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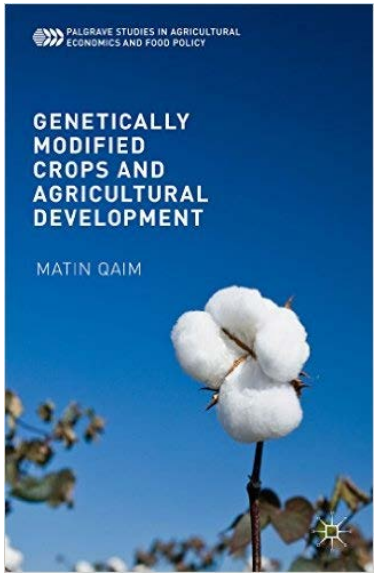
GÖTTINGEN

Genetically Modified Crops and Agricultural Development



Palgrave Macmillan, 2016

Matin Qaim

Seminar at UC Davis,
7 November 2016

Why more agricultural technology?

1. Environmental problems of agricultural production
2. Existing food insecurity
3. Growing global demand and resource scarcity
4. Many of the poor in Africa and Asia depend on small-scale farming as the key source of income

Common approaches in plant breeding

- Mass selection
- Backcrossing
- Wide crosses
- Hybridization
- Mutagenesis
- Marker-assisted selection
- Protoplast fusion

"Conventional breeding"

("natural" and "safe")

- Agrobacterium-mediated gene transfer
- Biolistics
- Genome editing (CRISPR/Cas etc.)

"Genetic engineering (GMOs)"

("unnatural" and "risky")

GMOs: controversial topic

- The public and policy debate is primarily focused on risks
- Regulatory procedures were put in place that treat GMOs very differently from other technologies
- However, 30 years of research and 20 years of commercial experience have shown that GM crops are not more risky than conventionally bred crops

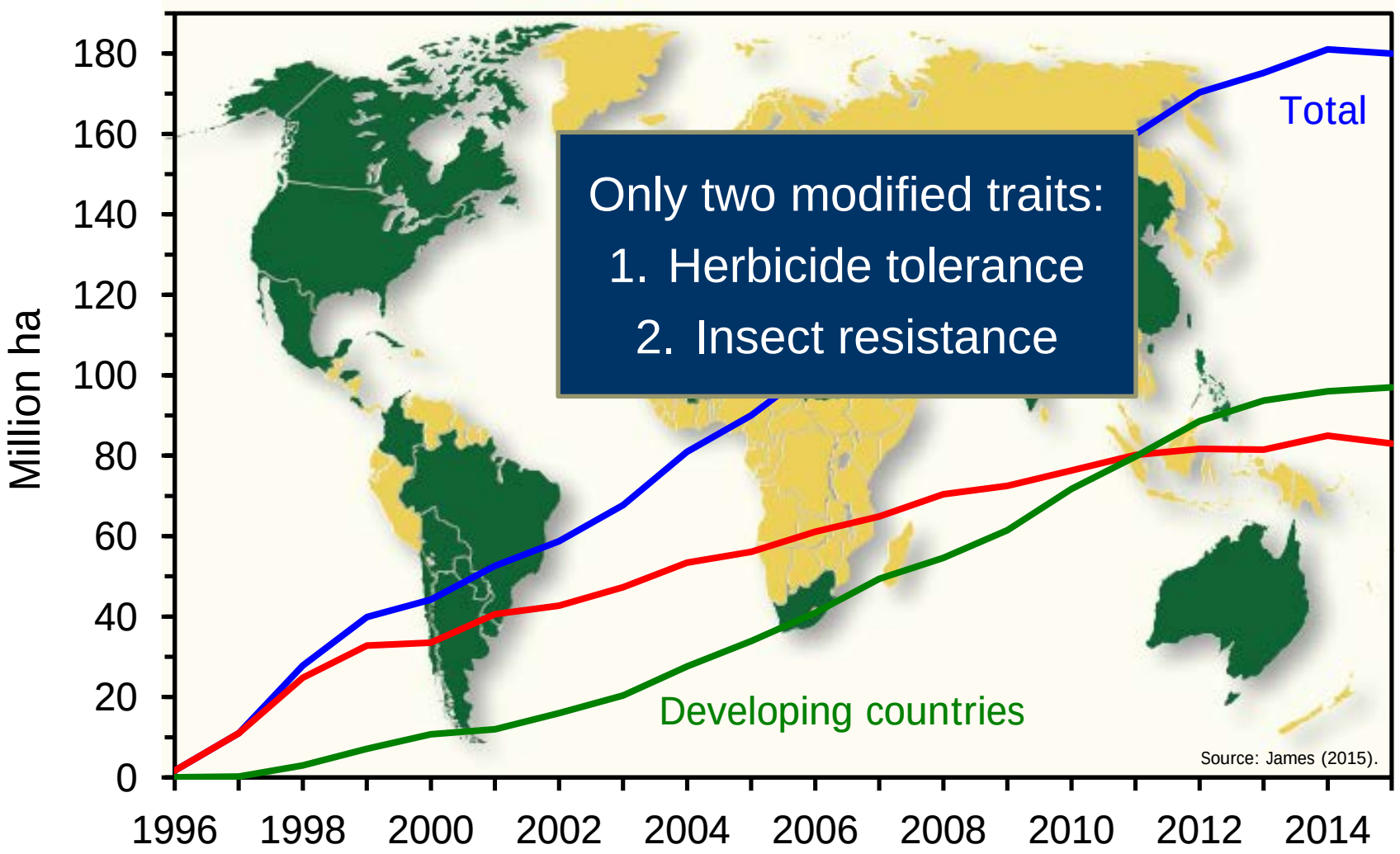
This conclusion was drawn by:

- WHO
- FAO
- OECD
- European Research Directorate
- EASAC (European Academies)
- International Council for Science
- Union of German Academies of Science
- British Royal Society
- British Medical Association
- French Academy of Sciences
- French Academy of Medicine
- National Academy of Sciences (USA)
- Brazilian Academy of Sciences
- Mexican Academy of Sciences
- Indian Academy of Sciences
- Chinese Academy of Sciences
- Nuffield Council on Bioethics
- Etc.

- The public has not taken note of this scientific evidence

Beyond risks, what do we know about GM crop impacts?

Global area cultivated with GMOs



Impact studies

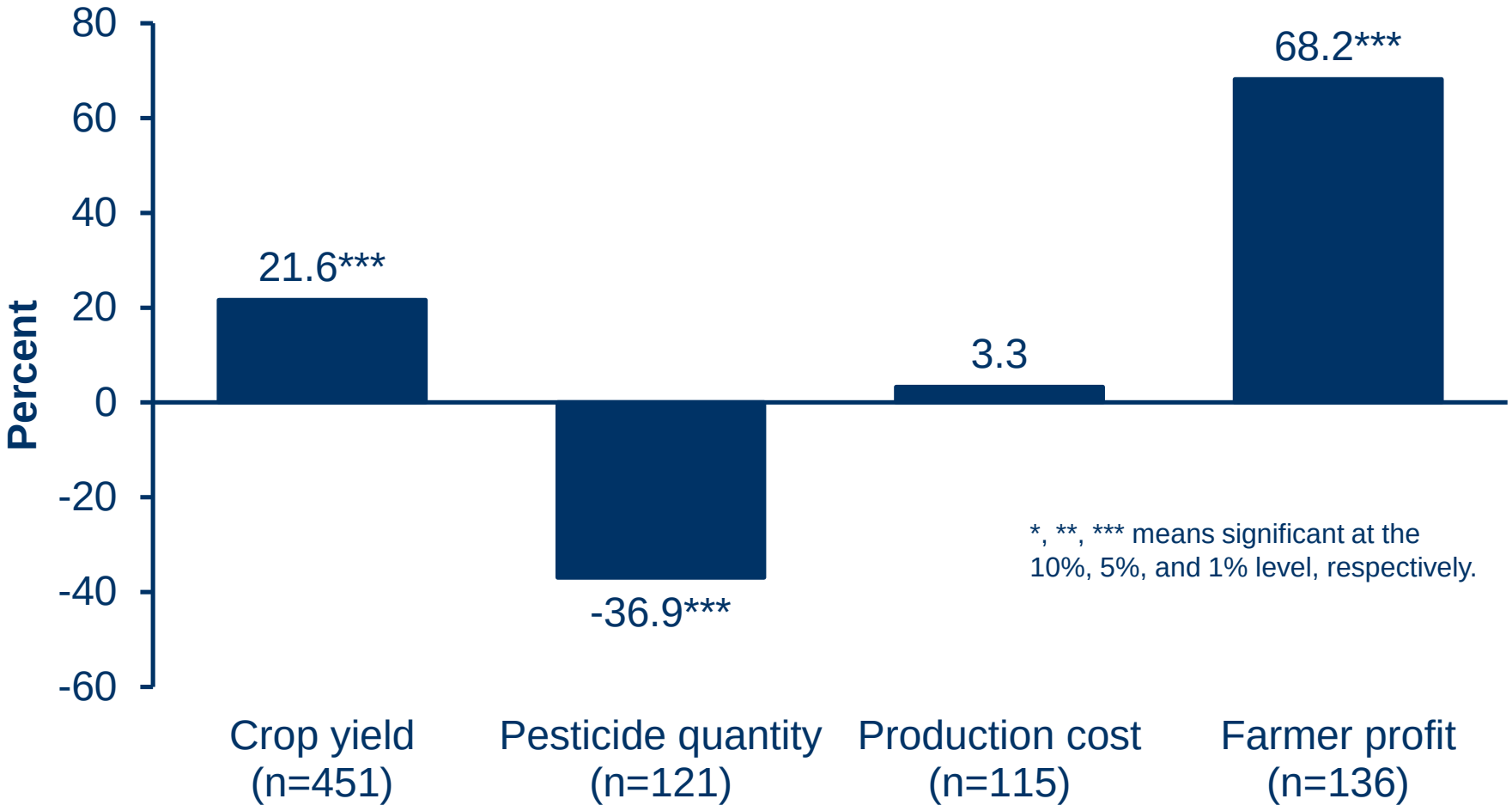
- Many impact studies carried out over the last 20 years:
  - ✓ Focusing on different countries
  - ✓ With different types of data
  - ✓ With different methodologies
  - ✓ With different results

