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Review of Recent Literature on Impacts of Agricultural R&D for Poverty, Nutrition and Resilience

Carl E Pray[1], William A. Masters[2] and Sabrina Ayoub[1]

1. Rutgers Univ., Dept. of Agricultural, Food & Resource Economics and Feed the Future Policy Research Consortium

2. Tufts University, Friedman School of Nutrition Science & Policy and Feed the Future Nutrition Innovation Lab

Tufts UNIVERSITY | Friedman School of Nutrition Science and Policy

Summary of the literature

- Agricultural R&D is still among the highest-return public investments
  - No decline over time or lower returns in specific regions
  - Gains arise from higher productivity of land and labor
  - Large impacts on poverty, nutrition and resilience
- Impacts revealed by diverse kinds of evidence
  - Individual household data for adoption and response to innovation
  - Aggregate country data for systemic change & structural transformation
  - Modeling food systems to estimate rates of return and private sector growth
- Recent history can help guide research priorities
  - To lower poverty, aim for large targets (species & systems) in poor places
  - To improve nutrition, aim at purchasing power for better diets (income/prices)
  - To improve resilience, aim at level *and* stability of poverty/nutrition outcomes

Outline of presentation

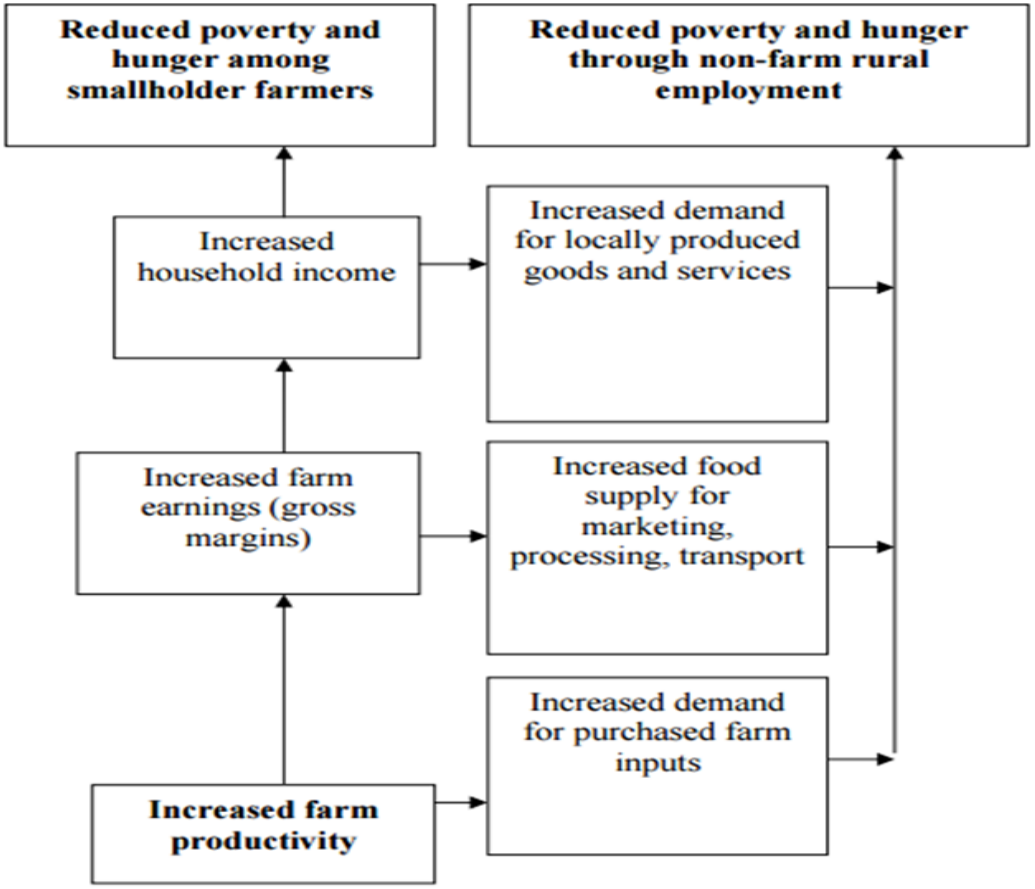
- Methodology for systematic literature review
- Causal mechanisms and types of evidence
- Summary of results
  - Poverty
  - Nutrition
  - Resilience
- Implications for priority-setting

