Increase in Calorie Intake Due to Eggplant Grafting: Proof of Concept With the Use of Minimum Datasets

Maria Erlinda M. Mutuc

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George W. Norton, Ph.D., Chairman

Anya McGuirk, Ph.D.

Bradford Mills, Ph.D.

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Maria Erlinda M. Mutuc

Committee Chairman: George W. Norton, Ph.D.

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(ABSTRACT)

Eggplant grafting implemented implemented in two field sites in the Philippines, in Nueva Ecija and Pangasinan are used as proofs of concept to illustrate and validate the feasibility of an impact assessment framework for determining the nutritional impact of technology-oriented agricultural activities. Nutritional impacts are assessed by disaggregating the market demand curve into demand curves by income groups using their separate price elasticities of demand. Considering only price effects, the increase in yields following a per unit cost reduction due to eggplant grafting has positive effects on the daily caloric intake per capita in the different income classes with the greatest impact on the lowest income class for both sites. Net increases in calorie intake ranges between 0.09 and 0.6 kilocalories per capita per day.

To God, my parents Julio and Erlinda, my brother and sisters, and Uncle Ben

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Chapter 1

Introduction

1.1 Background

Most economic assessments of IPM impacts have been completed both at the user as well as the aggregate or societal levels. More extensive protocols for impact assessment address equity and distributional issues in addition to the efficiency objective. Societal benefits are often estimated for producers and consumers using economic surplus analysis. Extensions to the basic closed economy model to include multiple markets and products as well as government policies and trade have been examined using this technique in conjunction with other procedures. However, welfare impacts remain largely expressed in terms of changes in consumer and producer surplus. Studies are sparse that are further able to translate these *intermediate* surplus changes into *final* changes in household incomes, nutritional status of specific income groups and other macroeconomic welfare and performance impact indicators with the use of *minimum data*. Lack of information on the impacts is a concern for policymakers who are interested in the impact of certain publicly funded programs on ultimate welfare indicators such as nutritional status, poverty incidence, food security, among others.

The United States Agency for International Development (USAID), interchangeably referred to as the Agency, is faced with the need to develop a broad-based agriculture impact assessment. To address this need, Economic Growth and Agricultural Development (EGAD)/AFS in 2001 organized an Impact Assessment Task Force that drafted a set of recommendations. In July 2002, a threefold plan was proposed by the Task Force with the overriding objective of improving upon the monitoring and evaluation of the Agencys agriculture and agriculture-related activities including livestock, fisheries, and natural resource management. The intent of the three parts was to (1) meet the need for categorizing in an easily accessible manner the agricultural projects and activities currently supported by USAID, (2) measure the impacts of these projects, and (3) communicate these impacts.

(1) *Portfolio Analysis and Reporting System (PARS)*

The main goal of PARS would be the institution of a mechanism to provide information about projects or programs in a systematic and standardized manner to allow USAID to extract and synthesize information easily. At the core of this mechanism would be a database containing basic geo-referenced information about inputs and outputs of its portfolio of projects and activities that would facilitate a standardized reporting system for the Agency, its missions and partners. Undertaking this requires the identification of a minimum set of data for agriculture and agriculture-related program of activities that will form the database.

(2) *Improving and Communicating Impact Assessment Case Studies*

The communications component would facilitate comparing results of impact case studies. To guarantee the widespread production and communication of case studies, it was recommended that agriculture projects/activities above a specified minimum size be required to complete impact case studies at the end of identifiable phases specific to each project (mid-term, end-of-project, etc.), or to at least compile pre-specified data to allow for impact assessments to be performed later. Communication of these case study results would take the form of a peer review and a one-page summary in a standard format made available on a website. These one-pagers with links to the full peer-reviewed studies would be included with the project descriptions in the PARS. It is recommended that (a) existing case studies produced by the Agencys partners be reviewed and classified and that (b) an agreed-on format for the one-pagers be developed.

(3) *A Minimum Data Approach to Impact Assessment*

The final portion of the plan would handle the problem of tracing the link between outputs of particular projects to higher-level Agency development goals such as reducing poverty and hunger. To achieve this linkage, a method based on a common analytical framework was proposed by the Task Force that would use simple models in conjunction with minimum required data to generate broader impact indicators. Note at the onset that common analytical frameworks are particular to the type of agriculture or agriculture-related activities including policy, technology, institutional capacity building and natural resource management, among others.

Each hierarchical framework would involve (a) several intermediate levels or hierarchies of impact starting from specific project activity outputs to national and human welfare impacts, (b) the use of models such as biophysical, land use, hydrological, agriculture sector, partial equilibrium, general equilibrium models, and (c) minimum project output data necessary to generate required impact indicators that serve as inputs to, and in combination with, simple models to generate a new and higher-level set of impacts. These results, again, would feed into other models as one moves up to a higher level of impact assessment in the impact chain. This sort of input-output process ends when human welfare impact indicators are finally derived.

1.2 Problem Statement

Initial efforts by the Task Force towards a minimum data approach to impact assessment spawned two hierarchical framework matrices for two particular types of agriculture and agriculture-related activities: (a) technology-oriented research and development, and (b) environment/natural resource management-oriented research and development (*refer to Tables 1.1 and 1.2*).

USAID is faced with the need to determine if these frameworks for minimum datasets and impact indicators should be more widely implemented and in what manner they can be altered. In particular, it needs to assess what impact indicators should be derived from each stage of the impact chain and what minimum datasets need to be provided by its partners to implement the frameworks.

This research addresses the problem of identifying and defining an appropriate hierarchical framework for the first type of agricultural activity: technology-oriented research and development projects.

Table 1.1: Hierarchical Framework for Minimum Datasets and Impact Indicators: Technology-oriented R&D

Impact Level		Typical Scale	Impact Example	Data Needs		Model Needs			Example Indicators
				Minimum	Optional	Bio/PS	PE/ASM	GE	
Human Welfare	Human consequences of enhanced agricultural performance	Countries	Increased incomes and nutrition status in rural households	Participation rates in production and consumption by target household types	Existing income (poverty) and nutrition status by household type				GDP/capita Calories/capita Income per rural household Share of malnourished Share of rural poor
Economic Systems	Value of eggplant production, consumption, and/or trade	Countries	Econmic benefits to specific producer and consumer groups	(None)	Time pattern of benefit and cost profiles and discount rate				Producer benefits Consumer benefits AgGDP/capita
Markets and Trade	Local and non-local (trade) market structure and characteristics	Regions	Total quantities produced and consumed (and hence traded) in each key market region	Total supply (Q) and consumption (C) in key market regions (local and trading partners)	Demand and supply elasticities. Population and income projections (local and RoW)				Commodity prices Value of production Value of trade Total Exports/Food Imports
Adoption Domains	Potential (ex ante) or actual (ex post) adoption domains	Regions	Account for spatial (and temporal) variation in performance of technology package across the (potential) adoption domains	Adoption levels Spatial variation in Y, C and selected environmental variable(s) for different agroecological conditions and farm types	Adoption dynamics Temporal variability in climate and soil conditions. Variability in access to credit and input and output markets.				Number of technologies adopted Share by farm type (incl. gender) Share of area under high-yielding varieties Fertilizer use per ha Pesticide use per ha
Projects	Output Evaluation	Farm, Communities, Watersheds	Recommended technology "package"	Known changes in product yields and production costs with and without the new technology Changes in environmental variables	Known changes in product quality, timing (changes in prices received)				Number of technologies released Changes in yields, input use and natural resource impacts (on a point/local basis)
Project Activity	Candidate technologies, practices, institutional arrangements	Plots, Farm	Testing IPM options with new cultivars	Experimental Data (e.g. ICASA)	Geo-referenced experimental data.				Changes in yields, input use and natural resource impacts (on a point/local basis)

Source: Impact Task Force Report, IFPRI

Table 1.2: (Very Rough Draft) Hierarchical Framework for Minimum Datasets and Impact Indicators: Environment/NRM-oriented R&D

Impact Level		Typical Scale	Impact Example	Data Needs		Example Model Needs			Example Indicators
				Minimum	Optional	Land Use	Hydrological	GCMs	
Human Welfare	Human consequences of agriculture related NRM		Potable water supply (quantity and quality) Food supply Recreation	Water Supply and Consumption by land use group	Existing income (poverty) and nutrition status by household type				Water supply/capita Incidence of waterborne diseases Loss of livelihoods
Global Environment	Scale of global climate systems and biogeochemical cycles	Global!	Endangered Species Coastal aquatic biodiversity	Species abundance GHG Concentration					Key species diversity Co_x, No_x Emissions
Ecosystems		Sub-national	Sediment deposition in riparian ecosystems Loss of habitat	Sediment runoff rate Forest and wetland conversion	Temporal variability in biodiversity				Sediment runoff Land use conversion rates Key species diversity Income from agrotourism
Watersheds		Local - Basin	Runoff quantity, quality and timing	Sediment runoff rate Water quantity and quality Vegetative cover	Temporal variability in climate, water and soil conditions				Share of area under riparian buffer zone management Fertilizer and pesticide sediments
Community/ Landscape		Landscape	Rangeland quality Common property resource management practices	Land use patterns Resource and institutional inventory					Share by land use type Proportion of forested land
Farm Level		Farm	Soil erosion rates Soil fertility Nutrient and pesticide use	Agricultural production practices NRM practices					Number of technologies released Changes in ecosystem service impacts (on a point/local basis)
Plot Level	Candidate technologies, practices, institutional arrangements		Environment services (e.g., water, carbon, biodiversity)	Survey data	Geo-referenced Survey				Changes in yields, input use and natural resource impacts (on a point/local basis)

Source: Impact Task Force Report, IFPRI

1.3 Justification

Wide implementation of the frameworks would allow the Agency to measure and trace the impact of a class of projects on ultimate welfare variables such as nutritional improvement. The framework can serve as a standard evaluation method that requires minimum data for similar projects. Using a relatively standard evaluation method can help ensure rigor and help facilitate aggregation and comparison across similar projects.

1.4 Objectives of the Study

The objectives of this study are:

(1) To illustrate and validate through case studies the feasibility of employing the above impact assessment framework to technology-oriented project activities. Pilot testing of the framework on specific IPM research that is being completed in developing countries under the USAID-supported Integrated Pest Management-Collaborative Research Support Program (IPM-CRSP) will serve as a “proof of concept”.

(2) To identify and recommend impact indicators appropriate and necessary at each level of the impact chain as well as minimum data required in deriving these indicators based on the results of the pilot tests; ultimately to refine the proposed framework for a class of projects geared to a specific welfare indicator.

This study will demonstrate how a final welfare impact, specifically increase in caloric intake, can be derived from technology-oriented activities such as eggplant grafting using resistant rootstocks to reduce bacterial wilt in eggplant and improve yields. This is an IPM CRSP activity funded by USAID in selected areas in the Philippines and Bangladesh. This research in this thesis focuses on the Philippine sites.

1.5 Research Hypotheses

(1) A practical framework can be designed that requires a minimum amount of data to assess the increase in the intake of calories of a productivity-enhancing activity that ultimately increases the supply of a commodity.

(2) Eggplant grafting has positive impacts on calorie intake of households belonging to various income classes.

The methodology in this research calculates the relative benefits by consumer income groups by disaggregating the market demand curve into demand curves by income groups. A given supply shift is distributed among different income classes by taking into account adjustments in consumption of all other goods through price changes and ultimately on caloric intake. Income effects due to increased profits for farmers are ignored. Thus, the results of this research should be taken with this in mind.

1.6 Thesis Organization

Chapter 2 presents an overview of the hierarchical framework matrix proposed for technology-oriented research and development activities. The chapter also discusses the various evaluation and economic models as well as methodologies contained in the framework. Chapter 3 details the background and methods for the two case studies that apply the framework. Chapter 4 discusses empirical results and Chapter 5 briefly concludes the study.

