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Poverty Impacts of Widely-Adopted CGIAR Innovations

SPIA Midterm Workshop on Widely-Adopted CGIAR Innovations
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Outline

- Background
- Project design
- Challenges encountered
- Findings to date

Background of project

- Critical reception for CGIAR
- Challenging, but now potentially feasible
  - With new techniques
  - Building on existing work
- R&D is vital for food security but we observe flagging enthusiasm on agricultural R&D

Project design

- Three legged stool
  - Literature review (on productivity gains and the role of CGIAR R&D)
  - Delphi survey (expert opinion from experts like you)
  - Backcasting with CGE (estimates of aggregate productivity gain and the attribution to CGIAR R&D)
- These three approaches are interlinked

Challenges encountered

- Previous literature asks a different question than what we are asking
  - Earlier research generally focuses on yield impacts and adoption rates
- Lukewarm response to Delphi
- Getting to details through backcasting

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Findings to date

Literature Review

- More than 55 papers (journal articles, book chapters) that looked at TFP elasticities with respect to R&D (CGIAR or other) were reviewed
  - Most covered geographical groupings such as the Latin America and Caribbean, Asia, and Africa, developed countries
  - A small share of these had specific CGIAR elasticities

Literature Review

- More than 23 reports/articles that looked at CGIAR impacts on crop yields were reviewed
  - Many were sent by Delphi survey respondents
  - A majority of these reports were relevant to our study

Some observations

- Elasticity of TFP with R&D include multiple R&D sources: local public, international public, CGIAR, private
- Some articles include geographical spill-in of R&D (regional public)
- Adoption rate as a variable included in only 2 articles
- Most articles with CGIAR R&D are Africa and Asia focused
- Studies that use econometric methodologies to estimate elasticity of TFP with respect to R&D efforts are selected.
- We focused on last 20-25 years period for the study

Elasticity of TFP with respect to Total R&D

Sectors	OECD	ASIA	LAC	MENA	SSA	Africa	Developed	LDC	World
Agricultural Sector	0.2741	0.2390	0.3749		0.1978	0.1755	0.2592	0.2671	0.1450
All Crops		0.1675							
Grains	0.0380								
Livestock	0.1090	0.2025							
Poultry	0.0710								
Dairy	0.0420								

Total = sum of national, international, CGIAR, private R&D
R&D is stock or flow variable.
Simple arithmetic average is used to compute elasticities for each region or sector

Elasticity of TFP with respect to CGIAR R&D

Sectors	OECD	ASIA	LAC	MENA	SSA	Africa	Developed	LDC	World
Agricultural Sector		0.0850			0.0747	0.0601			
All Crops		0.2525							
Grains									
Livestock		0.1210							
Wheat		0.75							
Poultry									
Dairy									

R&D is stock or flow variable.

Simple arithmetic average is used to compute elasticities for each region or sector.

Studies with CGIAR R&D included separately

Regions	TFP elasticity for CGIAR	Sector	Time span	Geographical span
Thailand	0.03 aggregate (for crops 0.046- 0.105) (for livestock 0.121)	National aggregate, crop, livestock	1971-2006	National data
Indonesia	0.087	Agriculture	1985-2005	Provincial data
India	0.113	Crop sector	1956-1987	District data
India	0.11	Aggregate agriculture	1980-2008	State level data
China	4.6% to 14% increase with CIMMYT varieties	Wheat	1982 - 2011	Provincial data
SSA	0.0403	Aggregate agriculture	1977-2005	36 countries, national data
SSA	0.146 for small sample and 0.109 for large sample	Aggregate agriculture	1980-2010	SSA panel data, every 5 years, 17 and 30 countries, 30 crops
Africa	0.031	Aggregate agriculture	1961-1991	47 countries, national data

Crop Yield Impacts

- A wider literature on impacts of CGIAR specifically, with impact on yields and adoption patterns reported
- Methodologies include surveys, statistical analysis, econometric methodologies, data collection, and analysis
- A few examples show the variety of regions, crops, and methodology

