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Program for the Study of Biofuels, Poverty and Food Security

A Concept Note about Setting Up an International Program for Studying the Effects of the Emergence of Biofuels on Global Poverty and Food Security

A collaborative effort between (in alphabetical order):

Chinese Academy of Sciences, Center for Chinese Agricultural Policy (CCAP)
International Food Policy Research Institute (IFPRI)
Stanford University, Freeman-Spogli Institute for International Studies (FSI)
—Food Security and Environment Program, FSI
—Shorenstein Asia-Pacific Research Center, FSI
—Program on Energy and Sustainable Development, FSI
University of Nebraska, Center for Energy Sciences Research

Program Proposers

Jikun Huang, Director and Professor, Center for Chinese Agricultural Policy, Chinese Academy of Sciences

Mark Rosegrant, Division Director, International Food Policy Research Institute

Scott Rozelle, Helen F. Farnsworth Senior Fellow, Shorenstein Asia-Pacific Research Center and Food Security and the Environment Program, FSI, Stanford University

Rosamond Naylor, Julie Wrigley Senior Fellow and Director, Food Security and the Environment Program, FSI, Stanford University

Walter P. Falcon, Professor (emeritus), and Director, Center for Environmental and Science Policy, FSI, Stanford University

David Victor, Professor of Law, and Senior Fellow and Director, Program in Energy and Sustainable Development, FSI, Stanford University

Kenneth Cassman, Professor and Director, Center for Energy Sciences Research, University of Nebraska

And collaborators in Brazil, Indonesia, India, Europe, Mozambique and Senegal

Program for the Study of Biofuels, Poverty, and Food Security

Executive Summary

The recent global expansion of biofuels production is an intense topic of discussion in both the popular and academic press. Much of the debate surrounding biofuels has focused on narrow issues of energy efficiency and fossil fuel substitution, to the exclusion of broader questions concerning the effects of large-scale biofuels development on commodity markets, land use patterns, and the global poor. There is reason to think these effects will be very large. The majority of poor people living in chronic hunger are net consumers of staple food crops; poor households spend a large share of their budget on starchy staples; and as a result, price hikes for staple agricultural commodities have the largest impact on poor consumers. For example, the rapidly growing use of corn for ethanol in the U.S. has recently sent corn prices soaring, boosting farmer incomes domestically but causing riots in the streets of Mexico City over tortilla prices. Preliminary analysis suggests that such price movements, which directly threaten hundreds of millions of households around the world, could be more than a passing phenomenon. Rapid biofuels development is occurring throughout the developed and developing world, transforming commodity markets and increasingly linking food prices to a volatile energy sector. Yet there remains little understanding of how these changes will affect global poverty and food security, and an apprehension on the part of many governments as to whether and how to participate in the biofuels revolution.

We propose an international collaborative effort to:

- *Understand and quantify the effects* of expanding biofuels production on agricultural commodity markets, food security, and poverty;
- *Develop training programs and policy tools* to harness the benefits and mitigate the damages from such expansion on both local and global scales; and
- *Build an international network* of scholars and government officials devoted to studying and managing biofuels development and its social consequences.

The research program will be directed by scientists and policy analysts from Stanford University, the International Food Policy Research Institute, the Chinese Academy of Sciences, and the Center for Energy Research at University of Nebraska, and will involve the participation of policymakers and scientists from Brazil, India, China, Indonesia, Mozambique, Senegal, and other developing countries. A primary goal of the program is to build analytic and leadership capacity in an array of developing countries likely to be most affected by the growth in biofuels. The program links directly on the Gates Foundation's interests in poverty, rural development, and energy issues. We expect the program to become the global clearinghouse for biofuels analysis and policy advice. We request $10.6 million over 5 years to fund program activities, which are detailed in full in the attached proposal.

Program for the Study of Biofuels, Poverty and Food Security:
A Concept Note

Motivation: Some Facts and a Lot of Questions

Are biofuels a fad? Or, are biofuels the biggest thing to hit the food economy since Mendelian genetics?

Supply is Greater than Demand: Falling Food Prices Are the Story of the 20th Century

For the past 100 years or more, the real price of food has fallen (Figure 1, page 25). Despite the Malthusian predictions that the rising population of the world would lead to mass starvation and globe-wide food shortages, the ability of humans to increase the production of food through genetic improvements, expansion of cultivated area and improvement to the quality of soil, nutrient management and water control has allowed the supply of food to outpace the demand for food throughout the 20th century.

And, until recently, almost all of the shocks that could be imagined—China's entering the world market, urban demands on the supply of water, general global prosperity and rise in the demand for meat, soil degradation, supermarketization of the food economy—have had little impact on the expected future world price of food. IFPRI's IMPACT model, the World Bank's projections work, FAO predictions, papers based on the Center for Chinese Agricultural Policy's CAPSiM model and many others largely concur that even the most severe economic shocks at most will lead to only a slowing in the rate of fall of food prices – or a leveling off, in the most extreme cases. In every case of serious economic analysis, Engels' Law (i.e., the empirical regularity which notes that people allocate a smaller part of their budget for food consumption as they grow less poor) and successive generations of Green Revolution seeds end up producing more food than the world's consumers can eat or use. The general results of all of these modeling exercises finds that the price of food tomorrow (or in 2010, 2020, or 2050) will be lower than it is today.[1]

Because of these trends, the world has become complacent about its food supply. Despite an increasingly urbanized world, many of the world's poor are still farmers, and falling food prices mire many farm economies in depression. With forecasts of future falling food prices, governments, banks and corporations with limited fiscal resources naturally divert their scarce financial assets to other sectors of the economy. As a result, farmers are often marginalized, live in environments that are rundown and neglected, and their prospects for future improvement are bleak. One of the greatest challenges for development economists and practitioners is to get government officials and international

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[1] Of course, falling prices are a two-edged sword. While lower future expected prices are not good for those (including the poor) that are engaged in farming, falling food prices are welcome by world's poor urban consumers. Without land, and often with household budgets fixed by the hourly wage and availability of work, when food prices are lower, urban consumers are better off.

donor agencies to understand the role of agriculture in the development process in general, and to make investments in the sector a key part of a nation's poverty alleviation strategy in particular.

Putting Biofuels into the Equation: Breaking the 100 Year Trend?

Biofuels could change everything. Based on recent experience, biofuels could *rewrite* the rules on the role of agriculture in rural development, *reposition* the sector on the list of investment priorities, and *be the force that snaps* the 100-plus year trend of declining real prices for food.

What makes biofuels so different? Biofuels technology takes food and turns it into energy. In its most basic sense, it is unlike the major technological breakthroughs over the past century (such as the Green Revolution) because it is a breakthrough that is fundamentally changing the demand rather than the supply of food. In doing so, it is linking food prices to energy prices, and demand for energy responds very differently than the demand for food as economic growth proceeds. In contrast to food, the demand for energy rises rapidly as people get richer (Figure 2, page 26). This means that if the world's economy continues to grow, the future price of energy will rise as long as its growth rate outpaces the supply of energy—which is most plausible within the foreseeable future. Thus the emergence of biofuels means that the price of food, instead of falling in the coming years, could rise – and perhaps rise rapidly, with abrupt discontinuity relative to historical trends.

We recognize that biofuels could be a temporary phenomenon that is being pushed to the headlines by the recent rise in oil prices. The demand for biofuels will almost completely depend on the price of energy, which has fluctuated over the past several decades. It is possible that in the future, the price of oil will fall and stay under $40/barrel for long periods of time. If this happens, at least with current technologies, the demand for biofuels would diminish.

Nevertheless, a number of factors suggest that the demand for biofuels is not a passing phenomenon. At the current pace of investment, the U.S. will produce 10 billion gallons of biofuel by 2010, and there are proposals to mandate 35 billion gallons by 2017. Of this total, 15 billion gallons would come from maize grain. This means that one-half of the current U.S. maize crop would be used as fuel, grain that formerly was used primarily as feed for livestock in the U.S. and the rest of the world. At this rate of growth, prices will have to rise sharply to bid maize away from the new biofuels plants (though there will be a by-product from the ethanol production process that can be used to replace some of the feed). These ethanol plants, it should be noted, are increasingly financed not from any government agency's budget, but out of the pocket of private investors—from investors that live and work in places as different as Des Moines, New Delhi, and New York.

Furthermore, biofuels are not merely an American phenomenon. The United States' plans for biofuels expansion pales in comparison to Brazil's plans to expand ethanol from sugarcane. Germany, France, Canada, Australia, China, Indonesia and Japan also have their own plans to expand the production of ethanol and biodiesel. If these plans are fully realized— and many of them are already being implemented in many cases—a significant share of the world's food supply will be diverted away from traditional food marketing channels. And, to the extent that food demand remains (there is no place for it to go!), the most probable outcome is that *the emergence of biofuels will have a major impact on world food prices*.

And although the emergence of biofuel production from cellulosic biomass produced from non-food crops or crop residues may eventually reduce pressures on the food versus fuel competition, large-scale deployment of cellulosic biofuel systems is at least 7-10 years away. During this time period, the expansion of biofuel production from food crops will likely have a tremendous impact on world food prices.

If Not a Fad, Then What?

The potential for significantly higher food prices represents both an opportunity and a threat. Higher prices are good news for producers, but the distributional impacts are unclear. Maize and soybean and sugarcane (and wheat and cassava) farmers will likely benefit, but what will happen to those who produce rice, horticultural and other commodities that are not used as feedstock for biofuel production? Will poor food producers in countries with large biofuel programs be able to take advantage of the higher prices? Will farmers in poor countries that do not have biofuel programs benefit? What about livestock producers and others that use maize, soybeans, and other feed grains as inputs? What about those citizens in developing countries that are net consumers, including the hundreds of millions of urban poor who live and work in cities like Bombay, Johannesburg and Sao Paulo, and who are sensitive to small movements in food prices? Higher prices also threaten the even greater numbers of rural poor who are net consumers, (either landless farm laborers or those with a plot so small that it can not feed the entire family for the whole year).

