Economic Impact: Sustainability of Current and Future Agricultural Technologies

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150-Year Downward Trend in Real* Grain Prices

• Since Malthus, prophets of doom have argued population growth will increase food demand faster than agricultural production can grow.

• Public and private sector investments in agricultural research have increased productivity faster than demand has grown.

• Where adaptive research investments have been made, surplus, not scarcity, has prevailed.

• The result was a 150-year downward trend in real price of grains, to the great benefit of the poor who spend a large share of their income on food.

*Adjusted for inflation.
## Share of Food* Expenditures in Total Expenditures (Percent)

<table>
<thead>
<tr>
<th>Quintile</th>
<th>Bangladesh</th>
<th>India</th>
<th>Indonesia</th>
<th>Philippines</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td>69.3</td>
<td>62.0</td>
<td>63.3</td>
<td>64.6</td>
</tr>
<tr>
<td>2nd</td>
<td>66.9</td>
<td>59.4</td>
<td>58.1</td>
<td>59.2</td>
</tr>
<tr>
<td>3rd</td>
<td>63.2</td>
<td>56.2</td>
<td>54.1</td>
<td>54.1</td>
</tr>
<tr>
<td>4th</td>
<td>58.7</td>
<td>50.8</td>
<td>49.0</td>
<td>47.7</td>
</tr>
<tr>
<td>5th</td>
<td>45.2</td>
<td>36.4</td>
<td>37.9</td>
<td>35.4</td>
</tr>
</tbody>
</table>

*“Food” in low income countries has much less value-added after the farm gate than in high income countries. Source: Asian Development Bank.*
Engel’s Law

• As their incomes rise, smaller and smaller fractions of each increment get spent on food.

• Larger and larger fractions of each increment to income are spent on goods & services produced in the rest of an economy, stimulating faster economic growth and job creation in the rest of the economy.
Hunger & Food Insecurity Widespread

• Of the world’s 7.2 billion people, 1.2 billion live on less that $1.25 per day*.
  – 870 million people (1 out of every 8 people in the world) lack the purchasing power to access 1,800 calories per day, not enough to put in even a medium level of physical activity.

• 2.4 billion (35% of the world population) live on <$2.00 per day*.
  – By $2.00 per day most hunger (calorie) problems solved, but 1 billion still suffer nutritional deficiencies.

## Number of People Living in Extreme Poverty (in millions, 2010)

<table>
<thead>
<tr>
<th>Region</th>
<th>&lt;$1.25/day*</th>
<th>&lt;$2.00/day*</th>
</tr>
</thead>
<tbody>
<tr>
<td>South Asia</td>
<td>506</td>
<td>1,075</td>
</tr>
<tr>
<td>Sub-Saharan Africa</td>
<td>414</td>
<td>592</td>
</tr>
<tr>
<td>East Asia &amp; Pacific</td>
<td>251</td>
<td>586</td>
</tr>
<tr>
<td>Latin America &amp; Carib</td>
<td>32</td>
<td>59</td>
</tr>
<tr>
<td>E. Europe &amp; Central Asia</td>
<td>3</td>
<td>11</td>
</tr>
<tr>
<td>Middle East &amp; N. Africa</td>
<td>8</td>
<td>38</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1,215</strong></td>
<td><strong>2,360</strong></td>
</tr>
</tbody>
</table>

*Income corrected for differences in purchasing power across countries.
Malnutrition Has a High Cost

- Under-nutrition in childhood (especially from -9 to +24 months of age) can stunt a people’s mental and physical development, reducing their productivity and lifetime earnings below the potential they had when conceived.

