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Assessing Farmers‘ Willingness-to-pay for Weather Derivatives

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SGA Tagung 2008
Agrarwirtschaftliche Aspekte zu Ursachen und Folgen von Veränderungen in Umwelt und Klima: 3.-4. April 2008, Rapperswil

Management Instruments for Weather Risks

- Choice of technologies
- Choice of products/crops
- Diversification
- Capacity reserves
- Technological regulation of the environment (e.g. irrigation)
- Liquidity reserves

On-farm risk management instruments

- Conventional disaster insurance
- Crop yield and crop revenue insurances
- **Index- based insurances (“Weather Derivatives“)**

external risk management instruments

Crop- vs. Index-based Insurances

Damage-based insurances		
Disaster insurance		
+ **Certain** indemnity payments – **Only** insurance against disaster – **High** transaction costs + **Low** moral-hazard-costs		

⇒ Benefit and relative competitiveness of weather derivatives for farmers?

Objectives

1. **Willingness-to-pay for weather derivatives = assessing the benefit for the farmer**
   - interdependency of instruments
   - dynamic adaptations
   - in an exemplary case

   Portfolio setting

2. **Optimal monopolistic pricing**
   - from the underwriter‘s point of view
   - in the exemplary case

Analyzed Risk Management Instruments

- **Weather derivative (standardized rainfall put option)**
  - **Index:** accumulated rainfall April to June
    at the capital’s meteorological station Berlin-Tempelhof
  - **Purchase date:** July 1, 2005
    Maturity: June 30, 2006
  - **Payoff:** 1 € per 1 mm shortfall of the strike level
  - **Strike level:** 151.6 mm
  - **Fair premium:** 16.85 €

- **Crop revenue insurance for winter wheat**
  - **Payoff:** shortfall of historical average wheat sales
  - **Fair premium:** 78.80 €

Statistical Analysis of Farm Data

- Stochastic single gross margins follow AR(1)

	Winter-Wheat	Sommer-Wheat	Winter-Rye	Winter-Barley	Sommer-Barley	Winter-Canola	Corn	Non-Food-Canola	Weather Derivative	Revenuel Insurance	Set aside land
Expectation value	410	290	367	365	317	610	13	559	0	0	75
Variance	165	146	133	166	135	260	170	228	25	129	0
Correlation Matrix											
Winter Wheat	1.00	0.85	0.74	0.66	0.71	0.53	0.17	0.57	-0.32	-0.40	
Summer Wheat		1.00	0.69	0.56	0.81	0.53	0.32	0.57	-0.38	-0.36	
Winter Rye			1.00	0.68	0.64	0.66	0.08	0.67	-0.31	-0.34	
Winter Barley				1.00	0.63	0.52	-0.02	0.48	-0.25	-0.41	
Sommer Barley					1.00	0.51	0.14	0.53	-0.41	-0.35	
Winter Canola						1.00	0.24	0.98	-0.27	-0.19	
Corn							1.00	0.19	-0.18	-0.20	
Non-Food Canola								1.00	-0.27	-0.15	
Weather Derivative									1.00	0.45	
Revenue insurance										1.00	

