Risk premiums and GM traits

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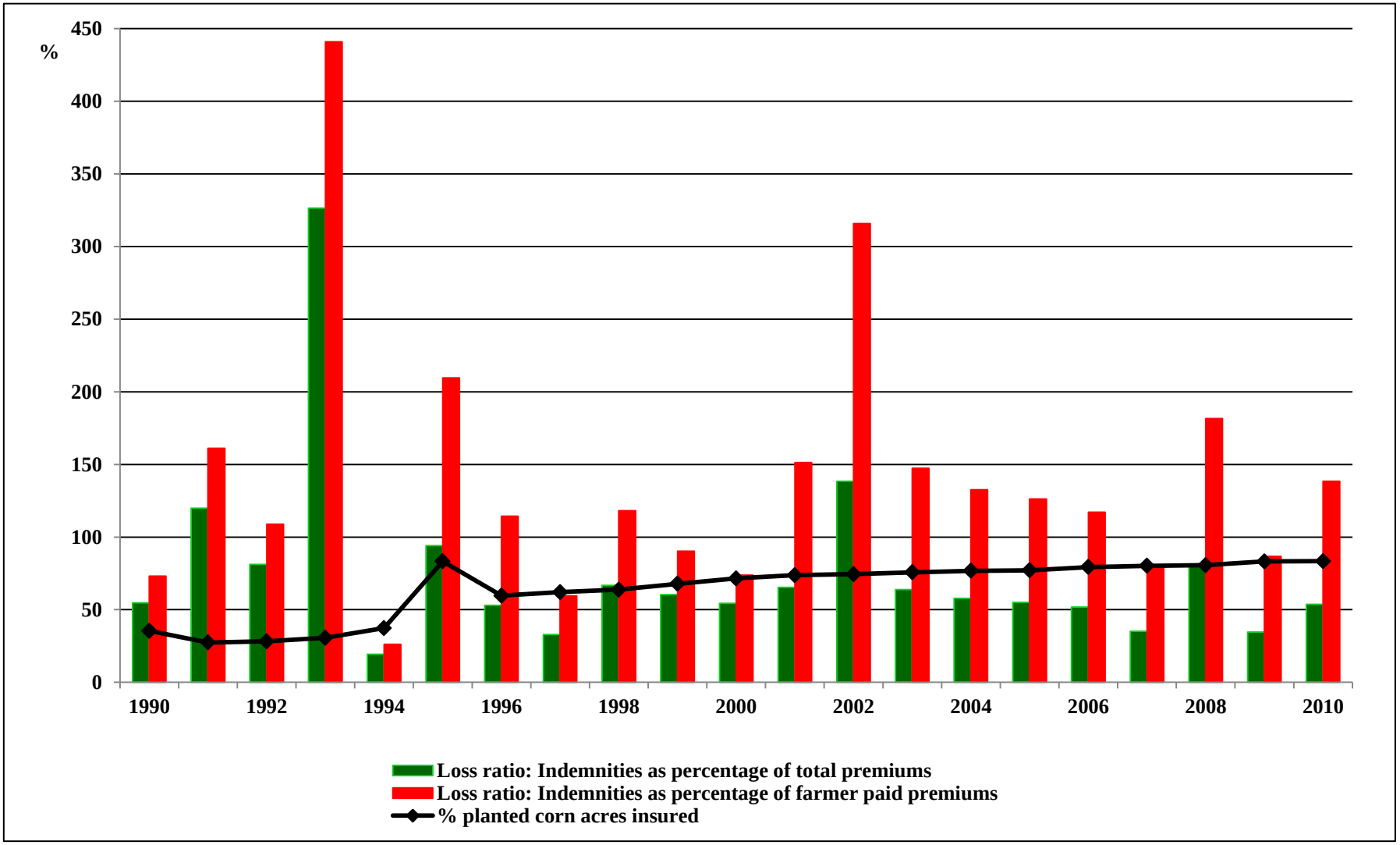
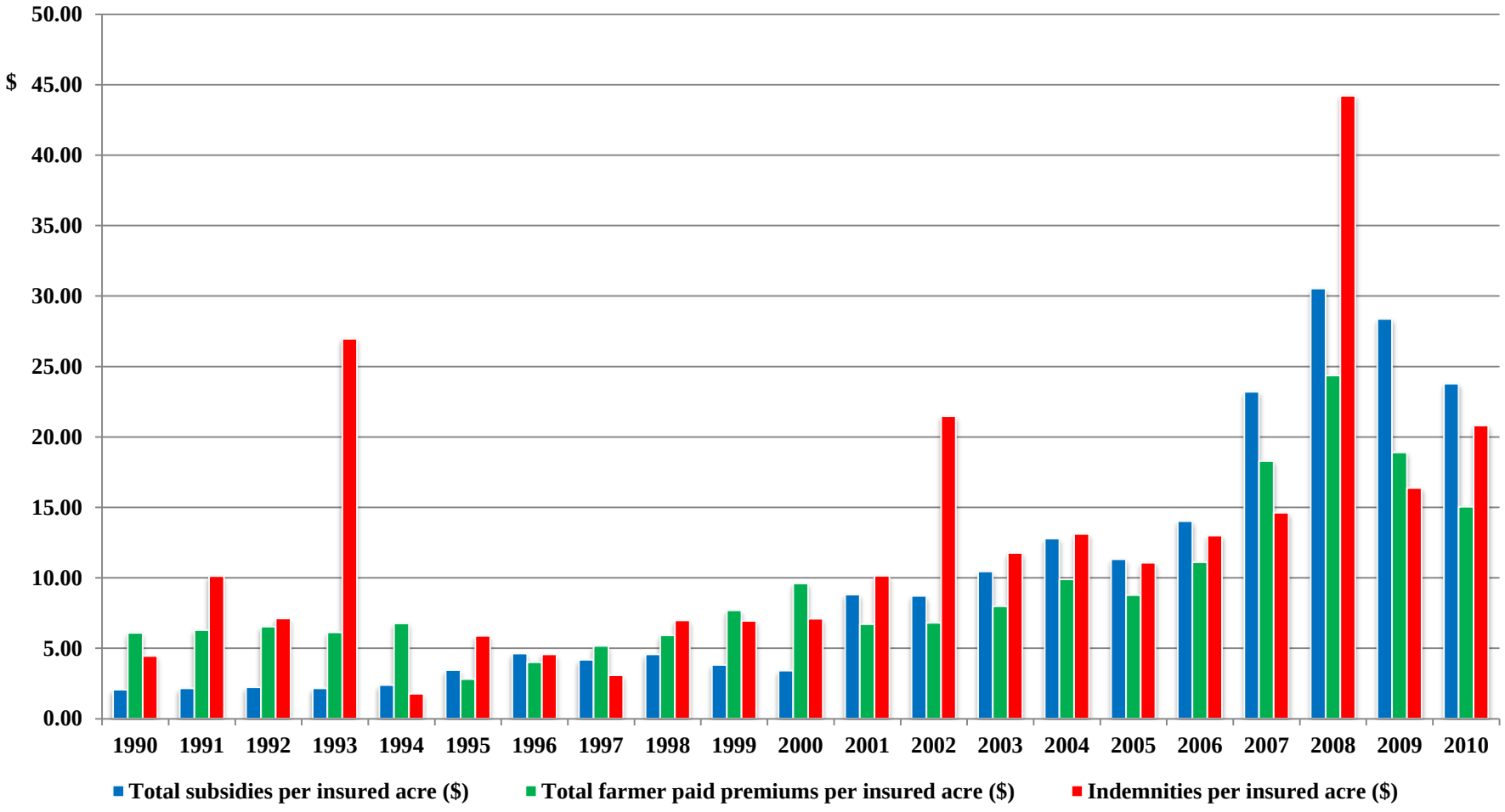
Background and Aims