Chapter 2

Review of Proposed Framework and Methods

This chapter presents in detail the proposed framework for evaluating productivity-related agricultural R&D. Each hierarchy is discussed as a section. Each section proceeds with a discussion of models, methods, tools, and data requirements.

2.1 Orientation and Impact of Agricultural Research and Development

Agricultural R&D activities may be oriented to effect changes in any or a combination of the following areas: (a) productivity; (b) environment/natural resource management, and (c) institutional/policy structure. For example, the introduction of biological pest control imbedded in IPM that restricts the use of pesticides enhances productivity by developing pest resistance in crops. If implemented over a wide area, pesticide sediments found in watersheds may ultimately be reduced. While this specific R&D is productivity-related, it embodies environmental consequences as well.

While the complementarities between productivity-related and environmental research activities can be easily described, equally interesting are the environmental and productivity consequences of changes in institutional arrangements or policies that stem from agricultural research. For instance, if, as a result of agricultural research, irrigation-dependent technologies or water-loving crop varieties are developed, this may result in change from dryland to irrigated farming. This change presents environmental opportunity costs inasmuch as it improves farm productivity in the production of irrigation crops such as rice, cotton, and vegetables. Water withdrawn from river systems and diverted to irrigation reduces water flow that contributes to the degradation of water quality (through problems with blue-green algae). Also, irrigation is associated with problems of salinization and return water contamination that lead to fisheries degradation (*Godden, 1997*).

Thus, the consequences of a specific research activity cannot be confined to a single area. However, impact assessment, to be fundamentally useful should be able to associate specific types of activities to a particular change whose impact can be assessed. As such, similar activities can be assessed against certain performance measures that will facilitate comparison of projects with similar consequences. The causal chain is that R&D efforts give impetus to project activities which, in turn, affect changes in productivity, the environment, or policies. These changes impact on human health, welfare and ecosystems.

This section discusses *the* common analytical framework proposed by the Task Force to assess the impact of productivity-enhancing research activities. In the context of this analytical framework, general principles, models, methodologies and techniques often used in impact assessments of IPM programs are discussed.

2.2 Assessing Productivity-Related R&D

2.2.1 Farm Level Impact

A substantial number of IPM economic impact assessments measure changes in costs that directly affect profitability, although several involve some measure of profitability risk (*Swinton and Williams, 1998*). At the user-level, IPM adoption changes the pattern of producer practices that, in turn, translate to changes in costs and returns (net returns). Various measures of expected profitability, reflected in the type of budgets analyzed, are used. Some measures use gross revenue minus the costs of IPM adoption obtained from partial budgets. Others include additional production costs, variable and fixed as detailed in enterprise budgets. In this case, data on quantities and prices for inputs such as seeds, fertilizer, pesticides, labor, water and machinery use for each level of operation (such as land preparation, planting, fertilizing, pest management, cultivating and harvesting) are collected. A third kind of budget, in addition to partial and enterprise, is the whole farm budget that includes all enterprises on a farm and thus considers any second-order changes in any activity as ensuing from the introduction of IPM practices (*Beddow et al, 2000*).

Partial Budgets: Most Commonly Used Profitability Measure

Partial budgets are most commonly used in assessing profitability of each IPM practice or a bundle of practices. It identifies cost and revenue items that will change with the adoption of alternative practices and the amount of the change (*Swinton and Day, 2000*). The term 'partial' in the case of partial budget does not imply less attention to detail relative to enterprise budgeting. While the enterprise budget includes all physical input requirements and the attendant outputs and prices for a unit of production, the partial budget is a practical application of marginal analysis (*Daku, 2002*). Essentially, a typical partial budget consists of:

A. Additions to Net Revenue

   1. Increased Returns
   2. Decreased Costs

B. Reductions in Net Revenue

   1. Decreased Returns
   2. Increased Costs

C. Net Income Increase = A − B

Thus, when benefits (due to increased revenue and decreased costs) outweigh burdens (due to decreased revenue and increased costs), a project is profitable and there is an incentive to undertake it.

Information on yields and input costs can be obtained from [1] on-farm trials conducted as part of the program, or [2] a survey of producers in the area targeted by the program using an interview questionnaire. Data collected from trial plots may not parallel those for farm-scale adoption of the program. Information can also be acquired from existing budgets from secondary sources, and benchmarking on these, expert opinion is elicited to estimate changes in the affected portions of the budget. While this is the least expensive, estimates by the experts may not be representative of the average farmer adopting the program.

2.2.2 Assessing Adoption: Scaling Up of Base Data

Expected yield increases, cost reductions and research costs derived from partial budgets can be combined with additional data on price changes (as well as the timing of these price changes), adoption estimates or projections, and with information on the responsiveness of supply and demand to price changes to obtain market-level economic effects.

Factors Affecting Adoption

While information on net returns with and without the technology or practice is available in the scale of plots, farms and communities for which experimental or survey data were collected, some scaling up of base data is needed. This is necessary to assess the overall impacts of adoption across the scale of analysis.

IPM adoption is largely influenced by the following types of characteristics (1) the technology itself; (2) farmer employing the technology or practice; (3) farm physical environment, and (4) farm institutional environment (*Feder et al. 1985*). Empirically, previous studies (*Fernandez-Cornejo et al., 1994; and Harper et al. 1990*) have found IPM adopters to often be younger and more educated. The timing of adoption is affected by farm size. Adoption is expected to take place earlier on larger farms than on smaller ones (*Fernandez-Cornejo et al. 1994*). The farm institutional environment also proves to be an important driving force in IPM adoption. For example, farmers in the Philippines who obtained loans from the land bank through their cooperatives were required to submit a farm plan that required pesticides. These pesticides, provided in kind to the farmers as part of the loan, had important ramifications for farmer incentives to adopt IPM practices (*Norton et al, 1999*).

While these four factors are each important in determining which farmers in what areas under what institutional arrangements will adopt a particular technology or IPM practice, discussion will usually focus first on the farm physical environment or spatial domains where new technologies are likely to have impacts.

Extrapolating Adoption Domains: Use of Agroecological Zones

Much of agricultural R&D is site-specific and knowledge of the agroecological factors that shape the various biophysical responses to a new technology (e.g. use of new cultivars or management practice) can substantially improve the estimate of the research-induced savings per unit cost of production used to calculate the benefits from research.

There are two general areas of application of agroecological analysis in research evaluation and priority setting of agricultural activities. In the first area, agroecological zones (AEZs) are used as a means of stratifying relatively homogenous research problem domains. In the second area, AEZs are used as a means of stratifying relatively homogenous research impact domains (*Wood and Pardey, 1997*). For example, the impact of grafting to control bacterial wilt in a particular rootstock can be assessed against all acreage allotted to that rootstock infected with the disease (problem domain), or it can be evaluated against all areas most likely to adopt the technology (impact domain) and saddled with the problem. In most ex-ante assessments, identifying potential technology spillovers by analyzing the spatial patterns of productivity and the physical production constraints that may help account for those patterns is important. Again, the degree of adoption is determined by physical production constraints as well as institutional factors. Thus, to extrapolate adoption domains, it is necessary to know to what extent may technologies developed in or for one area will be usable in, or adaptable for, other areas (*Wood, 1994*).

Crucial to agroecological analysis is the selection of variables that will be used to characterize AEZs. This set of variables will vary according to the research being evaluated and the role appropriated to ecology in that specific research. For example, understanding plant growth processes may suggest the use of a minimum set of variables that cover the influences of radiation, water availability, and soil nutrient status while studying land degradation processes imply the use of variables such as terrain, soil erodibility, rain energy and other land use or cover variables (*Wood and Pardey, 1997*). In a study conducted by *Debass* (*2000*), physiography, soil, land inundation and agro climate were used to delineate and define AEZs for which IPM CRSP activities in Bangladesh and Uganda may be transferable beyond the primary experimental sites. In Bangladesh, an altered schedule of hand weeding in cabbage production and Neem leaf powder as insectide for eggplants were assessed. In Uganda, the maize variety Longe-1 and seed dressing with Endosulfan for management of bean fly and root rot on beans were assessed.

Methods of Identifying Agroecological Space

There are three basic methods of characterizing agroecological space (*Wood, 1994; Wood and Pardey, 1997*):

(1) *Deductive Methods.* A priori, experts are asked to specify agroecological boundary criteria deemed appropriate for the research program. Consequently, the criteria are applied to a

spatial database of agroecological variables that result in the differentiation of ecological zones. Under this method, two subclasses of zones may be defined: (a) *generic zones*, and (b) *R&D-specific zones*. Generic zones are defined based on a general set of ecological variables relevant to a broad range of R&D associated with production systems and natural resource degradation hazards. When this set of ecological variables are broken down further and defined to suit a specific R&D targeted to different production systems or resource management practices, R&D specific zones are considered identified. Also, R&D specific zones are considered appropriate for research evaluation purposes. Generic zones are used by FAO, TAC/CGIAR while R&D specific zones are used by IFPRI.

(2) *Cluster Analysis.* Similar agroecological conditions are statistically grouped using cluster analysis and then experts are asked to assign clusters into classes appropriate to the research at hand.

(3) *Production Geography.* Also called the inductive method. Specific geographical areas having known research problems or expected to display similar responses to new technologies are characterized ecologically. This characterization is then used to identify similar ecological zones in other geographical areas.

Among the methods, the most practical and the easiest is the deductive method that defines R&D specific zones. In the deductive method, it is required, at the minimum, that one knows the agroecological factors relevant to the research program. On the other hand, cluster analysis and production geography entail some knowledge of the agroecological variables needed to delineate AEZs from one another and thus require more information.

2.2.3 Assessing Market and Trade Impacts

After (1) partial budgeting computations have been prepared, and (2) adoption domains in the form of either AEZs or problem domains have been identified, the results feed into an economic surplus model to assess the overall benefits of research. In this section we start with the basic commodity model of research benefits. This model is subsequently extended to the case where technology is transferred to or adopted by multiple regions within an economy. In enhancing the basic model to account for the identified AEZs, aggregation issues as well as various assumptions to make aggregation easier will be discussed.

Basic Economic Surplus Analysis

An economic approach to evaluating technology-oriented R&D starts with the basic model of research benefits for a specific commodity market. In Figure 2.1, S_0 is the supply function before a research-induced technological change and D_0 depicts the demand function. P_0 and Q_0 are the initial price and quantity, respectively. Any research that generates input saving or yield increasing technology reduces the unit cost of production, K and causes a shift down in the supply curve to S_1. This leads to an increase in both production and consumption to Q_1, and the market price falls to P_1.

As a result of the R&D, consumers are better off paying a lower price for the original quantity bought and further increasing the amount of commodity they are able to consume at the lower price. While producers receive a lower price per unit, those who adopt the new technology may still be better off because the unit costs of production, K per unit, have fallen by more than the fall in price.

Consumer surplus is equal to the area P_0abP_1 while producer surplus is equal to the area P_1bcd. Total benefits are measured as the sum of producer and consumer surplus and is approximated by the cost saving per unit multiplied by the initial quantity. Thus, the size of the market as suggested by the initial quantity as well as the size of the per unit cost of production savings are crucial factors in estimating the economic benefits from R&D.