- If widespread, this can reduce a country’s economic growth potential below what it could otherwise have been.
  - If widespread, this can increase the fraction of a country’s national income which must be devoted to health care.
2008 World Food Price Crisis

Source: IFPRI, based on FAO data.
Higher Food Prices Increase the Incidence of Hunger

- Low income people spend a large fraction of their incomes on food, so higher food prices reduce the purchasing power of their meager incomes.
- The 2007-2008 price spike increased number of people suffering hunger from 925 million to over 1 billion and precipitated political crises in many countries.
- The need for emergency food aid exploded, but higher grain prices meant that the amount that could be procured by food aid agencies, which operate on fixed annual budgets, dropped.
Global Demand for Food
<table>
<thead>
<tr>
<th>Region</th>
<th>2013</th>
<th>2050</th>
<th>Change</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>World</td>
<td>7,137</td>
<td>9,727</td>
<td>+2,590</td>
<td>+ 36</td>
</tr>
<tr>
<td>High Income</td>
<td>1,246</td>
<td>1,311</td>
<td>+ 65</td>
<td>+ 5</td>
</tr>
<tr>
<td>Low Income</td>
<td>5,891</td>
<td>8,416</td>
<td>+2,525</td>
<td>+ 43</td>
</tr>
<tr>
<td>East &amp; S.E. Asia</td>
<td>2,206</td>
<td>2,349</td>
<td>+ 143</td>
<td>+ 6</td>
</tr>
<tr>
<td>South Central Asia</td>
<td>1,846</td>
<td>2,531</td>
<td>+ 685</td>
<td>+ 37</td>
</tr>
<tr>
<td>Sub-Saharan Africa</td>
<td>926</td>
<td>2,185</td>
<td>+1,259</td>
<td>+136</td>
</tr>
<tr>
<td>Latin America/Carib</td>
<td>606</td>
<td>780</td>
<td>+ 174</td>
<td>+ 29</td>
</tr>
<tr>
<td>N. Africa &amp; W. Asia</td>
<td>459</td>
<td>721</td>
<td>+ 262</td>
<td>+ 57</td>
</tr>
</tbody>
</table>

Urbanization Changes Diets: How to Provision Megacities?

The U.N. projects that 60% of world population will live in cities by 2030, and 70% by 2050.

Dynamics of Food Demand Growth

• As their incomes start to rise, very low income people spend most of the first increments to income on food.

• By about $2 per day most “hunger” problems (ability to access enough calories) can be solved.

• As their incomes rise from about $2 to $10 per day, people eat more meat, dairy products, fruits, vegetables & edible oils, causing rapid growth in demand for raw ag commodities.

• After about $10 per day, people buy more processing, services, packaging, variety, and luxury forms, but not more raw ag commodities.
“Middle Class” Outside the U.S. Expected to Double By 2020 – Approaching 1 Billion Households

Foreign households w/real PPP incomes greater than $20,000 a year (in millions of households)

Middle class in developing countries projected to increase 160% by 2020 vs. just 15% in developed countries

Source: Global Insight’s Global Consumer Markets data as analyzed by OGA/FAS/USDA
Projected World Food Demand

- World food demand is projected to grow about 70% between now and 2050:
  - 35% increase from world population growth – from 7.1 to 9.7 billion – almost all in developing countries
  - 35% increase from broad-based economic growth and urbanization in low income countries
- How many presently low income consumers, who spend the largest fraction of their incomes on food, escape from poverty is the most important uncertainty concerning future global demand for food.
- With the growing use of agricultural commodities as raw materials in the of the bio-based economy, including biofuels, world demand for grain and oilseeds could double by 2050.
East and South Asia have more than twice as much of the world’s population than of the arable land, and virtually all of their arable land is already in production. The Middle East & North Africa have land, but lack water.

Global Supply Potential
Interpretation: The darker the shading, the larger the percent of the land under that pixel that is in crops. Source: Center for Sustainability and the Global Environment (SAGE), University of Wisconsin.
The Land Constraint

• There is at most 12% more arable land available worldwide that isn’t presently forested or subject to erosion or desertification, and…

• Loss and degradation of many soils continues:
  – Urbanization & infrastructure construction
  – Nutrient mining
  – Erosion
  – Desertification
  – Natural reserves
  – Reforestation
The Land Constraint (cont’d.)

• The area of land in farm production could be doubled…
  – But only by massive destruction of forests and loss of wildlife habitat, biodiversity and carbon sequestration capacity

• The only environmentally sustainable alternative is to double productivity on the fertile, non-erodible soils already in crop production.