Furthermore, will higher prices induce an expansion of cultivated area? Much of the remaining land upon which expansion is taking or could take place is ecologically sensitive, such as the Amazon Rainforest (soy) or the Indonesian archipelago (oil palm). It's also conceivable that higher prices could prompt U.S. farmers to plow up land that has been in the Conservation Reserve Program over the past two decades. Will such change in land use release 20 years of CO2 that has been sequestered? What will be the net effect on the world's land and the rural environment?

In the rush to promote biofuels, few people have been asking these questions. Even when they are asked, there are even fewer answers. The complexities are enormous. Available substitutions for both producers and consumers (farmers can grow other crops, people can eat other types of food), coupled with an increasingly fluid global trade in agricultural commodities, results in tight linkages across agricultural commodity markets. These linkages have complex implications for both input and output markets, for the countries and regions in which various crops are grown, and for the status of net purchasers of food. Biofuels development will also promote closer linkages between the agricultural and non-agricultural sectors of many economies, further complicating the analysis.

Other concerns abound. If food prices become linked with prices of energy, it is possible that all of the uncertainty that characterizes energy markets could be transferred to the agricultural sector. Energy traders, however, have instruments (e.g., insurance and option contracts and hedging trades) to minimize their risk; most farmers, especially those in developing countries, do not. Price movements could also affect public and private investment in research and development. They could also affect patterns of rural employment. The list goes on and on.

Motives for Entering the Biofuels Race

With so many unanswered questions, why are governments, corporations, and individuals rushing to get into the biofuels business? The motivations for the expansion of biofuels are complex and multidimensional. Above all, the expansion is motivated by the search for energy security, and the accompanying movements in energy prices. With the demand for fossil fuels growing and supplies being relatively limited, governments are searching for any and all means to increase the amount of energy that their nations can produce so as to reduce their dependence on costly fossil-fuel imports. In some cases (and certainly in the past) the demand for energy security has been a strong enough motivation to make governments willing to provide subsidies. Furthermore, if the price of oil goes high enough, or if the technology for producing biofuels improves enough, private firms and individuals will invest for the simple motivation of profits, as has been the case in recent months. Governments are also interested in biofuels because they may offer a carbon-neutral way to increase energy consumption, although the literature is still inconclusive on this point. Finally, some governments see biofuels as a way to support the politically powerful—or politically sensitive—farm sector.

With all of these mixed motivations, however, it seems that the potential effects on food security may have been forgotten. If the world price of food rises so much or if the demand for crops for use as fuels rises high enough, the age-old concern of governments and development practitioners—the global supply of food—may become a real issue for the first time in decades. How could we have forgotten to include a serious analysis of food security in our analyses of the potential of biofuels?

While such issues might appear obvious, one should be not too quick to blame any single individual or group of policy analysts for not making the connection—given the complexities of the issues. While food may be more expensive and while it may take more foreign exchange in some countries to import enough food (and in some countries they may not be able to import at all), in other countries higher food prices means higher profits for farmers and less poverty for those with land. So, the effect on national food security may be negative while the effect on household food security (for some) may be positive.

Goals and Objectives

Against this background of questions and uncertainties, the overall goal of our proposal is to create a systematic, research-based program on biofuels. Ultimately, we want to provide information and consultation to policy makers—especially to those in developing countries—on which they will be able to make better-informed decisions on their biofuels strategy.

The research program will strive to use only high quality and scientifically sound information to produce empirically grounded answers to some of the fundamental questions that have been raised about the effect of biofuels on the world food economy. Within the vast number of questions that arise when examining the nexus of biofuels and food, we will focus on understanding how the rise in demand for biofuels will affect food security at the national level, and how biofuels will create poverty or lead to poverty alleviation at the household level. The proposed work complements ongoing research in all four institutions on the environmental dimensions of biofuels development. In particular, our work can contribute to discussions on projected land-use change, water use, and chemical input in agriculture. The main focus of our proposed project, however, is on poverty and food security.

To meet this overall set of goals, we will seek to meet six specific objectives:

Objective 1: Creating a leadership group. We will bring together a set of economists, agricultural scientists, ecologists and energy experts who have experience in running international research projects, who understand questions of global food systems, poverty, land use and energy, and who are committed to working on issues of biofuels, poverty and food security. The combined knowledge of such a group of scholars who work well together is absolutely essential during early stages of work on a new subject. The team will have members from both developing countries and developed countries. This will be called the *program leadership group* and initially will be composed of the proposers (see cover page). This list can be expanded over time.

Objective 2: Training the South to train the South. Set up a board of policy advisors, which will be made up of high-level officials in each of the core and study countries (China, Indonesia, the U.S., Brazil, India, Mozambique, Senegal). The board will be the conduit through which the research-informed voice of the Program is heard at the policy making level, and will provide input to the Program from the point of view of the governments of developing countries. Another objective of this group is to have a body of informed policy markers in developing countries that can teach or pass on their knowledge and experience to policy makers in other developing countries.

Objective 3: Getting the data right. Collect, catalogue, and make available a set of databases and websites of information that can be used to study the effect of biofuels on poverty and food security in developing countries.

Objective 4: Tooling up—building the analysis platform and teaching others to use it. Create an analytical platform that can be used to track the effects of the emergence of biofuel development on the global food economy, quantifying the impacts on different sets of actors—including countries, groups within countries, producers and consumers in different economic sectors and regions of the country. The framework will account for the interactions among energy, food and other commodities; interactions among food commodities; interactions between consumers and producers; interactions between exporting nations and importing nations; interactions among actors within economies; and interactions between the economy and land use. The platform will be created to allow for interface between effects that arise in particular countries (due to markets or policies or some other event) and the world (and hence, to other countries in the world). In other words, if an R&D breakthrough increases the productivity of ethanol plants in the U.S., the model will track its impact on rice producers in China, wheat consumers in Africa, energy prices in Europe, and the area of land that is being converted from rainforest to crop land in Brazil or Indonesia.

A sub-objective (Objective 4b) will be to increase the human capital of policy analysts in developing countries so they can directly advise their governments on issues of biofuels and other issues of supply, demand and trade for agricultural products.

Objective 5: Charting the consequences of the rise of biofuels. Begin work on *core research projects* that are funded by the Program's initial funding base from our proposed grant. Funding for core research projects will be awarded by a steering committee that is made up of the Program's leadership group. It is expected that part of the funds will be allocated to projects that will be implemented by individuals in the leadership group (and their collaborators). Another part of the funds will be delivered in a small grants competition and proposals will be openly accepted and funded on the basis of their merit.

Objective 6: Developing a network to ensure sustainability and ability to scale up. Organize a network of scholars in developing and developed countries. The network will be set up to share data, research approaches and other types of information related to biofuels, poverty, and food security. It will encourage individuals and groups to work on problems within their specific countries, but coordinate the work so it can be integrated into the global analytical framework. In the earliest stages of the network, we want to actively recruit participants from the seven core countries in the program:

China
Indonesia
U.S.
Brazil
India
Mozambique
Senegal

We hope to add countries from other parts of the world, such as other countries in Africa, South Asia, Latin America, and Europe. We expect network membership will eventually be open to all countries, not just those listed above.

Approaches

Approach to objective 1: **Creating a leadership group**.

The initial Program Leadership group will be composed of the project proposers, that is, Huang from CCAP; Rosegrant from IFRPI; Falcon, Naylor; Rozelle and Victor from Stanford; and Cassman from the University of Nebraska. We propose that the funds be managed by Stanford University's Food Security and the Environment program, and that the leadership secretariat also be based at Stanford. A board of academic advisors will be appointed and will meet during the first year of the project and at least once every two years thereafter, and meet more frequently via phone and email to approve the Program's work and budget plans.

The Program Leadership Group itself will run studies in five core countries:

China
Indonesia
United States
Two African Countries (e.g., Mozambique; Senegal)

The Program Leadership Group will also be responsible for establishing contact with, mentor and coordinate with four additional study country teams. These additional country teams will come from:

Brazil
India
Other African Countries

Each core and study country team will have a member on the Board of Policy Advisors (see objective 2), participate in building and share in using the information center's data and information resources (see objective 3), send a modeling sub-team to attend training sessions to learn the modeling framework and methodology (see objective 4), receive a $500,000 to $1 million country grant to study "biofuels, poverty, and food security" in their country (by setting up a policy analysis model of their country) and to link these results to the global model (see objective 5), and participate in a network to share results (see objective 6).

Approach to objective 2: **Training the South to train the South**.

The board will be selected after careful thought and consultation within each country and will be made up of influential members of government (and/or their staff). For example, in China we will invite the Vice Director of the Reform and Planning Commission in charge of Energy (who is very powerful in China). The group has a long-standing relationship with the Ministry of Planning in Indonesia and with one of the main agricultural advisors to the top leaders in Brazil. IFPRI's vast network of policy makers in Africa will provide links to many countries in Africa and key policy makers and collaborators. This board will meet as a group at the beginning of the project for a dialogue. This meeting will set out on the table what officials in developing countries know about biofuels, and what they would like to know (and in what format). The individual members of the board will also meet regularly with the country teams in order to foster a two-way flow of information.

A newsletter and program briefs will be sent to the board regularly.

At the end of the project (or the first phase of the research phase of the project), a ***biofuels summit*** will be held with all of the officials in attendance to publicize results and take stock of the "state of the knowledge" of the world on biofuels, poverty, and food security. The main speakers at the conference will be the board members from the partner countries who will address policy analysts and policy makers from other countries about managing biofuels.

Approach to objective 3. **Getting the data right.**

Data will be collected from participating countries and made available on a shared website. This will be housed and maintained at Stanford University under the direction of Rozelle, Naylor and Falcon.

During the building of the databases, we will create a network of information resources from which the partner countries can draw for work on their country policy analyses. The principle of the project will be that all data are open to all project members. At the end of the project, the data will become international public goods and open and accessible to all users.

Information will include, at the global level:

Trade flows of agricultural commodities and energy products and other competing and complementary commodities
    [Note: The data are NOT currently available in a form that allows for detailed understanding of trade flows that will occur into and out of developing countries after the rise of biofuels.]
World prices
Trade barriers, taxes, tariffs, and other constraints
Information on world trade talks—as it pertains to biofuels and more general trade

At the country level:

See all information needed for national models (Appendix A1)

Approach to objective 4: **Tooling up—building the platform and teaching others to use it**.