Algebraically, these can be expressed as follows:

$$\Delta CS = P_0Q_0Z(1 + 0.5\ Z\eta) \tag{2.1}$$

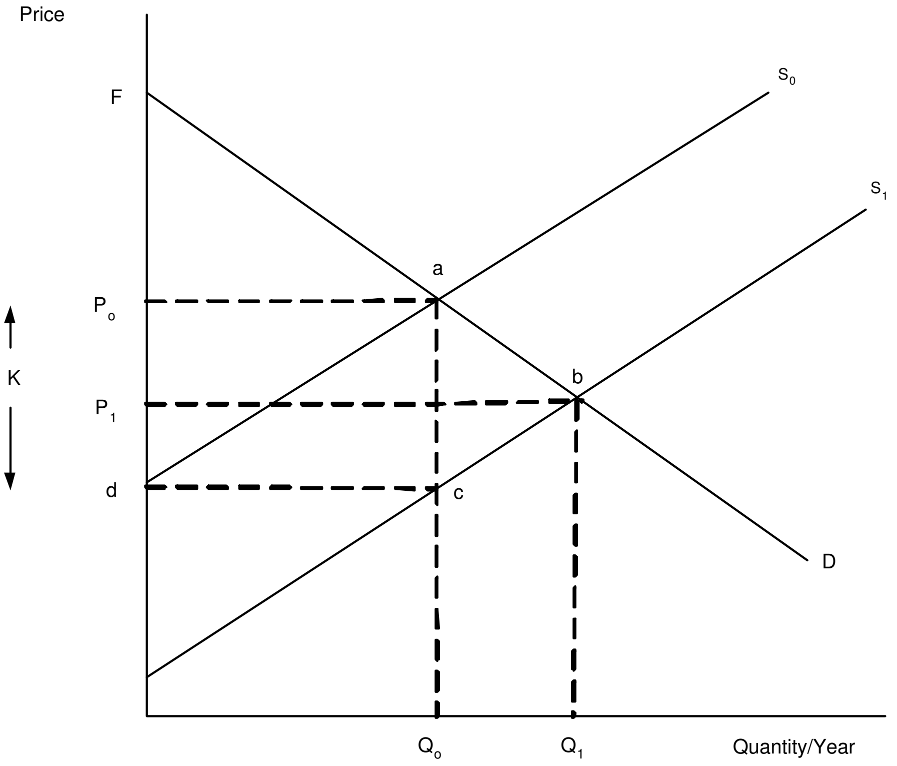
$$\Delta PS = P_0Q_0(K - Z)(1 + 0.5\ Z\eta) \tag{2.2}$$

$$\Delta TS = \Delta CS + \Delta PS = P_0Q_0K(1 + 0.5\ Z\eta) \tag{2.3}$$

where K is the vertical shift of the supply function as a proportion of the initial price (or the per-unit cost reduction referred to above), η is the absolute value of the elasticity of demand, ε is the elasticity of supply, and $Z = K\varepsilon/(\varepsilon + \eta)$ is the reduction in price, relative to the initial value, due to the supply shift.

A critical aspect of economic surplus analysis is the calculation or projection of the research-induced shift in the supply curve, K. Cost differences and adoption rates should be factored in as well as technological spillovers across regions.

Figure 2.1: Basic Economic Surplus Model



Spillovers of Research and Development: Extending the Basic Model

The standard economic surplus approach to research evaluation can be extended to account for multiple markets for a single commodity. In the absence of international trade, the closed economy model can be extended to accommodate interregional price and technology spillovers beyond the experimental sites. Price spillovers arise when a research-induced supply shift in one region generates a change in the price level faced by all other regions as this commodity is traded. When analyzed in an excess-supply, excess-demand framework, this occurs when the innovating region is a large region in trade.

Technological spillovers are usually such that a specific technology is transferred from one region to another in varying degrees, or a certain technology is made available for adoption to all regions at the same time but at differential rates. Unlike price spillovers, these spillovers induce corresponding supply shifts in other regions in addition to the supply shift in the innovating region. Thus, from the initial excess supply and excess demand situation, the excess supply shifts out and the excess demand curve shifts in and pushes prices further down.

General Multimarket Framework

In most cases, price spillovers are observed together with independent shifts in the supply and demand curves. This is best illustrated in the multimarket model detailed in *Alston, Norton and Pardey* (*1995*).

The model assumes that total quantity demanded and supplied are equal and prices are set competitively in the absence of transport costs across markets.

$$\text{Supply:} \quad Q_{s,i} = f_i(P_{s,i}, B_i) \tag{2.4}$$

$$\text{Demand:} \quad Q_{d,j} = g_j(P_{d,j}, A_j) \tag{2.5}$$

$$\text{Market Clearing:} \quad \sum_{i=1} Q_{s,i} = \sum_{j=1} Q_{d,j} \tag{2.6}$$

$$P_{s,i} = P_{d,i} = P_{s,j} = P_{d,j} = P \ \text{ for all } i \text{ and } j \tag{2.7}$$

where $Q_{s,i}$ is the quantity supplied, $P_{s,i}$ is the supply price, and B_i is a supply-shift variable for the ith group of suppliers; $Q_{d,j}$ is the quantity demanded, $P_{d,j}$ is the demand price, and A_i is a demand-shift variable for the jth group of demanders. (2.4) to (2.7) can be expressed in terms of relative changes and elasticities:

$$\text{Supply:} \quad E(Q_{s,i}) = \varepsilon_i[E(P_{s,i}) + \beta_i)] \tag{2.4'}$$

$$\text{Demand:} \quad E(Q_{d,j}) = -\eta_i[E(P_{d,j})\alpha_j)] \tag{2.5'}$$

$$\text{Market change:} \quad \textstyle\sum_{i=1} ss_i E(Q_{s,i}) = \sum_{j=1} ds_i E(Q_{d,j}) \tag{2.6'}$$

$$E(P_{s,i}) = E(P_{d,i}) = E(P_{s,j}) = E(P_{d,j}) = P \text{ for all } i \text{ and } j \tag{2.7'}$$

where E denotes relative changes (i.e., $E(Z) = dZ/Z = d\ln Z$), η_i is the absolute value of the elasticity of demand, and α_j is the vertical shift upwards of the jth demand function (relative to initial equilibrium demand price), ε_i is the elasticity of supply and β_i is the vertical shift down of the supply function (relative to the initial equilibrium supply price). β_i corresponds to K_i or the research-induced shift in the supply price in earlier discussions. [2.6'] spells out that the share-weighted sum of the relative changes in quantities supplied must equal to the share-weighted relative changes in the quantities demanded. The above set of equations only accommodates parallel shifts in the linear supply and demand functions whose slopes are unchanged even after a technological spillover. The relative change in price is:

$$E(P) = \sum_i (ds_i \alpha_i \eta_i - ss_i \beta_i \varepsilon_i)/(\sum_i ds_i \eta_i + ss_i \varepsilon_i) \tag{2.8}$$

Thus, a research-induced increase in supply in any one of the regions depresses the price in all regions. The extent of the shift depends on (1) the size of the shift, (2) relative importance of the region in trade, and (3) elasticities of supply and demand.

The price equation [2.8] can be used to solve for the endogenous relative changes in quantities as functions of the elasticities of supply and demand, shares and exogenous shift variables. Research benefits can be computed as:

$$\Delta CS_i = -P_{d,i} Q_{d,i} [E(P_{d,i}) - \alpha_i][1 + 0.5E(Q_{d,i})] \tag{2.9}$$

$$\Delta PS_j = P_{s,j} Q_{s,j} [E(P_{p,j}) + \beta_j][1 + 0.5E(Q_{s,j})] \tag{2.10}$$

$$\Delta TS = \sum_i \Delta CS_i + \sum_j \Delta PS_j \tag{2.11}$$

Calculating Supply Shifts

In the framework above, supply shifts or the β_is can be computed in different ways. If $\beta_{i,t}$ is the supply shift in region i, then the supply shift in region j is relative to $\beta_{i,t}$ and is equivalent to:

$$\beta_{j,t} = \theta_{ji} \beta_{i,t}$$

where θ_{ji} = the supply shift in j due to the research-induced supply shift in i ($\theta_{ii} = 1$).

More accurate estimates can be obtained if the probability of releasing a certain technology is taken into account in measuring $\beta_{i,t}$. Some studies have incorporated technology dissemination thresholds below which technologies are not adopted and net yield gains are not forthcoming (*Mills, 1997; Debass, 2000*). Expected net yield gains for region i is calculated as the product of two parameters: (a) probability of net yield gains exceeding the dissemination threshold, $\mathbf{Pr}(\beta_i > \beta_i*)$, and (b) the expected net yield gain conditional on exceeding the dissemination threshold, $E[\beta_i, |\beta_i, > \beta_i*]$. This product is also affected by the rate of adoption of technologies; for region i, $A_{i,t}$. A common adoption profile is trapezoidal with initially increasing adoption rate up to a maximum adoption (adoption lag) followed by the adoption plateau (maximum lag) and the declining adoption as the technology becomes obsolete (depreciation lag). Thus, $\beta_{i,t}$ for every period is calculated by:

$$\beta_{i,t} = \mathbf{Pr}(\beta_i > \beta_i*)E[\beta_i, |\beta_i > \beta_i*]A_{i,t}P_{i,o}/\varepsilon_i \tag{2.12}$$

where ε i is the supply elasticity of region i. $\beta_{i,t}$ varies over time due to the period specific to the adoption rate.

The Multimarket Framework: A Specific Model

(2.4)–(2.5) can be given specific linear functional forms:

$$\text{Supply:} \quad Q_{i,t} = \alpha_{i,t} + \beta_i PP_{i,t} \tag{2.13}$$

$$\text{Demand:} \quad C_{i,t} = \gamma_{i,t} + \delta_i PC_{i,t} \tag{2.14}$$

This holds for every region i in year t. The slopes are assumed to be constant through all the years for each region. The intercepts may grow over time to reflect growth in supply and demand owing to other factors other than research such as income growth. This exogenous growth in supply and demand are captured in the following equations:

$$\alpha_{i,t} = \alpha_{i,t-1} + \pi_i^Q Q_{i,t} \tag{2.15}$$

$$\gamma_{i,t} = \gamma_{i,t-1} + \pi_i^C C_{i,t} \tag{2.16}$$

where

π_i^C = growth rate of demand + income elasticity × income growth rate

π_i^Q = growth rate of supply

Regional Spillovers

If $k_{i,t}$ is the supply shift in region i, then the supply shift in region j is relative to $k_{i,t}$ and is equivalent to:

$$k_{j,t} = \theta_{ji} k_{i,t} \tag{2.17}$$

where θ_{ji} = the supply shift in j due to the research-induced supply shift in i ($\theta_{ii} = 1$). It is oftentimes assumed that the same trapezoidal adoption curve applies to every region. Note that there various other adoption profiles that are available.

Incorporating Effects of Research

$$\text{Supply:} \quad Q^*_{i,t} = \alpha^*_{i,t} + \beta_i PP^*_{i,t} \tag{2.18}$$

$$\text{Demand:} \quad C^*_{i,t} = \gamma_{i,t} + \delta_i PC^*_{i,t} \tag{2.19}$$

Welfare Decomposition

The change in producer and consumer surplus in zone i at time t are calculated as:

$$\Delta PS_{i,t} = (k_{i,t} + PP^*_{i,t} - PP_{i,t})[Q_{i,t} + 0.5(Q^*_{i,t} - Q_{i,t})] \tag{2.20}$$

$$\Delta CS_{i,t} = (PC_{i,t} - PC^*_{i,t})[C_{i,t} + 0.5(C^*_{i,t} - C_{i,t})] \tag{2.21}$$

$$\Delta TS_{i,t} = \sum_i \Delta CS_{i,t} + \sum_i \Delta PS_{i,t} \tag{2.22}$$

Market Clearing Conditions

The sum of the quantities supplied by all the regions equals the sum of the quantities demanded in each year, $Q_t = C_t$. Also, under free trade, the without-research and with-research market clearing prices are:

$$P_t = (\gamma_t - \alpha_t)/(\beta - \delta) \tag{2.23}$$

$$P^*_t = (\gamma_t \alpha^*_t)/(\beta - \delta) \tag{2.24}$$

No costs of trade or price bands are assumed.

