Real
Rate

Explainable Artificial Intelligence (XAI) in Ratings

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KI Community Meetup (Online)

Agenda

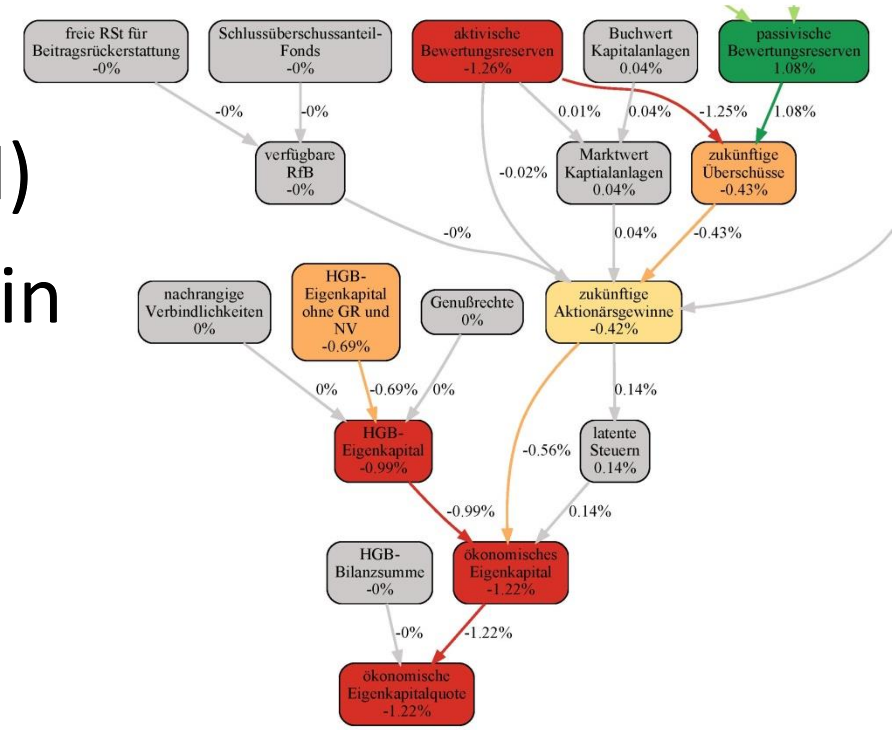
1) About RealRate
2) Causality Examples
3) Causal Analysis:
   Total Derivatives and Graph Theory
4) Causing Software
5) Application:
   Insurer’s Financial Strength Ratings

Part 1

About RealRate

AI Ratings

- Fully automated company ratings
- Financial strength
- Fair Explainable AI (XAI)
- Explainable within 2 min
- No conflict of interest



Business Model

- Selling seals of approval to companies for marketing / branding
- Automated report generation
- Highly scalable

Competitors

- Big Three: S&P, Moody‘s, Fitch
- Locals GER: Assekurata, Morgen&Morgen

Milestones

- Dec 2016: Founded in Germany
- Oct 2019: Going live RealRate.de
- Nov 2019: First customers
- Oct 2020: Accelerators: SBC, GSD

Next:

- Scale up over industries, entering US market

Awards

- Mar 2020: Top German AI startup by appliedAI
- Oct 2020: Winner PyTorch AI Hackathon
- Oct 2020: Top 25 Insurtech CEOs 2020
- Nov 2020: “Most Innovative Fully-Transparent AI Ratings Provider” by EU Business News

Founders

Dr. Holger Bartel, CEO (CV)

- Fintech founder (Prozentor, DigiOptions)
- Insurance manager (Gothaer, ERGO)

Harald Bartel, CMO, CTO (CV)

- Fintech founder (Prozentor, Adspert)
- CTO at Adspert

Prof. Dr. Mirko Kraft, Advisor (CV)

- Coburg University
- Insurance and Risk Management

Part 2

Causality Examples

Self-Driving Cars

Bank Loans

Part 3

Causal Analysis:

Total Derivatives and Graph Theory

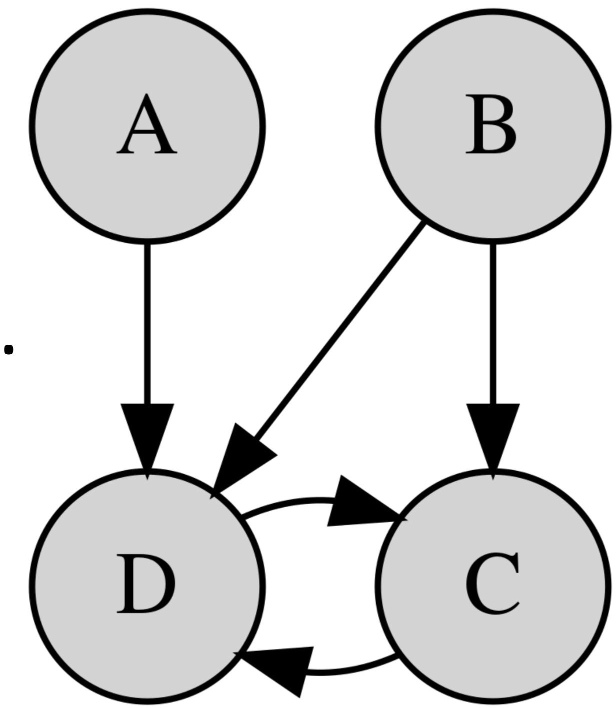
Causal Graph (1/2)

