Revisiting the Historical Green Revolution: Impacts on Global Food Security

Uris Lantz C. Baldos and Thomas W. Hertel

Department of Agricultural Economics
Purdue University
West Lafayette, IN 47907-2056
E-mail: ubaldos@purdue.edu

Selected Poster prepared for presentation at the
Agricultural & Applied Economics Association's 2014 AAEA Annual Meeting,
Minneapolis, MN, July 27-29, 2014.

Revisiting the Historical Green Revolution: Impacts on Global Food Security

Uris Lantz C. Baldos (*ubaldos@purdue.edu*) and Thomas W. Hertel

Department of Agricultural Economics, Purdue University, West Lafayette, IN, USA

I. Motivation and Research Questions

The historic rise in both crop production and yields over the past 50 years has been made possible by aggressive investments in agricultural research which led to the development of modern crop varieties.

In turn, the adoption of these innovations opened the doors to the Green revolution (GR) which contributed to around 20%-40% of the yield growth in developing regions over this historical period (Evenson, 2003).

Amongst the impacts of the Green revolution, *its effect on food security is the most relevant but there is a lack of studies* on quantifying the Green revolution's role in improving nutritional outcomes. This study contributes to the literature and attempts to answer three key research questions:

- **How much was the increase in average dietary energy consumption given the historical Green Revolution?**
- **With the GR, how many people avoided extreme caloric hunger?**
- **If a future African Green Revolution were to occur, what are its implications on food security outcomes**

II. Model and Methods (A)

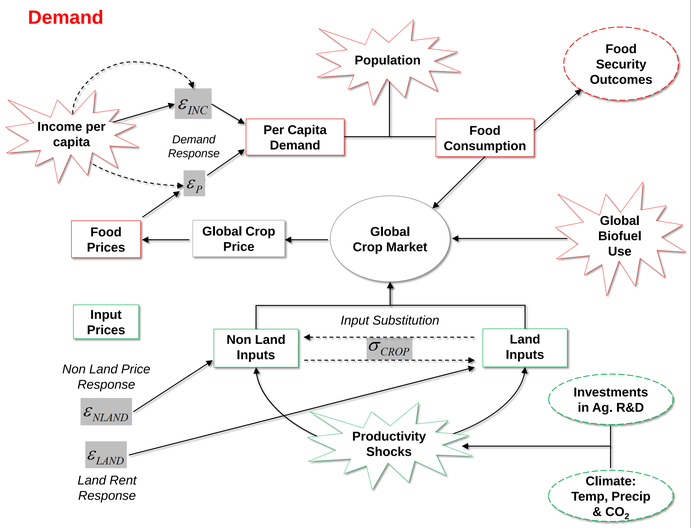

Figure 1. The SIMPLE Model

We assess the food security impacts of both historical and future Green Revolutions at the global level using the Simplified International Model of agricultural Prices, Land use and the Environment (SIMPLE). SIMPLE is a partial equilibrium economic model and as the name suggests, it is designed to be as parsimonious as possible.

The model has been demonstrated to faithfully reproduce long-run historic changes in crop production, cropland use and crop price at a global scale (Baldos & Hertel, 2013). More recently, SIMPLE has also been used in long-run food security analysis (Baldos & Hertel, 2014).

Consumer behavior

- Crop commodities are consumed directly as food and indirectly via the consumption livestock and processed foods
- Demand response to income and food prices diminishes as per capita incomes grows

Producer behavior

- Food sectors are defined for each region and are modelled using the Constant Elasticity of Substitution production framework
- Crops are produced using aggregate land and non-land inputs
- Crop and non-crop inputs are used in the livestock and the processed food sectors

V. Results and Conclusions

Historical Analysis (1961-2006): Baseline vs. no-Green Revolution

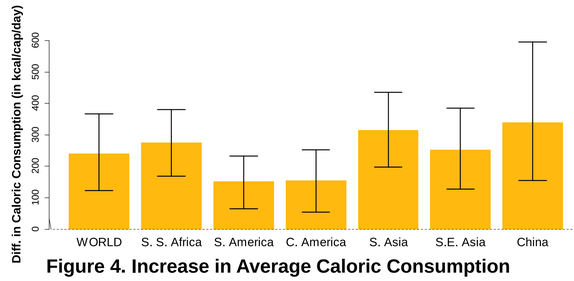

Figure 4. Increase in Average Caloric Consumption

The Green Revolution raised global average dietary intake by around 240 kcal/cap/day or roughly 10% of the global average intake in 2006.