Rice

- CIAT Bolivia: 15% more yield (63.4% of the total rice acreage used varieties released with CIAT participation)
- SSA – NERICA: 319 kg/ha increase in yield (NERICA varieties as a group occupied about 8% of the cultivated rice area of 6.8 million ha across 13 rice-growing countries in SSA)
- Philippines: 3.23% yield growth per year in wet season (2.77 t/ha in 2000), 2.75% yield growth per year in dry season (2.98 t/ha in 1996); elasticity of actual yield to the experimental yield of adopted varieties is 0.4 in the dry season, and 0.2 in the wet season

Wheat

- CIMMYT Semi-Arid Wheat Yield Trial over 17 year period shows 1% per year yield growth (multiple countries)
- Sharma et al. (2012): yield gains in CIMMYT spring bread wheat, during 1995-2009, ranged from 0.5% to 1.13% per year (multiple countries)
- Bangladesh, Dinajpur: 266 kh/ha yield increase from base of 2,540 kg/ha (40.96 ha from 108.67 ha)

Delphi Survey

- These surveys have three main questions:
  - Overall yield change and yield change due to CGIAR activities
  - To identify the key CGIAR innovations (variety, process, fertilizer type) that can explain these improvements
  - To identify a ranking the most important technologies in terms of labor, capital, land savings capacity

Delphi Survey

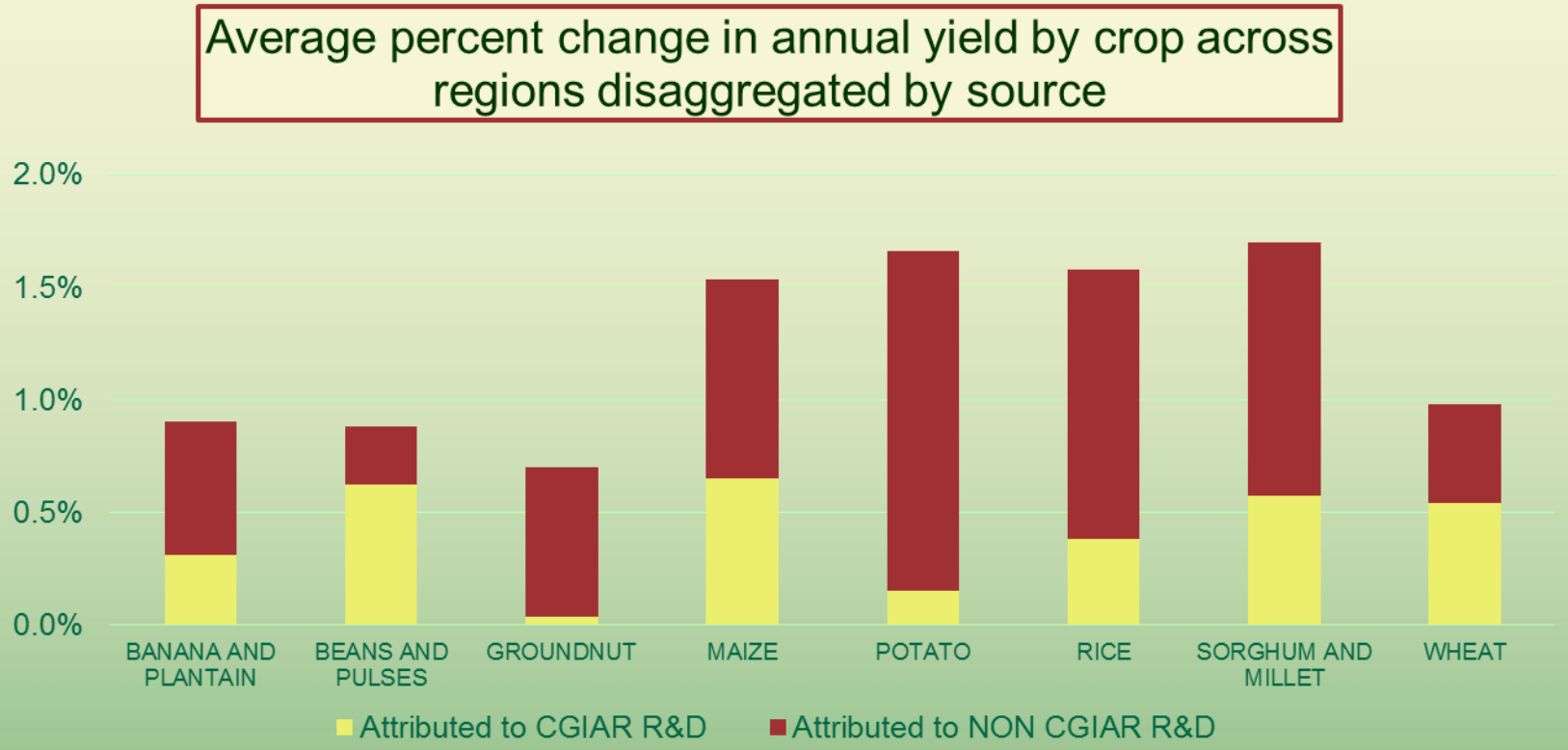
- The first iteration of the Delphi survey is complete, and the second iteration is underway
  - Aim is to review and narrow down the econometric estimates concerning the contribution of CGIAR R&D to productivity increase