- Causal graph shows causal dependencies between variables (vertices / nodes).
- Arrows (edges / vertices) are causal directions ”→” instead of symmetric correlations.
- Causal graph of direct effects is a structural model, total effects are reduced form model.
- A means for explainable artificial intelligence (XAI) in neural networks

Causal Graph (2/2)

Each arrow indicates a direct cause. Example:

- D depends on A, B, C.
  C depends on B, D.
  A and B are independent.
- A, B exogenous (no arrow in).
  C, D endogenous.
- Cyclic graph since C, D
  cause each other



Causal Analysis

- Causal analysis of sensitivity:
  <u>Effect</u> of a variable on another
- <u>Mediation</u> analysis:
  Decomposition of effects over child variables

Effect Formulas

Total exogenous and endogenous effects:

$$E_x = \left(I_n - M_y\right)^{-1} M_x$$

$$E_y = \left(I_n - M_y\right)^{-1} \left(I_n \circ \left(I_n - M_y\right)^{-1}\right)^{-1}$$

Mediation exogenous and endogenous effects on y_j:

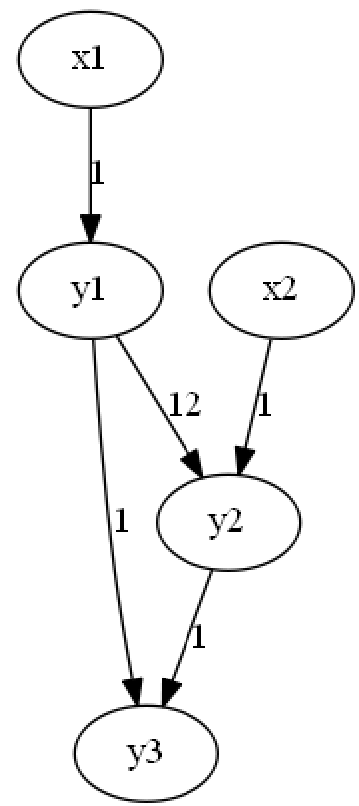
$$F_x^j = \left(\left(\left(I_n - M_y\right)^{-1}\right)_{(j)}^{T} \mathbf{1}_{(m)}\right) \circ M_x$$

$$F_y^j = \left(1_{nn} - I_n\right) \circ \left[\left(\left(I_n - M_{y11}\right)^{-1}\right)_{(j)}^{T}, \ldots, \left(\left(I_n - M_{ynn}\right)^{-1}\right)_{(j)}^{T}\right] \circ M_y$$

Example (1/7)

- $y_1 = x_1$
  $y_2 = 2y_1^2 + x_2$
  $y_3 = y_1 + y_2$
  Note: read (=) as (←)
- Exogenous $\mathbf{x} = \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} 3 \\ 2 \end{bmatrix}$
- Solution $\mathbf{y} = \begin{bmatrix} y_1 \\ y_2 \\ y_3 \end{bmatrix} = \begin{bmatrix} 3 \\ 20 \\ 23 \end{bmatrix}$
- Partial graph: denote edges by non-zero partial derivatives M_x, M_y at $\mathbf{x}$

<u>Partial Graph</u>



Example (2/7)

- Simple nonlinear, acyclic system with non-constant matrix of partial derivatives:

$$\underset{(n\times m)}{M_x} = \frac{\partial \mathbf{y}}{\partial \mathbf{x}^T} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \\ 0 & 0 \end{bmatrix},$$

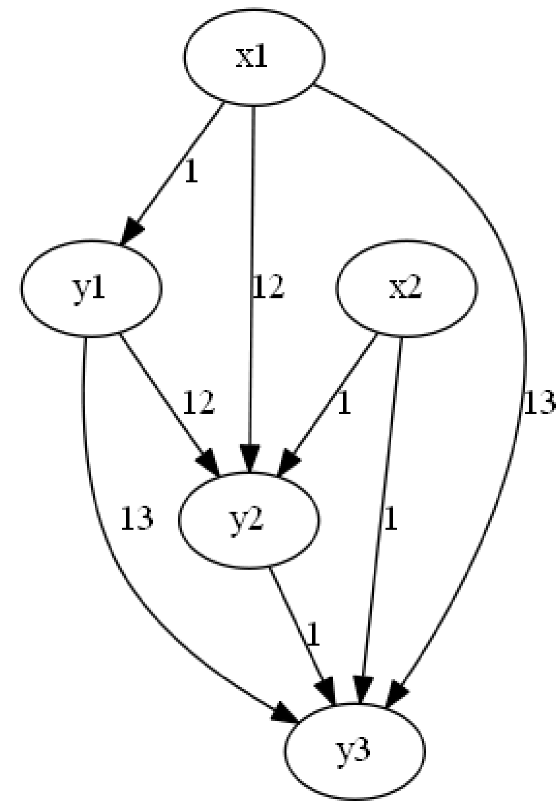
$$\underset{(n\times n)}{M_y} = \frac{\partial \mathbf{y}}{\partial \mathbf{y}^T} = \begin{bmatrix} 0 & 0 & 0 \\ 4x_1 & 0 & 0 \\ 1 & 1 & 0 \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 \\ 12 & 0 & 0 \\ 1 & 1 & 0 \end{bmatrix}$$

- Proxy: original model is neither linear nor homogeneous (dependence on individual $\mathbf{x}$)

Example (3/7)