Measuring Benefits

Once the level of detail or level of aggregation has been specified and relative changes in quantities have been projected throughout the life of the program or technology adoption together with various assumptions on the exogenous growth in demand and supply, research benefits can now be computed using the concepts of (a) net present value (NPV) and (b) internal rate of return (IRR). NPV computes the present value of a stream of benefits and costs through time back to the beginning of the base year using a discount rate. The IRR is that rate of return that will equate the present value of the expected flow of expenditures to the present value of the expected flow of benefits. These measures can be calculated for each zone or in total.

Data Requirements

The economic surplus measures build on basic data on yield and cost changes. They require, at the minimum, data on quantities produced and consumed, prices received and paid and the corresponding price elasticities of supply and demand for each identified group of producers and consumers. Supply and demand elasticities may be obtained from secondary sources; in fact, some rules of thumb exist for different commodities. Prices and quantities for benchmarking in ex-ante assessments are available from national statistical yearbooks. Estimates on probabilities of adoption and success of the research if adopted may be elicited from experts as well as information on relevant ecological and agroecological variables or characteristics of potential adopters. In some cases, spatial databases are available from government sources. Data on prices and quantities of exports and imports, population rate and income growth, government price policies are optional and may be required for some commodities. A discount rate for measuring benefits is essential.

2.2.4 Moving Beyond Economic Surplus to Other Human Welfare Indicators

There is a broad choice of welfare indicators that measure the impact (i.e., food security, nutrition, poverty, the environment and capacity strengthening) of agricultural research. And while most assessments portray consumer and producer surplus, there may be a need to further decompose the distribution of these outcomes to effectively influence policy. Thus, the problem is how to distribute the total surplus derived from an economic surplus model of a commodity as income changes among different socioeconomic groups, and how to translate these income changes into ultimate measures of changes in poverty. *In some cases, however, the economic surplus model as an intermediate step to determining final welfare impacts is skipped.* In some cases results derived from partial budgets can directly be inputted into *other* partial equilibrium models to calculate particular poverty and nutrition indicators.

But first let us proceed to review how the decomposition of total surplus is commonly done and what models are used. The focus is on poverty and nutritional impact indicators.

Examples of Poverty and Nutrition Indicators

The most common measure of poverty is the number of households whose per capita income falls below the required annual per capita income to provide for the minimum basic food and non-food requirements from which a profile of poverty incidence across and within income classes is derived. In some cases, once a poverty threshold is specified, it is more meaningful to compute for the poverty gap, the difference between the poverty threshold and the average income of households in a particular grouping. Nutritional indicators that stem from changes in food consumption due to supply shocks or changes in technology and other domestic policies include changes in average per capita calorie or protein intake/consumption. The amount of calorie intake, in turn, impacts on the percentage of malnourished preschool children (0 to 5 years old), another indicator for child malnutrition.

Roads to Welfare Indicators

There are various classes of analytical frameworks used in mapping out the poverty impacts of exogenous shocks, including policy changes. Some rely on social accounting matrices (SAM) while others create Computable General Equilibrium (CGE) models that build upon the initial SAM conditions.

The distinction between partial and general equilibrium lies in which variables are endogenous and which ones are considered exogenous. In a partial equilibrium framework, there is only one price that clears a particular market whereas in a general equilibrium setting, there is a vector of related prices that clears different markets. In lieu of this, partial equilibrium observes only one sector of the economy holding the other sectors in a standstill while general equilibrium considers all sectors within a model as changing all at the same time. Note, however, that this distinction is not clear-cut as even the most sophisticated models have to assume that some sectors do not change and yet are referred to as general equilibrium models. As such, most models used in decomposing distributional outcomes oftentimes are in-between.

Social Accounting Matrices (SAM)

SAMs have been used in various studies to map the impact of changes in the structure of production to the income distribution of factors of production and consequently onto household income distribution. The SAM provides a disaggregated and comprehensive picture of the socioeconomic system for a given year (Table 2.1). It is a square matrix in which each transactor or account has its own row and column. The payments or expenditures are listed in columns and the receipts in rows. As all expenditures must equal the total sum of receipts or income for all accounts, row sums must equal the column sums. Basically, there are six accounts in the SAM (*Thorbecke, 2001*):

(1) *Production activities* buy raw materials and intermediate goods and services to produce sectoral goods and services. Value is added to these intermediate goods that is distributed to the factors of production in terms of wages and rent to fixed factors. Also, production activities pay indirect taxes (value-added tax) to the government. Receipts of production activities come from sales to households, exports, and the government.

(2) *Factors of production* usually include labor and capital accounts. They receive income in the form of wages, rent, and net factor income received from abroad or from other regions from the sale of their services to production activities. These revenues are distributed to households as labor incomes and to companies as distributed profits. Sometimes a distinction is made between production activities and commodity accounts when a given production activity produced different commodities. Commodity accounts represent domestic product markets.

(3) *Institutions* include households that are typically further broken down by socioeconomic groups, companies, and the government. Households receive wages, other labor income, rent, interest and profits as well as transfers from the government and remittances from abroad. Households spend on consumption goods from the region or from abroad, pay income taxes with excess savings transferred to the capital account. Companies receive profits and transfers and pay taxes, and spend on transfers with their residual savings transferred into their capital account.

(4) The *government account* spends on buying the services of the production activities account. Transfers and subsidies to households and companies also form part of government expenditures and the remaining services are transferred to the capital account. The government receives tax revenues and current transfers from abroad as sources of income.

(5) The combined *capital account* collects savings from households, companies, government as well as foreign savings as income. These aggregate savings are then turned into investment.

(6) Transactions between domestic residents, and foreign residents are recorded in the *rest of the world accounts*. Receipts of this account include household consumption of imported final

Table 2.1: Basic Social Accounting Matrix (SAM)

		Expenditures							
		1	2a	2b	3	4	5	6	
		Factors of production	Institutions: Current accounts: Households	Institutions: Current accounts: Companies	Institutions: Current accounts: Government	Institutions: Combined capital	Production activities	Rest of the world combined account	Totals
Receipts	1 Factors of production						Value added payments to factors	Net factor income received from abroad	Incomes of the domestic factors of production
	2a Institutions: Current accounts: Households	Allocation of labour income to household	Current transfers between households	Profits distributed to domestic households	Current transfers to domestic households			Net non-factor incomes received from abroad	Incomes of the domestic institutions after transfers
	2b Institutions: Current accounts: Companies	Allocation of operating surplus to companies			Current transfers to domestic companies				
	3 Institutions: Current accounts: Government		Direct taxes on income and indirect taxes on current expenditures	Direct taxes on companies plus operating surplus of state enterprises		Indirect taxes on capital goods	Indirect taxes on inputs	Net non-factor incomes received plus indirect taxes on exports	
	4 Institutions: Combined capital account		Household savings	Undistributed profits after tax	Gov't current account surplus			Net capital rec'd from abroad	Aggregate savings
	5 Production activities		Household consumption expenditures on domestic goods		Gov't current expenditure	Investment expenditures on domestic goods	Raw material purchases of domestic goods	Exports	Aggregate demand-gross outputs
	6 Rest of the world combined account		Household consumption expenditures on imported goods			Imports of capital goods	Imports of raw materials		Imports
	Totals	Incomes of the domestic factors of production	Total outlay of households	Total outlay of companies	Total outlay of government	Aggregate investment	Total costs	Total foreign exchange receipts	

Source: Thorbecke (1988)

Table 2.2: Simplified SAM

		Expenditures				
		Endogenous Accounts			Exogenous	Totals
		Factors	Institutions (Households & Companies)	Production Activities	Sums of Other Accounts	
		1	2	3	4	5
Receipts		Endogenous Accounts				
Factors	1	0	0	T_{13}	x_1	y_1
Institutions (Households & companies)	2	T_{21}	T_{22}	0	x_2	y_2
Production Activities	3	0	T_{32}	T_{33}	x_3	y_3
		Exogenous Accounts				
Sums of other accounts	4	l'_1	l'_2	l'_3	t	y_x
Totals	5	y'_1	y'_2	y'_3	y'_x	

Source: Thorbecke (2002)

goods as well as imports of capital goods and raw materials. Expenditures of the rest of the world include income earned from exports and factor and non-factor income. The difference between total foreign exchange receipts and imports is the net capital received from abroad and foreign savings.

Use of SAM Multipliers (Thorbecke, Thorbecke & Jung)

The SAM framework can be used to simulate and estimate the effects of exogenous changes such demand adjustments that lead to movements in sectoral output. However, there is a caveat. It is assumed that there is excess capacity in that prices remain constant as well as expenditure propensities of endogenous accounts remain constant. While the use of SAM multipliers embodies the assumption that production activities, including agriculture, are demand-driven, some authors have managed to relegate agriculture as an exogenous account – agriculture being more supply-constrained than demand-driven in a village context (*Sabramanian and Sadoulet, 1990*).

Government, rest of the world and capital accounts are normally considered exogenous and the rest endogenous. Following this delineation, a simplified SAM appears in Table 2.2.

There are five endogenous transformations: (a) T_{13} is the matrix that allocates the value added by the various production activities into income of the factors of production, (b) T_{33} covers the requirements of intermediate inputs or the input-output transactions, (c) T_{32} is spending by various institutions on commodities or production activities that they consume, (d) T_{21} maps the factorial income distribution into household income distribution oftentimes by household groups, and (e) T_{22} shows inter-institutional transfers among different types of households or between households and companies.

Given this simplified schematic of the SAM, exogenous changes in the x's (exogenous accounts) generate changes in incomes of the endogenous accounts: (a) factor incomes, y_1, (b) institutional incomes, y_2, and (c) incomes of production activities, y_3 (*Thorbecke and Jung, 1996*). Exogenous changes such as increases in the demand for sectoral outputs are accompanied by increases in actual sectoral output.

By dividing any entry in any of the endogenous accounts by the column total (total income) in which the entry is found, we derive a measure for average expenditure propensity. Repeating the same thing to all the entries of the endogenous accounts generates a corresponding matrix of average expenditure propensities, A_n, for the endogenous part of the transaction matrix:

$$A_n = \begin{pmatrix} 0 & 0 & A_{13} \\ A_{21} & A_{22} & 0 \\ 0 & A_{32} & A_{33} \end{pmatrix} \tag{2.25}$$

From this we have each endogenous total income, y_n, as:

$$y_n = A_n y_n + x \tag{2.26}$$

Each row sum is just equal to the sum of the (1) product of the average expenditure propensity and the corresponding column sum, and (2) exogenous income, x. Solving for y_n yields:

$$y_n = (I - A_n) - 1\ x = Max \tag{2.27}$$

Max is the accounting multiplier matrix. Note, however, that this implies expenditure elasticities of one as the average expenditure propensities in A_n apply to any incremental injection into the economy. While this assumption can be maintained for all other elements of A_n, it does not make sense to uphold it when referring to the expenditure pattern of household groups, A_n. A way to escape this unrealistic assumption is to specify a matrix of marginal expenditure propensities, C_n, instead. As such:

$$C_{13} = A_{13}, \quad C_{33} = A_{33}, \quad C_{21} = A_{21}, \quad C_{22} = A_{22} \text{ but } C_{32} \neq A_{32}. \tag{2.28}$$

With marginal expenditure propensities, we can express changes in incomes (dy_n) resulting from changes in injections (dx):

$$dy_n = C_n dy_n + dx = (I - C_n) - 1 \ dx = M_c dx \tag{2.29}$$

M_c is called the fixed-price multiplier matrix (*Pyatt and Round, 1979*).