- GMO supporters and opponents refer to their “preferred studies” in the debate, leading to further polarization

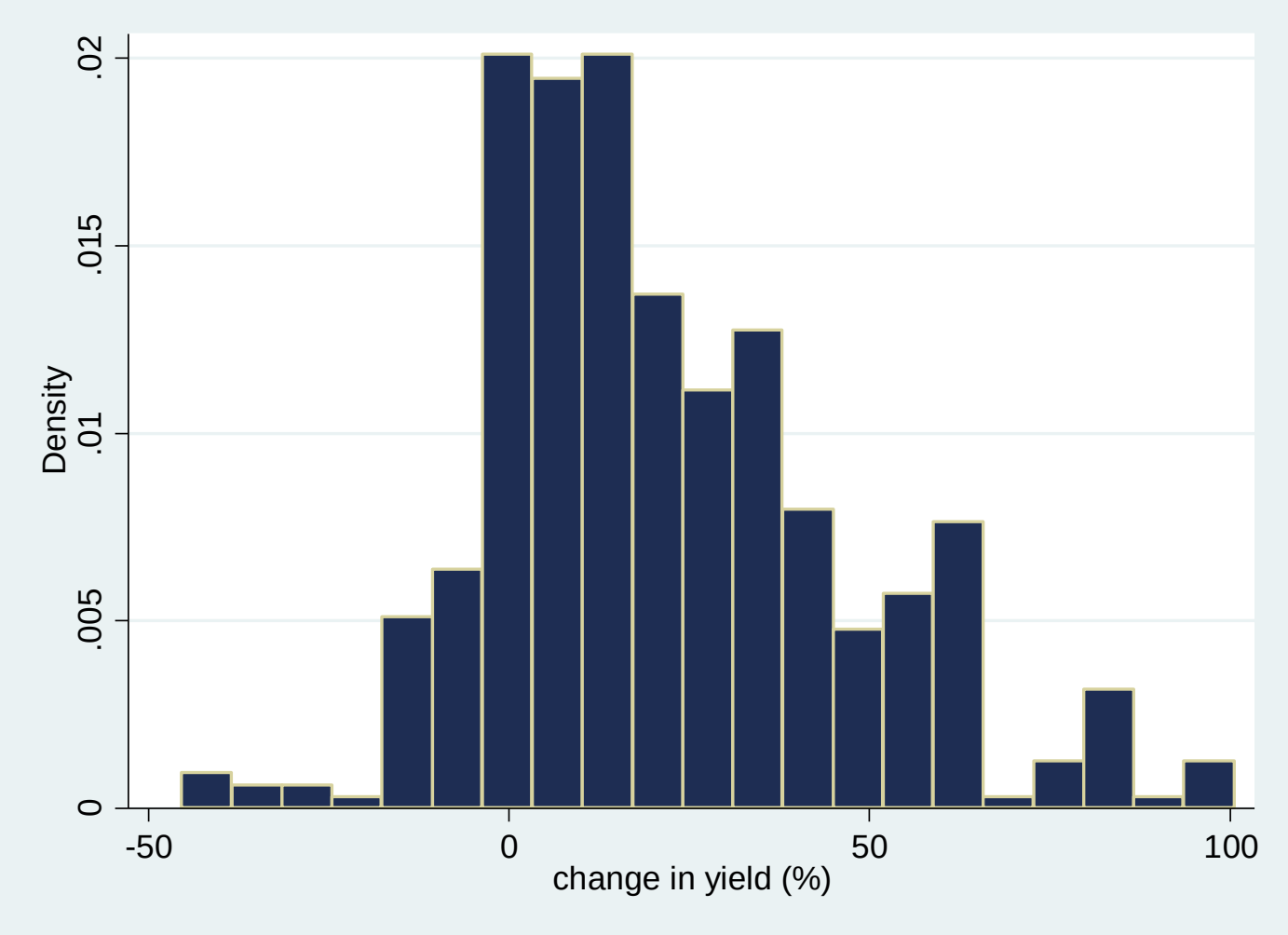
- Meta-analysis can be useful to:
  - ✓ Draw broader lessons from the cumulated evidence
  - ✓ Explain reasons for heterogeneity in impacts