- Total graph: denote edges by non-zero total effects $\mathrm{E_x}$, $\mathrm{E_y}$ at $\mathbf{x}$
- Don’t show total own effects ($\equiv 1$)
- More arrows than partial graph because of indirect effects

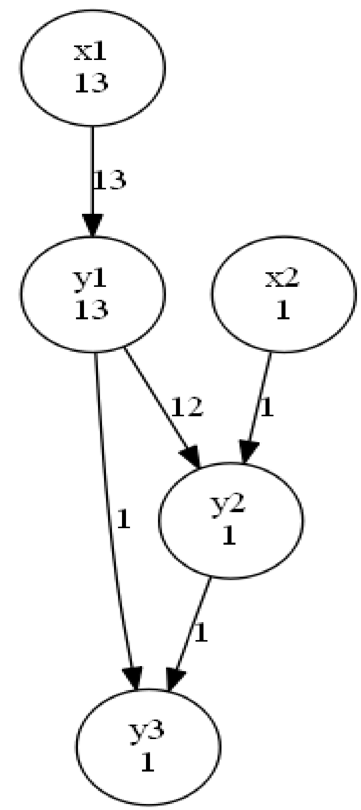
Total Graph



Example (4/7)

- Mediation analysis for final variable y_j with $j = 3$
- Mediation effect: is total effect, partitioned over all outgoing edges
- Mediation graph: denote edges by non-zero mediation effects F_x^j, F_y^j at own effects are defined to be zero, denote nodes by total effects

Mediation Graph



Example (5/7)

Total Effects:

$$E_x = \left(I_n - M_y\right)^{-1} M_x = \begin{bmatrix} 1 & 0 & 0 \\ 12 & 1 & 0 \\ 13 & 1 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ 0 & 1 \\ 0 & 0 \end{bmatrix}$$

$$= \begin{bmatrix} 1 & 0 \\ 4y_1 & 1 \\ 4y_1 + 1 & 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 12 & 1 \\ 13 & 1 \end{bmatrix}$$

$$E_y = \left(I_n - M_y\right)^{-1} \left(I_n \circ \left(I_n - M_y\right)^{-1}\right)^{-1}$$

$$= \begin{bmatrix} 1 & 0 & 0 \\ 4y_1 & 1 & 0 \\ 4y_1 + 1 & 1 & 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 12 & 1 & 0 \\ 13 & 1 & 1 \end{bmatrix}$$

Example (6/7)

Mediation Effects:

$$\mathrm{F}_{\mathrm{x}}^{3} = \left(\left(\left(\mathrm{I}_{\mathrm{n}} - \mathrm{M}_{\mathrm{y}}\right)^{-1}\right)_{(3)}^{\mathrm{T}} \mathbf{1}_{(\mathrm{m})}\right) \circ \mathrm{M}_{\mathrm{x}}$$

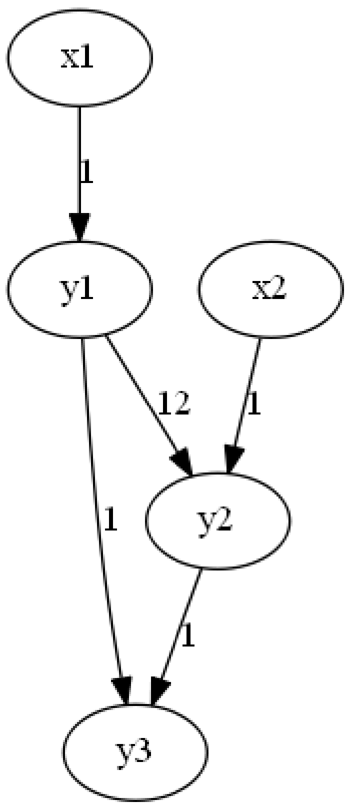
$$= \begin{bmatrix} 13 & 13 \\ 1 & 1 \\ 1 & 1 \end{bmatrix} \circ \begin{bmatrix} 1 & 0 \\ 0 & 1 \\ 0 & 0 \end{bmatrix} = \begin{bmatrix} 13 & 0 \\ 0 & 1 \\ 0 & 0 \end{bmatrix}$$

$$\mathrm{F}_{\mathrm{y}}^{3} = (1_{\mathrm{nn}} - \mathrm{I}_{\mathrm{n}}) \circ \left[\left(\left(\mathrm{I}_{\mathrm{n}} - \mathrm{M}_{\mathrm{y11}}\right)^{-1}\right)_{(3)}^{\mathrm{T}}, \ldots, \left(\left(\mathrm{I}_{\mathrm{n}} - \mathrm{M}_{\mathrm{ynn}}\right)^{-1}\right)_{(3)}^{\mathrm{T}}\right] \circ \mathrm{M}_{\mathrm{y}}$$