This platform will be created, maintained, and managed collaboratively by the Center for Chinese Agricultural Policy, under the direction of Huang and IFPRI under the direction of Rosegrant. Rosegrant will be the chief economist for global modeling; Huang will be the chief economist for the national modeling efforts. The modeling methodology section below contains a brief discussion on the proposed analytical approach. In addition, see Appendix A1 for details of the current modeling work in CCAP on which the national-level biofuels work will be built (in collaboration with IFPRI), and Appendix A2 for details of the current modeling work in IFPRI on which the global modeling also will be based (in collaboration with CCAP).

The analytical platform is a key part of the proposed project, and we believe that we already have all of the pieces in place from the global economy, to the food sector, to the household level in rural and urban areas that will allow us to meet the overall goal of the Program. In short, this part of the project is building on two of the most comprehensive, well-utilized models in the world (see Appendices B1 and B2 for references on previous uses of these modeling platforms).

The Core Modeling Team (at CCAP in Beijing) also will be responsible for the training of other country modeling teams in how to set up the research work in their country and how to integrate their work with other teams through the global trade model. In this way, there is a real capacity building objective. IFPRI will provide support services and assist in mentoring the policy analysts. In his role as a long-term collaborator with CCAP, Rozelle will take on the role of chief coordinator of training. One of the attractive parts of this proposal is that this will be a case in which research teams from developing countries (China) are interacting with, training and mentoring research teams from the rest of the world (South and Southeast Asia; Africa and Latin America).

We also have two key technology coordinators in our Project Leadership Team. Ken Cassman will be the chief coordinator for the technology to be used for manufacturing biofuels. Cassman will also be involved in the work on agricultural R&D and the creation of scenarios about how fast technology can respond to the rises in prices and the future growth of agricultural supply (a key parameter in all simulation-modeling projects).

On the energy side, David Victor will provide coordination for the energy production from biofuels, the competition with other energy sources and the world flow of energy—including information on the future supply, demand and trade. This will be a key input into the world model on biofuels and energy sector as it interacts with agricultural commodity supply, and demand and trade.

Approach to objective 5: **Charting the consequences of the rise of biofuels**.

> This effort will be jointly managed by the Program Leadership Group. The first set of grants will be allocated to research on issues of biofuel development in the core countries: Indonesia (managed by Naylor and colleagues); biofuel development in China (managed by Huang, Rozelle and colleagues); and biofuel technologies—in the field and in the plant in the U.S. (managed by Cassman and colleagues). This work will be above and beyond the work done to set up the global modeling framework (in Objective 3).
>
> In addition, we will also conduct studies in four other countries:
>
> > Brazil
> > India
> > Mozambique
> > Senegal
>
> We will actively seek collaborators and will issue a call for proposals. The Program Leadership Group will manage the review and granting of the funds (under the direction of the Board of Academic Advisors). The Program Leadership Group will help coordinate the research so it will fit the Program's goals and integrate the results into a global framework.

Approach of objective 6. **Developing a network to ensure sustainability and ability to scale it up**.

> The development of this network will be the primary responsibility of Rosegrant at IFRPI and Rozelle at Stanford. A senior staff director will be hired to facilitate the networking activities.

Modeling Methodology

In this project we will make use of an integrated modeling framework that leverages the strengths of the participating institutions, and that combines the detailed specificity of agricultural sector models with the economy-wide vantage of general equilibrium models, and their ability to incorporate energy needs into the overall picture of growth in the global economy. Such models are the best available means to analyze the effects of changes in the agricultural sector on the global economy (and vice versa), and are useful ways to assess how various policy choices related to biofuels might affect poverty and food security. The type of methodology that we propose is unique among the numerous quantitative assessments that have been done on biofuel potential to date. Its uniqueness comes from a variety of sources, enumerated in more detail below:

(1) The combination of both global-scale models with country-level models, to allow for a more detailed look at country-level adaptation and response to global-level trends and socio-economic drivers.

(2) The combination of partial and general equilibrium modeling tools, in a way that ensures both consistency between the trajectories of socio-economic and demographic growth and between the growth of agricultural production, output and its contribution to total value-added growth in the economy.

(3) Linkage to detailed household-level data that permits examination of the socio-economic impacts of various scenarios for biofuel growth among the various types of households, stratified both with respect to socio-economic status as well as geographical location.

These unique characteristics of our modeling approach allows us to answer a much broader array of research questions than has been done with other types of assessments, which typically focus on either OECD countries, and which are usually restricted to the particular type of modeling tool that is available to the researcher. Given our particular interest in examining the impact of biofuels on the livelihoods of the rural poor and their food security status, we have assembled a much more comprehensive set of tools that can be linked in a way that ensures consistency and allows for feedback between all sectors being examined.

It is important to note that such large-scale modeling exercises are much more than mere academic obscura. They are often (and certainly in this case) the only way to quantitatively test important hypotheses concerning complex systems, and as such are often the only way to make policy-relevant predictions about the response of these systems to economic or political change. Without a quantitative understanding of how biofuel development will affect commodity markets, we would have little to say about biofuels' potential impact on poverty and food security.

Linking Partial and General Equilibrium Models

In most assessments of this type, researchers typically choose a specific model and try to incorporate as many dimensions of interest as is allowable within that particular modeling approach. As a result, the researcher is limited by what the particular model can and cannot allow for, and is often forced to make very broad assumptions about the other dimensions of the larger socio-economic picture that cannot be directly addressed. We are attempting to overcome these limitations by linking both partial and general equilibrium models, so that we can use the detail and flexibility of the partial equilibrium framework to give us the needed level of detail on the specifics relevant to agriculture, while maintaining the broader picture of growth in the all sectors of the economy and their own demands for energy, that a general equilibrium model can provide.

This type of linkage also allows us to check for the consistency between the socio-economic "drivers" of change that are used by both types of model – in terms of population growth, income change, growth in total sectoral value-added or even factor prices – so that we are not overly ambitious when projecting agricultural growth in response to biofuel demand, or guilty of ignoring the constraints that might be present in the rest of the economy. The simplified schematic, shown in Figure 3 (page 27), shows the types of linkages and consistency checks that are possible, when partial and general equilibrium models are combined in this way.

An Integrated Framework for Biofuels Assessment

Following the general outline of model linkage seen in Figure 3, we can build further detail into this picture to demonstrate our comprehensive framework for assessing the welfare and environmental impacts of global growth in biofuels. In our framework we hope to capture a number of key issues:

1. The impact of market-induced changes in consumption patterns on the nutritional status of vulnerable households
2. The changes in household incomes and welfare as a result of changes in market-prices for biofuel feedstock crops and the status of net consumers and producers of these crops
3. How changes in technology – particularly for the conversion processes of biofuel production – might affect the welfare impacts discussed above, and relieve pressures on the environment
4. Which trade policies can help in ‘softening’ the market impacts of rapid growth in biofuels production, either in terms of trade in the feedstock crops or trade in the biofuel products themselves.

To convey the more nuanced nature of the linkages between the various sectors of the economy that must be considered, we present a more detailed schematic of our analytical framework in Figure 4 (page 28). This schematic shows the passing of information between the general equilibrium and agriculture sector models in terms of prices and the demand for agricultural crop feed stocks for biofuels.

The key linkages which are relevant for the modeling of biofuel production and growth occur between the expressed demand for energy that is generated within an economy-wide context, and the implied demand for biofuel feedstock that comes from the agricultural sector. The price of oil is also a key determinant of fertilizer prices, which have direct impacts upon the agricultural sector. The nature of the conversion technologies used to produce biofuel from a given feedstock crop is a key determinant to how efficiently biomass can be converted into utilizable energy, and can be affected through the level of investment and technological innovation that is generated within the energy sector. We will generate specific scenarios for both technological change, as well as other key socio-economic parameters, to explore what their implications are for biofuel growth and impacts on the rural poor and their livelihoods.

Outputs

We will deliver the following measurable outputs:

A. An integrated analytical framework for global modeling of biofuel development and its effects on poverty and food security.
B. A database that can be used as a international public good by others.
C. Seven national policy analysis modeling platforms (or which six are in developing countries).
D. Modeling framework and training protocol that can be adopted by other countries. (We believe more than 25 other countries would be interested and able to adopt our modeling work.)
E. Training of 25 policy modelers in five developing countries (five per country) by the policy analysis team in the sixth developing country (China).
F. Formation of Board of Policy Advisors who will advise policy makers in six countries; and will train policy advisors in up to 20 other countries.
G. Formation of network of biofuel analysis collaborators (up to 200 researchers, policy analysts, policy makers in 25 countries).
H. Formation of key Program Leadership Group to develop a global modeling and policy analysis framework and database management and training/mentoring for international program on the impact of biofuels on the world.

