# Assessing Impacts of Crop Biotechnology Research

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## Objectives of presentation

- Highlight the need for biotech impact assessment
- Describe multiple levels and types of impact analysis
- Discuss approaches and issues that need addressing in biotech impact assessment

## Audiences for Biotechnology Impact assessment

- Farmers
- Scientists and administrators
- National and International Funding Agencies
- General Public

## Need for Impact Assessment of Improved Technologies

- Establish program priorities
- Assess profitability to make recommendations to farmers
- Estimate benefits to society
  - Economic – including distribution
  - Environmental/health
  - Nutrition

## Multiple purposes implies multiple **levels** of benefit analysis, multiple **indicators**, and multiple **methods** of analysis

| Level | Benefit Indicator | Method of Analysis |
|---|---|---|
| 1. Project, field trial | ○ Yield change, cost reduction, profitability<br>○ Reduction in Pesticide use per hectare | ○ Budgeting<br>○ Calculate changes in lbs. of active ingredient (a.i.) |
| 2. Market | ○ Adoption, changes in production, prices, trade, income<br>○ Change in pesticide risk | ○ Surveys, model market & econ. surplus changes<br>○ Relate a.i. changes to risk and value them |
| 3. Human Welfare | ○ Poverty reduction<br>○ Improved rural nutrition<br>○ Reduced environmental and health problems | ○ Calculate poverty indicator<br>○ Calculate share malnourished<br>○ Medical assessments, etc |

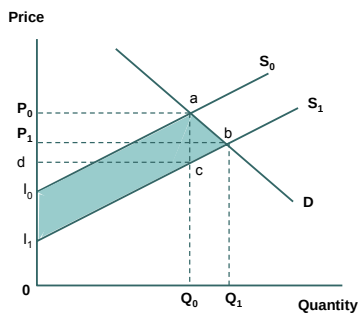
## Level 1: Economic assessment -- Budgeting

- Data collection from field trials – Input and output quantities and prices
- Partial budgeting of the new technology

## Level 2: Aggregate Economic Assessment – "Economic Surplus Analysis"

- Consider quantity produced, price, nature of product and input markets
- Assess extent of adoption and combine with effects of technology on yield and cost changes to estimate income changes (Economic Surplus)

Research shifts the supply curve from S0 to S1




## Steps in Assessment

- Define technology domains
- Define market domains
- Define time lags, regulatory costs
- For ex ante analysis, must consider: technical probability of success, market prob. of success, regulatory prob. of success
- Apply economic surplus formulas

## Measuring or projecting technology adoption

- Surveys
- Expert opinion
- Statistical analysis to project adoption using primary or secondary data

## Accounting for time lags and costs due to regulatory process

- India example:
  - Institutional bio-safety committees
    - Approves contained research
  - Review committee on genetic manipulation
    - Approves ag biotech research up to large scale field trials; permits to import GM material
  - Genetic engineering Approval Committee
    - Approves large-scale field trials and commercial release
  - Agronomic trials
- Cost: $100,000 - $2,000,000, 5-10 years

## Computer programs for economic surplus calculations

- Spreadsheets
- DREAM – Standardized program for market-level impact assessment

$$\Delta income = K_i P_i Q_i \left(1 + 0.5 K_i \varepsilon\right)$$

## Example: Philippines: *Bt* Rice

- Yellow stemborer problem
- 2.4% average yield loss
- Mamaril assessed benefits given import situation for rice
- Benefits to the Philippines over 15 years: $270 million

## Philippines *Bt* rice example with general equilibrium model

- One year benefits of $76 million
  - Considers multi-sector effects including input and output markets

Comparison of potential (annual) economic benefits of transgenic rice in selected countries (millions $) (Source: Hareau et al)

| | Stemborer resistance | Drought tolerance | Herbicide tolerance |
|---|---|---|---|
| China | 441 | 230 | 190 |
| India | 552 | 674 | 487 |
| Indonesia | 258 | 281 | 95 |
| Bangladesh | 99 | 163 | 17 |
| Vietnam | 24 | 26 | 73 |
| Thailand | 15 | 55 | 124 |
| Philippines | 76 | 98 | 303 |
| Japan | 404 | 431 | 114 |
| Rest of Asia | 429 | 602 | 339 |
| World total | 2278 | 2522 | 2169 |

## Level 2: Environmental impact Assessment

- Potential Benefits
  - Pesticide reduction
- Potential costs
  - Gene flow?
  - Effects on non-target species?
  - Reduced biodiversity?