- **One argument in favour of GM hybrids is that the traits are risk decreasing.**
  - **Claims that pest resistant traits in corn lead to improved drought resistance**
  - **The Risk Management Agency (RMA) considers that triple stacked hybrids provide a lower yield risk**
  - **Based on actuarial reports on Monsanto field trials**
- **On this basis insurance premiums for corn growers who plant approved hybrids have been reduced by between 14 per cent and 20 per cent under the Biotech Yield Endorsement (for 2008) and its successor, the Pilot Biotechnology Endorsement (for 2009-2011).**
- **We investigate whether the presence in a corn hybrid of a GM trait, or a combination of GM traits, is likely to increase or decrease risk.**

Percentage acres insured and loss ratios



Insurance per insured acre



Crop insurance

- **Federal Crop Insurance Corporation develops products or approves products developed by private insurers**
  - **All contracts now sold by private insurers**
- **Premium rates and insurance terms and conditions established by FCIC**
  - **Coverage between 50% and 85% of Average Production History yield**
  - **Producers also selects percentage of predicted price to insure**
- **If harvested amount less than yield insured producer is paid an indemnity**
- **Private insurers reinsured (subsidised) by FCIC**

Loss ratios

- Loss ratio (indemnities/premiums) should be no more than 0.70 if insurance is to be commercially viable
- Congress has given RMA an objective of charging farmers a pre subsidy premium that would generate a loss ratio of 1.075.
  - This is on the basis of covering indemnities only and ignoring costs
- 83% of corn acres were insured in 2010
- Compared with 35% in 1990
- Corn insurance performs better than overall crop insurance
- But loss ratios as a percentage of farmer paid premiums have increased since 2008