Methodology for systematic literature review

- Topic is longstanding and broadly defined, so we focus on:
  - recent studies (most are since 2010, earliest cited is 1996)
  - peer-reviewed, high-impact work (mostly journals, include gray literature)
  - target regions (mostly Africa and South Asia, some Latin America)
  - relevance for specific objectives (poverty, nutrition and resilience)
- Research uses diverse methods and terminology
  - repeated searches with different search terms
  - personal outreach to individual scholars and practitioners
- Research uses different kinds of data:
  - Qualitative studies (for questions without numerical data)
  - Statistical estimates (both household surveys and aggregate data)
  - Simulation models (from farm and specific crops to global models)

Causal mechanisms and types of evidence

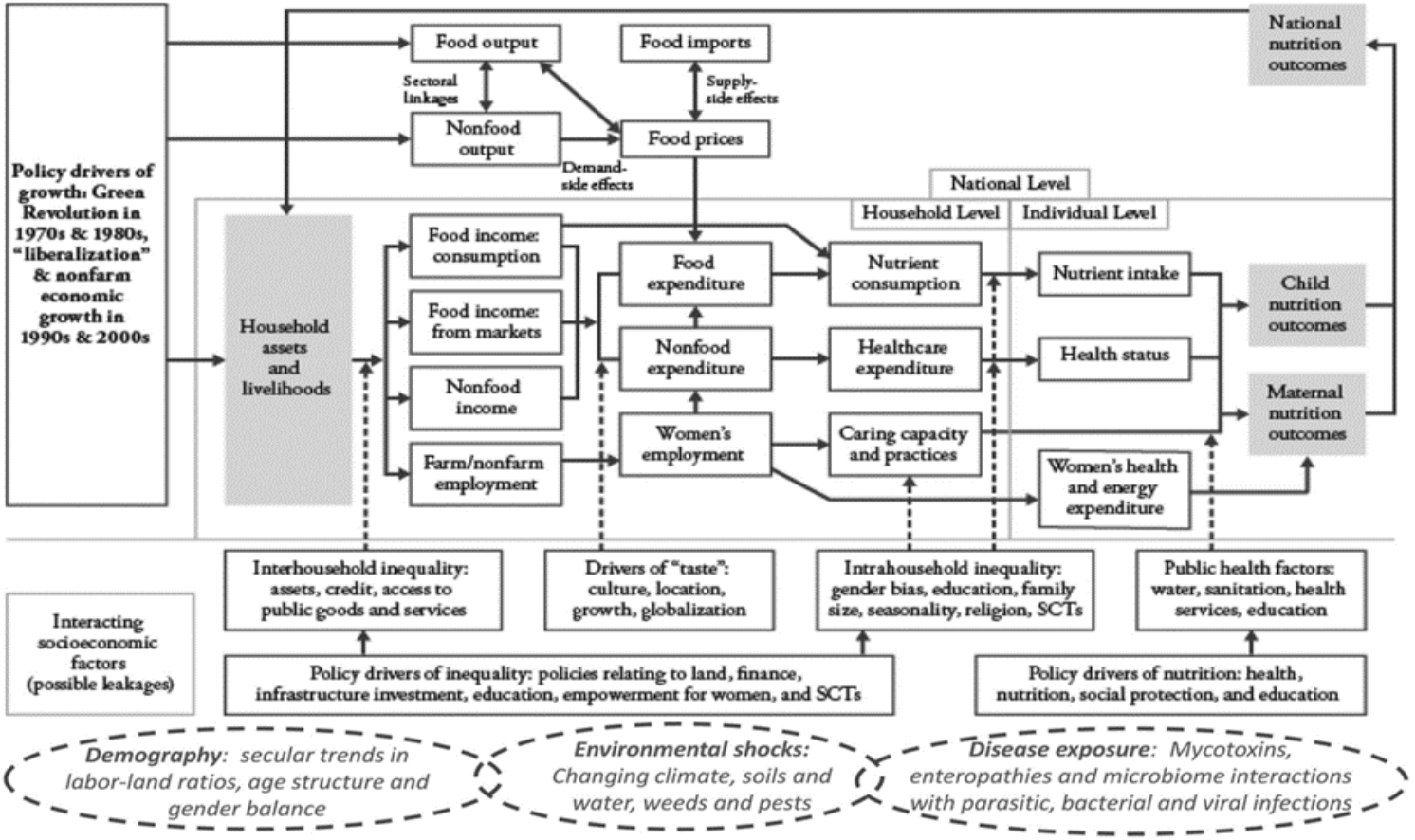
Impacts of R&D occur through systemic change