Delphi Survey I

Crop Choices	Region Choices
Wheat	Asia (South, Central, and South East)
Rice	North Africa and Middle East
Maize	Sub-Saharan Africa
Sorghum and Millet	Latin America and Caribbean
Beans and Pulses	World
Potato	
Cassava	
Banana and Plantain	
Groundnut	
All Crops	

Delphi Survey I

- With 29 responses, we were able to make estimates of yield growth disaggregated by source of innovation for most crop/region combinations.



The estimated annual yield increase was averaged across regions, to which we applied the estimated ratio attributed to CGIAR R&D. Please note that the region ‘World’ is not included here.

Delphi Survey I

Average percent change in annual yield by crop-region combination attributed to BOTH CGIAR and other R&D

Crops	ASIA	LAC	MENA	SSA	WORLD
Banana and Plantain		1.32%		0.70%	1.12%
Beans and Pulses	0.70%		1.00%	1.25%	1.88%
Groundnut	0.70%				
Maize	3.00%			1.55%	1.96%
Potato	2.00%	1.32%			
Rice	1.81%			2.00%	1.00%
Sorghum and Millet	1.70%				
Wheat	1.39%		0.85%	1.00%	1.18%

*These were calculated using the estimate of global annual yield increase, averaging it out by crop/region combination, and applying the estimated share attributed to CGIAR R&D.

*The region category ‘WORLD’ is not an aggregate of the other regions, rather a direct estimate from respondents.

Delphi Survey I

Average % change in annual yield by crop-region combination attributed only to CGIAR

Crops	ASIA	LAC	MENA	SSA	WORLD
Banana and Plantain		0.40%		0.27%	0.17%
Beans and Pulses	0.32%		0.24%	1.09%	1.13%
Groundnut	0.04%				
Maize	0.15%			0.90%	0.36%
Potato	0.04%	0.26%			
Rice	0.40%			0.30%	0.30%
Sorghum and Millet	0.57%				
Wheat	0.74%		0.30%	0.65%	0.41%

*These were calculated using the estimate of global annual yield increase, averaging it out by crop/region combination, and applying the estimated share attributed to CGIAR R&D.

*The region category ‘WORLD’ is not an aggregate of the other regions, rather a direct estimate from respondents.