Comparison of all crops with corn

Total Crop Year Statistics as of 31 January 2011			
Item	**1990**	**1999**	**2009**
	Number ('000)		
Policies	895	1288	1171
Net acres insured	101361	196918	264621
	Billion dollars		
Farmer paid premium	0.62	1.35	3.52
Premium subsidies	0.22	0.95	3.82
Total premium	0.84	2.3	8.95
Indemnities	0.97	2.43	5.43
Insurance protection	12.83	30.94	79.5
	Percent		
Loss ratio	116	105	58
Loss ratio net of subsidies	156	180	154

Crop Year Statistics for corn as of 31 January 2011			
Item	**1990**	**1999**	**2009**
	Number ('000)		
Policies	295	451	504
Net acres insured	26304	52472	71893
	Billion dollars		
Farmer paid premium	0.16	0.4	1.36
Premium subsidies	0.05	0.2	2.04
Total premium	0.21	0.6	3.4
Indemnities	0.12	0.36	1.18
Insurance protection	4.04	8.6	31.1
	Percent		
Loss ratio	55	60	35
Loss ratio net of subsidies	75	90	87

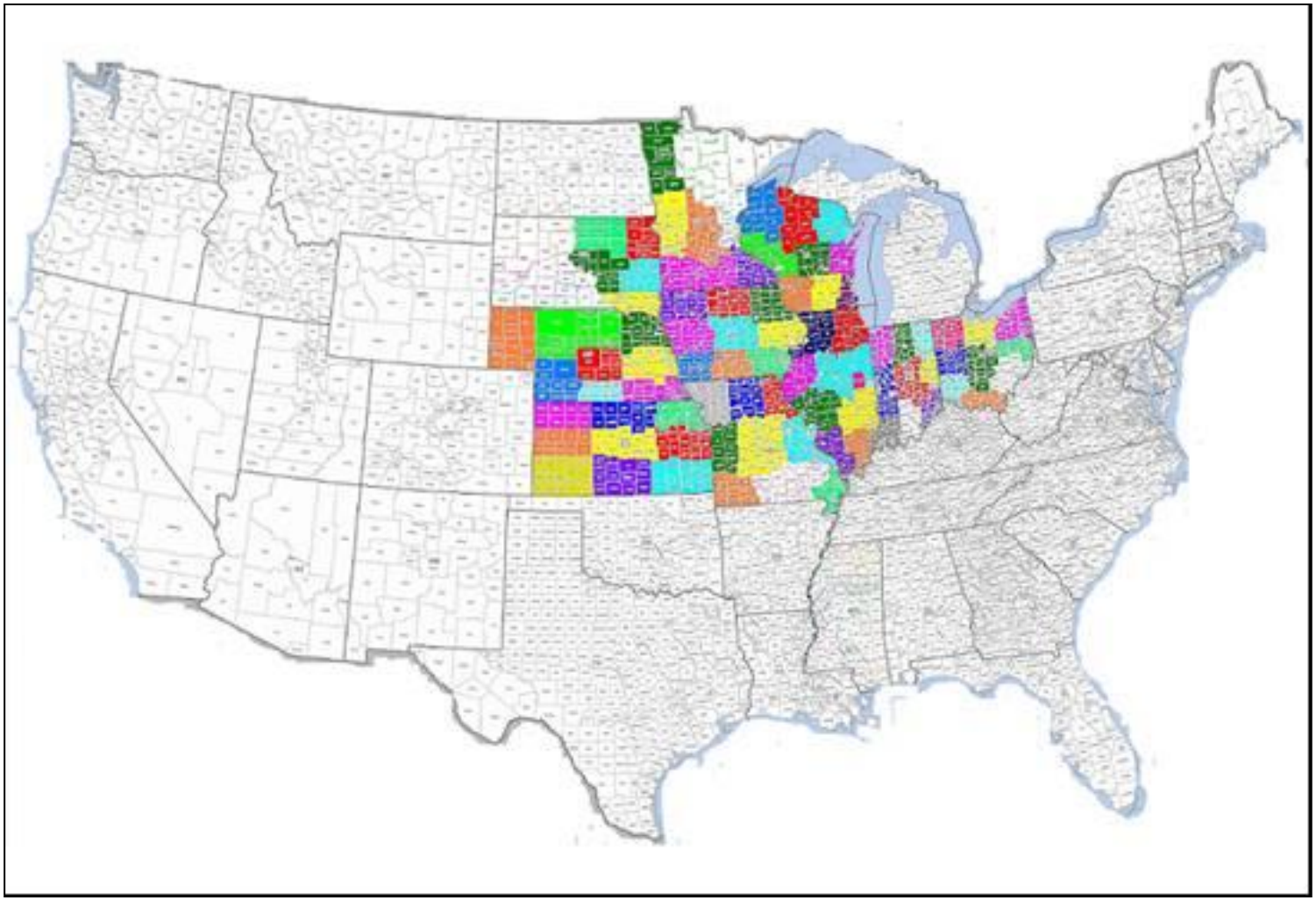
Pesticides and risk

- Bt hybrids provide nearly complete control of European corn borer and/or Corn rootworm
- Still debate about how pesticides affect risk
  - GM traits can be considered as “super pesticides”
- Some (for example Feder) consider pesticides to be risk reducing
- Pannell (1991) and Horowitz and Lichtenberg (1993) consider that pesticides may be risk increasing if output uncertainty is the dominant cause of randomness
  - Depends on effect of states of nature
- If pesticides (or GM traits) are risk increasing, then premium reductions may not be justifiable
- We use a large dataset to estimate mean contribution to yield of GM traits and their marginal variance

Data

- **compiled from reports of actual yield results from experimental field trials of corn hybrids submitted by corn breeders to the State Agricultural Extension Services of ten universities from 1990-2009**
  - **Illinois, Indiana, Iowa, Kansas, Minnesota, Missouri, Nebraska, Ohio, South Dakota and Wisconsin**
- **yield in bushels per acre for**
  - **226,918 individual trials**
  - **of 20,508 hybrids**
  - **at 335 locations**
  - **submitted by 430 companies**

CRDs represented in dataset



Independent variables

- GM traits and the degree of stacking
- Site details and agronomic practices
  - seeding rate
  - soil type
  - cultivation type (conventional vs minimum or no till)
  - previous crop,
  - early or late trial
  - irrigated or dryland
  - nitrogen application in lbs/ac
- Climatic conditions
  - monthly rainfall April to September
  - average minimum and maximum temperatures April to September

Method

- **Heteroskedastic production functions allow the variance of the stochastic errors to vary with the level of managed inputs (Anderson and Griffiths 1981; Just and Pope 1978; Just and Pope 1979)**