Source: Oehmke et al. 2010

Causal mechanisms and types of evidence

Adding nutrition and resilience requires even more data



Source: Masters, Webb, Griffiths, & Deckelbaum (2014), modified from Gillespie, Harris and Kadiyala (2012).

Principal results – driving force is productivity

Series of econometric studies by Keith Fuglie and Nick Rada ERS/USDA show that in most cases public ag R&D has major on total factor productivity (TFP)

- Fuglie et al. (2012) 87 countries 1961-2009 TFP accounted for 40% of ag. growth and public and private sector R&D was a statistically significant determinant of agricultural TFP (except in SSA)
- Fuglie and Rada (2012) 37 countries of SSA. International research and national public research account for all TFP growth in SSA.
- Country studies in Brazil and India found major impacts of public research but in Indonesia policy changes and increased trade accounted for the TFP growth.

Principal results – links to private investment

Public research attracts private investment, using public findings; privately-financed research still very limited in developing countries

- Private R&D and TFP in US (Huffman & Evenson 2006) & India (Evenson, Rosegrant & Pray 1998)
- Private poultry research increased poultry productivity globally (Narrod & Pray 2001)
- Case studies show important impacts of private sector hybrid maize, pearl millet and sorghum on productivity in India and maize in Tanzania; many on GMO cotton, maize and soybeans in developing countries (summarized in Pray & Fuglie 2014)

Principal results – rates of return

- Meta-analysis of 78 countries developing countries generally have higher rates of return (median of 41%) than developed countries (median return of 34%) well above what government can borrow money (Rao, Hurley & Pardey 2016)
- Africa similar results
  - Pardey et al. (2016) review 113 studies in 25 countries of SSA from 1975 to 2014, internal rates of return with a median of 35 percent and mean of 42 percent.
  - Raitzer & Maredia (2006) use data from 23 studies to aggregate the total costs and benefits of CGIAR–NARS partnership investments in SSA for the period 1966–2004. US$17 billion investments generated benefits of $26-28 billion
- Jutzi and Rich (2016) CG livestock research
  - Rinderpest eradication, goat parasites, dairy policy change, new forages, and natural resource management techniques had high rates of return for all but control avian influenza.

Returns to national and international agricultural research in Sub-Saharan Africa (SSA)

National and international research systems	Internal rate of return	Benefit-cost ratio
	% per year	*10% discount rate*
Large countries	43	4.4
Medium-size countries	29	2.6
Small countries	17	1.6
Average for all Sub-Saharan African countries with CGIAR	29	2.8
Average for all Sub-Saharan African countries without CGIAR	24	2.2
CGIAR centers in Sub-Saharan Africa	58	6.2

CGIAR=Consultative Group for International Agricultural Research.

Source: ERS. Derived from econometric results (see appendix).

Principal results – poverty reduction

- Thirtle, Lin and Piesse (2003) 48 developing countries 10% increase in ag research reduces poverty by 1%
- Thirtle and Piesse (2007) more sophisticated model, same data, same results
  - research increases yield/ha,
  - yield/ha increases GDP per capita,
  - yield reduces the inequality in aggregate and in Asia and in Africa, but it increases inequality in Latin America.
  - increasing GDP per capita and reducing inequality reduces poverty.
- Alene and Coulibaly (2009) 28 countries of SSA1980 to 2003
  - R&D expenditures by the CGIAR centers in Africa and by African governments increased agricultural value added/hectare,
  - value added/hectare increases GDP per capita
  - increases in GDP per capita reduces the percentage of people living on less than $1 per day. Double research reduces poverty by 8%