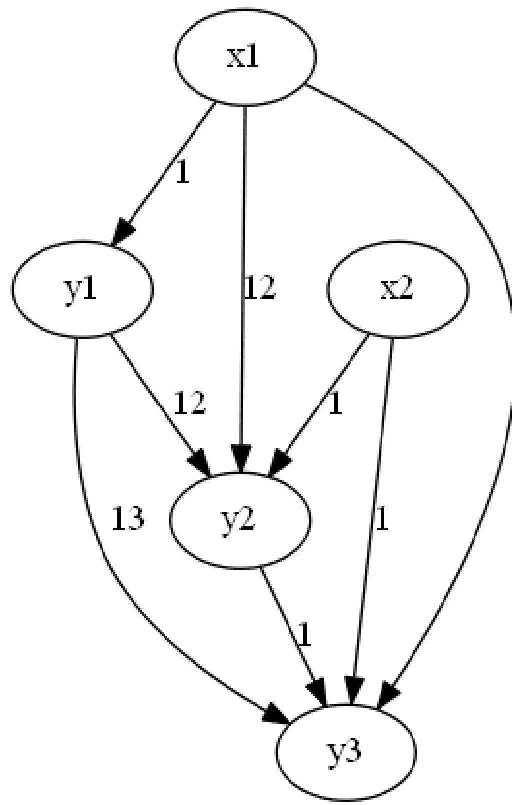
$$= \begin{bmatrix} 0 & 0 & 0 \\ 12 & 0 & 0 \\ 1 & 1 & 0 \end{bmatrix}$$

Example (7/7)

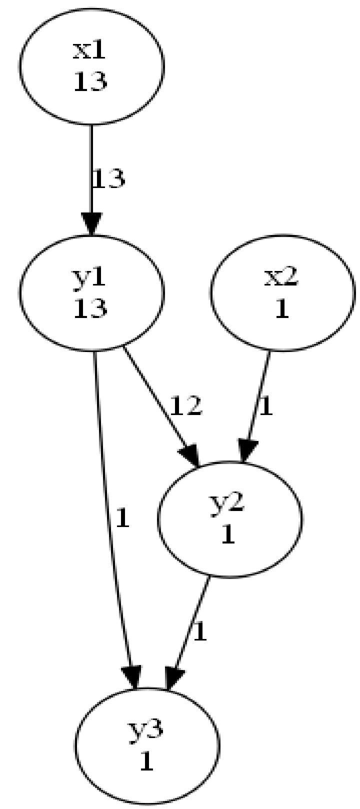
Partial Graph
(direct effects)



Total Graph
(total effects)



Mediation Graph
(mediation effects on final variable y_3)



Part 4

Causing Software

Causing Software

- Causing: CAUsal INterpretation using Graphs
  https://github.com/HolgerBartel/Causing
- Real World Example:
  Wages of young American workers
  https://github.com/HolgerBartel/Causing/blob/master/education.md

Part 5

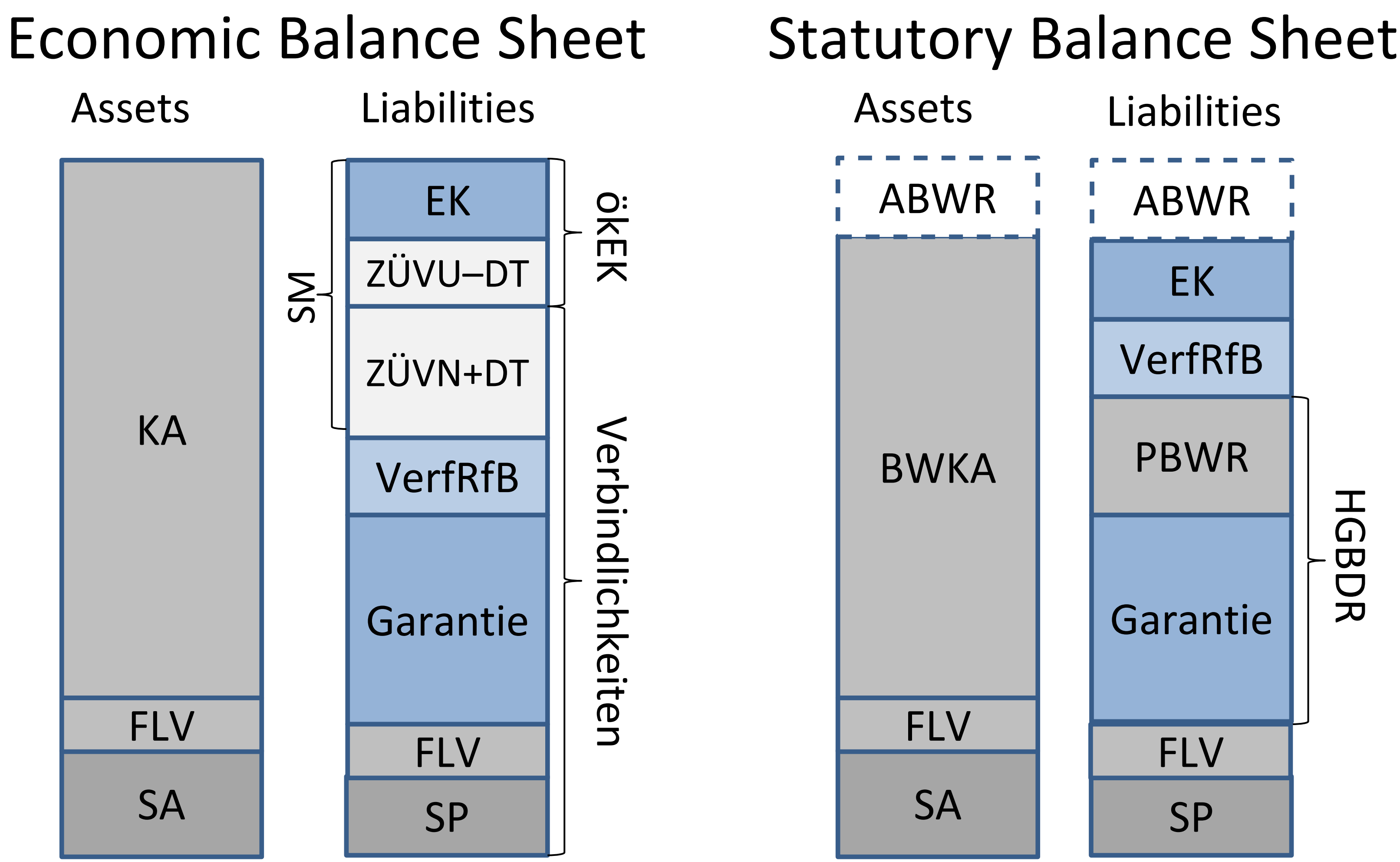
Application:

Insurance
Financial Strength Ratings

Application: Insurance Ratings

- Application to financial strength ratings of German life insurers
- Model equations from expert system
- Holistic approach instead of just key figures
- Public input data from balance sheet
- Revaluation to market values
- Simple: no simulation, no cash flows
- Final variable is economic capital ratio (ökonomische Eigenkapital-Quote, ökEK)

Economic Balance Sheet



Model Equations (1/2)

1) EK = EKoGRNV + GR + NV
2) VerfRfB = FreieRfB + SÜAF
3) DR = HGBDR – ZZR
4) MRZ = (ZA – ZZRA) / DR
5) KE = KAE – KAA
6) ZE = KE – ZA
7) JÜV = JÜ + GewAb + Steuer
8) RÜ = JÜV + ZRfB + DG
9) RÜE = RÜ – ZE
10) BABRate = ZVF / (DR + FLV)
11) D = 1 / (BABRate + R)
12) KA = BWKA + ABWR
13) Assets = BS + ABWR
14) MWDR = DR * (1 + D*(MRZ–R))
15) ZÜVT = RÜE * D
16) ZÜKA = DR – MWDR + ZZR
17) PBWR = ZÜKA + ZÜVT
18) Garantie = HGBDR – PBWR
19) ZÜ = ABWR + PBWR
20) GuO = … *see Bartel (2014)*
21) ZÜVU = ZÜVUdet – GuO
22) ZÜVN = ZÜ – ZÜVU
23) DT = TaxRate * ZÜVU
24) Puffer = ZÜVN + VerfRfB + DT

Model Equations (2/2)

25) ökEK = EK + ZÜVU – DT
26) ökEK-Quote = ökEK / BS

27) SM = EK + VerfRfB + ZÜ
28) SM-Quote = SM / BS
29) NVZ = KE / BWKA
30) GVZ = MRZ + ZÜVN / (DR * D)
31) SA = BS – BWKA – FLV
32) SP = BS – EK – VerfRfB – HGBDR – FLV

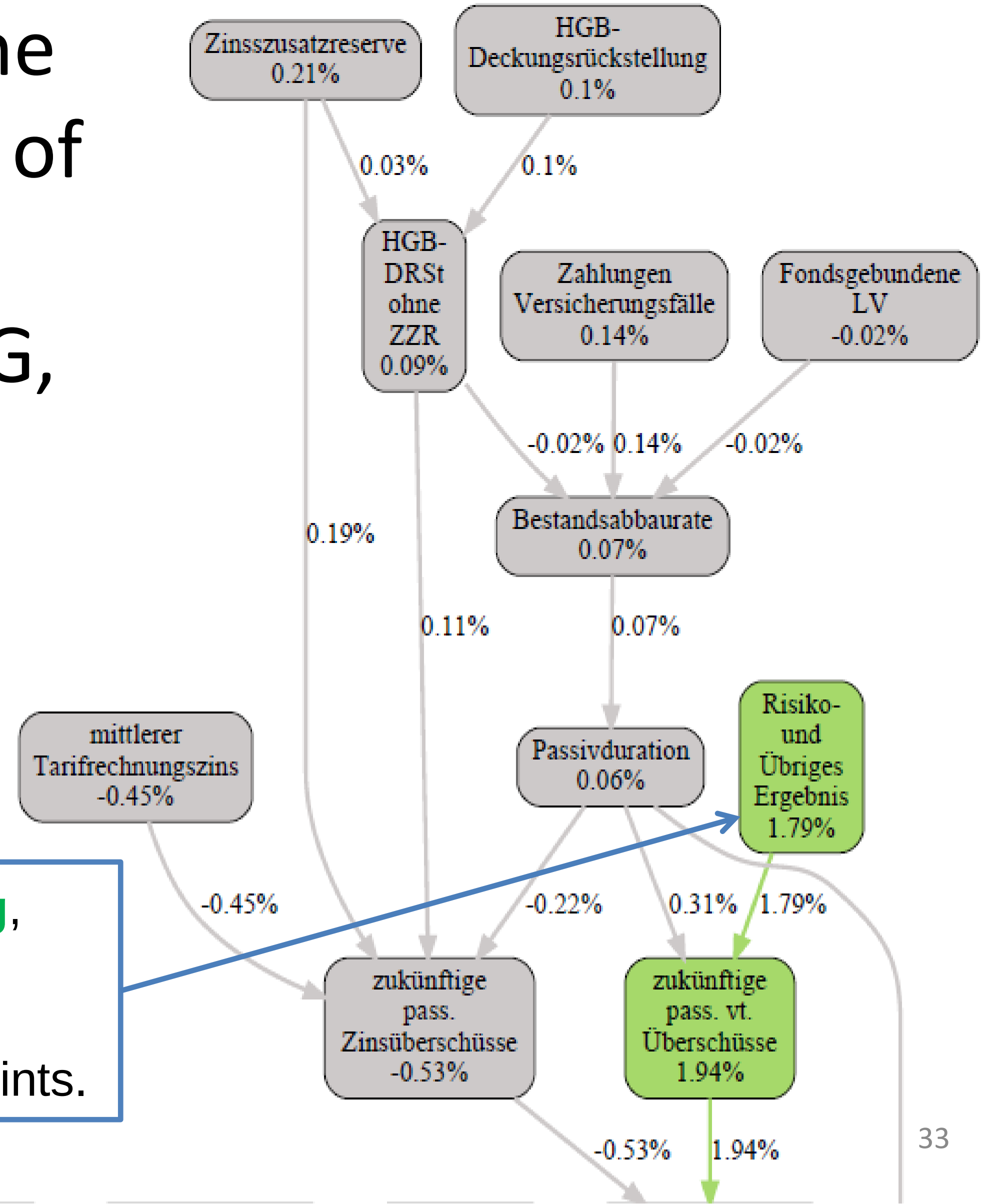
See Bartel, H. (2020) for abbreviations.