- **Just and Pope (1978) suggested a production function that allows input levels to affect risk, as defined by the variance of output, independently of their effect on expected output.**
- **Relaxes restriction that increases in inputs will increase production variability.**

Method

- **The more flexible specification of Just and Pope is**

$$Y_{it} = f(X_{it}) + u_{it} = f(X_{it}) + h^{1/2}(Z_{it})\,\varepsilon_{it} \text{ with } E(\varepsilon_{it})=0,\ var(\varepsilon_{it}) = 1$$

where f(.) is the deterministic component of production (representing the mean of production)

u_{it} is the stochastic component (representing its variance), usually written, according to Harvey (1976) as

$$var(u_{it}) = \exp(h(Z_{it}))$$

- **Nothing is imposed on the characteristics of the set {Zit}, that may (or may not) coincide with the set of inputs in the deterministic part of the production function, {Xit},**
  - **or on the functional form of h(.), that may or may not be identical to f(.).**
- **Inputs x influence mean output and output risk independently because**

$$E(y) = f(X) \text{ and } var(y) = var(u) = h(X)\sigma^2_{\varepsilon.}$$

Method

- We use a large unbalanced panel dataset of actual yield results
  - Individual corn hybrids are the cross sectional elements
  - Using experimental data, we can avoid the identification problems common with production data.
- Using random effects we estimate mean yield function
- We then use the residuals from that estimation to estimate the variance, and regress the log variance on the individual inputs to find marginal variance for each input.

Main results

Mean function					**Variance function**			
lnyield	Coef.	z	P>|z|		lnvariance	Coef.	t	P>|t|
trend	0.01	12.68	0.00		trend	0.02	18.60	0.00
trendsq	-0.0001	-2.79	0.01		trendsq	-0.0003	-4.90	0.00
lnseedingrate ('000)	0.55	90.02	0.00		lnseedingrate ('000)	1.15	88.86	0.00
nomintill	-0.04	-18.86	0.00		nomintill	-0.08	-17.00	0.00
irrigated	0.18	65.70	0.00		irrigated	0.38	66.47	0.00
early	-0.02	-13.36	0.00		early	-0.09	-25.75	0.00
lnnlbs	0.03	23.41	0.00		lnnlbs	0.07	25.96	0.00
cbo	0.03	9.92	0.00		**cbo**	**0.04**	**10.37**	**0.00**
rwo	-0.01	-0.48	0.63		**rwo**	**-0.03**	**-1.22**	**0.22**
hto	-0.01	-2.36	0.02		**hto**	**-0.02**	**-2.41**	**0.02**
cbht	0.01	3.13	0.00		**cbht**	**0.02**	**3.70**	**0.00**
rwht	0.06	5.19	0.00		**rwht**	**0.11**	**7.90**	**0.00**
cbrw	0.06	5.05	0.00		**cbrw**	**0.09**	**5.45**	**0.00**
cbrwht	0.05	11.47	0.00		**cbrwht**	**0.10**	**14.81**	**0.00**
_cons	4.13	37.08	0.00		_cons	7.18	31.20	0.00
Number of obs	189840				Number of obs	189840		
Number of groups	8731				F(52,189787)	1836.29		
Wald $chi^2(52)$	73520				Prob > F	0.00		
Prob > chi^2	0				Adj R-squared	0.33		