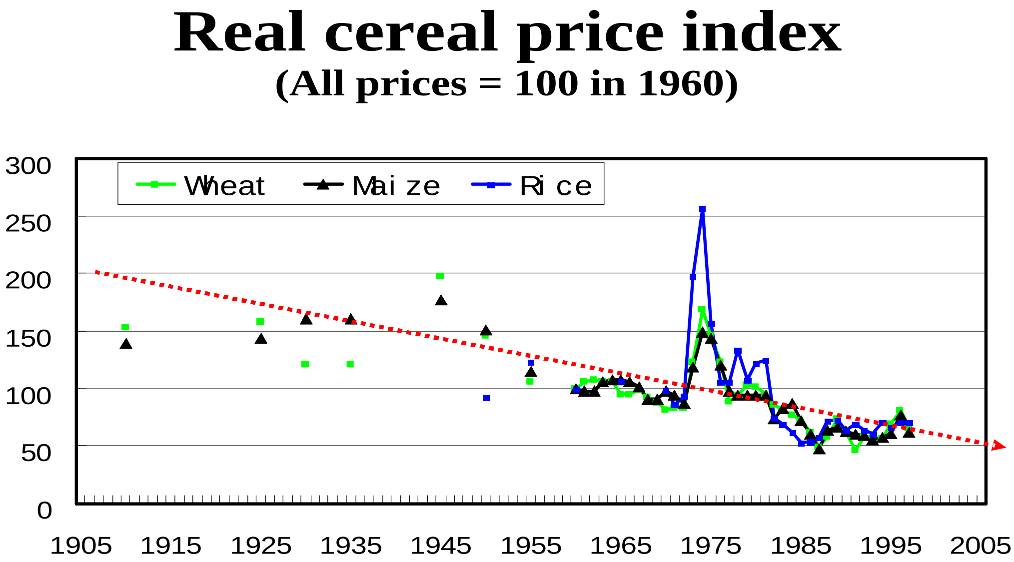
Timeline of Activities

Activity	Year 1				Year 2				Year 3				Year 4			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Objective 1 activities (Organization of the Program Leadership Team)																
Recruit program leadership team (PLT--sign agreements; meet for organization)	x	x														
Hold opening workshop (“state of the art”)		x														
Objective 2 activities (South Training South—Board of Policy Advisors)																
Invite “Board of the Policy Advisors” [BPA]		x														
Invite industry reps and scholars with special skills (as BPA technology and finance and issues advisors) BPA-Advisors’s		x														
First BPA meeting			x													
Regional meetings in each country hosted by PLT and local BPA member (state of the art; what are the issues; local talents and ideas)					x	x	x									
Organize intensive BPA training (first step towards South training South)									x	x						
Organize follow up local workshops													x	x		
Objective 3 (Getting the data right – and keeping it right)																
Identify data needs (also in Objective 4 below)				x	x											
Creating website and open access storage sites					x	x	x	x								
Data consulting services for PAT and Networking members									x	x	x	x	x	x	x	x
Objective 4a activities (Building the Global Model and a Country-specific policy analysis framework)																
Modeller’s workshop (sponsored by IFPRI and CAS, China)		x														
Creation of Modelling Plan		x	x													
Modeling in Beijing and DC			x	x	x	x	x									
Country training curricula for country modules					x	x	x									
Conferences for presenting framework and results						x			x							
Objective 4b activities (Building Capacity in the Developing World)																
Recruit policy analysis teams (PATs) in core countries – in collaboration with BPA			x	x												
PATs with PLT (in collaboration with BPA) will create country-specific policy brief; issues paper and plan for policy analysis (responding to needs and situation in each country)				x	x											
Identify data needs and data collection plan				x	x											
PAT training program in Beijing							x	x	x	x						
Objective 5 activities (Country Analyses)																
Request for Proposal from country teams			x	x	x											
PAT modeling					x	x	x	x	x	x						
Regional workshops									x	x	x	x				
PAT reports											x	x	x	x	x	
PAT final conference																x
Writing clinics and presentation forums for PAT members											x	x	x	x	x	
Objective 6 activities (creating a permanent network and scaling up)																
Request for Proposal for Network participation									x	x						
Network workshop											x					
Network working paper series; global news note; website											x	x	x	x	x	x
Networking steering committee to create future network plans													x	x	x	x

Preliminary Budget

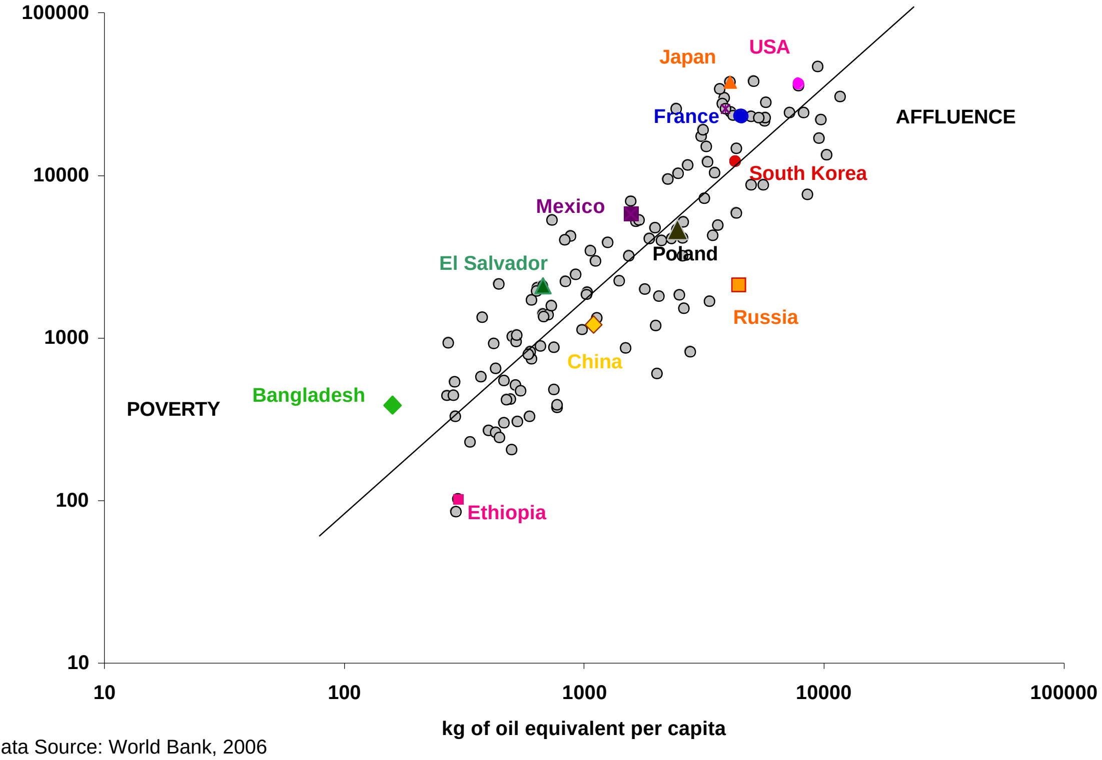
ACTIVITY	BY YEAR				TOTAL	COMMENTS
	Year 1	Year 2	Year 3	Year 4		
Objective 1: Organization of the Program Leadership Team						
Recruit program leadership team (PLT-- sign agreements; meet for organization)	200000	200000	200000	200000	800000	To ensure focus on project, 2 months of salary will be provided to all PLT members (10 individuals) at rate of salary recovery (approximately $10,000/ month)
Hold opening workshop ("state of the art")	100,000				800,000	international workshop -- joint between industry; academia and representatives from PLT countries
Objective 2: South Training South—Board of Policy Advisors						
Invite "Board of the Policy Advisors" [BPA]	100,000	100,000	100,000	100,000	400,000	to ensure focus on the project, 1 $10,000 grant per year will be given to each of 10 BPA
Invite industry reps and scholars with special skills (as BPA technology and finance and issues advisors) BPA-Advisors	100,000	100,000	100,000	100,000	400,000	Advisors to Policy Advisors will be given $5,000 travel allowance per year (5 industry and 5 academic advisors). In addition, each will be paid $1,000/day for up to 5 days of consulting per year
First BPA meeting	200,000				200,000	
Regional meetings in each country hosted by PLT and local BPA member (state of the art; what are the issues; local talents and ideas)		200,000			200,000	four regional workshops at $50,000/workshop
Organize intensive BPA training (first step towards South training South)			300,000		300,000	This will be an intensive 2 to 3-week session in a core participating country (e.g., Senegal). which will train the BPA about the nuances of policy advising … and teach them how to teach …
Organize follow up local workshops				200,000	200,000	four regional workshops at $50,000/workshop
Objective 3: Getting the data right – and keeping it right						
Identify data needs (also in Objective 4 below)	100,000	100,000	100,000	100,000	400,000	Hire data handling staff (one full-time person in U. of Nebraska with computing and web and database skills (100000 x 4 years)
Creating website and open access storage sites	200,000	30,000	30,000	30,000	290,000	computing servers, storage and equipment … grants for country team members (total $30,000 per year)
Data consulting services for PAT and Networking members				250,000	250,000	extra assistance for last year of project (2 RAs and a travel budget for local consulting)

ACTIVITY	BY YEAR				TOTAL	COMMENTS
	Year 1	Year 2	Year 3	Year 4		
Objective 4a :Building the Global Model and a Country-specific policy analysis framework						
Modeller's workshop (sponsored by IFPRI and CAS, China)	500,000	500,000	500,000	500,000	2,000,000	modelling team support: in CCAP (China): $1 million … in IFPRI (DC): $1 million … this will support modellers salaries; equipment; and office space
Creation of Modelling Plan		25,000			25,000	workshop on modelling
Modeling in Beijing and DC		25,000	25,000		50,000	travel budget for cross-team collaborations
Purchase data or modules from third parties (e.g., CARD's model in U.S.)		50,000	50,000			contracting with third parties who have countries models build for: U.S. and Europe and Japan
Country training curricula for country modules		150,000	150,000		300,000	6 $50,000 grants will be given for participation of PAT personnel to come to Beijing and learn modelling … grant includes all travel, in-country costs and training stipend (does not include country grants) -- half in year 2; half in year 3
Conferences for presenting framework and results				100,000	100,000	
Objective 4b: Building Capacity in the Developing World						
Recruit policy analysis teams (PATs) in core countries – in collaboration with BPA		500,000	500,000	500,000	1,500,000	6 Policy Analysis Teams (PATs) will be given grants which on average are for $50,0000 … grants distributed equally over years 2, 3 and 4
PATs with PLT (in collaboration with BPA) will create country-specific policy brief; issues paper and plan for policy analysis (responding to needs and situation in each country)			100,000	100,000	200,000	travel budget for CCAP and IFPRI modeling team to work with each country team (100000/year) in years 3 and 4
Identify data needs and data collection plan			included		0	included above
PAT training program in Beijing			included		0	included above
Objective 5: Country Analyses						
Request for Proposal from country teams					0	included above
PAT modeling					0	included above
Regional workshops			200,000		200,000	4 regional workshops
PAT reports					0	included above
PAT final conference				200,000	200,000	
Writing clinics and presentation forums for PAT members			100,000	100,000	200,000	all travel expenses to Stanford and living expenses in Palo Alto
Objective 6: Creating a Permanent Network and Scaling Up						
Request for Proposal for Network participation					200,000	a lump sum of 200,000 is needed to run network activities (all internal project participants are covered)
Network working paper series; global news note; website						included above
Networking steering committee to create future network plans						included above
Overhead and Totals						
	Year 1	Year 2	Year 3	Year 4	TOTAL	
Subtotal	1,500,000	1,980,000	2,455,000	2,480,000	9,215,000	
Overhead	225,000	297,000	368,250	372,000	1,382,250	
Total	1,725,000	2,277,000	2,823,250	2,852,000	10,597,250	



Data Source: Johnson, 1999; Chicago Board of Trade Website.