Delphi Survey I

Average share of percent change in annual yield attributed to input types						
Crops	Fertilizer	Improved farm management	Improved seed varieties	Irrigation	Pesticides & Herbicides	Machinery
All Crops	16%	2.5%	35%	10.5%	12.5%	7.25%
Banana & Plantain	32.75%	23.5%	21.25%	16.25%		6.25%
Beans and Pulses	4.5%	22.75%	62.5%	3%	1.87%	2.87%
Groundnut	20%	20%	20%	20%		20%
Maize	28.71%	12.14%	51.8%	2%	1.42%	3.57%
Potato	26.5%	16%	13.5%	11.5%	6.5%	26%
Rice	14.28%	14.57%	30.42%	17.28%	11%	11.85%
Sorghum and Millet	13.5%	22.5%	40%	9.5%	5%	10%
Wheat	23.44%	16%	39.55%	11.22%	3.33%	5.33%

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Backcasting in CGE

TFP shock calibration for the CGE

- Study period after 1995
- Steps:
  - Identification of shocks
  - Regional and commodity disaggregation
  - Implementation of shocks

Identification of Shocks

- Three basic methods of eliciting shocks:
  - Productivity analysis using factor shares from a model
  - Literature survey of TFP gains from:
    - All research
    - CGIAR research
  - Delphi process using experts in & outside CGIAR
    - First to elicit estimates of yield gains & CGIAR contribution and to help identify relevant literature
    - Second to review initial estimates

Shocks by region and commodity

- Delphi survey asks for yield growth rates by major crop and by region
  - Total yield growth & growth from CGIAR research
- Literature survey estimates tend to be for TFP in agriculture by region
- Productivity analysis estimates TFP growth by major crops and by region
  - Will provide these estimates to Delphi respondents
- Research team will consolidate evidence
  - Will seek further feedback

Implementation of shocks

- Will impose productivity shocks on the MIRAGRODEP global general equilibrium model
  - Productivity ↑ raises farm output
    - May raise wage rates by raising productivity of farm labor
    - May lower output prices
    - Depends on nature & rate of TFP growth & on elasticities
  - Will estimate changes in prices & in factor prices

Implementation of shocks

- Impose shocks on 300,000 household models
  - Productivity raises output of farm business
  - Changes prices they face & receive
  - Shocks to wage rates - especially wage rate for unskilled labor
- Assess impacts on household incomes & poverty

Backcasting: Why?

- Our main quantitative framework is a dynamic CGE: MIRAGRODEP
- This model describes all economic sectors, including different crops, and different regions in the model consumers and producers through a set of behavioral structural equations.
- Our goal is to simulate the global economy and agricultural markets from 1992 to 2012 to be able to run scenarios with alternative technological scenarios over this period (“what if” approach).
- This will allow us to identify the TFP by crop and region in our structural model.

Backcasting: How?

- Step 1: building a dataset with key indicators for the period 1992-2012 (GDP, population, relative prices, production, yields, land use, etc.)
- Step 2: Starting from 2012, the model is run in a reverse dynamic from 2012 to 1992.
  - Some exogenous **variables** are directly used as input in the model: e.g. population
  - Some behavioral **parameters** are directly used from historical data: e.g. saving rates;
  - Some variables, normally endogenous to the model, are “fixed” and used to calibrate structural parameters: e.g. national GDP is used to calibrate national average TFP.
  - Using a vector of such “targeted” variables, we can adjust an equivalent number of parameters in the model both on the demand and the supply side.
  - One of this parameter is a crop-country specific TPF parameter that is our starting point to build alternative scenarios.