Example: Insurance Economic Capital

- Financial strength rating
- HUK-COBURG Lebensversicherung AG
- Accounting year 2017
- Mediation effects with respect to market mean

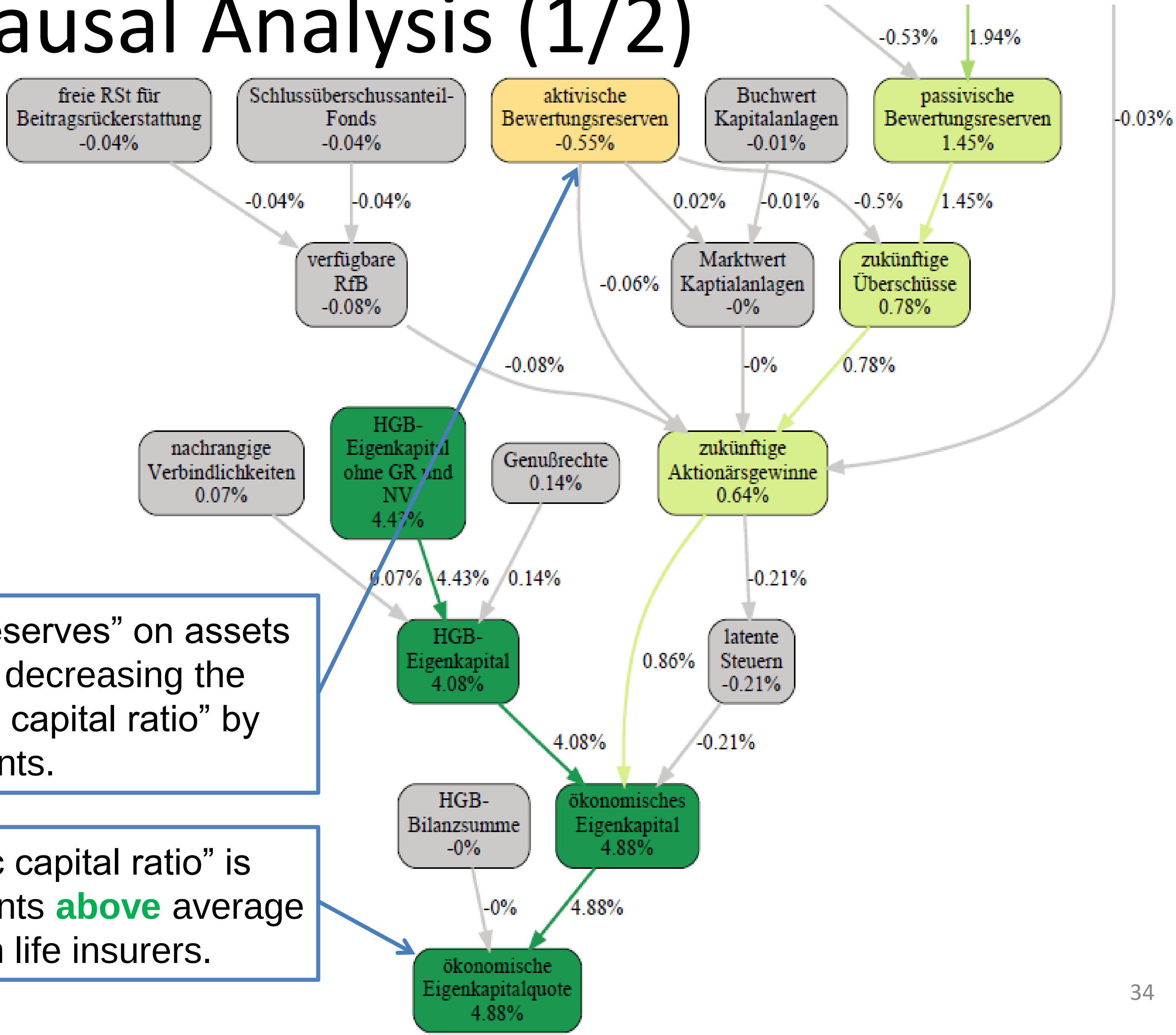
Graphical Causal Analysis (1/2)

Mediation graph for the economic capital ratio of HUK-COBURG Lebensversicherung AG, Accounting year 2017



"Risk and other result" is very **strong**, compared to average of German life insurers, increasing the final variable "economic capital ratio" by 1.79%-points.