Change in Demand for and Output of Different Production Activities

From the partition of the matrix of marginal expenditure propensities, C_n:

$$C_n = \begin{bmatrix} 0 & 0 & C_{13} \\ C_{21} & C_{22} & 0 \\ 0 & C_{32} & C_{33} \end{bmatrix} \tag{2.30}$$

Corresponding changes in exogenous accounts are translated to changes in income:

$$dy_1 = C_{13} dy_3 + dx_1 \tag{2.31}$$

$$dy_2 = C_{21} dy_1 + C_{22} dy_2 + dx_2 \tag{2.32}$$

$$dy_3 = C_{32} dy_2 + C_{33} dy_3 + dx_3 \tag{2.33}$$

These yield:

$$dy_1 = C_{13} dy_3 + dx_1 \tag{2.34}$$

$$dy_2 = (I - C_{22})^{-1} C_{21} dy_1 + (I - C_{22})^{-1} dx_2 \tag{2.35}$$

$$dy_3 = (I - C_{33})^{-1} C_{32} dy_2 + (I - C_{33})^{-1} dx_3 \tag{2.36}$$

Following an exogenous change in demand for a given sectoral output (dx_3), the impact on the incomes of the different household groups (dy_2) is specified by that part of the fixed multiplier matrix that links production activities to household groups, M_{c23}. Any element of this matrix, say m_{ij}, shows the total direct and indirect effects of an increase of one unit in the demand for (and the output of) production activity j on the incremental incomes received by socioeconomic group i (*Thorbecke, 2002*).

Decomposing the Change: Distributional and Interdependency Effects

The magnitude of each element in the above matrix M_{c23}, which maps the impact of changes in production activities onto changes in household incomes can further be decomposed into two: a portion that represents distributional effects, and the other part embodies interdependency effects. Distributional effects are the *initial* effects of a change in output of the production activities on the incomes of various socioeconomic groups. Interdependency effects, on the other hand, represent the direct and indirect effects of spending and respending by a particular household group and other groups that benefited from the exogenous output injection. The greater the intersectoral linkages on the production side and the transfer linkages among household groups, the higher these effects. On the consumption side, the more consumers spend on domestic goods and the more diversified their consumption pattern, the higher the interdependency effects.

Suppose output of a given production activity is increased by one unit. This generates additional demand for intermediate inputs, which in turn, need other intermediate inputs to be produced. These rounds of effects are captured by matrix $(I - C_{33})^{-1}$. Similarly, demand for primary inputs will also increase. This demand for factors of production is carried by C_{13}. C_{21} shows the flow of these additional incomes to the households with the corresponding factors needed. Lastly, income transfers between and among different socioeconomic groups are reflected in $(I - C_{22})^{-1}$. The total *distributional effects* are:

$$D = (I - C_{22})^{-1} C_{21} C_{13} (I - C_{33})^{-1} \tag{2.37}$$

and can be broken down as $D = D_3 D_2 D_1$

$D_3 = (I - C_{22})^{-1}$	or the transfer effects (inter-household transfers)
$D_2 = C_{21} C_{13}$	or the direct distributional effects (factor ownership to households)
$D_1 = (I - C_{33})^{-1}$	or the inter-sectoral production effects (input-output)

As the initial impact of the change in sectoral output is translated into incremental incomes captured by the households, these, in turn, generate additional demand for which attendant output is obtained. This generates another indirect flow of incomes for the poor as a result of a series of spending and respending. Decomposing each element, say m_{ij}, of M_{c23} into two factors:

$$M_{ij} = r_{ij} d_{ij} \tag{2.38}$$

and with d_{ij} as the distributional effects:

$$m_{ij} = r_{ij}d_{ij} = r_{ij}d_{3ij}d_{2ij}d_{1ij} \tag{2.39}$$

Recall that $dy_2 = M_{c23}dx_3$, and suppose dy_{2i} is an element of vector dy_2, and dx_{3j} is an element of vector dx_3. Then

$$dy_{2i} = m_{ij}dx_{3j} = r_{ij}d_{3ij}d_{2ij}d_{1ij}dx_{3j} \tag{2.40}$$

Treating Agricultural Sectors as Exogenous

All traditional SAM models operate behind the assumption that all production activities are endogenous and that any increase in demand from the exogenous accounts are met by adjustments in production. Moreover, no price adjustments occur, only quantity adjustments. Also, the production technology is assumed to be unaltered.

In the case of agriculture, some authors have purported that agriculture is supply-constrained rather than demand-driven in a village context. This assumption, if accommodated within the SAM framework, requires the modification of the traditional multipliers used. *Subramanian and Sadoulet* (*1990*), in studying the effect of changes in technology and of weather-induced fluctuations in agricultural output on total output, employment and income distribution in a village in India, treated the agricultural sectors as exogenous activities. Unlike the traditional SAM, a different closure was specified for the model:

(1) For commodities produced by the now exogenous agricultural sectors, the exports played the role of an adjuster such that exports adjust to compensate for the difference between the increase in the exogenously given supplies and the amount endogenously absorbed for domestic use. For example, if supply remains unchanged and domestic use increases, exports fall. Conversely, supply increases are easily translated to increases exports.

(2) Government services are exogenous and the governments output is fixed. All entries in the rest of the world account are exogenous since a change in the level of production in the village economy should not affect them.

The traditional SAM was modified as:

	endogenous	*exogenous*
endogenous	$\Delta N = A_n \Delta\widehat{y_n}$	$\Delta X_1 \Delta X_2$
exogenous	$\Delta L_1 = A_{i1}\Delta\widehat{y_n}$	$\Delta R_{11}\Delta R_{12}$
	ΔL_2	$\Delta R_{21}\Delta R_{22}$

It contains n endogenous and $m+2$ exogenous accounts - m exogenous activities plus rest of the world and government services accounts in ΔX_1, ΔL_1 and ΔR_{11}. The rest are exogenous accounts. The coefficient matrices A_n, A_{l1} and A_{l2} (for block ΔL_2) are the usual matrices of marginal expenditure propensities. $\Delta R_{11} = \Delta R_{21} = \Delta R_{22} = 0$ as there are no activities between these entries. Imports and payments to rest-of-India, ΔL_1 are endogenously determined using A_{l1}. Thus, a change in the exogenous accounts is traced in three matrices: (a) change in the use of inputs and factors, ΔX_2, (b) change in taxes to the rest of India, ΔR_{12}, and (c) the change in the commodity supplies by these activities, ΔL_2.

Conditions for equality of row and column sums for the three sets of accounts are specified as:

$$\Delta N i_n + \Delta X_1 i_2 + \Delta X_2 i_m = \Delta N' i_n + \Delta L_1' i_2 + \Delta L_2' i_m \tag{2.41}$$

$$\Delta L_1 i_n + \Delta R_{12} i_m = \Delta X_1' i_n \tag{2.42}$$

$$\Delta L_2 i_n + \Delta X_2' i_n = \Delta R_{12}' i_2 \tag{2.43}$$

i_k is a vector of k ones. (3) is satisfied as for each exogenous activity, the change in total commodity supply equals the change in output. (2) balances the government and the rest of India accounts in the aggregate. After some operations, (1) can be expressed as:

$$(I - A_n)\Delta y_n = \Delta x_1 + \Delta x_2 - (\Delta l_2 - \widehat{a_2}\Delta y_n) \tag{2.44}$$

where

$\Delta x_i = \Delta X_i i_2$	$=$	row sum vector for ΔX_i
$\Delta l_2 = \Delta L_2' i_m$	$=$	transposed column sum vector for ΔL_2
$a_2 = A_{12}' i_m$	$=$	transposed column vector for A_{12}
$\widehat{a_2}$	$=$	diagonal matrix, the diagonal elements of which are the elements of a_2
$(\Delta l_2 - \widehat{a_2}\Delta y_n)$	$=$	difference between exogenous changes in commodity supplies from exogenous activities and changes in the supply of these commodities required to equilibrate supply and demand

Note that $(\Delta l_2 - \widehat{a_2}\Delta y_n)$ as the change in commodity exports, Δx_1, balances the commodity accounts.

Partitioning $\Delta y_n'$ into $\Delta y_1' \Delta y_2'$ where Δy_2 is the change in commodity supplies from the exogenous activities. Partitioning Δl_2 and $\widehat{a_2}$ also conforming the partition of Δx_1 to conform to Δy_n:

$$\Delta l_2 - \widehat{a_2}\Delta y_n = \begin{pmatrix} 0 \\ \Delta l_{22} \end{pmatrix} - \begin{pmatrix} 0 & 0 \\ 0 & \widehat{a_{22}} \end{pmatrix} \begin{pmatrix} \Delta y_1 \\ \Delta y_2 \end{pmatrix} = 0 \tag{2.45}$$

Note that the nonzero elements of a_2 and Δl_2 correspond to the commodity accounts. Thus, $\Delta y_2 = \widehat{a_{22}}^{-1}\Delta l_{22}$. Equation (4) can now be written as

$$(I - A_n) \begin{pmatrix} \Delta y_1 \\ \Delta y_2 \end{pmatrix} = \begin{pmatrix} \Delta x_{11} \\ \Delta x_{12} \end{pmatrix} + \Delta x_2 \tag{2.46}$$

where Δx_2, Δx_{11}, Δy_2 are all known; the first of which is the vector of injections from exogenous activities, the second is the vector of injections from rest of India account into the endogenous accounts and the third is the total change in supply for the commodities produced by the exogenous activities. The rest of the unknowns can be solved accordingly.

Portraying agriculture as supply-constrained instead of demand-driven and treating agricultural activities exogenous in a village SAM multiplier model, *Subramanian and Sadoulet* were able to simulate the effects of a 10 percent weather-induced decline in agricultural output on the incomes of different household groups. Changes in income levels and distribution were shown to be strongly dependent on how factor and intermediate use in agriculture respond to fluctuations in output under different scenarios.

Data Requirements

SAMs are area-specific (i.e. village, region, country) and the more disaggregated the desired structure, the more extensive the data required to come up with one. The first basis of SAMs should be the National Income Accounts of a national economy. Creating SAMs entail the compilation of two sets of accounts at the very least (if required in a short period of time): commodity balances and outlays and incomes of institutions to include expenditure and incomes of households. I-O tables can be used to come up with commodity balances; other sources include census of production, agricultural statistics and external trade statistics. Outlays and incomes of institutions can be derived from household surveys. If these household surveys contain labor force characteristics of household members, then data from labor force surveys can be used to map factor incomes into production activities and households. Employment statistics can be used to balance factor income receipts and payments. Central bank statistics are needed for the flow of funds accounts and other financial data. Government accounts can be sourced from government surveys and statistical yearbooks (*Hayden & Round, 1982*).

Linkage with the Multimarket Economic Surplus Framework

The sum of the quantities supplied by all the regions as derived from the multimarket framework with research spillovers can be used to calculate the actual change in aggregate supply of a commodity. Once this actual change is determined relative to the initial quantity supplied of this commodity, then this is specified as the amount of the exogenous change in agricultural output transmitted through the SAM multiplier model. This can be done for each year to better reflect output fluctuations that reflect the rate of adoption of certain technological or productivity-related improvements.

Thus, relative changes in quantities projected throughout the lifetime of a project, and aggregated for all regions for which there is technology adoption (together with assumptions on exogenous growth in demand and supply) provide the basis for the amount of the exogenous change in agricultural output or commodity output injected into the SAM framework with supply constraints. These quantities link the multimarket model and the SAM. Consequently, changes in income levels and in their distribution are determined.

In a multi-market model using economic surplus measures, price changes reflect unit cost changes that provide the impetus for changes in quantities supplied and demanded. An equilibrium price is computed that sets quantity demanded equal to quantity supplied. This equilibrium price is based on these unit cost changes as well as assumptions on supply and demand elasticities together with actual data on production and consumption shares for each region. The resulting equilibrium price is then imputed into the computation of the change in quantities supplied and demanded. When these derived quantities are carried over to the SAM multiplier framework, no further rounds of price changes are admitted. In fact, SAM multipliers do not take into account substitution effects.