Figure 1. Real Cereal Price Index for the World, 1905 to 2005



Data Source: World Bank, 2006

Figure 2. Relationship between energy consumption and per capita GDP. Each data point represents a country. More than 75% of the world's population live in countries with per GDP below $1000 dollars (including China, India, and Indonesia) and currently use relatively little energy. However, high rates of economic growth in these countries portend rapid growth rates in global energy demand.

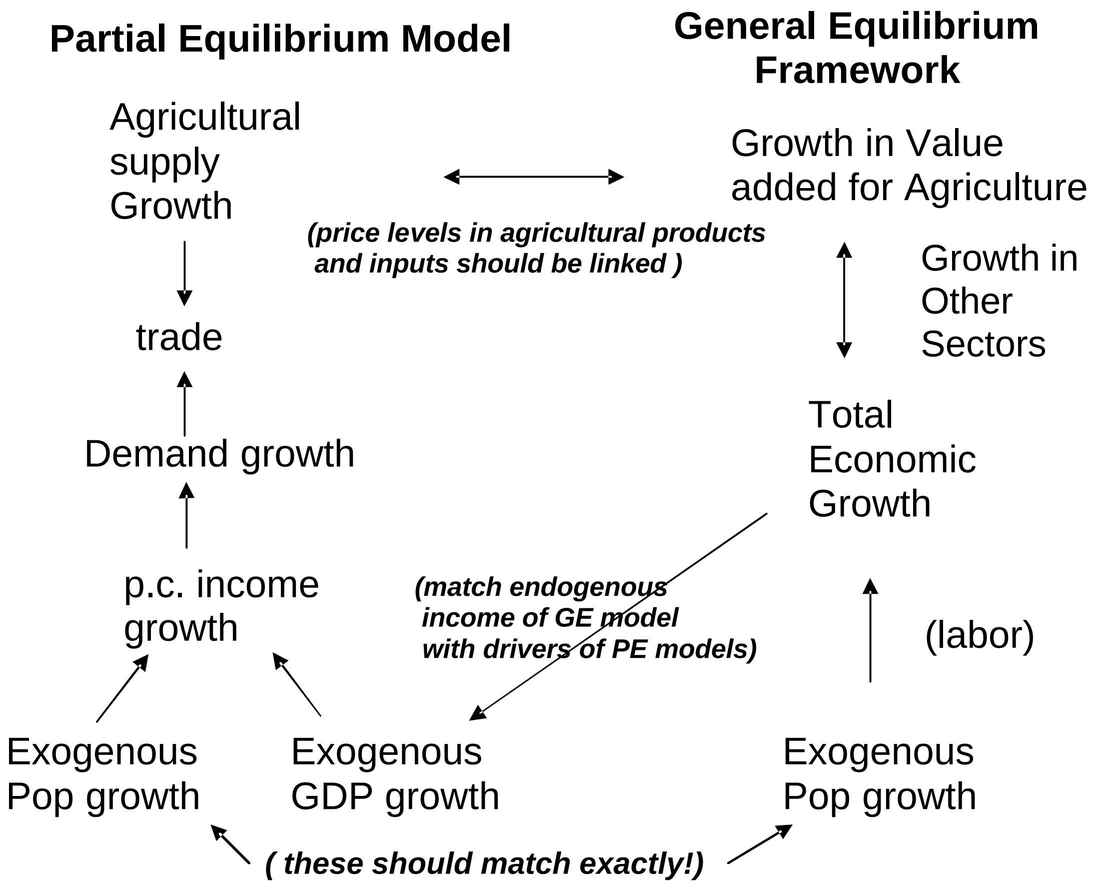


Figure 3: Linkages Between Partial and General Equilibrium Models

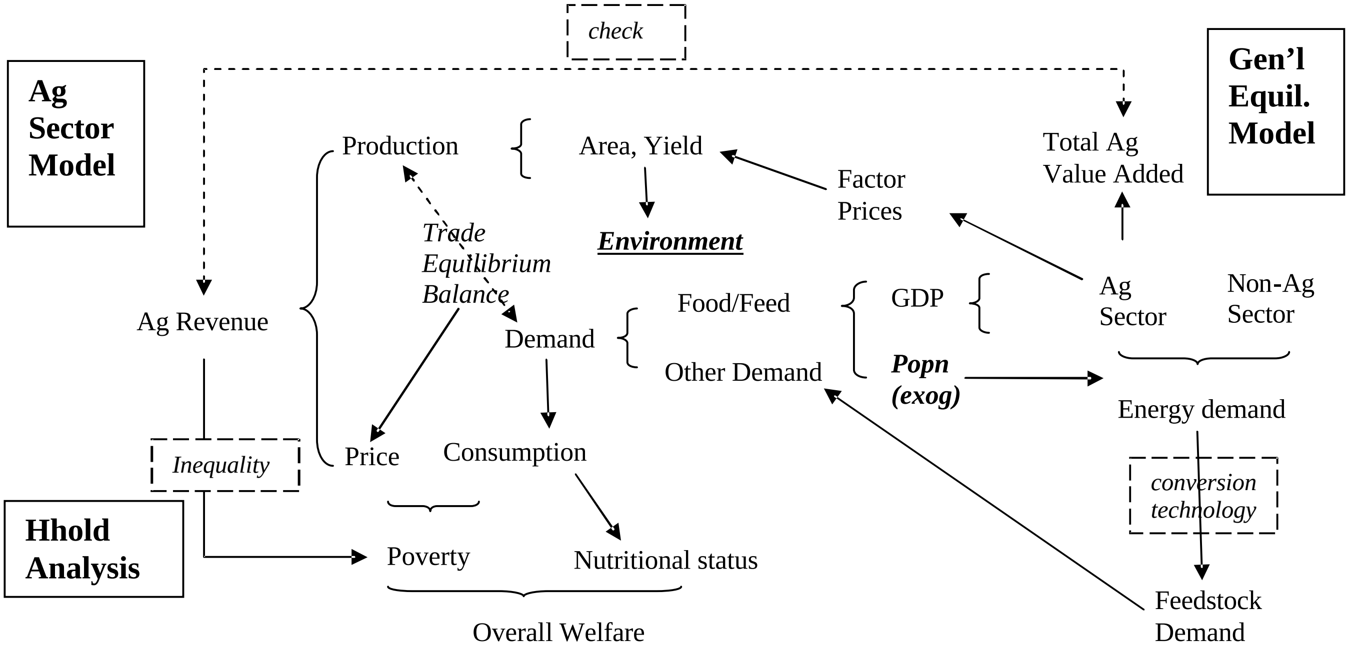


Figure 4: Model Linkages Relevant to Energy and Biofuels

Appendix A1
CCAP's current modeling framework and proposed uses in biofuels work

Building a realistic, policy-relevant model to track the impact of the emergence of biofuels is challenging because we want to pick up three types of effects: a.) the effect on the agricultural sector (its crops, livestock, and interregional effects); b.) the effect on individual households—both those in rural areas and those in urban areas, and those that engage in different types of enterprise (e.g., those that produce maize compared to those that produce rice); and c.) global effects that measure the effect on one country from the action in another through international trade.

To do this, we propose taking three sets of existing models and adapting them so we can look at the three effects, and tying them together to get one set of consistent changes from the emergence of biofuels. We propose to do this across a set of case study countries so we can compare effects across the globe on agricultural production (at the sectoral level), the effects on households in the rural and urban economy, and the effects on international trade.

Sub-Model 1: Examining the Impact of Biofuels on China's Agricultural Sector Using CAPSiM

Introduction

China's Agricultural Policy Simulation and Projection Model (CAPSiM) was developed by the Center for Chinese Agricultural Policy (CCAP) in the middle 1990s as a response to the need to have a framework for analyzing policies affecting agricultural production, consumption, price and trade in China (Huang et al., 1999; Huang and Chen, 1999). Since then CAPSiM has been periodically updated and expanded at CCAP to cover the impacts of policy changes at regional and household levels (Huang and Li, 2003; Huang et al., 2003).

Model Structure and Data

CAPSiM is a partial equilibrium model for 19 crop, livestock and fishery commodities, including all cereals (four categories), sweet potato, potato, soybean, other edible oil crops, cotton, vegetable, fruits, other crops, six livestock products, and one aggregate fishery sector, which accounted for more than 90% of China's agricultural output. CAPSiM is simultaneously run at national, provincial (31) and household (by different income groups) level. It is the first comprehensive model for examining the effects of policies on China's and regional food economies as well as household income and poverty.

CAPSiM includes two major modules in terms of supply and demand balance for each of 19 commodities. Supply includes production, import and stock changes. Demand includes food demand (specified separately for rural and urban consumers), feed demand, industrial demand, other demand, and export demand. An example of crop model is given in Figure 1 (page 33). Marketing clearing is reached simultaneously for each agricultural commodity and all 19 commodities (or groups).

Production equations, which are decomposed by area and yield for crops and total output for meat and other products, allow producer's own- and cross-price market responses, as well as the effects of shifts in technology stock on agriculture, irrigation stock, three environmental factors—erosion, salinization, and the breakdown of the local environment, yield change due to exogenous shock of climate and others (Huang and Rozelle, 1998b; deBrauw et al., 2004). Demand equations, which are decomposed by urban and rural, allow consumer own- and cross-price market responses, as well as the effects of shifts in income, population level, market development and other shocks (Huang and Rozelle, 1998a; Huang and Bouis, 2001; Huang and Liu, 2002).