Global meta-analysis of GM crop impacts

Klümper and Qaim (2014, *PLoS ONE*)



Distribution of GM yield effects



Source: Klümper and Qaim (2014).

Meta-analysis

Breakdown by type of technology

	(1) All GM crops	(2) Insect resistance	(3) Herbicide tolerance (HT)
Yield	21.6***	24.9***	9.3**
Pesticide quantity	-36.9***	-41.7***	2.4

Source: Klümper and Qaim (2014).

- HT has helped to reduce soil tillage and GHG emissions
- In some regions, weed resistance to glyphosate has reduced the benefits of HT crops over time

Breakdown by geographical regions

Meta-regression results (percentage point effects)

	Yield	Pesticide	Farmer profit
Developing country (dummy)	14.17***	-19.16***	59.52***
N	451	193	136

Source: Klümper and Qaim (2014).

Developing-country farmers benefit more because:

1. They suffer more from pest and disease problems
2. Most GM technologies are not patented there, so that seed prices are cheaper than in developed countries

What do we know about GM crop impacts in a small farm context?

Bt cotton adoption in India

In 2015: 11.6 m ha (97%)

Grown by around 8 million smallholders

Impact analysis with panel data

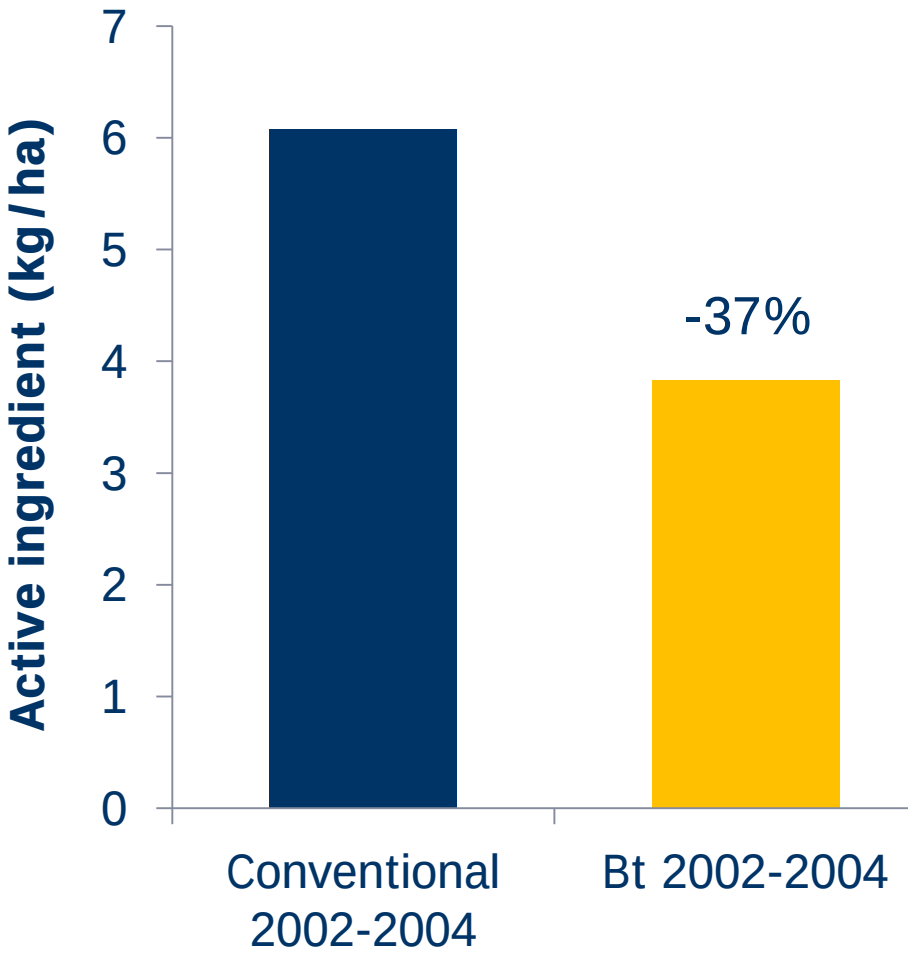
Survey of 530 farm households in:

- Maharashtra
- Andhra Pradesh
- Karnataka
- Tamil Nadu

Survey carried out four times between 2002 and 2009

Statistical differencing techniques to control for biases

Bt impact on insecticide use



Source: Krishna and Qaim (2012).

Bt impact on yield and farmer profit in India

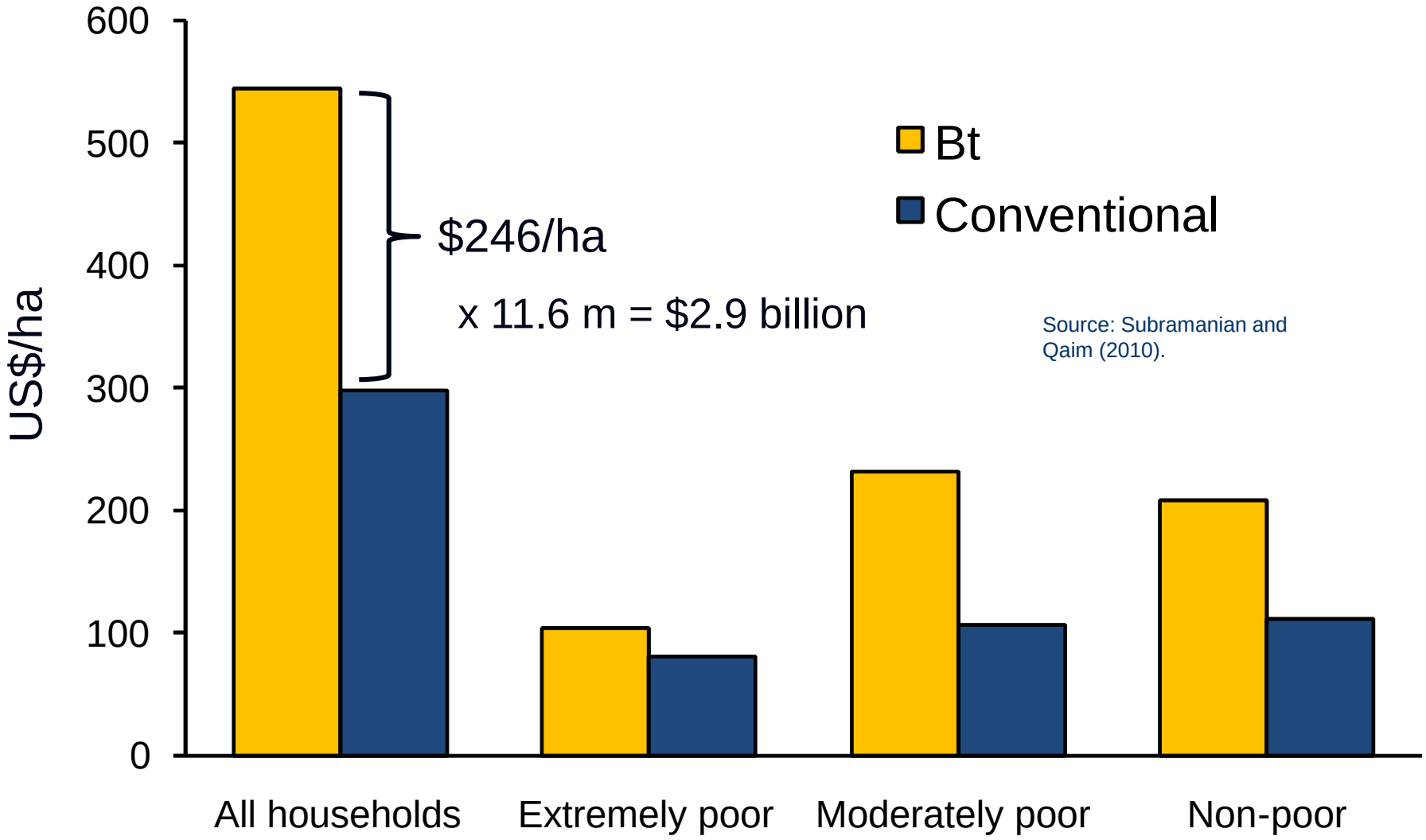
	Yield (kg/ha)	Profit ($/ha)
Bt effect	311*** (+24%)	94*** (+50%)
Change over time	0 / +	0 / +