Conclusions

- **Both mean yield and variability are increasing over time, at a decreasing rate**
- **Coefficients for mean yields and marginal variance are positive for Bt corn borer resistance by itself and in all combinations**
- **Bt rootworm resistance individually has no statistically significant effect on yield or on variability**
- **Herbicide tolerance individually has a statistically significant and negative effect on yield, but no statistically significant effect on variability**
- **If pest resistance traits increase mean yield, but also increase variability, the policy of reducing crop insurance premiums on the basis that these traits are risk decreasing does not appear, on the face of it to be justified**
  - **For example, loss ratios as a proportion of farmer paid premiums have increased since 2008**

Climate variables

Mean function					**Variance function**			
lnyield	Coef.	z	P>|z|		lnvariance	Coef.	t	P>|t|
lnaprrain	0.01	9.07	0.00		lnaprrain	0.01	9.49	0.00
lnmayrain	-0.02	-19.41	0.00		lnmayrain	-0.05	-20.37	0.00
lnjunrain	0.02	20.99	0.00		lnjunrain	0.04	22.25	0.00
lnjulrain	0.04	46.88	0.00		lnjulrain	0.10	49.06	0.00
lnaugrain	0.01	7.02	0.00		lnaugrain	0.01	6.75	0.00
lnseptrain	0.00	-5.92	0.00		lnseptrain	-0.01	-9.53	0.00
lnminapr	-0.21	-14.85	0.00		lnmaxapr	1.38	41.76	0.00
lnminmay	0.31	17.79	0.00		lnminapr	-0.46	-15.99	0.00
lnminjune	0.52	24.43	0.00		lnmaxmay	-0.26	-5.45	0.00
lnminjuly	-0.18	-6.57	0.00		lnminmay	0.73	20.20	0.00
lnminaug	0.24	9.74	0.00		lnmaxjune	-0.39	-9.88	0.00
lnminsept	0.01	0.40	0.69		lnminjune	1.13	25.43	0.00
lnmaxapr	0.64	39.56	0.00		lnmaxjuly	0.24	3.97	0.00
lnmaxmay	-0.05	-2.24	0.03		lnminjuly	-0.42	-7.44	0.00
lnmaxjune	-0.22	-12.02	0.00		lnmaxaug	-4.10	-58.90	0.00
lnmaxjuly	0.07	2.28	0.02		lnminaug	0.71	13.70	0.00
lnmaxaug	-1.89	-56.85	0.00		lnmaxsept	1.18	29.70	0.00
lnmaxsept	0.57	29.65	0.00		lnminsept	0.08	2.79	0.01

State dummy variables

Mean function					**Variance function**			
lnyield	Coef.	z	P>|z|		lnvariance	Coef.	t	P>|t|
IL	0.14	47.80	0.00		IL	0.28	49.09	0.00
IN	0.12	34.62	0.00		IN	0.26	38.23	0.00
IA	0.03	8.29	0.00		IA	0.07	9.71	0.00
KS	0.10	31.47	0.00		KS	0.23	33.65	0.00
MN	0.13	32.35	0.00		MN	0.28	34.15	0.00
NE	0.13	36.13	0.00		NE	0.28	39.44	0.00
OH	0.10	30.44	0.00		OH	0.25	36.51	0.00
SD	0.15	33.42	0.00		SD	0.34	37.24	0.00
WI	0.18	51.14	0.00		WI	0.36	52.69	0.00