Computable General Equilibrium Models (CGE): An Example

Unlike the SAM, CGE models are price responsive and all accounts are endogenous. The agents exhibit certain behavior reflected in systems of equations under specific assumptions. Producers maximize profit from which factor demands and quantity of output are derived on the basis of prices. Producers also decide the allocation of their output to domestic and external markets. Households maximize utility given their budget constraint, from which levels of consumption are derived as a function of income and prices. Other accounts such as government expenditures, however, are set constant and do not respond to prices. Likewise, tax payments, savings and distribution of factor incomes to various institutions are given.

Market clearing conditions are imposed on the product, factor and foreign exchange markets in that supplies of commodities, factors and foreign exchange must equal demand for these accounts. Equilibrium is achieved with price adjustments until equilibrium commodity prices, factor prices and exchange rate are determined within the system.

A simple CGE model is presented by *Resosudarmo* (*2000*). Resosudarmo's model analyzes the overall impact of the integrated food crop pest management program (IPM) on economic growth and on household incomes for various socioeconomic groups in Indonesia. The logical structure of the model runs from the direct impact of IPM that reduces the use of pesticides by farmers to the second string of effect that increases output due to IPM practices plus lower use of pesticides. Reduced use of pesticides consequently lowers pesticide-related illnesses that, in turn, increase farmer productivity with less man-days lost in production. Decreased pesticide-related illnesses also imply lower health costs and enables households to spend money on other goods, like food. A total of 9 equations are estimated.

Production Block

Equations (2.47) to (2.52) pertain to the production block:

$$VA_i = HE_i \cdot \alpha \cdot \left(\sum_f \beta^v_{i,f} \cdot FACDEM_{i,f}^{-\rho^v_i} \right)^{-\frac{1}{\rho^v_i}} \tag{2.47}$$

$$HE_i = \left(1 - \frac{RAD_i}{DA_i}\right) \quad \forall\ i \in \text{ crop sectors} \tag{2.48}$$

$$HE_i = 1 \quad \forall\ i \notin \text{ crop sectors} \tag{2.49}$$

$$X_i = \alpha_i^x \cdot \left(\beta_i^x \cdot IN_i^{-\rho_i^x} + (1-\beta_i^x) \cdot VA_i^{-\rho_i^x}\right)^{-\frac{1}{\rho_i^x}} \tag{2.50}$$

$$\begin{aligned} \alpha_{RICE}^{x,t} &= \bar{\alpha}_{RICE}^{x} \cdot \left(1 - \frac{IPMFARM^t}{FACDEM_{RICE,AGLAB}^t}\right)\gamma_{NOIPM} \\ &+ \bar{\alpha}_{RICE}^{x} \cdot \left(\frac{IPMFARM^t}{FACDEM_{RICE,AGLAB}^t}\right)\gamma_{IPM} \end{aligned} \tag{2.51}$$

$$\begin{aligned} iomi_{PEST,RICE}^{t} &= \overline{iomi}_{PEST,RICE} \cdot \left(1 - \frac{IPMFARM^t}{FACDEM_{RICE,AGLAB}^t}\right) \\ &+ \overline{iomi}_{PEST,RICE} \cdot \left(\frac{IPMFARM^t}{FACDEM_{RICE,AGLAB}^t}\right) \cdot 0.44 \end{aligned} \tag{2.52}$$

where:

i = index for production sectors

VA_i = value-added for sector i

HE_i = impact of human pesticide-related illness on the value-added production activity

$FACDEM_{i,f}$ = demand for factor input f in sector i

RAD_i = number of man-days lost caused by pesticide-related illness

DA_i = number of man-days available if no pesticide-related illness occur

X_i = gross domestic sectoral outputs

IN_i = composite intermediate inputs

γ_{IPM} = 1.10. IPM farmers are 10% more efficient than non-IPM

$\hat{\alpha}_{RICE}^{x}$ = initial shift parameter of rice sectoral production

$\alpha_{RICE}^{x,t}$ = shift parameter of rice sectoral production in year t

$IPMFARM^t$ = number of IPM farmers in year t

$FACDEM_{RICE,AGLAB}^t$ = total number of rice farmers in year t

0.44 = IPM farmers able to reduce pesticide use by 56%

$\overline{iomi}_{PEST,RICE}$ = initial input-output coefficient of pesticide use

$iomi_{PEST,RICE}^{t}$ = input-output coefficient of pesticide use in year t

Note that factor inputs are expressed as a constant elasticity of substitution (CES) function.

Consumption Block

Each household is a utility maximizer under a Cobb-Douglas function (except for goods related to health treatments of pesticide-related illnesses) subject to its budget constraint.

$$U_k = \alpha_k \cdot \prod_{i \neq aph} (HCD_{i,k})^{chs_{i,h}}; \quad \sum_{i \neq aph} chs_{i,h} = 1 \tag{2.53}$$

subject to:

$$\sum_{i \neq aph} PQ_i \cdot HCD_{i,h} \leq YH_h - HTAX_h - HSAV_h - CDHE_h - HHTR_h \quad (2.54)$$

where:

h	=	index for household groups
aph	=	index for health services consumed by households that experience pesticide-related illness
YH_h	=	income of household h
PQ_i	=	price of commodity i
$HTAX_h$	=	income taxes
$HSVA_h$	=	household savings
$HHTR_h$	=	net household transfers
$CDHE_h$	=	health costs to recover from pesticide-related illnesses

Amount of Health Spending by Households

The amount of health spending depends on the number of cases of pesticide-related illnesses that occur:

$$PESHLT_{ag,ph} = apesht_{ag,ph} \cdot iomi_{PEST,ag} \cdot IN_{ag} \cdot R(AGLAB) \quad (2.55)$$

where:

ag	=	index for agricultural sectors
ph	=	index for pesticide-related illnesses
$PESHLT_{ag,ph}$	=	number of pesticide-related illnesses
$apesht_{ag,ph}$	=	pesticide-health coefficient
$iomi_{PEST,ag} \cdot IN_{ag}$	=	amount of pesticide used in agricultural sector
$R(AGLAB)$	=	ratio between agricultural labor in any simulation and in a benchmark case

Investment Block

Government and savings are the sources of new capital investments that add onto existing capital carried over from the previous period minus depreciated capital:

$$FACDEM^{t+1}_{i,CAPITAL} = FACDEM^{t}_{i,CAPITAL} \cdot (1 - depr_i) + DK^t_i \quad (2.56)$$

where:

$depr_i$	=	depreciation rate
DK_i^t	=	new capital invested in year t

The above model was used to simulate the impact of increased implementation of IPM through increased numbers of IPM farmers working through the systems of equations.

Data Requirements

Data on value-added, intermediate inputs, other structure of production, income and consumption can be derived from complete social accounting matrices and input-output tables. Factor inputs need to be classified in such a way that agricultural labor can be distinguished from other types of labor such as manual-clerical or professional, among others. Different economies would have different types of classification. Likewise, household classes need to be divided in such a way as to segregate agricultural from non-agricultural employees. The former should further be divided into small, medium, or large farmers according to the amount of land owned. Household classes can also be classified as rural non-labor, rural low income, rural high income, urban non-labor, urban low income, urban high income. The number of pesticide-related illnesses may be sourced from secondary sources of information as well as past simulations.

The food crop sector can further be partitioned into specific crops such as rice, bean, corn, tuber, among others. Pesticide production can be teased from production activities, usually under the chemical and base metal sector.

Linkage with the Multimarket Economic Surplus Framework

Under the production block of this CGE model, IPM farmers are distinguished from non-IPM farmers. For a particular commodity sector, farmers who implement IPM can increase their yields above those of non-IPM implementers. Though this is the distinction in Resosudarmo's model, IPM adoption is usually a matter of degree. To represent this increase in yields, a shift parameter of the commodity production function that is a function of the number of farmers who adopt IPM is estimated as shown in *Equation (2.50)* under the production block. In this equation, there is an initial shift parameter of the commodity production and this is scaled up by the amount that IPM farmers are more efficient than non-IPM farmers. Using the with-research quantities derived from the multimarket model throughout the lifetime of the technology or project and comparing these quantities under the without-research quantities, a more accurate scaling factor can be used for each year. This time, technology adoption profiles are taken into account. The initial shift parameter of the commodity production can also be linked to the unit cost reductions incurred by implementing IPM. In short, they can be linked to the supply shifts calculated in the economic surplus framework.

Sector Models: Example: IFPRIs IMPACT Model

This methodology makes use of the results of most ex-ante assessments to project the time path of yield growth that feeds into the supply component of the model. The IMPACT model is a methodology for analyzing different scenarios for global food demand, supply and trade. It consists of 36 countries and regions that account for almost all of the worlds food production and consumption, and 16 commodities. These include cereals, soybeans, roots and tubers, meats, milk, eggs, among others. A set of regional sub-models or countries is specified that are linked through trade. For each country block, supply, demand and prices for agricultural commodities are determined. A system of supply and demand elasticities is incorporated into a series of linear and nonlinear equations to approximate the underlying production and demand functions.

For each country block, demand projections emanate from data on urban growth and changes in food habits (i.e., demand elasticities) as well as population projections. Supply estimates are a function of area elasticities with respect to crop prices, yield elasticities with respect to crop, labor and capital prices and area and yield growth rates. Domestic prices are a function of world prices, adjusted by the effects of price policies and marketing margin. Domestic supply and demand projections are then juxtaposed to determine net trade carried out by the country. The world price is then that price that clears the global market.

Crop Production

Crop production is a composite of (1) area, and (2) yield response functions. Harvested area is determined by the crops own price, price of other competing crops, and the projected rate of exogenous (non-price) growth trend in harvested area. This exogenous trend pertains to changes in the area harvested such as expansion due to population growth and contraction due to soil degradation or land conversion from agricultural to non-agricultural owed to industrialization. Yield is a function of commodity price, price of capital and labor and a projected exogenous trend reflecting technological change. Domestic annual production is then estimated as the product of these two factors: area and yield. Sources of growth accounted for in projecting trend factors are public research, private sector agriculturally-related R&D, agricultural extension, markets, infrastructure and irrigation. As such, supply projections induced by technological transfer or research that are derived from the economic surplus approach aid in projecting the time path of non-price yield trend.

$$\text{Area response:} \quad AC_{tni} = \alpha_{tni} \times (PS_{tni})^{\varepsilon_{iin}} \times \prod_{j \neq i} (PS_{tni})^{\varepsilon_{ijn}} \times (1 + gA_{tni}) \tag{2.57}$$

$$\text{Yield response:} \quad YC_{tni} = \beta_{tni} \times (PS_{tni})^{\gamma_{ikn}} \times (1 + gCY_{tni}) \tag{2.58}$$

$$\text{Production:} \quad QS_{tni} = AC_{tni} \times YC_{tni^{jn}} \tag{2.59}$$

where

AC	=	crop area
YC	=	crop yield
QS	=	quantity produced
PS	=	effective producer price
PF	=	price of factor or input k
$\prod$	=	product operator
i, j	=	commodity indices specific for crops
k	=	inputs such as labor and capital
n	=	country index
t	=	time index
gA	=	growth rate of crop area
gCY	=	growth rate of crop yield
ε	=	area price elasticity
γ	=	yield price elasticity
α	=	crop area intercept
β	=	crop yield intercept

Livestock Production

Total population for a livestock is a function of its own price, price of competing commodities, prices of feeds considered as intermediate input, and a trend variable linked to the growth of livestock slaughtered. Unlike crop production, livestock yield only considers the effects of expected developments in technology. Total production is the number of slaughtered animals multiplied by the yield per head.