Bt impact on household living standard

	Household consumption value (US$)	Calorie consumption (kcal/person)	Calories from high-value food (kcal/person)
Bt effect	321** (+18%)	145*** (+5%)	47*** (+7%)

Sources: Kathage and Qaim (2012), Qaim and Kouser (2013).

Household income effects per ha of cotton



Source: Subramanian and Qaim (2010).

Environmental and health effects of Bt

Effects on pesticide use by toxicity class (per ha)

	Total	Tox I	Tox II	Tox III & IV
Bt effect (2002-2004)	-2.74***	-1.38*	-1.21*	-0.15
Bt effect (2006-2008)	-4.42***	-2.67***	-1.63***	-0.15*

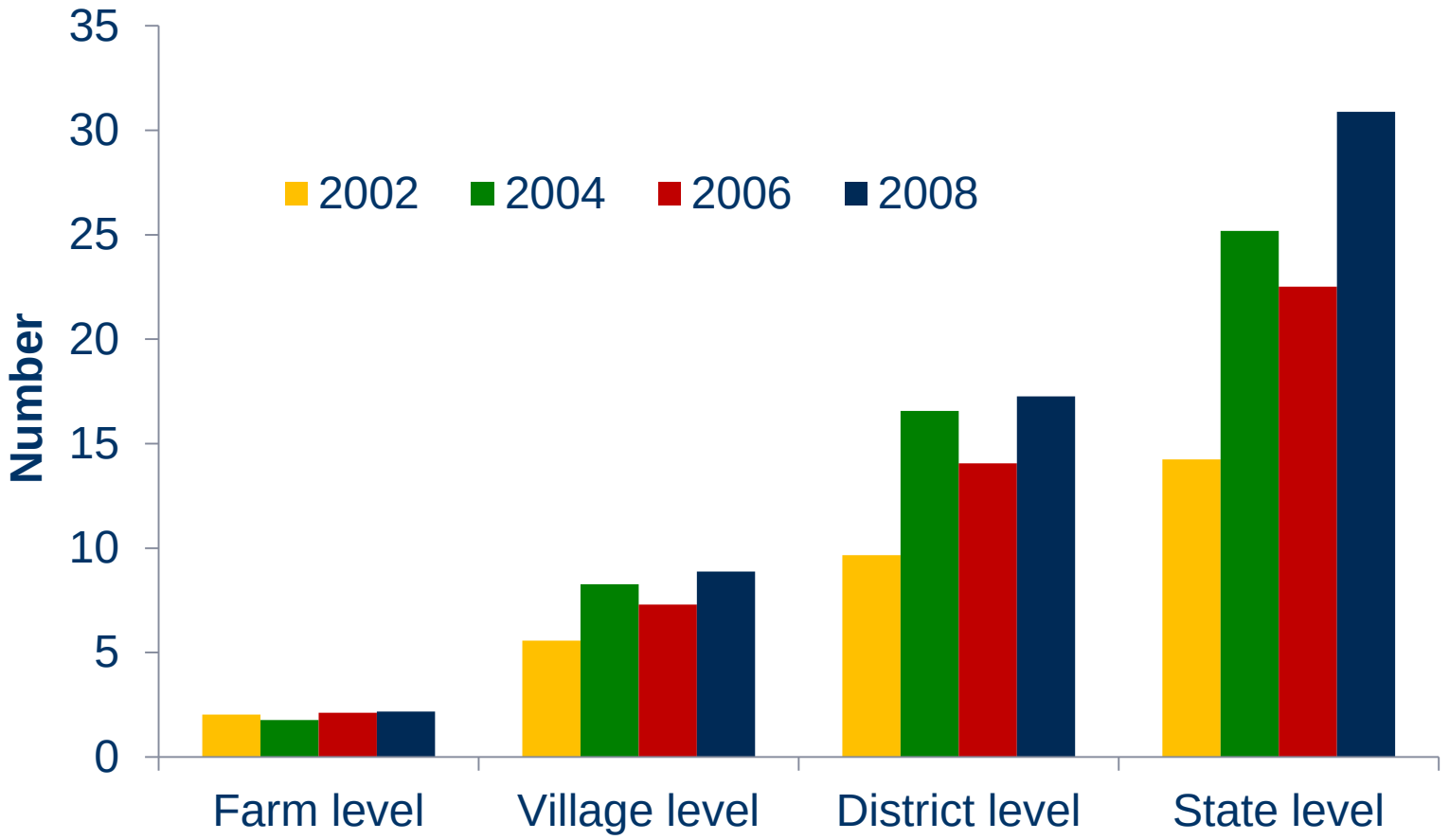
Effects on cases of acute pesticide poisoning