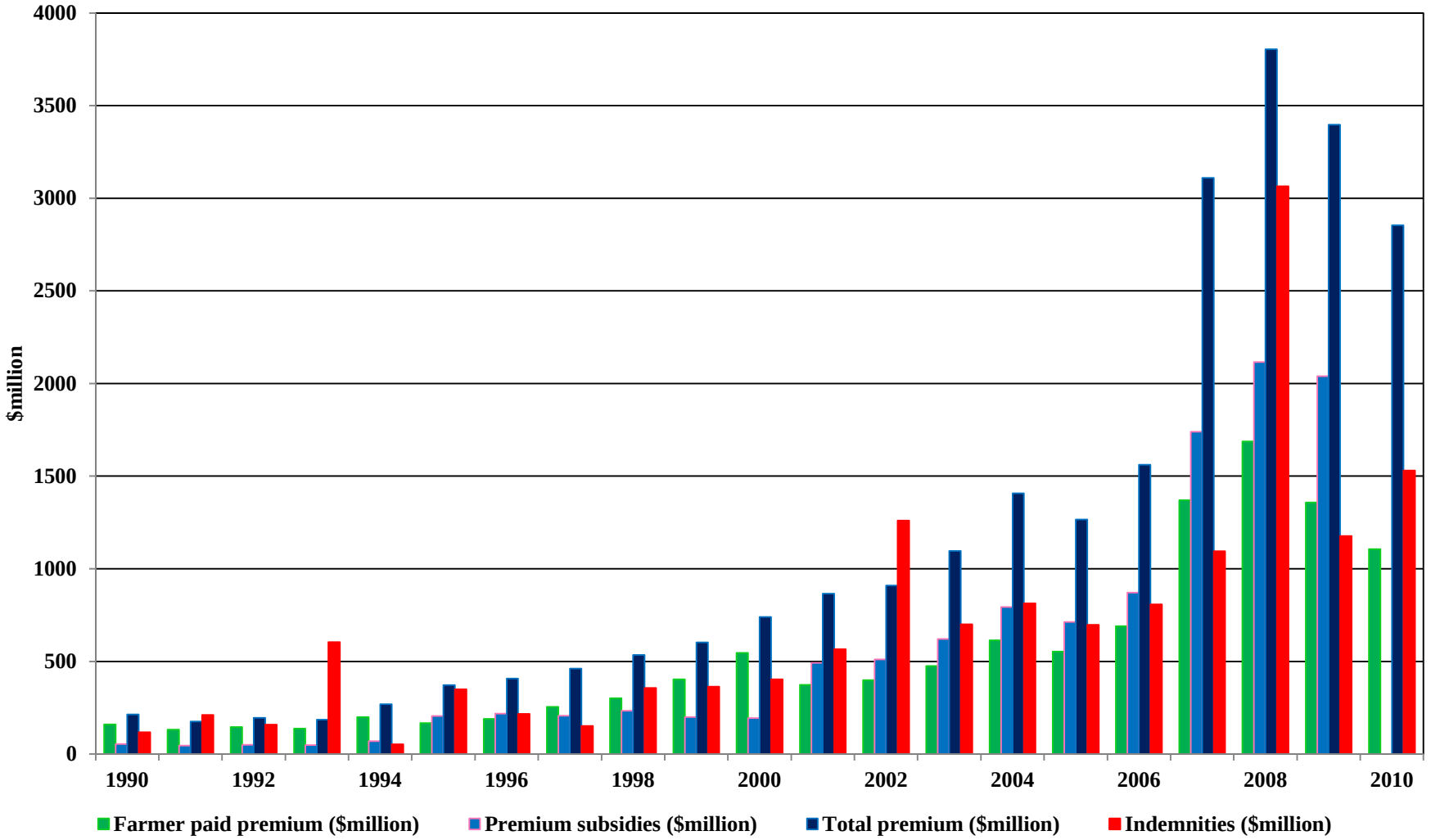
Rotations and soils

Mean function					**Variance function**			
lnyield	Coef.	z	P>|z|		lnvariance	Coef.	t	P>|t|
corn	-0.04	-18.44	0.00		corn	-0.09	-19.89	0.00
wheat	-0.04	-16.76	0.00		wheat	-0.11	-20.08	0.00
alfalfa	0.02	3.86	0.00		alfalfa	-0.01	-1.04	0.30
other	-0.08	-23.67	0.00		other	-0.18	-25.35	0.00
clay	-0.10	-23.96	0.00		clay	-0.20	-22.93	0.00
siltyclayloam	-0.01	-3.77	0.00		siltyclayloam	-0.01	-3.38	0.00
clayloam	-0.01	-3.65	0.00		clayloam	-0.03	-6.47	0.00
loam	-0.04	-17.48	0.00		loam	-0.09	-16.61	0.00
sandyloam	-0.01	-3.84	0.00		sandyloam	-0.04	-7.29	0.00
sand	-0.14	-15.93	0.00		sand	-0.34	-18.07	0.00