• Most available cropland is in remote areas of South America and Sub-Saharan Africa where infrastructure is minimal and soils are inferior in quality to many already in production.
Inherent Land Quality Assessment
Water--A Growing Constraint

• Farmers account for 70% of the world’s fresh water use.

• With the rapid urbanization underway, cities will outbid agriculture for available fresh water.

• The world’s farmers, who are being called on to double food production, will have to do it using less fresh water than they are using today.
  – i.e., they will have to more than double the “crop per drop,” the average productivity of the water they use.

• This will require investments in research to develop water saving technologies and to increase the drought tolerance and water use efficiency of the crop varieties being grown.
Solving the Water Constraint

• There is one source of optimism that the productivity of the water used in agriculture can be increased. Water is priced at zero to most of the world’s farmers, signaling that it is much more abundant than it is in reality.
  – Anything priced at zero will be wasted.

• There are better technologies available today to increase water use efficiency than farmers are using in many parts of the world, but with water priced at zero, it doesn’t pay to adopt them.

• If the politically difficult hurdle of charging farmers for water can be overcome, this would stimulate adoption of the available technologies."
Grain Yields Around the World

Interpretation: Grain yields (in metric tons per hectare) rise from lowest (dark blue) to highest (dark red)

Source: Center for Sustainability and the Global Environment (SAGE), University of Wisconsin.
Climate Constraints Changing

- Warming greater over land than over water and greatest at higher latitudes.
- Changing spatial distribution of precipitation
- Increased frequency of extreme climatic events

Source: International Institute for Applied Systems Analysis, Laxenburg, Austria.
Adaptations Will be Required Due to Global Climate Change

• As all agro-ecosystems shift with climate change, need larger public and private investments in adaptive plant and animal breeding just to sustain present productivity levels.
  – e.g. introduce more drought or heat tolerance.
• Change the mix of what crops are produced in a some geographic locations.
• Rely more on international trade.
Sustainability Will Require Increased Global Food System Productivity

• Make presently unusable soils productive
• Increase genetic potential (of individual crops and/or farming system) (ditto for farm animals)
• Achieve as much of that potential as possible by:
  – Improving nutrition of that crop
  – Increasing water availability and control
  – Reducing competition from weeds for water, nutrients and sunlight
  – Reducing losses from disease and insects
• Reduce post-harvest losses
Global Yield Performance of Organic vs. Conventional Farming Systems

“...organic yields are typically lower than conventional yields. But these yield differences are highly contextual, depending on system and site characteristics, and range from 5% lower organic yields (rain-fed legumes and perennials on weak-acidic to weak-alkaline soils), 13% lower yields (when best organic practices are used), to 34% lower yields (when the conventional and organic systems are most comparable).”

Agricultural Production Economics

• A commodity by definition is undifferentiated in the eyes of the consumer. As a result, producers of bulk commodities are price takers. Margins of price over cost of production are kept small by competition.

• The only way for a commodity producer to increase income is to get bigger—to produce more units each with a small margin.
Economics of Organic Production

• To get a higher price and larger margin, it is necessary for producers to differentiate their product in the eyes of the consumer.

• There needn’t be a real difference. The consumer just has to believe there is.
  – This is what branding is all about.

• To the extent that consumers believe that organic foods are superior in some way, this creates opportunities for small farmers to earn a higher income.
  – However, niches fill fast.
Economic Benefit to Food Retailers

• Consumers who buy organic foods generally say it is because they believe them to be more nutritious and to avoid pesticide residues.

• Retailers like to sell organics (and other niche products like non-GMOs) because they see opportunity for much higher mark-ups.
"While many studies demonstrate qualitative differences between organic and conventional foods with respect to pesticide residues and nutrients, it is premature to conclude that either food system is superior to the other. Pesticide residues, naturally occurring toxins, nitrites, and polyphenolic compounds exert their health risks or benefits on a dose-related basis, and data currently do not exist to ascertain whether the differences in the levels of such chemicals between organic foods and conventional foods are of health significance."