Causal Analysis (1/2)



"Hidden reserves" on assets are **weak**, decreasing the "economic capital ratio" by 0.55%-points.

"Economic capital ratio" is 4.88%-points **above** average of German life insurers.

Mediation Effects: Strengths

Größe[0]	Rang[1]	HUK	Markt[2]	Effekt[3] ökonomische Eigenkapitalquote
Quote HGB-Eigenkapital ohne GR und.	1	6,16%	1,73%	4,43%
Quote HGB-Eigenkapital	1	6,37%	2,29%	4,08%
Quote zukünftige pass. vt. Übersch.	4	17,34%	7,87%	1,94%
Quote Risiko- und Übriges Ergebnis	5	1,37%	0,68%	$\boxed{1{,}79\%}$
Quote passivische Bewertungsreserv.	6	11,64%	4,55%	1,45%
Quote zukünftige Überschüsse	16	19,71%	15,88%	0,78%
Quote zukünftige Aktionärsgewinne	17	4,77%	3,91%	0,64%
Quote Zinszusatzreserve	14	6,63%	5,71%	0,21%
Quote Zahlungen Versicherungsfälle	51	5,33%	6,59%	0,14%
Quote Genußrechte	4	0,14%	0,00%	0,14%
...	...	...	...	...

[0] Ratio with respect to total assets

[1] out of 59 insurers, descending order

[2] Median

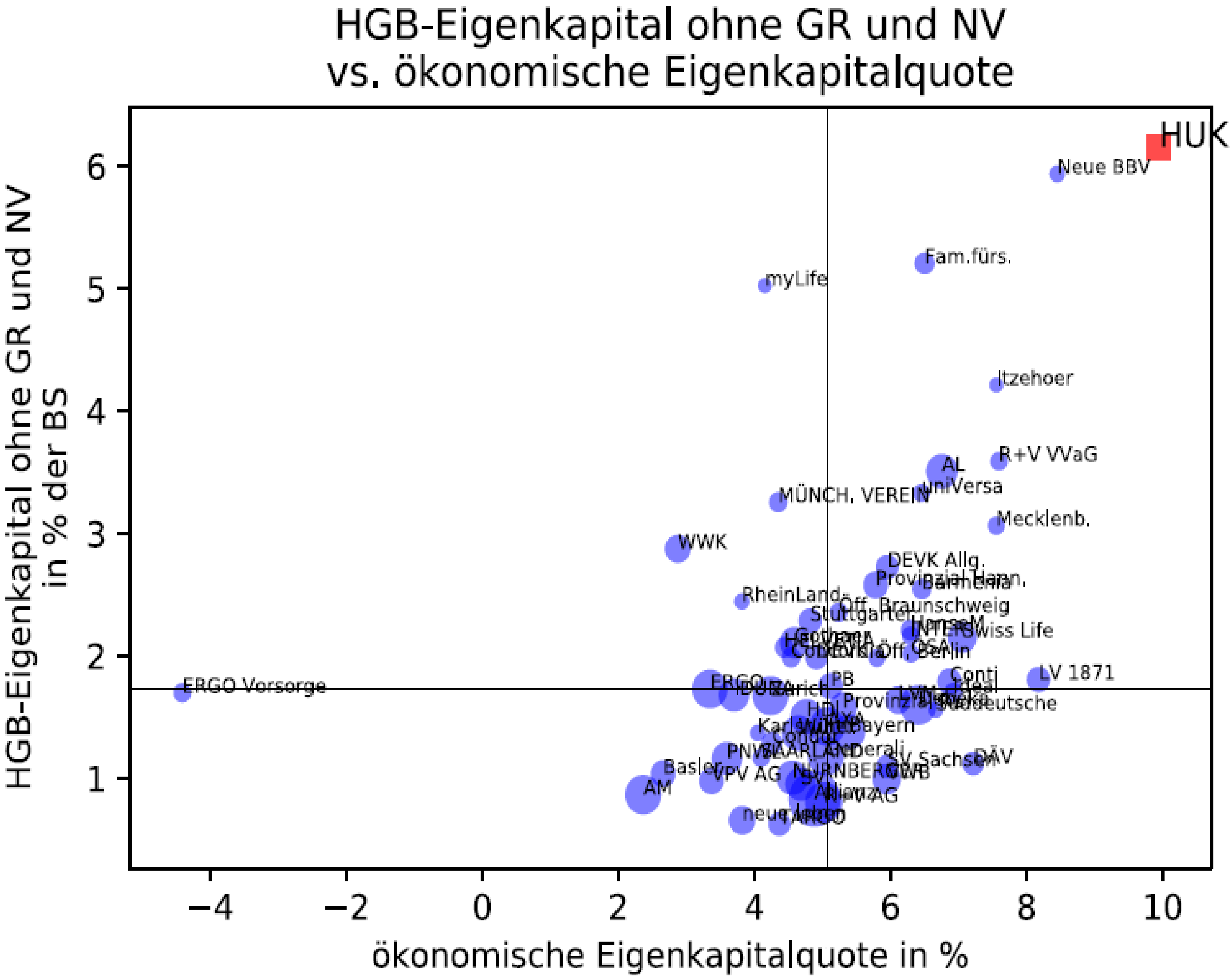
[3] Change in percentage points

Mediation Effects: Weaknesses

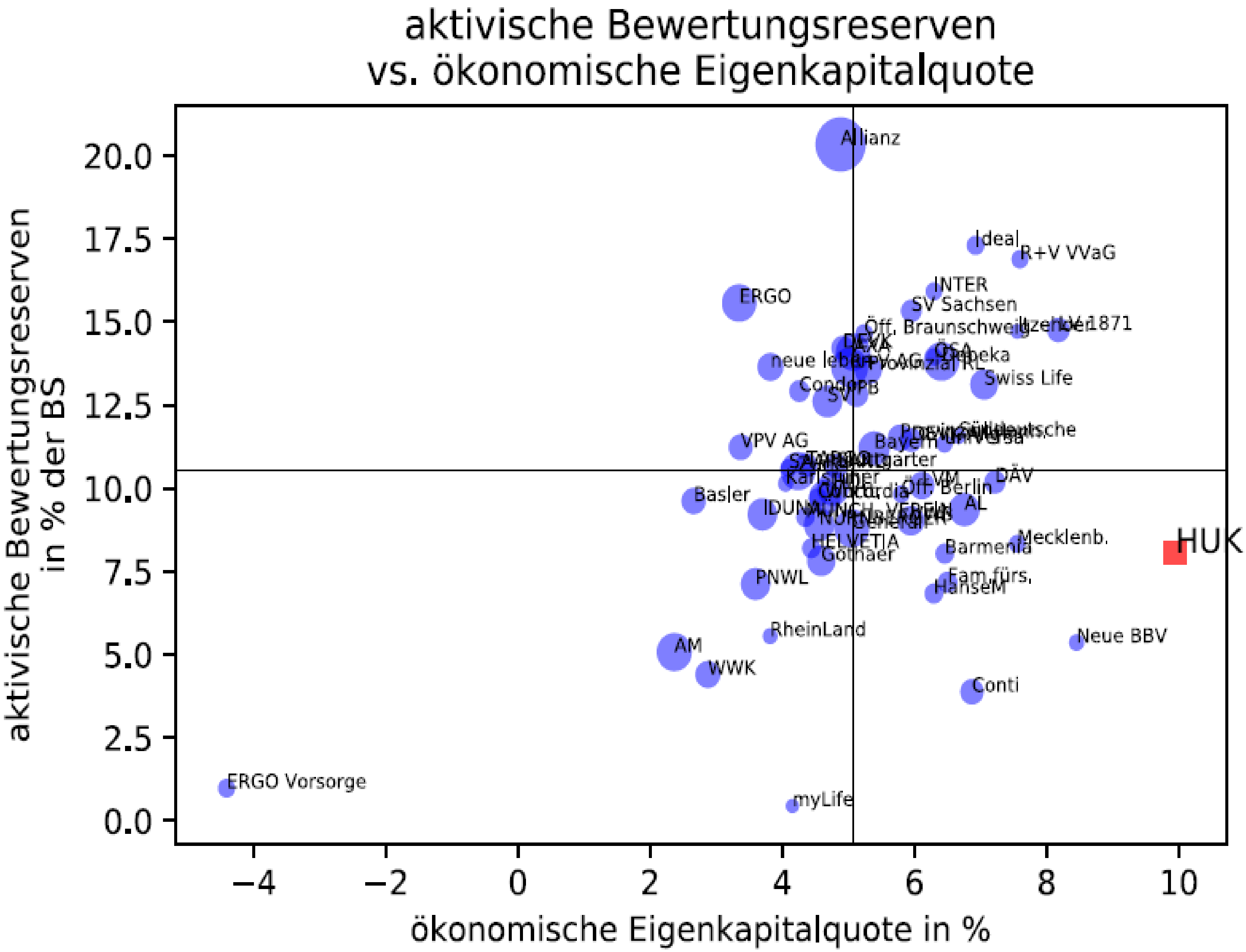