Portfolio Model

- **Factors determining the benefit from risk management instruments**

1. Costs → loading (!)

2. Performance → risk inherent in production

→ (negative) correlations

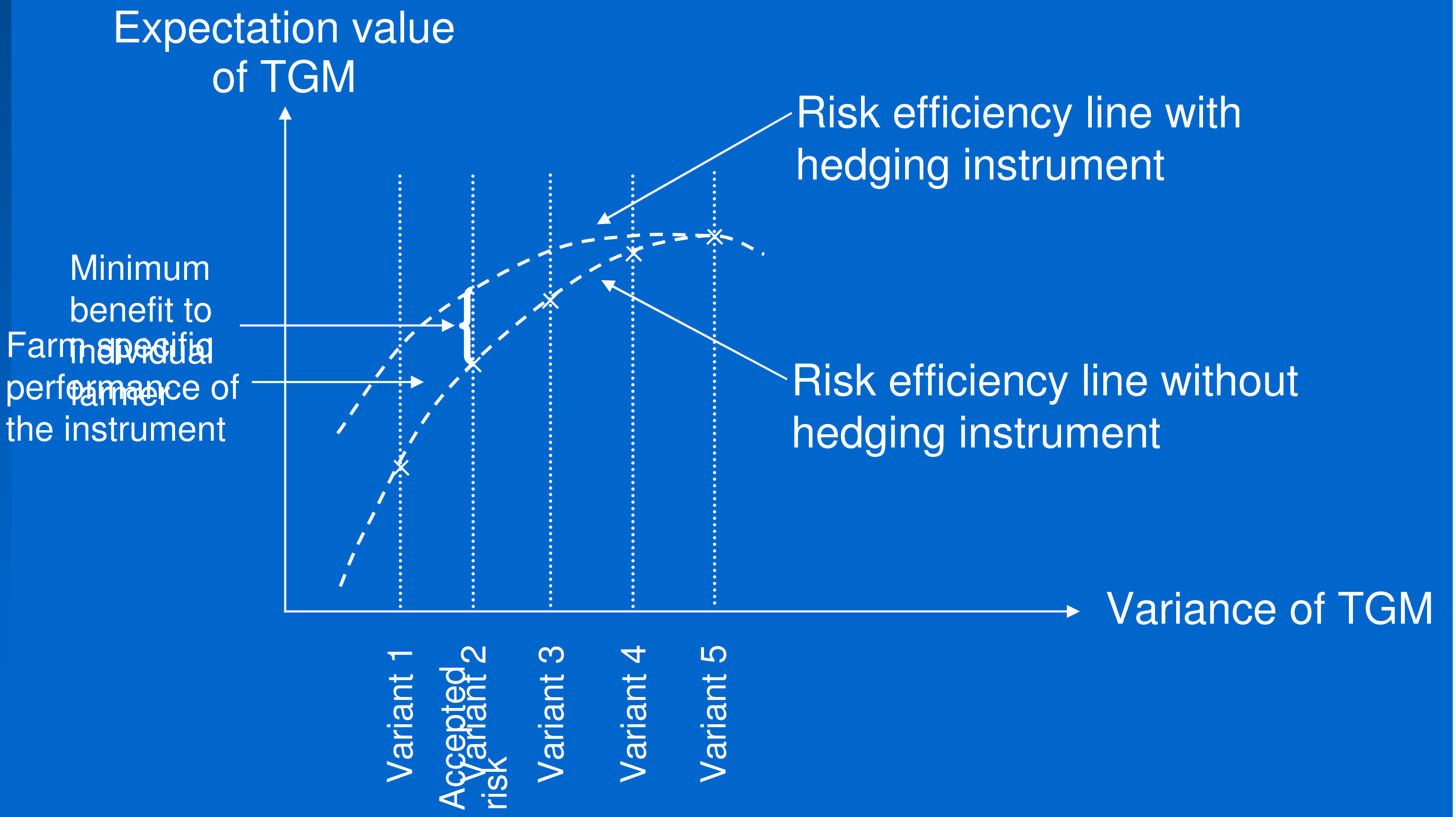
→ interdependence with other instruments

3. Risk acceptance of the individual farmer

→ **Whole-farm stochastic optimization approach repeatedly solved for**

- **different loadings**
- **different maximum variances**

Portfolio Model (cont.)