Agricultural Research Potential

• There remains more productivity enhancement potential from classical plant and animal breeding, especially with modern genomics, and genetic engineering opens new frontiers: e.g.
  – Improve nutritional content of grains, etc.
  – Increase tolerance to drought, wetness, temperature, salt, aluminum toxicity, …. (to increase yields and/or planted area under adverse or variable conditions)
  – Internalize resistance to diseases; viruses
  – Reduce pesticide use, esp. insecticides
  – Herbicide-resistant varieties
  – Slow down product deterioration
Advantage of Genetic Engineering over Classical Plant Breeding

TRADITIONAL PLANT BREEDING BY SEXUAL CROSSES

PARENT PLANT #1
Desired Gene
Chromosome

×

PARENT PLANT #2
Chromosome

NEW VARIETY
Traditional breeding combines many genes from two parents at once. Several generations of additional breeding are required to remove undesired genes.

BREEDING BY BIOTECHNOLOGY

SOURCE VARIETY (may or may not be same species)
Desired Gene

COMMERCIAL PLANT VARIETY

IMPROVED VARIETY
Using plant biotechnology, a single gene is added to the genome in the first generation.

Two Separable Issues

• The biological research tool of genetic engineering
  – Every national academy of science that has looked at it says biotech plants are neither safer nor less safe than the products of classical plant breeding.

• Who does the research (public vs. private)? Is it patented? Do farmers have to buy inputs (every year) to access the improved technology?

• Failure to recognize that these are completely separate issues confuses a great deal of the debate concerning GMOs.
### Academies of Science
- Brazil
- China
- France (both Science and Medicine)
- India
- Italy
- Mexico
- Morocco
- Philippines
- Third World
- United Kingdom (Royal Society)
- United States

### Government Agencies
- WHO
- FAO
- AMA
- IFT
- FDA
- EPA
- USDA
- EU Joint Research Council
- EU Food Safety Authority
- AAAS
Public vs. Private Biotech Research

• Private sector role in biological ag research only took off after late 1970s when Congress and European parliaments cut appropriations and encouraged private sector to take on this role.

• As tools of biotechnology were being developed, governments were reducing investments in ag research – both at home and in their foreign aid.
  – The latter often due to strong lobbying by transnational NGOs which now demonize the private sector for controlling most of the biotech-based technology.

• There is nothing inherent in biotechnology that says it must be done by private sector.
Intellectual Property Protection

• To satisfy their shareholders, the private sector has to be able to internalize return on its investment in ag research
• If public sector doesn’t pay for the agricultural research, farmers must pay for it (both successes and failures) in the price of the inputs they buy each year
• The challenge is how to serve low income farmers’ needs in foreign-exchange constrained countries.
Is GMO Food Safe to Eat?

- Over 300 million Americans and millions more in Canada, Argentina and Australia have been eating GMO foods for a decade with NOT ONE illness attributable to GMOs.
- Most beer and cheese consumed in the world is produced with GMOs already (as are innumerable pharmaceuticals, e.g. immunizations against Hepatitis A and B).
- GMO foods are subjected to an unprecedented amount of testing before being put on the market.
Environmental Benefits

• Large reduction in insecticide use
• More effective weed control using less energy
• Natural resistance to diseases
• Increase water use efficiency
• Preserve hundreds of millions of hectares of forests
• Reduce pressure on fragile lands
Conclusions

• Developing countries have greatest need to exploit the power of modern biology to ensure food security

• Genetic engineering will not solve all problems of 21st century agriculture, but it would be unconscionable to deprive the world’s poor of the potential benefits to them
Long-Run Prospects

• Now we need a big increase in world food production by 2050 using less water and little more land than today.
• Urgently need to restore past levels of foreign aid going to agriculture and rural development, especially for agricultural research and rural infrastructure.
• Future world market price trends will depend on whether productivity of the entire food system grows faster than world demand for food grows—or not.
Two Essential Facts

• All food is “organic.”

• No one alive today has ever eaten a mouthful of food that has not been genetically modified.
Thank You.

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