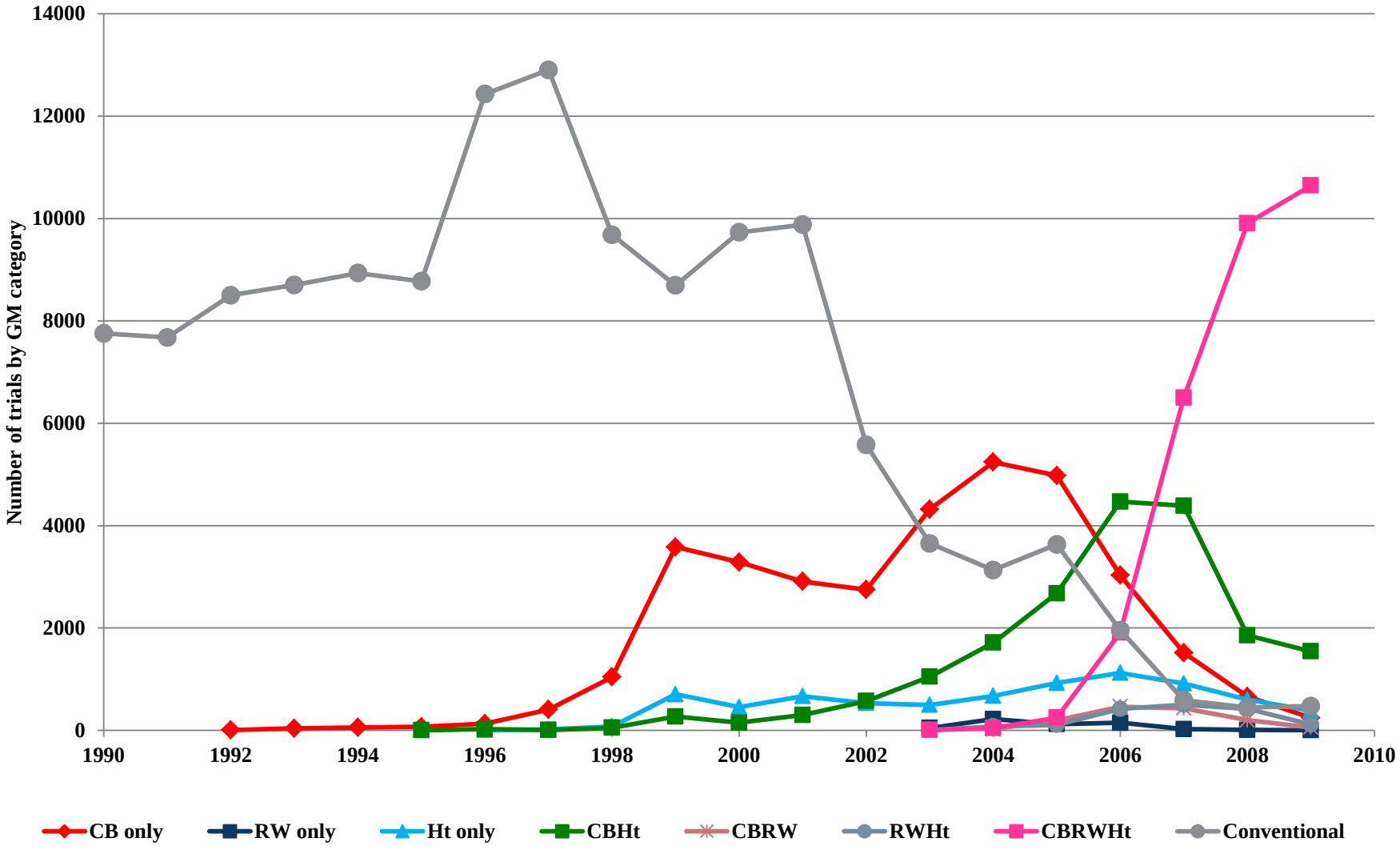
Variable	Definition	Mean	Std. Dev.	Min	Max
Yield	Bushels per acre of shelled grain (56lb/bu)adjusted to a moisture content of 15.5%	174.28	41.57	1	317
Seeding rate	Seeding rate in thousands of kernels per acre	28.52	38.22	10.14	43.5
No or min till	Dummy variable indicating no or minimum till	0.09	0.28	0	1
Conventional	Conventional soil preparation methods (base case)	0.91	0.28	0	1
Irrigated	Dummy variable indicating crop grown with irrigation	0.16	0.36	0	1
Dryland	Crop grown without irrigation (base case)	0.84	0.36	0	1
Early	Dummy variable indicating an early trial	0.21	0.41	0	1
Late	Dummy variable indicating a late trial (base case)	0.79	0.41	0	1
Soybean	Dummy variable indicating that soybean was the previous crop in the rotation (base case)	0.78	0.42	0	1
Corn	Dummy variable to indicating that corn was the previous crop in the rotation	0.11	0.32	0	1
Wheat	Dummy variable to indicating that wheat was the previous crop in the rotation	0.06	0.23	0	1
Alfalfa	Dummy variable to indicating that alfalfa was the previous crop in the rotation	0.02	0.13	0	1
Other	Dummy variable to indicating that a crop other than those mentioned above was the previous crop in the rotation	0.04	0.19	0	1
Silt loam	Dummy variable indicating silt loam soil (base case)	0.59	0.49	0	1
Clay	Dummy variable indicating clay soil	0.02	0.15	0	1
Silty clay loam	Dummy variable indicating Silty clay loam soil	0.16	0.37	0	1
Clay loam	Dummy variable indicating Clay loam soil	0.09	0.29	0	1
Loam	Dummy variable indicating Loam	0.06	0.25	0	1
Sandy loam	Dummy variable indicating Sandy loam soil	0.06	0.24	0	1
Sand	Dummy variable indicating Sand	0.004	0.06	0	1
N in lbs/ac	Nitrogen application in lbs per acre	136.48	80.72	0	380
No GM	Dummy variable indicating conventional hybrids (base case)	0.58	0.49	0	1
CB	Dummy variable indicating hybrid has corn borer resistant trait only	0.16	0.37	0	1
RW	Dummy variable indicating hybrid has corn rootworm resistant trait only	0.002	0.04	0	1
Ht	Dummy variable indicating hybrid has herbicide tolerant trait only	0.03	0.16	0	1
CB and Ht	Dummy variable indicating hybrid has both corn borer resistant and herbicide tolerant traits	0.08	0.27	0	1
RW and Ht	Dummy variable indicating hybrid has both corn rootworm resistant and herbicide tolerant traits	0.01	0.09	0	1
CB and RW	Dummy variable indicating hybrid has both corn borer resistant and corn rootworm resistant traits	0.01	0.08	0	1
CB, RW and Ht	Dummy variable indicating hybrid is at least triple stacked with corn borer resistant, corn rootworm resistant and herbicide tolerant traits	0.14	0.34	0	1