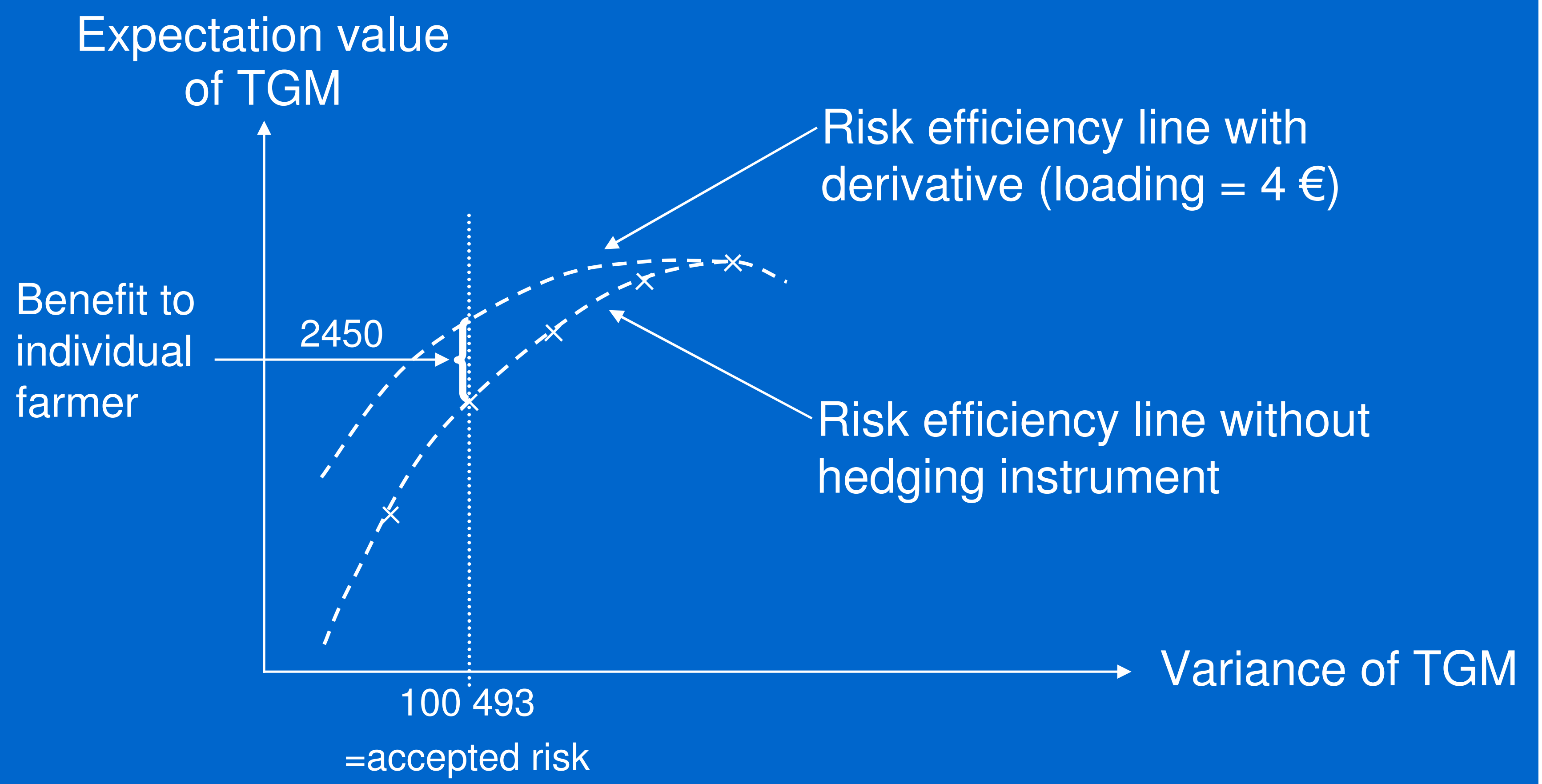


Results of Portfolio Analysis I

- Benefit of the derivative for the farmer

	Risk neutral farmer	Situation without the instrument	Situation with the instrument	
Loading of derivative (€)		–	0	4
Farmer‘s demand (no)		–	1 528	791
Farmer‘s expected total gross margin (€)	**294 700**	**287 410**	+6 890 € **294 300**	+2 450 € **289 860**
TGM-standard deviation	108 024	100 493	100 493	100 493

Results of Portfolio Analysis II



Expectation value of TGM

Benefit to individual farmer

2450

Risk efficiency line with derivative (loading = 4 €)

Risk efficiency line without hedging instrument

Variance of TGM

100 493

=accepted risk

Results of Portfolio Analysis III

- Optimum loading from the monopolistic underwriter‘s point of view

Loading of derivative (€)	0	4	4.45	6	10	≥ 12.21
Farmer‘s demand (no)	1 528	791	717	490	96	0
Farmer‘ increase in TGM (€)	6 890	2 451	2 111	1 181	101	0

Underwriter‘s “GM” (€)	0	3 162	3 190	2 941	965	0

* for the accepted variance of 100 493 €

Results of Portfolio Analysis IV

- Derivative vs. revenue insurance

	Weather derivative	Revenue insurance for wheat
Fair Pren	16.85	78.80
Optimal l	4.45 (26.4%)	23.68 (30.1%)
Farmer's	717	148
Farmer' increase in TGM (€)	2 111	2 161
Underwriter's "GM" (€)	3 190	3 481
Minimum "innovation gain" (€)	5 301	5 642

+291 €

Sufficient for cost coverage and profit margin?

* for the accepted variance of 100 493 €

Summary

- Analysis of the minimum willingness-to-pay that a rational farmer whose utility can be reflected through an EV-model *should theoretically have*.

- Results: benefits for farmers and insurers suggest

  - a relevant trading potential

  - if there is no political interference

Conclusions and further research

1. **More comprehensive willingness-to-pay analysis**
   - Broader data base! (results are not generalizable)
   - Inclusion of more hedging instruments
   - Assessment of transaction costs
2. **Assessment of farmers' attitude towards instruments with inherent basis risk**
3. **"Theoretical demand" of rational actor vs. real market potential (market studies)**

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Thank you very much for your attention!

