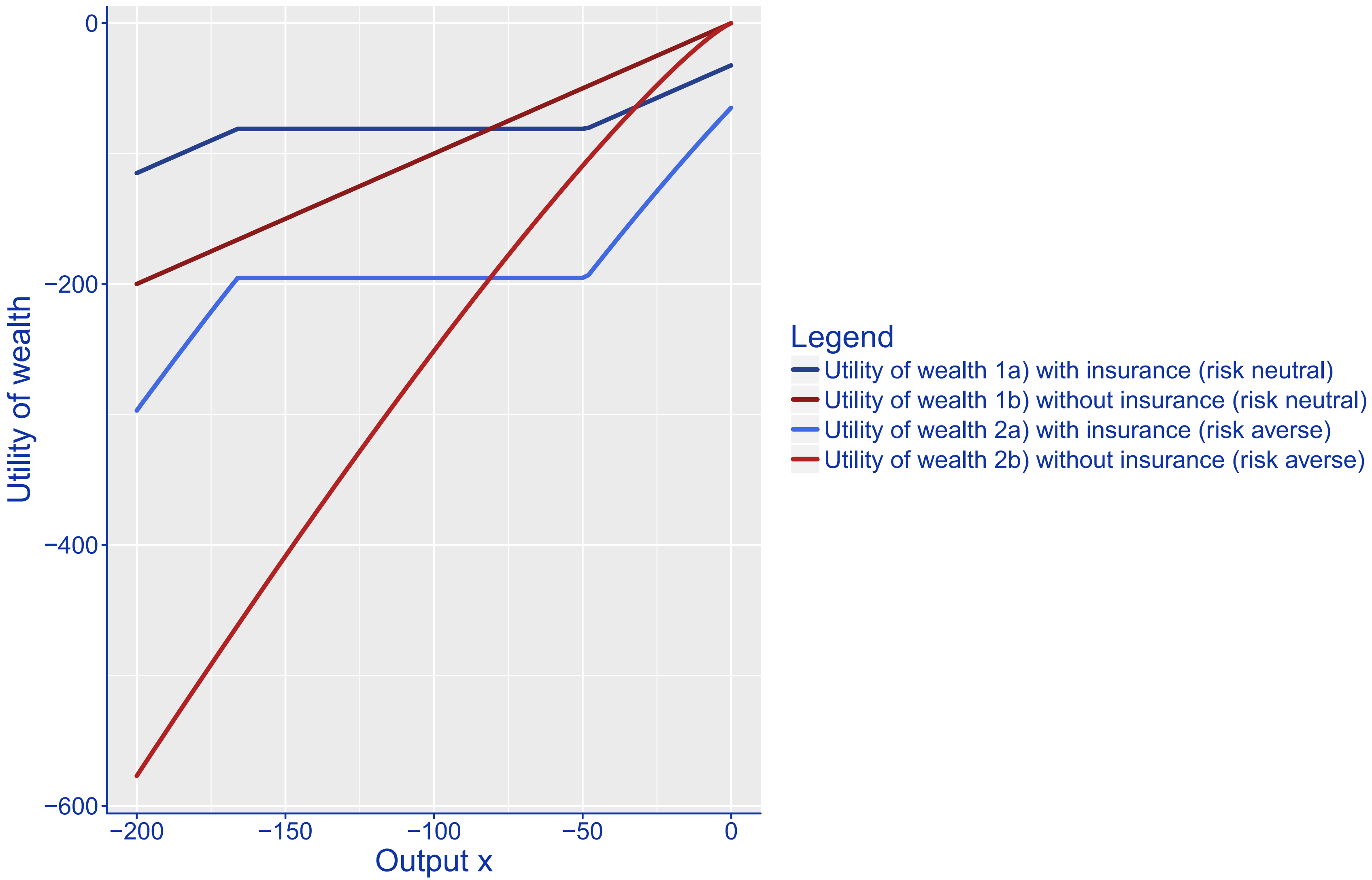
3. Results
Influence of Effort on the Distribution of Risk X