Principal results – specific examples

Authors	*Location*	*Subsector*	*Method*	*Outcome*
Research on production agriculture				
Asfaw, Kassie, Simtowe & Lipper, 2011.	Tanzania	Pigeon pea public	Ex post adoption and poverty reduction	Adoption of improved pigeon pea varieties significantly decreased inequality & severity of poverty, by 4.4–8.1 percentage points
Chagunda et al., 2016	SSA	Improved dairy technology		In Sub-Saharan Africa (SSA), smallholder dairy improved with 3 approaches: ecological, genetic, and socio-economic intensification
Larochelle, 2015	Uganda/ Rwanda: Common beans	Common beans CIAT	Ex post adoption and poverty reduction	Impacts on poverty were 0.4% in Rwanda and 0.1% in Uganda, proportional to small area & small part of diet
Moyo, Norton, Alwang, Rhinehart, & Deom, 2007	Eastern Uganda	Peanuts. Public sector in Uganda, by ICRISAT in Malawi,	Ex ante impact analysis of adopting Rosette-resistant seed varieties by all peanut producers	Full adoption would give 10.5% decline in severity of poverty.
Oehmke et al., 2011	Kenya	USAID supported productivity programs for maize, livestock and vegetables	Ex post analysis using Tegemeo panel of HHs	Between 2004 and 2008, net poverty in the direct treatment group decreased by 4.9%. Among indirect beneficiaries of the programs, a net poverty rate reduction of 9.9%. In 2006- 2008, poverty among female-headed households potentially benefitting from the USAID programs declined from 76% to 67%.
Zeng et al., 2015	Ethiopia	Maize varieties from CGIAR	Ex post based on survey data	0.8-1.3% decline in poverty due to adoption but the poor benefitted least because of their small land holdings

Principal results – postharvest food systems

- Insect resistant corn reduces mycotoxin exposure of the poor in South Africa (Pray et al 2013)

- Some case studies in Africa show that mechanization of cassava processing and improved maize storage can reduce poverty

- Policy changes clearly can reduce poverty
  - Jayne et al Kenya liberalization of maize and fertilizer marketing creates important economic benefits for Kenyan farmers and consumers.
  - Kaitibie, et al (2010). Kenyan dairy policy change 55% ROR

Principal results – from poverty to nutrition

	Comparisons to base case (percent changes)	
	With no MVs in developing countries (NGR)	With no IARC programs (NIARC)
Crop yields		
Developed countries	2.4 to 4.8	1.4 to 2.5
Developing countries	−19.5 to −23.5	−8.1 to −8.9
Cropped area		
Developed countries	2.8 to 4.9	1.6 to 1.9
Developing countries	2.8 to 4.9	1.6 to 1.9
Crop production		
Developed countries	4.4 to 6.9	1.0 to 1.7
Developing countries	−15.9 to −18.6	−6.5 to −7.3
Crop prices, all countries	35 to 66	18 to 21
Increase in imports by developing countries	27 to 30	6 to 9
Percent of children malnourished, developing countries	6.1 to 7.9	2.0 to 2.2
Calorie consumption per capita, developing countries	−13.3 to −14.4	−4.5 to −5.0

Evenson and Gollin 2003

Principal results – nutrition and health

- Barnwell et al 2017 use the timing and location of modern variety (MV) introduction, relative to the timing and location of 600,000 births in 37 developing countries, and find that each standard deviation increase in MV diffusion led to a large 9% decrease in all-cause infant mortality.

- Masters et al 2014 show how agricultural productivity drives the establishment of cities and the growth of nonfarm activity, while Darrouzet-Nardi and Masters (2017) identify the resulting decline in vulnerability to poverty and malnutrition within rural areas.

Principal results – resilience

Pathways by which agricultural research can increase resilience of farm households include:

1. Increase productivity which could increase the incomes of the poor & make households more resilient to shocks.
2. Reduce vulnerability of crop and livestock to biotic and abiotic stress through
   - developing resistant crop and livestock varieties,
   - developing pesticides and vaccines,
   - crop/livestock management strategies and agroecological biodiversity.
3. Develop more effective policies and programs to reduce vulnerability such as famine relief programs, food stamps and crop insurance.