Most of the elasticities used in CAPSiM were estimated econometrically by Rozelle and Huang using state-of-the-art econometrics and with assumptions that make our estimated parameters consistent with theory (e.g. that demand and supply elasticities change over time). Recently, CAPSiM shifted its demand system from double-log to An Almost Ideal Demand System (AIDS, Deaton and Muellbauer, 1980), to mak demand elasticities vary over time and across income groups.

CAPSiM generates annual projections for crop production (area, yield and production), livestock and fish production, demand (food, feed, industrial, seed, waste, etc), stock changes, prices and trade. The base year is 2001 and is currently updated to 2003. The model is written in Visual C++.

Applications

CAPSiM has been frequently used by CCAP and its collaborators in various policy analyses and impact assessments. Some of examples include China's WTO accession and implications (Huang and Rozelle, 2003; Huang and Chen, 1999), trade liberalization and food security and poverty (Huang et al., 2003; Huang et. al., 2005a and 2005b), R&D investment policy and impact assessments (Huang et al., 2000), land use policy change and its impact on food prices (Xu et. al., 2006), China's food demand and supply projection (Huang et. al., 1999; Rozelle et al., 1996; Rozelle and Huang, 2000), and water policy (Liao and Huang 2004).

Tracking Changes from the Sector down to the Household Level: CAPSiM-micro model interface module

Because the analysis based on the original CAPSiM framework can only be done *at the national level*, we have to modify the original model in order to allow us to disaggregate the national impacts into household production, consumption and poverty effects that the emergence of biofuels will have *on households in different income groups* (and households that have different characteristics—e.g., ethnic status; or those households with access to off-farm jobs; or those with certain cropping structure). To do so, we get access to the raw data from the China National Bureau of Statistics (CNBS) for 80,000 rural households (using 2001 data) and 30,000 urban households (also using 2001 data). The raw data is created into household modules that produce different types of crops. There characteristics are linked.

Using a programming platform that allows interaction between the output of the CAPSiM model and the database itself, we can see how households are affected when the price of a set of crops change. The direct impacts on household income and consumption can be tracked. Then, we allow the households in an optimization routine to response (using elasticities that are consistent with CAPSiM) and the effect on the household after the response to the shocks to the model can be tabulated.

After the response of each household is recorded, the total shifts can be summed for different groups. For example, we could sum the effects on all household under a certain income level (say, the poverty line) and compare it to the effect of the farmers in the middle decile and/or top decile. The effects on a certain minority group could also be tracked as could the effect on suburban or remote farms. This work (linking households to a sectoral and international trade model) is among the first to be carried out in a developing country. .

Tracking Global Effects Using GTAP

The Global Model is needed for three reasons: first, to understand how China affects the rest of the world; second, to track how the rest of the world affects China; and third, to understand the general equilibrium effects of changes in the agricultural sector (since CAPSiM is partial equilibrium only, the GE effects can be tracked by interfacing CAPSiM with GTAP).

To examine these global (and general equilibrium) effects, we will use the model developed by the Global Trade Analysis Project (GTAP) to analyze the global trade effects of the emergence of biofuels (in China and in other nations). The GTAP model is a multi-region, multi-sector computable general equilibrium model, with perfect competition and constant returns to scale.[2] In the GTAP model, taxes and other policy distortions are represented as *ad valorem* tax equivalents; the same would be true for the emergence of biofuels. Such shocks create wedges between the "base" prices (e.g., prices without biofuels) and the post-biofuels prices. Using the GTAP model, we will assess how biofuels affect agricultural prices and trade in China and the rest of the world via simultaneous shifts in domestic and international supply and demand functions embedded in the model. The GTAP model has been used extensively by members of our project

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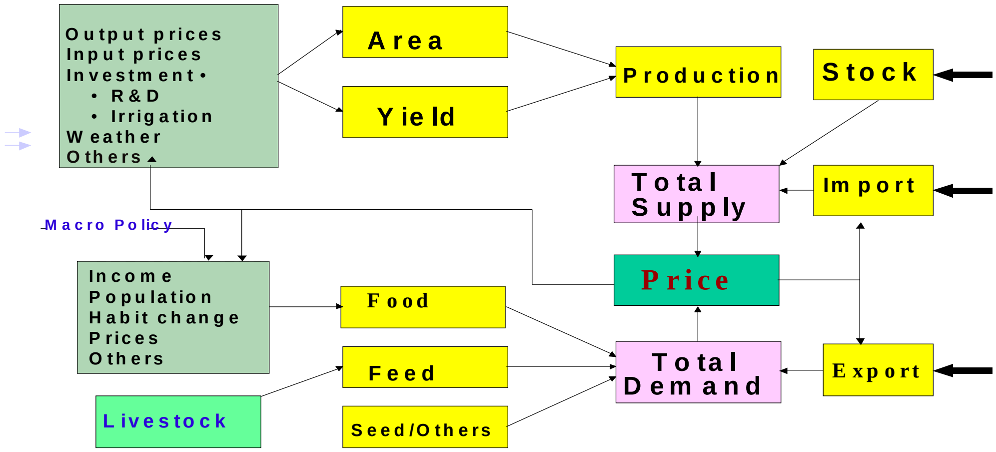
[2] The model is fully described in Hertel (1997). It has been used to generate projections of policy impacts in the future (Arndt et al., 1996; Hertel and Martin, 1999; Hertel, 1997).

team, including Rozelle, Huang, and Yang (a research fellow at CCAP who is a skilled trade modeler).

To implement the GTAP model, we will modify the standard (and publicly available) database that contains detailed bilateral trade, transport and protection data in a variety of ways. For example, we will create larger aggregations for country and sector specification in the model, and we will update some of the Chinese parameters such as demand elasticities (response of demand to prices and income), input-output coefficients, and import and export tariff equivalents of agricultural commodities. In addition, because the existing country input–output databases do not distinguish between many types of grains (e.g., maize and other feed grains), we will modify the comodity sector data for all ag-trading countries in the model—not only for China but all of the major players (e.g., Brazil, the U.S., Europe, Japan, Australia, Africa, India, Indonesia, etc.) using data from the United Nation's Food and Agricultural Organization (FAO) and, in a few cases, from surveys of Ministries of Agriculture and Statistical Bureaus of key exporting and importing countries.

In the end the goal is to have a flexible, transparent modeling framework that can be used in many different countries and then link the agricultural, individual household and the rest of world together to answer many of the questions about the effect of biofuels on poverty, food security and the rural environment.



Appendix Figure 1: Overview of Individual Crop in CAPSiM

[Note: Linkages to the Global GTAP model and household-level decision-making models are not shown.]

Appendix A2
IFPRI's current modeling framework and proposed uses in biofuels work

IMPACT – the **I**nternational **M**odel for **P**olicy Analysis of **A**gricultural **C**ommodities and **T**rade – was developed at IFPRI at the beginning of the 1990s, upon the realization that there was a lack of long-term vision and consensus among policy makers and researchers about the actions that are necessary to feed the world in the future, reduce poverty, and protect the natural resource base. In 1993, these same long-term global concerns launched the 2020 Vision for Food, Agriculture and the Environment Initiative. This initiative created the opportunity for further development of the IMPACT model, and in 1995 the first results using IMPACT were published as a 2020 Vision discussion paper: *Global Food Projections to 2020: Implications for Investment* (Rosegrant, Agcaoili-Sombilla and Perez, 1995), in which the effects of population, investment, and trade scenarios on food security and nutrition status, especially in developing countries, were analyzed.

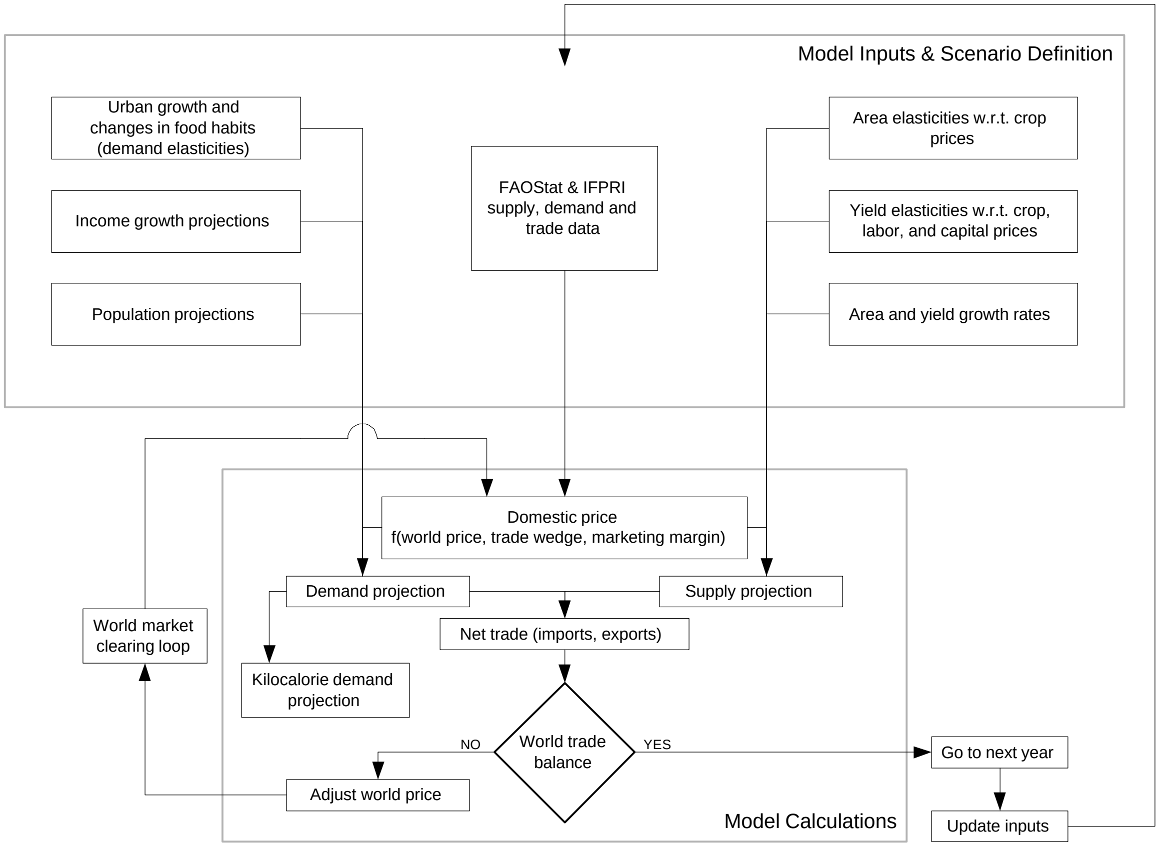
IMPACT has been used in several important research publications, which examine the linkage between the production of key food commodities and food demand and security at the national level. Such examples can be found in the paper looking at the relationship between meat-intensive diets in developed nations and food security in developing countries, *Alternative Futures for World Cereal and Meat Consumption* (Rosegrant, Leach and Gerpacio, 1999); or the article *Global Projections for Root and Tuber Crops to the Year 2020* (Scott, Rosegrant and Ringler, 2000), which gives a detailed analysis of roots and tuber crops and their importance to the food economies of the poor. The report *Livestock to 2020: The next food revolution* (Delgado *et al.*, 1999) assesses the rise in livestock demand in developing countries that was trigged by rising incomes in recent decades, and considers the current and expected future developments of this "livestock revolution," as well as its implications for policy.