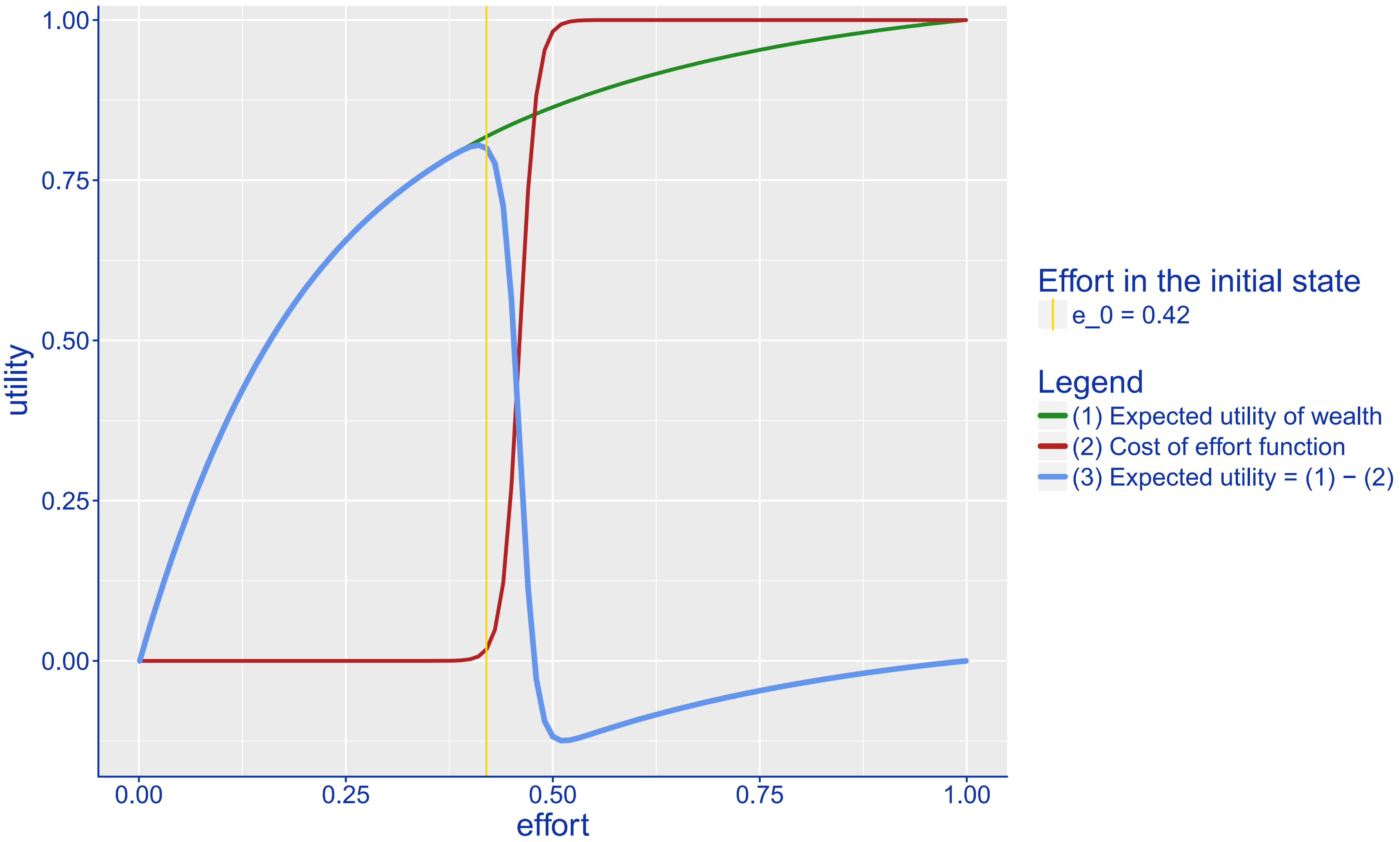
3. Results
Influence of Reimbursement on Wealth



3. Results
Utility of Wealth and Risk Aversion



3. Results
Initializing the Algorithm: Calibrating the Model



3. Results
Optimal Contract Resolution Algorithm

- The Optimal Contract Resolution Algorithm converged
- We obtained the optimal contract (optimal premium and reimbursement function) for each insured
- With the new contract design, the expected annual profit of the insurer increases up to 320% (in a monopolistic market)

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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