Year	Number of trials	CB only	RW only	Ht only	CBHt	CBRW	RWHt	CBRWHt	Total GM	Total conventional
1990	7757								0	7757
1991	7675								0	7675
1992	8509	7							7	8502
1993	8740	39							39	8701
1994	8990	56							56	8934
1995	8846	69			2				71	8775
1996	12595	131		6	25				162	12433
1997	13342	408		20	8				436	12906
1998	10856	1042		78	53				1173	9683
1999	13250	3582		705	269				4556	8694
2000	13624	3286		456	151				3893	9731
2001	13759	2910		668	301				3879	9880
2002	9434	2750		533	572				3855	5579
2003	9578	4319	47	497	1047		8	7	5925	3653
2004	11125	5242	219	672	1713	25	77	44	7992	3133
2005	12885	4979	122	925	2678	194	107	247	9252	3633
2006	13519	3030	149	1,123	4467	462	421	1912	11564	1955
2007	14865	1517	24	916	4387	433	501	6498	14276	589
2008	14101	661	9	599	1856	200	423	9908	13656	445
2009	13468	246	2	384	1544	58	114	10645	12993	475
Total	226918	34274	572	7582	19073	1372	1651	29261	93785	133133

Insurance funding



Trials by type of GM hybrids by year



Insurance statistics

Year	Policies	Net acres insured	Total corn acreage	% planted corn acres insured	Farmer paid premium ($million)	Premium subsidies ($million)	Total premium ($million)	Indemnities ($million)	Insurance protection ($million)	Loss ratio: Indemnities as percentage of total premiums	Loss ratio: Indemnities as percentage of farmer paid premiums
1990	295940	26304113	74166000	35	160	54	214	117	4041	55	73
1991	23009	20836437	75957000	27	131	45	176	211	3284	120	161
1992	217814	22377950	79311000	28	146	50	196	159	3614	81	109
1993	217955	22396828	73239000	31	137	48	185	604	3484	326	441
1994	289755	29443750	78921000	37	199	70	269	52	4586	19	26
1995	609352	59563723	71479000	83	167	205	372	350	6762	94	210
1996	501308	47257750	79229000	60	189	218	407	216	6625	53	114
1997	463306	49382809	79537000	62	255	206	461	152	7670	33	60
1998	440845	51136667	80165000	64	302	233	535	357	8949	67	118
1999	451043	52472614	77386000	68	403	200	603	364	8577	60	90
2000	487677	56867167	79551000	71	546	194	740	403	10184	54	74
2001	479800	55848318	75702000	74	374	492	866	566	10702	65	151
2002	475305	58699556	78894000	74	399	511	910	1260	11424	138	316
2003	481312	59494042	78603000	76	475	621	1096	700	12608	64	147
2004	493072	62088635	80929000	77	614	793	1407	814	15544	58	133
2005	486301	63052666	81779000	77	553	713	1266	698	14086	55	126
2006	486392	62150450	78327000	79	690	871	1561	808	16774	52	117
2007	487027	74969521	93527000	80	1371	1739	3110	1095	31444	35	80
2008	494875	69324968	85982000	81	1688	2116	3804	3065	37534	81	182
2009	503671	71893226	86382000	83	1358	2039	3397	1177	31073	35	87
2010	503881	73513939	88,192,000	83	1106	1748	2854	1530	31665	54	138