The IMPACT model has also been employed in regional studies, such as the *Asian Economic Crisis and the Long-Term Global Food Situation* (Rosegrant and Ringler, 2000) and *Transforming the Rural Asian Economy: the Unfinished Revolution* (Rosegrant and Hazell, 2000), which were both written in response to the Asian financial crisis of 1997 and which try to assess its impact on the regional food economy. The most comprehensive set of results for IMPACT are published in the book *Global Food Projections to 2020* (Rosegrant *et al.*, 2001). These projections – which were presented in 2001 at the IFPRI-sponsored conference in Bonn entitled *Sustainable Food Security for All by 2020* – are presented with details on the demand system and other underlying data used in the projections work, and cover both global and regionally focused projections. This publication is also the first in a series of research outputs that IFPRI hopes to use to provide policy advice on the necessary investments that need to be made by national and regional policy makers in order to sustain the levels of food production and nutrition that are required by projected global demographic and economic changes. IMPACT also provided the first comprehensive policy evaluation of global fishery production and projections for demand of fish products in the book *Fish to 2020: Supply and Demand in*

Changing Global Markets (Delgado, Wada, Rosegrant, Meijer and Ahmed, 2003). A complete list of the research published using the IMPACT modeling framework is provided in Appendix B2, including reports for international organizations, such as the World Bank, the Asian Development Bank, the FAO, and national governments.

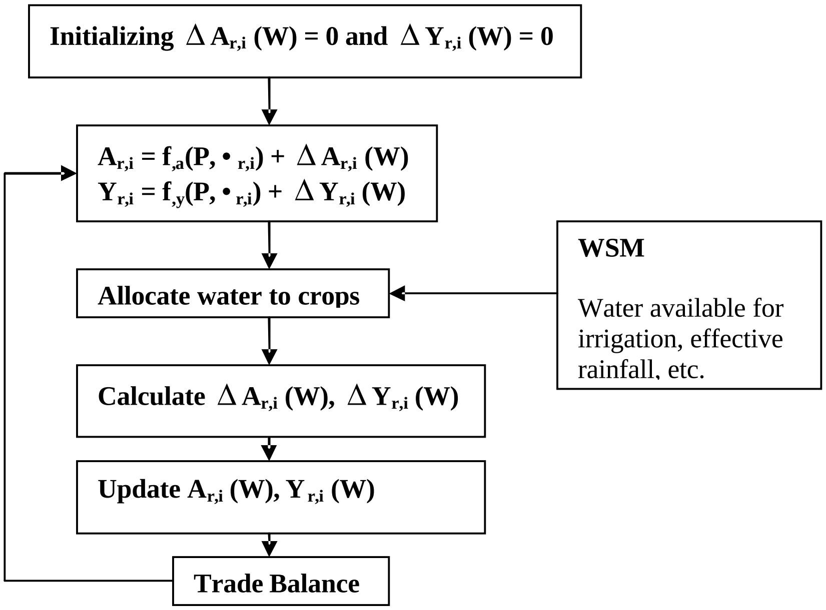
IMPACT is based on a partial-equilibrium representation of perfect, competitive world agricultural market for crops and livestock with supply and demand relationships that are linked to exogenously determined, socio-economic drivers of population and income, as well as productivity and land-use change. The model computes the country or regional-level supply and demand quantities that correspond to a global market price for each agricultural commodity. Supply and demand quantities at the country and regional levels are linked globally, through trade, and account for differences in country-specific subsidy or protection policies towards various agricultural goods.

The schematic in Figure 2, below, shows the key linkages in supply, demand and trade, that are embedded in the basic food sector modeling methodology of IMPACT.



Appendix Figure 2. Schematic representation of the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT)

While the original IMPACT model has gained recognition within the policy research community as a leading agricultural sector model for the assessment of the global food production and the performance of global food markets, it assumes “normal” base climate conditions, which is maintained throughout its 30-year projections horizon. As such, the impacts of annual climate variability on food production demand and trade are not embodied within the model or reflected in its results. The recognition that the long-term change in water demand and availability—and particularly the rapidly increasing demand in non-agricultural water uses—as well as the year-to-year variability in rainfall and runoff would affect future food production, demand, and trade led to a renewed effort on the part of IFPRI and partner collaborators to make more explicit linkages between food production and water availability in an integrated modeling framework. The result of this research has led to the development of the IMPACT-WATER model, which integrates the primary IMPACT model with a water simulation module (WSM) that balances water availability and uses within various economic sectors, at the global and regional scale. A schematic of how the “food” and “water” modules of the IMPACT-WATER model are linked to each other, is shown in Figure 3, below.



Source: Rosegrant et al. (2002).

Appendix Figure 3¾Flow chart of the IMPACT-WATER methodology

As shown in the schematic, the allocations of water (W) create “shocks” that the price-driven supply of irrigated and rainfed crops responds to, through changes in area ($\Delta A_{r,i}$ **(W)**,) and yield ($\Delta Y_{r,i}$ **(W)**), for any given crop (i) or region (r). Through these adjustments to both prices (P) and water availability, the supply-side of the model is able to represent shocks to crop production that could not be captured solely through market forces. The area and yield functions ($f_a(\mathbf{P}, a_{r,i})$ and $f_y(\mathbf{P}, g_{r,i})$, respectively) respond to both a vector of market prices $(\mathbf{P})$ as well as to region and crop specific factors ($a_{r,i}$ and $g_{r,i}$, respectively).

IMPACT-WATER – through the combination of the IMPACT and WSM models – incorporates water availability as a driving variable with observable flows and storage to examine the impact of water availability on food supply, demand and prices. This framework allows exploration of the relationship between water availability and food demand at trade at a variety of spatial scales – ranging from river basins, countries and more aggregated regions, to the global level. Water supply and demand and crop production are first assessed at the river-basin scale, and crop production is then summed to the national level, where food demand and trade are modeled. While the original IMPACT model divided the world into 36 countries and regions, the IMPACT-WATER model uses a finer disaggregation of 281 "food-producing units" – which represent the spatial intersection of 115 economic regions and 126 river basins – out of recognition of the fact that significant climate and hydrologic variations within regions make the use of large spatial units inappropriate for water resource assessment and modeling. Of the countries represented within the IMPACT-WATER model, China, India and the United States (which together produce about 60 percent of the world's cereals) have the highest level of sub-national disaggregation and are divided into 9, 13 and 14 major river basins, respectively, while the other countries or regions considered in IMPACT are combined into the remaining 90 basins.

Ongoing research has also expanded the set of agricultural crop commodities to 40, which include fish from both capture and aquaculture, groundnuts, cotton, fodder crops and major dryland grains and pulses, such as sorghum, millet, chickpeas and pigeonpeas. Given the prominence of many of dryland crops in the semi-arid tropics and their important linkage to livestock through feed, along with other fodder crops, we felt these additions were necessary to fully understanding the drivers behind projected future growth in global oil, meat and milk demand. The importance of many of these commodities, including aquaculture, in global water demand also warranted their full inclusion into the model.

Policy analyses based on alternative scenarios analyzed with IMPACT-WATER were published in an IFPRI book titled *World Water and Food to 2025: Dealing with Scarcity* (Rosegrant, Cai and Cline, 2002). Another paper that has used results from IMPACT-WATER to make policy evaluations is a study prepared for the North American Commission for Environmental Cooperation titled *Modeling Water Availability and Food Security: A North American Application of the IMPACT-WATER Model* (Rosegrant, Runge and Cai), which looked at implications of NAFTA on water use and agricultural production in North America. IMPACT-WATER is also currently used for a World Bank report on the role of agriculture to achieve the Millennium Development Goals and a small effort by the U.S. EPA on the role of greenhouse gas mitigation for rice in China.

Examining the Impact of Biofuels on Global Agriculture Using IMPACT

Basic Approach

In order to meet the stated objectives of this study, several analytical components would be integrated to IFPRI's extended IMPACT-WATER model, in order to better measure the response of energy crop cultivation to domestic policy changes and the effect of resultant cropping and energy use patterns on greenhouse gas emissions.