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Trends in agricultural policy

EC-treaty: Art. 87 (2)(b) and (3)(b)
exempt some categories of aid from the prohibition to grant distorting aids:
„aid to make good the damage caused by natural disasters or exceptional occurrences“

EU-Commission debate
- harmonized risk- and crisis management in the EU (2005)
- subsidies on insurances

Limitations of subsidies
- max. 80 % of insurance premiums (natural desasters)
- max. 50 % of insurance premiums (adverse weather conditions)

From 01.01.2010
- reduction of natural desaster aids by 50 %,
- if the farmer has not insured a minimum of 50 % of his production

→ Lobbying for more subsidies for the insurance industry
  - subsidized insurance premiums
  - state as a free-of-charge reinsurer

→ Lobbying for more subsidies for crop insurances

Aids for insurances – the legal background

Structure of Article 87: Article 87 comprises three paragraphs.

Article 87(1) sets out a prohibition in the following terms: (1) Save as otherwise provided in this Treaty, any aid granted by a Member State or through State resources in any form whatsoever which distorts or threatens to distort competition by favouring certain undertakings or the production of certain goods shall, insofar as it affects trade between Member States, be incompatible with the common market.

Article 87(2) exempts some categories of aid from this prohibition altogether:

87(2)(a) — aid having a social character, granted to individual consumers, provided that such aid is granted without discrimination related to the origin of the products concerned;

87(2)(b) — aid to make good the damage caused by natural disasters or exceptional occurrences;

87(2)(c) — aid granted to the economy of certain areas of the Federal Republic of Germany affected by the division of Germany, insofar as such aid is required in order to compensate for the economic disadvantages caused by that division.

Aids for insurances – an economic view

- **subsidies to the industry in whatever form**
  - → artificial demand of insurance products
  - → primary welfare loss
  - → loss of transparency (hidden subsidies)
  - → desired / undesired distributional effects
- **discriminating subsidies for certain insurance products**
  - → price distortions
  - → secondary welfare loss

Wirkung einer subventionierten Hoferlösversicherung

	Budget (€)	**Farmer's income (€)**			**Transfer-efficiency (%)**
		Direct payment	TGM	Total TGM	
Without discriminating subsidy*	-8 390	8 390	**291 210**	299 600	100
Subsidized revenue insurance**	-8 390	0	294 610	294 610	41

* loading of revenue insurance for farmer: **35%** Aufpreis,
loading of weather derivative: 15%

** loading of revenue insurance for farmer: **0%** Aufpreis,
loading of weather derivative: 15%

Statistical Analysis (cont.)

AR(1) processes found for all production activities

$$GM_{t^*}^{j} = E(GM_{t^*}^{j}) + \chi_{t^*}^{j}$$

$$= \alpha_0^j + \alpha_1^j \cdot GM_{t^*-1}^{j} + \chi_{t^*}^{j}$$

$$\text{with } \left|\alpha_1^j\right| < 1$$

Statistical Analysis (cont.)

	W-wheat	S-wheat	W-rye	W-barley	S-barley	W-canola	Corn	Non-Food-Canola	Weather Derivative	Crop revenue
const										
a1 (ar(1,	0,96	0,94	0,96	0,93	0,92	0,94	0,89	0,92		
a2 (ar(1)=0)										
b1										
b2										
E(GM)	409,69	289,70	366,84	365,17	316,99	610,21	13,39	559,12		
s	164,94	145,95	133,02	166,31	134,60	260,36	169,72	227,97	24,67	128,79

Portfolio Model (cont.)

$$\underset{x_{t^*}^{j}}{\text{maximize}} \; E(TGM_{t^*}) = \sum_{j=1}^{J} E(GM_{t^*}^{j}) \cdot x_{t^*}^{j}$$

s.t.:

$$\sum_{j=1}^{J} a_{t^*}^{i,j} \cdot x_{t^*}^{j} \leq b_{t^*}^{i}, \text{ for } i = 1, 2, \ldots, I$$

$$\sqrt{\sum_{j=1}^{J} (x_{t^*}^{j} \cdot \sigma^{j})^{2} + 2 \cdot \sum_{j=1}^{J} \sum_{k<j}^{J} x_{t^*}^{j} \cdot \sigma^{j} \cdot x_{t^*}^{k} \cdot \sigma^{k} \cdot \rho^{j,k}} \leq \overline{S}_{t^*}$$