Number slaughtered:

$$AL_{tni} = \alpha_{tni} \times (PS_{tni})^{\varepsilon_{iin}} \times \prod_{j \neq i} (PS_{tnj})^{\varepsilon_{ijn}} \times \prod_{j \neq i} (PI_{tnb})^{\gamma_{ibn}} \times (1 + gSL_{tni}) \tag{2.60}$$

Yield:

$$YL_{tni} = (1 + gLY_{tni}) \times YL_{t-1,ni} \tag{2.61}$$

Production:

$$QS_{tni} = AL_{tni} \times YL_{tni} \tag{2.62}$$

where

AL	=	number of slaughtered livestock
YL	=	livestock yield per head
PI	=	price of intermediate (feed) inputs
i, j	=	commodity indices specific for livestock
b	=	commodity index specific for feed crops
gSL	=	growth rate of number of slaughtered livestock
gYL	=	growth rate of livestock yield
ε	=	price elasticity of number of slaughtered livestock
γ	=	feed price elasticity
α	=	intercept of number of slaughtered livestock

Demand Functions

The total demand for food, feed and other uses is the domestic demand for a commodity. Food demand is a function of (a) the price of the commodity, (b) prices of other competing commodities, (c) per capita income, and (d) total population. Per capita income and population grow annually following country-specific population and income growth rates. Feed demand is derived from changes in livestock production, fed ratios, and own- and cross-price effects of feed crops as well as a technology parameter that reflects improvements in feeding efficiencies. Demand for other uses is a proportion of food and feed demand. As livestock is used chiefly for food, demand for livestock contains only food demand.

Demand for food:

$$QF_{tni} = \alpha_{tni} \times (PD_{tni})^{\varepsilon_{iin}} \times \prod_{j \neq i} (PD_{tnj})^{\varepsilon_{ijn}} \times (INC_{tn})^{\eta_{in}} \times POP_{tn} \tag{2.63}$$

where

$$INC_{tn} = INC_{tn-1,ni} \times (1 + gI_{tn}) \tag{2.64}$$

$$POP_{tn} = POP_{tn-1,ni} \times (1 + gP_{tn}) \tag{2.65}$$

Demand for feed:

$$QL_{tnb} = \beta_{tnb} \times \sum (QS_{tnl} \times FR_{tnbl}) \times (PI_{tnb})^{\gamma_{bn}} \tag{2.66}$$

Demand for other uses:

$$QE_{tni} = QE_{t-1,ni} \times \frac{(QF_{tni} + QL_{tni})}{(QF_{t-1,ni} + QL_{t-1,ni})} \tag{2.67}$$

Total demand:

$$QD_{tni} = QF_{tni} + QL_{tni} + QE_{tni} \tag{2.68}$$

where

QD = total demand

QF = demand for food

QL = derived demand for feed

QE = demand for other uses

PD = the effective consumer price

INC = per capita income

POP = total poplulation

FR = feed ratio

FE = feed efficiency improvement

PI = the effective intermediate (feed) price

i, j = commodity indices specific for all commodities

l = commodity index specific for livestock

b, o = commodity indices specific for livestock

gI = income growth rate

gP = population growth rate

ε = price elasticity of food demand

γ = price elasticity of feed demand

η = income elasticity of food demand

α = food demand intercept

β = feed demand intercept

Prices

Prices are determined within the model. World prices adjusted for the effect of price policies (in terms of producer subsidy equivalent (PSE), consumer subsidy equivalent (CSE), and the marketing margin (MI)) determine domestic prices. The implicit level of taxation borne by producers or consumers relative to world prices is measured by PSEs and CSEs. At the same time, they account for the wedge between domestic and world prices. Transport and marketing costs are captured in the MI. PSEs, CSEs and MI are all fractions or percentages of the world price. Removing MI from and adding the PSE value to the world price, producer prices are obtained. On the other hand, removing the CSE value from and adding MI to the world price, consumer prices are calculated. As wholesale instead of retail prices are used, the MI of intermediate prices is smaller. Otherwise, intermediate prices are similarly computed as consumer prices.

Producer prices:

$$PS_{tni} = [PW_i(1 - MI_{tni})](1 + PSE_{tni}) \tag{2.69}$$

Consumer prices:

$$PD_{tni} = [PW_i(1 + MI_{tni}](1 - CSE_{tni}) \tag{2.70}$$

Intermediate (feed) prices:

$$PI_{tni} = [PW_i(1 + 0.5MI_{tni}](1 - CSE_{tni}) \tag{2.71}$$

where

PW = the world price of the commodity
MI = marketing margin
PSE = producer subsidy equivalent
CSE = consumer subsidy equivalent
i, j = commodity indices specific for all commodities

International Trade Linkage

Each regional model which contains its own supply and demand projections and can either be net exporters or net importers are linked to each other through trade. Changes in stock are computed at the average 1996-98 average levels to represent the value for the 1997 base year. As such, production and demand values are not equal in the base year. Stock changes in the base year are gradually diminished during the first three years of the projections period to achieve long-run equilibrium so that supply will equal demand with no annual changes in stocks.

Net trade:

$$QT_{tni} = QS_{tni} - QD_{tni} \tag{2.72}$$

where
QT = volume of trade
QS = domestic supply of the commodity
QD = domestic demand of the commodity
i = commodity index specific for all commodities

Solving the Equilibrium Condition

After net trade of all sub-regions or countries in the system has been computed, the sum of all net trades is obtained which then gives rise to the world market price. The sum of net trade is then minimized using the GAMS procedure to seek a world market price for a commodity that satisfies the equation:

$$\sum_n QT_{tni} = 0 \tag{2.73}$$

If world trade does not balance, such that the sum of world exports is not equal to the sum of world imports, the world price will continue to adjust. Each adjustment is passed back to the effective consumer and producer prices through the price transmission equations. These changes in domestic prices, in turn, affect commodity supply and demand. The adjustment process ends when world trade balance is achieved.

Demand Changes Impact on Malnutrition

Changes in domestic price that arise from adjustments in the world equilibrium prices directly affect demand projections for each commodity. These projections then impact on the amount of kilocalorie demand projections for each sub-region or country in the system. These kilocalorie demand projections are inputs to the determination of the percentage and number of malnourished preschool children (0 to 5 years).

To project the percentage of malnourished children, the functional relationship below is estimated:

$$MAL = -25.24 * \ln(KCAL_t) - 71.76\ LFEXPRAT_t - 0.22\ SCH_t - 0.08\ WATER_t \tag{2.74}$$

where

MAL	=	percentage of malnourished children
$KCAL$	=	per capita kilocalorie availability
$LFEXPRAT$	=	total female to male life expectancy at birth
SCH	=	total female enrollment in secondary education (any age group) as a percentage of the female age-group corresponding to national regulations for secondary education
$WATER$	=	percentage of population with access to safe water

Projected per capita calorie consumption (KCAL) has two components. The first one is derived from commodities included in the model. These are computed by converting projected per capita food consumption of commodities included in the model. 1997 per capita food consumption is used as a benchmark for each country expressed in kilocalories per commodity. The second one consists of calories from commodities outside of the model. The kilocalorie contribution is projected using the base year kilocalorie contribution and the specified income elasticity of demand for calories from the remaining commodities. Projected life expectancy ratios, female enrollment rates, and percentage of population with access to safe water are based on country-level trends accounting for projected investment levels and diminishing returns as prevalence rates improve.

The percentage of malnourished children is then applied to the projected population of children 0 to 5 years to compute the number of malnourished children:

$$NMAL_t = MAL_t \times POP5_t \tag{2.75}$$

where

$NMAL$ = number of malnourished children, and

$POP5$ = number of children 0 to 5 years old in the population

Data Requirements

Supply and demand data are sourced from the FAOSTAT database (www.fao.org). The United Nations database can be used for population data. Elasticities and growth rates can be obtained from literature reviews and expert estimates. Most prices come from the World Bank publication *Global Commodity Markets: A Comprehensive Review and Price Forecast (World Bank, 2000).* Other sources of price data include FAO, and USDAs National Agricultural Statistical Service (NASS). The OECD also provides some measure of PSEs and CSEs.

The World Health Organizations Global Database on Child Growth and Malnutrition (*WHO, 1997*) supplemented by the *World Development Indicators (World Bank)* provide data on prevalence of child malnutirition. Calorie availability can be sourced from FAO FAOSTAT database; other human development indicators also come from World Development Indicators and UNESCO UNESCOSTAT database.

Linkage with the Multimarket Economic Surplus Framework

Yield in the IMPACT model is a function of commodity price, price of capital and labor and a projected exogenous trend reflecting technological change. Sources of growth accounted for in projecting trend factors are public research, private sector agriculturally-related R&D, agricultural extension, markets, infrastructure and irrigation. As such, supply projections induced by technological transfer or research that are derived from the economic surplus approach aid in projecting the time path of this exogenous, non-price yield trend.

Another Partial Equilibrium Model: *Tun and Yetley (1985)*

Apart from the class of general equilibrium models, various simple models with the texture of partial equilibrium are also used. More often than not, these models require minimum data and simple regression techniques. Such is a methodology developed by *Tun and Yetley (1985)* to assess the effects of food supply shocks on consumption in developing countries.

Effects of Food Supply Shocks on Consumption

The method proceeds in two stages. In the first stage, the idea is to compute the percentage change in the quantity of any food or combination of foods and to translate these to expected percentage changes in the price of each food using national aggregate data. The rationale behind this is that all additional quantity placed on the market, the appropriate elasticity to use in relating prices and quantities are those in the national aggregate matrix since all consumer groups face the same market. In the second stage, various elasticities specific to various consumer groups as well as the percentage price changes derived in the first stage are used to obtain the corresponding change in quantities for the consumer groups. These are then converted to calories or grams of protein consumed. This procedure works under the following assumptions: (1) increased supply of food commodities are distributed through a competitive market system, (2) consumer disposable income remains constant, and (3) demand structure stays the same.

The quantity of food purchased is a function of its own price, prices of other goods, and the buyers income. In equation form:

$$Q_{ih} = f(P_i, P_j, P_{j+1}, \ldots, P_k, Y_k) \tag{2.76}$$

where

Q_{ih} = quantity of the ith food purchased by household h

P_i = is the price of the ith food, $i = 1, \ldots, n$

$P_j, P_{j+1}, \ldots, P_k$ = the prices of other foods, $i = j$

Y_h = is the household food expenditure

This equation may be specified for each food group which then obtains a system of equations with n rows and $n + 1$ columns.

Using the (1) quantity purchased, (2) price, and (3) expenditure information contained in a typical household survey, the parameters of this system may be estimated using the seemingly unrelated regression (SUR). If these estimates can be made for specific consumer groups that are mutually exclusive and exhaustive, then the weighted sum of the parameters of each consumer group is an estimate of the aggregate or the country level parameters.

If the above data are transformed to logarithms, the statistical estimates of the parameters interrelate food prices and expenditures to quantities purchased. In matrix form the diagonal elements are their own price elasticities and the off-diagonal values are cross-price elasticities while the last column are expenditure elasticities:

$$\begin{bmatrix} E_{11} & E_{12} & \cdots & E_{1k} & E_{1y} \\ E_{21} & E_{22} & \cdots & E_{2k} & E_{2y} \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ E_{k1} & E_{k2} & \cdots & E_{kk} & E_{ky} \end{bmatrix}$$

Expressing the equation in matrix form:

$$[Q_i] = [E_{ij}][P_j] + [E_{iy}]Y \tag{2.77}$$

Or in percentage changes (a hat denotes percentage changes):

$$[\widehat{Q}_i] = [E_{ij}][\widehat{P}_j] + [E_{iy}]\widehat{Y} \tag{2.78}$$

In the short run, $\widehat{Y} = 0$. Disposable income and the structure of food demand, as represented by the $[E_{ij}]$ and $[E_{iy}]$ matrices remain constant. In short, food expenditure is not altered. The percentage quantity change, $\widehat{Q_i}$, is shocked and is translated to percentage price changes, $\widehat{P}_i$:

$$\widehat{P}_j = [E_{ij}]^{-1}[\widehat{Q}_i] \tag{2.79}$$

since $[E_{ij}]\widehat{Y} = 0$ since income does not change.