	Cases per ha	Cases in total India (million)
Bt effect	-0.26***	-2.98***

Source: Kouser and Qaim (2011),

Effects on varietal diversity

Mean number of cotton varieties grown by sample farms



Source: Krishna, Qaim, Zilberman (2016).

Future prospects

- Evidence suggests that GM crops can be beneficial for farmers, consumers, and the environment.
- So far, very limited range of GM technologies. Future technologies could be much more beneficial.
- Many interesting GM technologies tested in the field:
  - Drought-tolerant and salt-tolerant maize, rice, and wheat
  - Maize and rice with higher nitrogen use efficiency
  - Micronutrient-rich rice, sorghum, cassava, and banana
  - Pest- and disease-resistant rice, cassava, pulses, vegetables
  - Etc.
- Will these technologies ever be commercialized?

Threat of overregulation

Many countries in Africa and Asia have established EU-style regulatory systems that are stricter and more politicized than for any other agricultural technology.

Regulatory procedure in the EU form GMO approval

- Application/ regulatory dossier reviewed by EFSA
- Based on EFSA opinion, EU Commission prepares proposal for or against approval of the technology
- Proposal discussed in member country committee
- If committee agrees, proposal adopted by EU Commission; otherwise, Council of Agricultural Ministers gets involved
- Without qualified majority in the Council, the case is returned to the Commission

Example of Bt/HT maize in Europe

- In 2000, Pioneer applied for approval of maize 1507 in EU
- EU moratorium for any approvals between 2000-2003
- In 2004, EFSA asked Pioneer for additional data; first positive EFSA opinion in 2005
- In 2006, Commission asked for additional data; second positive EFSA opinion in 2006
- Additional data requested several times; up till now, maize 1507 received seven positive EFSA opinions
- In 2013, EU Commission issued proposal for approval
- In 2014, EU Parliament passed resolution not to adopt proposal: “long-term effects of maize 1507 are unclear”
- Maize 1507 not yet approved in EU
- For comparison, maize 1507 approved in USA in 2001

Effects of overregulation

- Fuels public notion that GM crops are dangerous
- Makes technology unnecessarily expensive (regulatory procedure can easily cost applicant >30 million EUR)
- Contributes to industry concentration (multinationals)
- Contributes to focus on large countries (regulatory approval required in every country)
- Contributes to focus on crops and traits with large commercial potential
- Even humanitarian projects suffer from the same hurdles (who is willing to finance such costly regulatory procedures with uncertain outcomes?)
- EU anti-biotech attitudes have far-reaching global implications

Conclusion

- GMOs are not a panacea, but there is strong evidence that they can contribute to sustainable development
- Like for any technology, there are certain issues that need to be addressed, but a GMO ban (as effectively observed in Europe and other regions) has no scientific basis

- We need:
  - ✓ More integrity in GMO debate
  - ✓ Reform of regulatory policies
  - ✓ More public research and competition in the plant biotech industry

Further reading:

Palgrave Macmillan, 2016