$$x_{t^*}^{j} \geq 0$$

Results of Portfolio Analysis (in detail): I

	Standard deviation (in €)	Expectation value of the total gross margin (in €) for varying loadings of the weather derivative**			
		$E(GM^D) = -\infty$ (without derivative)	$E(GM^D) = 0$ (loading = 0)	$E(GM^D) = -4$ (loading = 4)	$E(GM^D) = -10$ (loading = 10)
1	92 962	271 280	286 880 (100 110)	281 580 (97 457)	275 710 (94 885)
2	94 844	275 620	289 370 (102 160)	284 310 (98 671)	279 610 (96 591)
3	96 727	279 920	291 250 (103 980)	286 360 (99 767)	282 650 (97 929)
4	98 610	284 170	292 940 (105 760)	288 170 (101 100)	285 230 (99 116)
5	100 493	287 410	294 300 (107 320)	289 860 (102 620)	287 510 (100 570)
6	102 376	289 610	294 700 (108 024)	291 430 (104 160)	289 610 (102 380)
7	104 258	291 520	294 700 (108 024)	292 690 (105 490)	291 520 (104 250)
8	106 141	293 280	294 700 (108 024)	293 760 (106 680)	293 280 (106 140)
9	108 024	294 700	294 700 (108 024)	294 700 (108 024)	294 700 (108 024)

Results of Portfolio Analysis (in detail): II

	Standard deviation	Hedging effectiveness (in %) for varying loadings of the weather derivative			
	(in €)	$E(GM^D) = 0$	$E(GM^D) = -2$	$E(GM^D) = -4$	$E(GM^D) = -10$
1	92 962	7.7	6.0	4.8	2.1
2	94 844	7.7	5.3	4.0	1.8
3	96 727	7.5	4.8	3.1	1.2
4	98 610	7.3	4.4	2.5	0.5
5	100 493	6.8	4.0	2.1	0.1
6	102 376	5.5	3.2	1.7	0.0
7	104 258	3.6	2.2	1.2	0.0
8	106 141	1.8	1.0	0.5	0.0
9	108 024	0.0	0.0	0.0	0.0

On the Optimisation Approach IV

- Quadratic optimisation problem

$$\underset{x_{t*}^{j}}{\text{maximize}}\, E(TGM) = \sum_{j=1}^{J} E\left(GM_{t*}^{j}\right) \cdot x_{t*}^{j}$$

$$\text{s.t.} \qquad \sum_{j=1}^{J} a_{t*}^{i,j} \cdot x_{t*}^{j} \le b_{t*}^{i}, \text{für } i = 1, 2, \ldots, I$$

$$V \le V_{emp}$$

$$x_{t*}^{j} \ge 0, \text{für } j = 1, 2, \ldots, J$$

with:
TGM:total gross margin
x^j: weight of the activity *j*
$a^{i,j}$: requirements on capacities *i* of activity *j*
b^i: restrictions of capacities *i*
V: variance of the total gross margin in the optimised program
V_{emp}: accepted variance of the total gross margin by the farmer

- Technical procedure of the optimisation
  - For MS-EXCEL Premium-Solver to large
  - We use genetic algorithms (heuristic search procedures) which are able to solve complex optimisation problems by mimicking the optimisation strategy of biological evolution

Relevance of Volumetric Weather Risks

Worst drought on record hits Australian agriculture (2001-2007)

Flood disasters hit thousands of Asian farmers every year

Drought disasters threaten livestock and the livelihood of the rural poor in Africa

Extreme weather conditions threaten food production through pests and diseases

On-farm Data Gathering

- **Production program of North-east German crop farm**
- **Yields and single gross margins 1980-2005**
- **On-farm restrictions**
    - acreage
    - labour
    - crop rotation constraints

- **Main crops in 2005 / 2006**
    - wheat
    - rye
    - barley
    - winter canola
    - corn

Results of Portfolio Analysis IV

- Derivative vs. revenue insurance

	Weather derivative	Revenue insurance for wheat
Fair Pren	16.85	78.80
Optimal l	2.53 (15%)	27.58 (35%)
Farmer's	1 050	123
Farmer' increase in TGM (€)	3 800	1 600
Underwriter's TGM (€)	2 657	+291 € → 3 392
Minimum collective benefit (€)	5 301	5 642

Sufficient for cost coverage and profit margin?

* for the accepted variance of 100 493 €