Principal results – resilience

- Biotic stress
  - Much of the public research after the initial Green Revolution focused on breeding MVs with insect and disease resistance.
  - Private sector research also played an important role in developing pesticides, equipment to control weeds and GM crops to control insects, weeds, and disease.
- Abiotic stress
  - Drought tolerant maize – many ex ante studies of maize in Africa – CIMMYT and Virginia Tech
  - Submergence tolerant rice in Eastern India and Bangladesh – RCTs on Sub-1 varieties.
  - Both will have limited adoption unless stress tolerance is bundled with yields, pest resistance or index insurance

Principal results – resilience

- Agricultural research confers resilience not only within species but also through increasing biodiversity on farms and in the broader agroecosystem Melinda Smale (2006)

- Natural resource management practices such as conservation agriculture have proven to increase resilience of larger farmers in Zimbabwe and Zambia(Michler et al 2016) as well as the large commercial farms in North and South America

- Agricultural R&D can also confer resilience through new types of crop insurance (index insurance) and new kinds of capital markets (futures markets)

Principal results – synergies with other public investments

Effects of R&D investment scenarios (MED-REGION) show trade-offs, complementarities with irrigation (IX), water saving (ISW) & infrastructure (RMM)

Scenario	Avg. Annual Cost	2030						2050					
		SLO1	SLO2		SLO3			SLO1	SLO2		SLO3		
		GDP	Ag Supply	Hunger	Water Use	GHG	Forest	GDP	Ag Supply	Hunger	Water Use	GHG	Forest
MED	1.4	0.7	1.4	-6.5	0.0	-5.5	0.03	1.9	2.7	-9.3	-0.2	-15.4	0.13
HIGH	2.0	1.3	2.8	-12.4	-0.1	-7.5	0.04	3.4	5.7	-16.6	-0.4	-24.3	0.20
HIGH+NARS	3.0	1.6	3.7	-15.8	-0.1	-8.9	0.04	4.3	7.7	-20.2	-0.4	-26.5	0.22
HIGH+RE	2.0	2.6	6.4	-24.4	-0.2	-12.7	0.06	4.2	7.5	-20.0	-0.4	-26.9	0.22
REGION	2.5	1.1	2.4	-10.9	-0.1	-6.5	0.03	3.1	5.1	-15.4	-0.3	-22.6	0.18
IX	3.6	0.1	0.1	-1.3	2.6	-1.8	0.01	0.2	0.2	-1.1	2.9	0.7	-0.01
IX+WUE	8.3	0.4	0.9	-4.5	-7.2	-1.9	0.01	0.5	0.9	-2.7	-7.5	-0.2	-0.01
ISW	5.0	0.2	0.5	-2.1	-1.5	-0.5	0.00	0.5	0.9	-3.0	-2.9	-1.1	0.01
RMM	11.9	1.0	1.6	-5.8	0.1	6.4	-0.02	0.8	1.5	-4.2	0.0	8.9	-0.08
COMP	26.4	4.1	9.8	-30.6	-9.0	-11.5	0.07	5.7	11.5	-24.4	-11.0	-25.4	0.22

Less Advantageous — Neutral — More Advantageous

Note: costs are in billion USD, while other values are percentage differences in each indicator relative to the REF_HGEM scenario

Source: Rosegrant et al. 2016

Notes: Strategic objectives are SLO1: Reduced poverty, SLO2: Improved food and nutrition security and health, SLO3: Improved natural resource systems and ecosystem services. Policy scenarios are as defined in Table 4.

Implications for priority setting

- Agricultural research remains the highest-return driver to reduce poverty, improve nutrition and build resilience.
- To reach nutrition and resilience objectives more quickly, use a sequence of investment criteria such as the following:

1. Is the investment likely to improve real and diversified incomes for those at risk?

   ➔ usually aim for large targets (species & systems). in poor places

2. Is the investment likely to lower and stabilize the real cost of nutritious food, and non-food influences on nutrition outcomes?

   ➔Usually aim at purchasing power for better diets (income / prices)

   ➔Also limit disease exposure via sanitation and food safety, and help empower women and other caregivers

3. Is the investment likely to improve non-food influences on nutritional outcomes?

   ➔ To improve resilience, aim at level *and* stability of poverty/nutrition outcomes