→ for each crop (i) and each region (r), we have calibrated agricultural production function overtime (t) such as:

$$Y_{i,r,t} = TFP_{i,r,t}.F_{i,r}(Capital_{i,r,t}, Land_{i,r,t}, Labour_{i,r,t}, Inputs_{i,r,t})$$

$TFP_{i,r,"1992"}$=1

Preliminary Backcasting results 1992-2012

Total TFP annual growth rate estimates for main crops
Production weighted for regional average
(within region range in brackets)

	Maize		Rice		Wheat	
Africa	1.4%	[-0.2 ; 5.1]	0.7%	[-0.1 ; 4.1]	1.7%	[0.2; 3.4]
East Asia	0.9%	[0.1 ; 0.9]	0.6%	[0.1 ; 0.8]	1.6%	[0.5 ; 1.9]
South and South-East Asia	2.4%	[0.8 ; 6.1]	1.3%	[0.1 ; 2]	1.2%	[0.1 ; 3.7]
Europe	1.1%	[0.8 ; 2.5]	1.4%	[0.2 ; 2.3]	0.8%	[0.4 ; 2.1]
North America	0.9%	[0.7 ; 1.5]	1.1%	[1.1 ; 1.1]	1.0%	[0.8 ; 1.4]
South America	2.9%	[0.1 ; 3.9]	2.6%	[-0.5 ; 3.2]	1.3%	[0.1 ; 2.4]
Oceania	0.9%	[0.9 ; 0.9]	0.7%	[0.7 ; 0.7]	0.5%	[0.5 ; 0.5]

Conclusion

- Any feedback would be welcome
- Thank you!

Link between the scenario design and the model

Scenario implementation

- From the back-casting exercise, for each crop (i) and each region (r), we have calibrated agricultural production function overtime (t) such as:

$$Y_{i,r,t} = TFP_{i,r,t}.F_{i,r}(Capital_{i,r,t}, Land_{i,r,t}, Labor_{i,r,t}, Inputs_{i,r,t})$$

$$TFP_{i,r,"1992"} = 1$$

- Main case: Neutral technological change
  - From the scenario definition, a share $\theta_{i,r}$ of the TFP increase is driven by CG interventions;
  - The model is then run for the period 1992-2012 assuming the following form, i.e. with a lower TFP rate:

$$Y_{i,r,t} = [1 + (1 - \theta_{i,r})(TFP_{i,r,t} - 1)].F_{i,r}(Capital_{i,r,t}, Land_{i,r,t}, Labour_{i,r,t}, Inputs_{i,r,t})$$

During these simulations, θ, TFP, and the structural parameters of F are exogenous

While the vector $(Capital_{i,r,t}, Land_{i,r,t}, Labour_{i,r,t}, Inputs_{i,r,t})$ is endogenous.

Extension: Biased technological change

- Let's simplify and rewrite our production function with X_k, the different factors of production *k*, and introducing a factor specific productivity item $FPX_{k,i,r,t}$:

$$Y_{i,r,t} = TFP_{i,r,t} F_{i,r}\left(X_{k,i,r,t}\right) = F_{i,r}\left(FPX_{k,i,r,t} X_{k,i,r,t}\right)$$

- Assuming neutral TFP, as in the previous slide, is equivalent to: $TFP_{i,r,t} = FPX_{k,i,r,t}\ \forall k$

$$Y_{i,r,t} = F_{i,r}\left([1 + (1 - \gamma_{k,i,r}\hat{\theta}_{i,r})(TFP_{i,r,t} \ -1)].X_{k,i,r,t}\right)$$

$\gamma_{k,i,r}$ is a vector of weights showing the technology bias of CG technologies and a scenario input with $\sum_k \ \gamma_{k,i,r} = 1$

- In this case,$\hat{\theta}_{i,r}$ has to be calibrated numerically to check given the same inputs vector $\bar{X}_{k,i,r,t}$, we generate the same output change as in the neutral TFP case(left hand side) for each scenario:

$$F_{i,r}\left([1 + (1 - \theta_{i,r})(TFP_{i,r,t} \ -1)].\bar{X}_{k,i,r,t}\right) =$$
$$F_{i,r}\left([1 + (1)(TFP_{i,r,t} \ -1)].\bar{X}_{k,i,r,t}\right)$$