Key GR regions which benefitted greatly from these improvements include Sub Saharan Africa, South Asia, Southeast Asia and China. Improvements in caloric consumption due to the historical GR are robust to parameter uncertainty as indicated by the error bars.

Globally, the incidence of caloric malnutrition is lower by roughly 7% due to the Historical GR.

On average, Sub Saharan Africa and South Asia experienced sharp reductions in the incidence of caloric malnutrition – by around 14% and 11%, respectively – given the productivity improvements from the historical Green Revolution. For China, the error bars suggest that it is uncertain whether the Historical GR led to the reduction of caloric malnutrition incidence in this region.

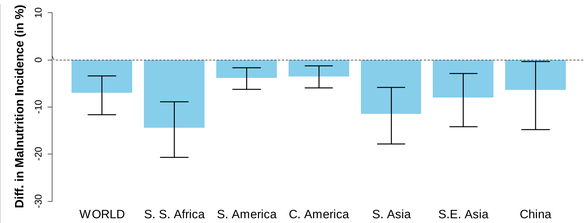

Figure 5. Reduction in Malnutrition Incidence

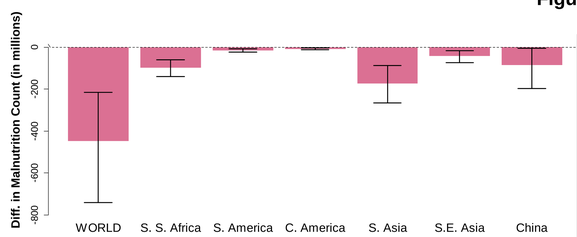

Figure 6. Reduction in Malnutrition Headcount

Roughly 450 million persons avoided extreme caloric hunger due to the Historical Green Revolution.

The difference in global malnutrition count between the baseline and no GR scenario ranges from 742 to 216 million persons. Most of the people who avoided caloric malnutrition resided in Sub Saharan Africa and South Asia

Without the Green Revolution, the average depth of caloric hunger would have been 13% higher compared to 2006 values

The historical GR helped reduce the depth of caloric hunger – alleviating the intensity of hunger faced by malnourished persons – particularly in Sub Saharan Africa, South Asia, Southeast Asia and China. These reductions are robust to parameter uncertainty

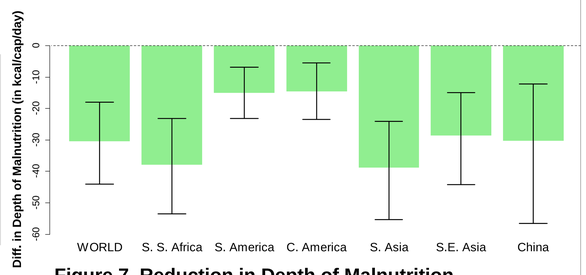

Figure 7. Reduction in Depth of Malnutrition

Future Projection (2006-2051): Baseline vs. African Green Revolution

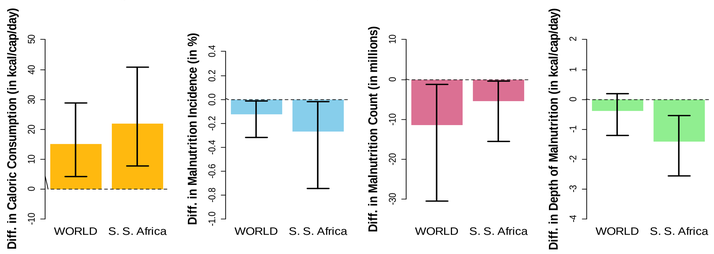

Figure 8. Changes in Food Security Outcomes under an African Green Revolution

The impacts of a Future African Green Revolution on food security is ambiguous

On average, we see improvements in food security outcomes both at the global level and for Sub Saharan Africa. However, the impacts of a Future GR in Africa is quite sensitive to model parameters and shocks

VI. Future Research Areas

- Exploring the implications international trade on both historical and future scenarios
- Endogenize future productivity growth as a function of agricultural research spending
- Examine the environmental costs/implications of an African Green Revolution

II. Model and Methods (B)

We employ the food security module developed by Baldos and Hertel (2014) and report not just changes in average dietary energy intake but also *shifts in the caloric distribution* within a region. The distribution of food calories is assumed to be *log-normal* following FAO (Neiken, 2003).