Größe[0]	Rang[1]	HUK	Markt[2]	Effekt[3] ökonomische Eigenkapitalquote
...	...	...	...	...
Quote sonstige Passiva	3	13,14%	5,04%	0,00%
Quote Buchwert Kapitalanlagen	22	94,35%	92,17%	-0,01%
Quote Fondsgebundene LV	45	1,67%	4,59%	-0,02%
Quote Schlussüberschussanteil-Fond.	56	0,18%	1,54%	-0,04%
Quote freie RSt für Beitragsrücker.	57	0,41%	2,12%	-0,04%
Quote verfügbare RfB	59	0,59%	3,73%	-0,08%
Quote latente Steuern	17	1,19%	0,98%	-0,21%
mittlerer Tarifrechnungszins	14	3,27%	3,02%	-0,45%
Quote zukünftige pass. Zinsübersch.	52	-5,69%	-3,09%	-0,53%
Quote aktivische Bewertungsreserve.	47	8,07%	10,51%	-0,55%

[0] Ratio with respect to total assets
[1] out of 59 insurers, descending order
[2] Median
[3] Change in percentage points

Market Plot: Top Strength



Market Plot: Top Weakness



Example Summary

- Company‘s economic capital: 938 Mio. Euro.
- Economic capital ratio: 9,95%.
- First place of 59 German life insurers.
- Top strength: Statutory equity
- Top weakness: Hidden reserves

HUK-COBURG Leben

1.Platz

von 59
Lebensversicherern
2018

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