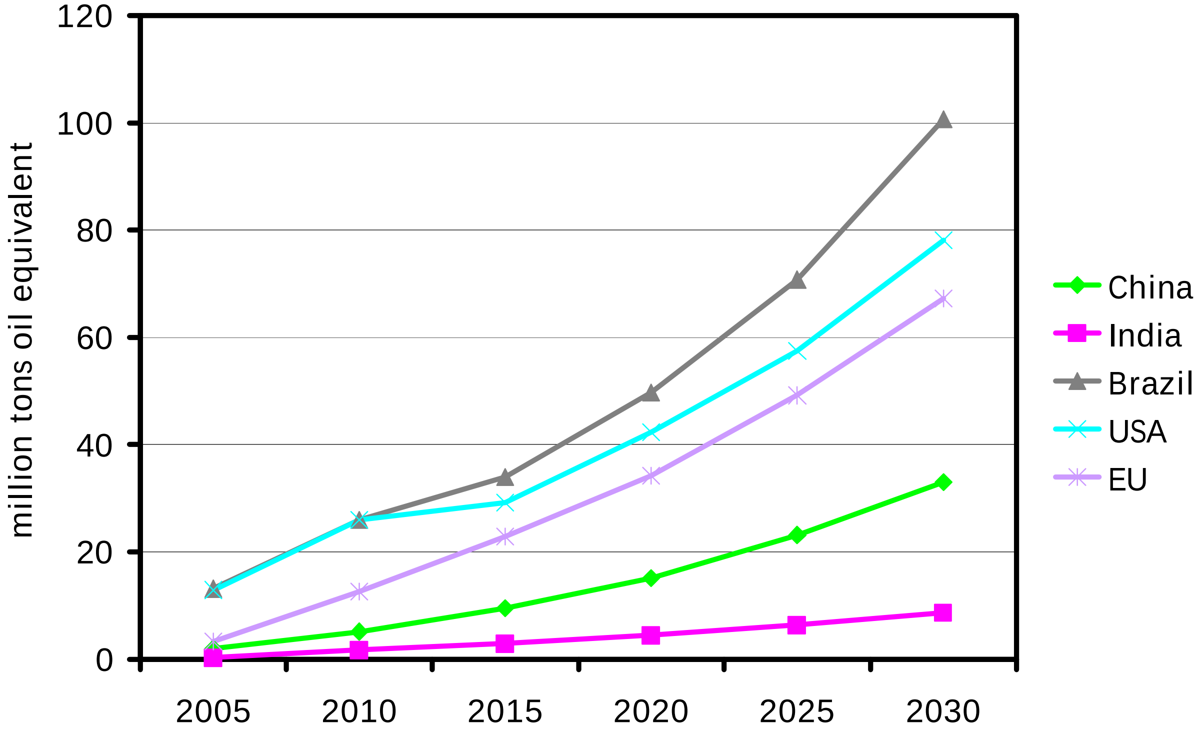
In order to translate the projected changes in biofuel demand into projected increases in bio-fuel feedstock production, we will draw upon energy growth scenarios provided by Worldwatch, IEA or other sources, in order to infer the increased levels of ethanol that are needed to supply transport fuel needs. Using known feedstock-to-fuel conversion rates (which are technology-specific), we would then translate increases in fuel demand into that for feedstock demand, which would then directly affect the domestic demand for the feedstock crop within that country. These changes in domestic demand would then equilibrate with domestic supply and imports for each country, and lead to changes in global market conditions for that feedstock crop, within the IMPACT-WATER model.

Given the interactions with irrigation demand that are built into IMPACT-WATER that are built into the model, increases in supply of feedstock crops are also translated into increases in water requirements for irrigated and rainfed agriculture, which must balance with basin-level availability of water. In this way, we are able to evaluate the changes in environmental stress that are introduced by various scenarios for biofuel expansion, and determine which crops are the most viable candidates for biofuel feedstock production, based on the country-level water availability. Within this framework we are able to make policy recommendations, both in terms of yield and crop productivity improvements, as well as in terms of environmental policy and necessary investments in irrigation and water supply.

Preliminary Results

IFPRI has already undertaken preliminary quantitative analysis of biofuel production scenarios with an earlier version of IMPACT, so as to show the potential impacts on malnutrition and food calorie consumption, for a limited set of scenarios and countries. The biofuel production scenarios that we used in our analysis are shown in Figure 4, which were based on published projections as well as our own representation of 'aggressive' patterns of global biofuel adoption.

The projected impacts on prices under alternative scenarios are shown in Figure 5, and contrast the price impacts both with and without crop productivity improvements, as well as the coming on-line of second generation ligno-cellulosic technologies for ethanol production. These results illustrate the importance of both agricultural sector-focused investments, as well as those aimed at the biofuel industry itself. See Rosegrant *et al.* (2006) for further details on these scenarios.

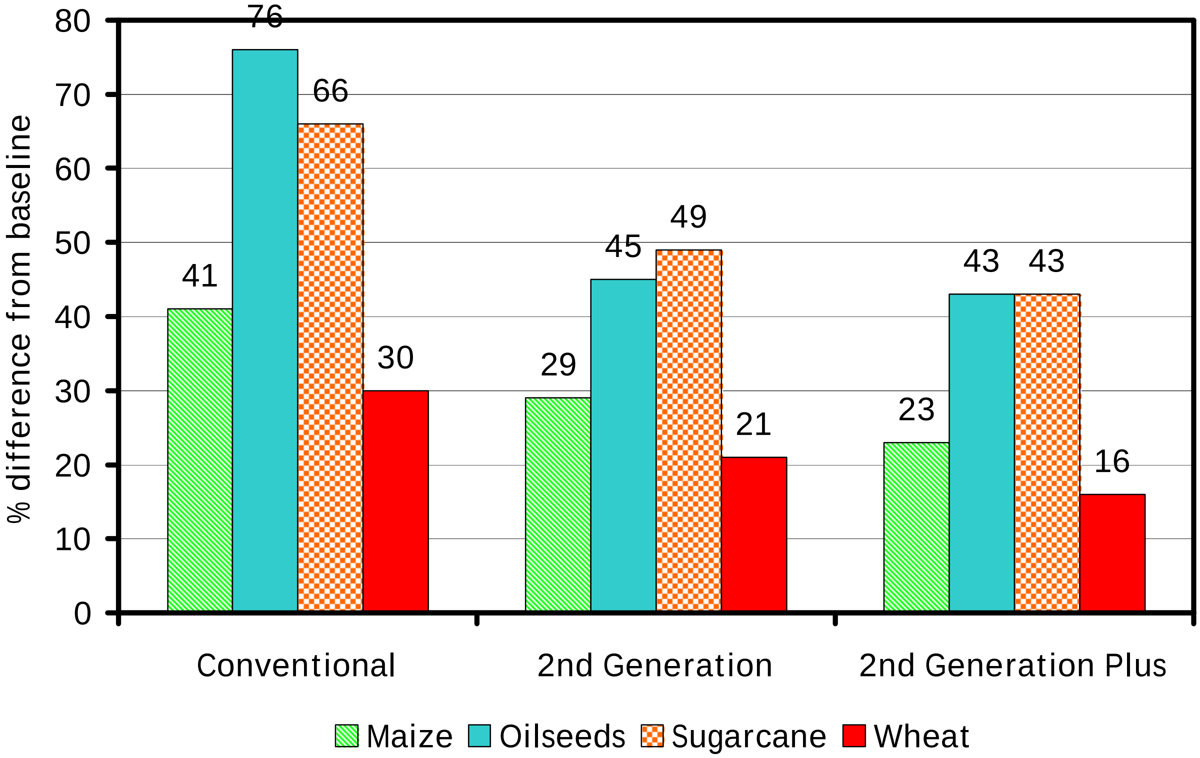


Source: author calculations

Appendix Figure 4: Simulated Total (Bioethanol + Biodiesel) Biofuel Production for Transport

Further Extensions

An important component to integrate into this modeling framework are the dynamics of land use change, which determine the pattern of cropping over time, and how agricultural land use would be expected to expand or contract with the movement of forest, rangeland, urban area or even desertification, over time. By linking IMPACT-WATER with a detailed spatial land use model, which incorporates both the land-use classes and classifications of crop suitabilities, we can be able to project the dynamics of the underlying drivers of agricultural and non-agricultural land use over time, so as to make our projections consistent with other important environmental or socio-economic forces that are also embedded in our scenarios. Possible candidate land-use models would be the AgLU model of the Joint Global Change Research Institute in Maryland (Sands and Leimbach, 2003), or the IMAGE model of the Environmental Assessment Agency of the Netherlands (Hoogwijk *et al.*, 2005).



Source: IMPACT projections

Figure 2: Changes in Global Commodity Prices from Baseline Across Scenarios in 2020

By building further upon our preliminary results and methodology, and developing a more detailed land-use change component, we will be better able to model the substitution between alternative crops as market conditions evolve in tandem with other land use pressures over time. We would also like to link the IMPACT-WATER model to a partial-equilibrium energy model, so that we can generate more realistic scenarios around energy consumption patterns over time, while also capturing the substitution possibilities between fossil-based and other renewable forms of energy. At a later stage of the work, we can make broader linkages within a general equilibrium framework. Building upon our existing work, we would translate our current methodology into the newer modeling framework (with land use change analysis included) and undertake an additional set of activities, which would include the following:

1) Developing the agricultural systems component with the best-suited model—or combination of models—will enable the production and trade components of IMPACT-WATER to link with the projected land use changes that

are consistent with a given socio-economic scenario for economic growth and energy demand, under given environmental conditions.

2) Evaluate the crop yield improvement possibilities in each of the candidate biofuel producing countries, so as to establish the upper limits of what types of feedstock crop production intensification could be possible.

3) Expanding the set of current bio-fuel production scenarios to include possible large-scale biodiesel production in other South, Southeast and East Asian countries, besides India and China, as well as in Sub-Saharan Africa, along with a globally expanded set of biodiesel feedstock crops, such as oilseeds crops and oil palm, and an enriched set of energy projections for these countries.

4) Following testing and calibration of the model to a baseline for both agricultural production, in terms of food, feed and energy crops, assuming the technical conversion factors from conventional bioethanol and biodiesel production technologies – we could also evaluate the potential impacts from cellulosic conversion technologies, and compare the potential impacts on agricultural markets and local economies.

5) A comprehensive set of results will be analyzed and presented at the regional and global scale, which will highlight the impact of various biofuel production scenarios on food production, demand prices and trade, as well as malnutrition, calorie consumption, and environmental impacts induced by changes to water supply and demand, as well as land use change.

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