## Example: Environmental evaluation of reduced pesticide use on onion in Philippines (Cuyno et al 1999)

- Expected pesticide reductions based on on-farm trials
- Risk level assigned to each active ingredient
- Willingness to pay to reduce risk assessed through a farmer survey
- Risk and willingness-to-pay info combined

Risk scores for onion pesticides applied in the study area/affected by IPM practices (5 = high environmental risk … 0 = no toxicity).

| Active Ingred. | Human | Animal | Birds | Aquatic | Beneficial |
|---|---|---|---|---|---|
| Benomyl | 4 | 4 | 3 | 5 | 5 |
| Mancozeb | 3 | 3 | 3 | 5 | 5 |
| Fluazifop | 4 | 4 | 0 | 5 | 5 |
| Glyphosate | 4 | 4 | 3 | 3 | 3 |
| Oxyflourfen | 4 | 4 | 1 | 5 | 5 |
| Chlopyrifos + BMPC | 3 | 3 | 5 | 5 | 5 |
| Cypermethrin | 3 | 3 | 5 | 5 | 5 |
| Deltamethrin | 4 | 4 | 3 | 4 | 5 |
| Lambdacyhalothrin | 3 | 3 | 3 | 4 | 5 |

Willingness-to-pay for and Economic Benefits from Risk Avoidance

| Category | Mean WTP (pesos per season) | WTP adjusted for % of pesticides on onions | Economic benefits (WTP adjusted by % risk avoided) |
|---|---|---|---|
| Human Health | 680 (219)* | 476 | 305 |
| Beneficial Insects | 580 (197) | 406 | 248 |
| Birds | 577 (200) | 385 | 231 |
| Animals | 621 (198) | 434 | 278 |
| Aquatic | 551 (210) | 404 | 250 |

Standard deviation in parentheses
Source: Cuyno, 1999

## Impact on local area

- Environmental benefits of onion IPM program worth about $150,000 per year to the 4600 local residents in six villages

## Level 3: Nutritional and poverty impacts

- Nutritional: Calculate changes in calories consumed per day as a result of increased in production causing price changes, which induce changes in consumption of various foods
- Poverty: Calculate changes in poverty indicators such as number people below the poverty level

## Example of Nutritional Impact Assessment

- Grafted eggplant seedlings in Nueva Ecija and Pangasinan, Philippines
  - Production changes shift supply curve resulting in price reductions and adjustments in foods consumed.
  - Household survey data was used to estimate consumption changes by income class.
  - Projected increase in calorie consumption by at least 90 calories per day.

## Example of poverty impact

- Example: Peanut CRSP/IPM CRSP joint impact assessment: Rosette virus resistance
  - Data collected for economic surplus estimation of the technology benefits was combined with farm-household survey data from IFPRI to calculate reduction in poverty

## Poverty impact assessment (continued)

- The Foster Greer Thorbecke (FGT) poverty measures used to measure poverty in the region before and after technology adoption

$$P_\alpha = \frac{1}{n}\sum_{i=1}^{q}\left[\frac{z - y_i}{z}\right]^\alpha$$

- where $n$ = total # of households; q = # of poor households; $y_i$ = income or expenditure of the $i^{th}$ poor household; z = poverty line (measured in the same units as is y); and α = parameter of inequality aversion. α = 0, α =1, α = 2.
- Poverty reduced by 1.3% in the region where adoption is occurring, once adoption reaches 50%

## Conclusion

- Multiple levels of impact assessment
- Multiple indicators of benefits
- Careful data collection from several sources is the time-consuming part
- Input market and regulatory differences can have significant effect on net benefits in biotech case