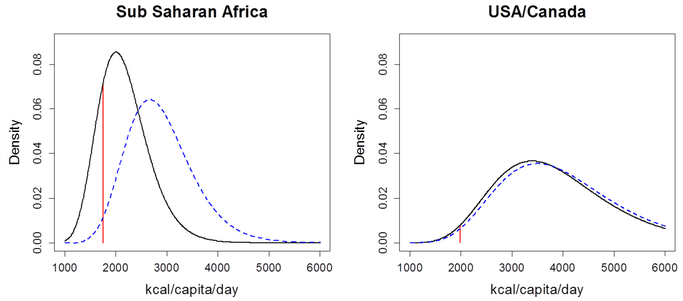

Figure 2. Caloric Distribution for Sub Saharan Africa and USA/Canada in 2006 (black) and in 2051 (in blue). The red lines represent the minimum caloric requirement

We track the changes in three key metrics of food security:

- **Caloric Malnutrition Incidence** – the proportion of the population whose daily caloric consumption is less than the minimum caloric requirement
- **Caloric Malnutrition Headcount** – the number of people who are considered malnourished in terms of daily caloric consumption
- **Depth of Caloric Malnutrition** – reports the average daily caloric deficit faced by malnourished persons

IV. Experimental Design

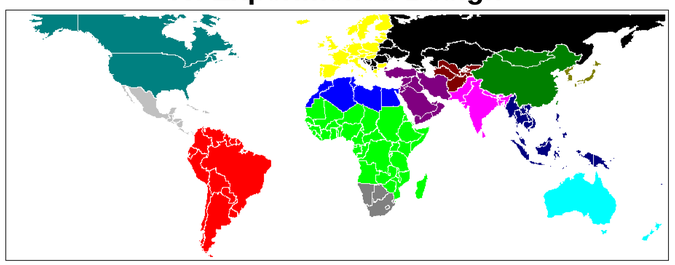

Figure 3. Coverage of the SIMPLE model

***Historical Analysis* (1961 to 2006)**

We first simulate the baseline given the historical growth rates in *population*, *per capita incomes* and *total factor productivity* in the crop, livestock and processed food sectors.

A counter-factual scenario is then simulated by deducting the contribution of the Green Revolution to productivity growth through crop genetic improvements using estimates from Evenson (2003)

Future Projections (2006 to 2051)

Similar to the historical simulations, a future baseline is established given the future growth rates in *population*, *per capita incomes, biofuel use* and *total factor productivity* in the crop, livestock and processed food sectors.

An African Green Revolution scenario is then simulated using the historical estimates from Evenson (2003) as a guide.

References:

Baldos, U. L. C., & Hertel, T. W. (2014). Global food security in 2050: the role of agricultural productivity and climate change. Australian Journal of Agricultural and Resource Economics. doi:10.1111/1467-8489.12048

Baldos, U. L. C., & Hertel, T. W. (2013). Looking back to move forward on model validation: insights from a global model of agricultural land use. Environmental Research Letters, 8(3), 034024. doi:10.1088/1748-9326/8/3/034024

Evenson, R. E. (2003). Production impacts of crop genetic improvement programmes. In R. E. Evenson & D. Gollin (Eds.), Crop Variety Improvement and its Effect on Productivity: The Impact of International Agricultural Research (pp. 447–472). Oxon, UK; Cambrigde, USA: CAB International.

Neiken, L. (2003). FAO methodology for estimating the prevalence of undernourishment (Proceedings: Measurement and Assessment of Food Deprivation and Undernutrition). Rome, Italy: FAO.