The resulting price changes represent the new market clearing prices at the aggregate level under open market conditions. Once complete demand elasticities for various consumer groups have been estimated for all food categories, national aggregate elasticities can be computed as the weighted sum of the values derived for each consumer group:

$$E_{ij} = \frac{e_{ij(m)} P_m Q_{im}}{P_{(m)} Q_{i(m)}} \tag{2.80}$$

where

E_{ij} = aggregate level own- and cross-price elasticity value

$e_{ij(m)}$ = own- and cross-price elasticity values specific to consumer group m

$P_{(m)}$ = is the population of consumer group m

$Q_{(m)}$ = is the average daily per capita quantity purchased by group m

In the same manner, the inverse of the aggregate elasticity matrix $[E_{ij}]$ is the weighted average of the inverted elasticity matrix for each consumer group.

The appropriate elasticities to use in relating prices and quantities when the quantity of food is increased in the market are those in the national aggregate matrix, since consumer groups face the same generally the same market. On the other hand, the demand elasticities necessary for estimating consumption changes in specific consumer groups are those derived from each group. Thus, to estimate the change in consumption for group m, the percentage change in prices at the aggregate level due to changes in the quantity of food are calculated. This percentage price change that is derived is then used in equation (6) for each of the m groups. This then provides an estimate of the change in consumption for each commodity for each consumer group m based on its own demand structure:

$$[\widehat{q}_{im}]_{(m)} = [e_{ij}]_{(m)}[\widehat{P}_j] \tag{2.81}$$

where

$[e_{ij}]_{(m)}$ = elasticities specific to a consumer group m

$[\widehat{q}_{im}]_{(m)}$ = change in the percentage quantity demanded by consumer group m

$[\widehat{P}_j]$ = percentage price change determined at the national level

Finally this change in quantity demanded by consumer groups can be translated into the calories or protein consumed by the consumer groups by calculating the actual quantity change and correspondingly calculating the nutrient composition of each food commodity:

$$dq_{i(m)} = \overline{Q}_{i(m)}\widehat{q}_{i(m)} \tag{2.82}$$

This equation gives the change in real quantity equivalent to a certain amount of calories. This framework can be used to evaluate the effect of any short-run change in supply. This evaluation facilitates the analysis of the impact on consumption of a change in market supply from any source.

Data Requirements

This procedure requires the use of minimum data sources. Family income and expenditure surveys are important sources of data needed in the computation of elasticities specific to consumer groups. However, most household surveys do not give explicit prices at which different commodities were purchased by different households especially in cross-section data. Prices are derived, instead, by dividing actual expenditures by the amount of commodity purchased.

Linkage with the Multimarket Economic Surplus Framework

This procedure takes off from an estimated percentage change in quantity supplied in the market for a particular commodity. This percentage change may be more accurately derived from equilibrium quantities computed within the multimarket framework that generates aggregate changes in quantity supplied per year for the duration of technology adoption.

2.2.5 Summary: Tracing Through the Linkages

Among the most important output data generated by the multimarket economic surplus model is the quantity supplied by each of the regions, which, under the model, is also the quantity demanded after an equilibrium price is computed that is a function of the research-induced supply shift. Supply shifts are expressed as a proportion of the per-unit cost of production derived from partial budgets.

In the approaches outlined, equilibrium quantity data (from the multimarket framework or other economic surplus models) enter into supply estimation, either through yield equations in the IMPACT model or via the production function in general equilibrium models. On the other hand, when substitution effects are ignored and initial price conditions are unaltered, fixed price models can be used; in which case, with and without research quantities are compared to determine the percentage or amount by which to shock social accounting matrices.

Figure 2.2 presents a schematic presentation linking the different models that runs in hierarchical order from the plot level where profitability is initially assessed using partial budgets up until impact indicators are derived.

Starting from the plot level, experimental yield and cost data are derived as well as research costs. These are analyzed under a partial budgeting framework where cost and revenue items that may differ with the adoption of the technology are specified and net income income changes are computed. The outputs of partial budgeting come in the form of per unit cost reduction values for a given quantity or in terms of yield increases per area for a given price with and without the project activity.

If at this point, it is preferred to aggregate over a wide area, AEZs are identified and data extrapolated over these AEZs. These are then assembled within a multimarket framework with technology spillovers. Under this model, estimates of probability of adoption and probability of success are important. Together with these estimates, production and consumption shares of each region as well as price elasticities of supply and demand in each region are used to compute the equilibrium price that holds for each and every region. This equilibrium price is then imputed in the computation of supply and demand quantities, which in the model, coincide. These supply and demand quantities can then be summed up to come up with an aggregate quantity change. This aggregate quantity change is then infused into a SAM multiplier model if initial prices remain unaltered or if prices are assumed to be constantly changing, into a GE model such as the IMPACT. In general, quantity changes enter in the estimation of production or yield functions. These production and quantity changes give rise to changes in factor demand and factorial income that consequently alters income distribution. Changes in income distribution can then be translated into changes in income-based poverty measures.

2.2.6 Aggregation Issues

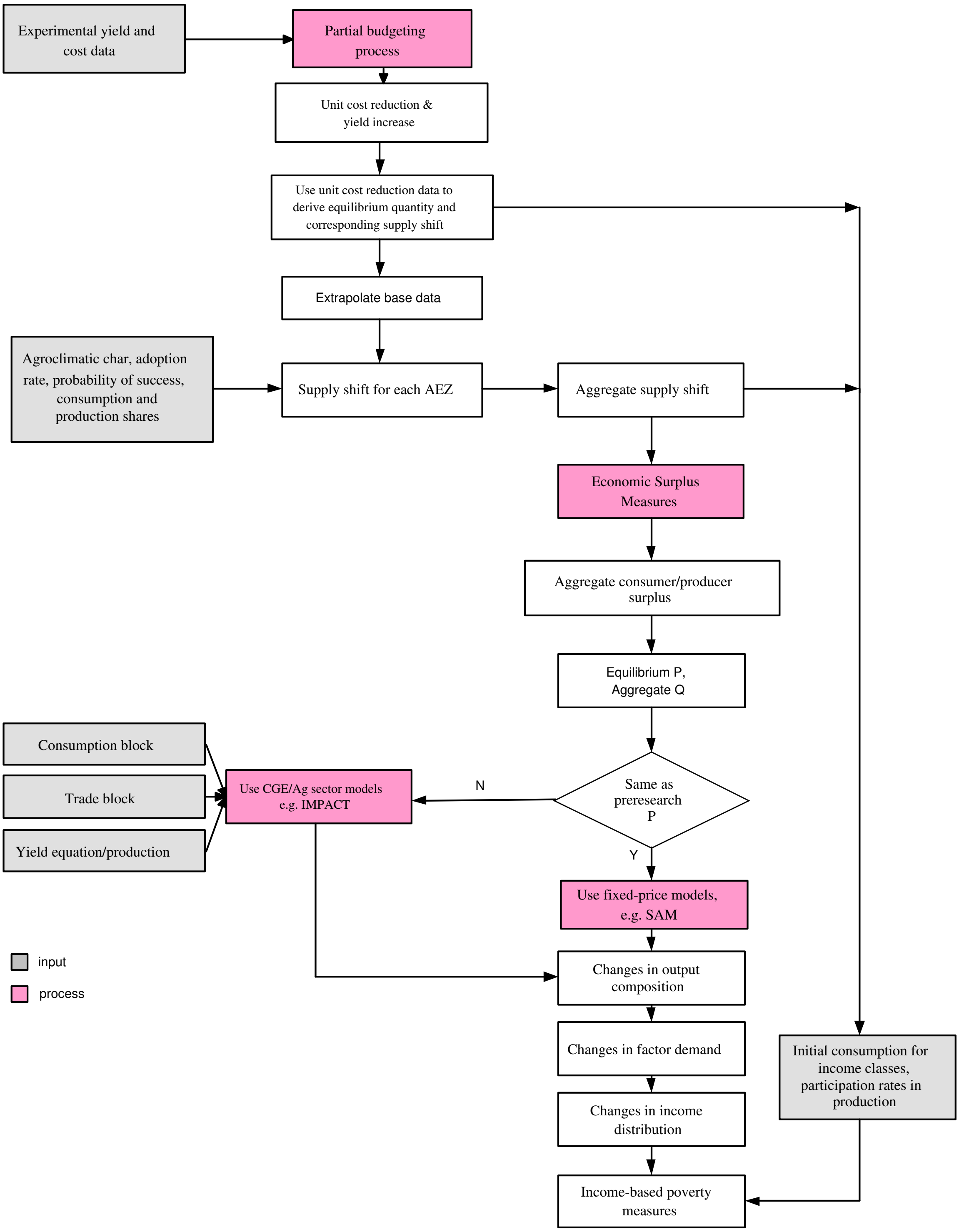
If aggregation is postponed until final welfare indicators are derived, then household income and expenditure surveys generated for specific regions or villages can be used to come up with local or area-specific indicators. These can then be later summed to come up with aggregate indicators. This route towards aggregation requires the most information but yields more accurate results than if one proceeds to aggregate at an early stage.

The point of aggregation will determine which models to use in building up specific welfare indicators. For example, in a closed economy model of a particular region, it may be enough to directly use household surveys and allocate supply shifts according to initial consumption values for different income classes by using another partial equilibrium model such as that done *Tun and Yetley* and by *Pinstrup-Andersen, et al.* [1] Thus, it is possible to skip the use of the economic surplus

[1] This type of allocation according to initial consumption values can also be done using aggregate quantity derived from a multi-market model of economic surplus

model in the simplest case which will be presented in this research.

Figure 2.2: Schematic of Linkages



Chapter 3

Research Background and Methods

In this chapter, the methodology and data used are presented. This methodology can be applied a limited area where a productivity-enhancing technique such as eggplant grafting is introduced as a new agricultural practice. It is assumed that farm field data on yields can be used to approximate industry yields. Taking off from the discussion in Chapter 2, this is the simplest route that can be done with the use of minimum data to assess the increase in calorie intake of households that belong to different income classes. In the methodology that follows, the relative benefits by consumer income groups are calculated by disaggregating the market demand curve into demand curves by income groups. Several price elasticities of demand by consumer group are obtained and then applied to calculate benefits by group.

3.1 Methodology

The methodology employed in this research provides for a model that will estimate the nutritional impact of expanding the supply of any commodity available to the consumer. Only the nutritional impact due to changes in calorie intake is considered. Likely impacts due to changes in other nutrients are ignored. The model is the same as that in *Pinstrup-Andersen, Ruiz de Londono, and Hoover (1976).*

3.1.1 Model

The model[2] best fits the situation of a hypothetical supply increase of any good available to a population and addresses the question of how this supply increase is distributed among different income classes after taking into account the subsequent adjustments in consumption of all other goods through price changes and the ultimate impact on calorie nutrition.

The methodology proceeds in two stages. In the first, a price elasticity of demand matrix is estimated for each of the income strata using the methodology developed by Frisch (1959). In the second stage, a set of equations quantifies the change in calorie intake by income strata caused by a shift in the supply curve of a commodity.

Price Elasticity of Demand Matrix

In most cases, to estimate price elasticities, we need to observe demand patterns under different price conditions that require time series data. Faced with cross-sectional income and expenditure survey data that rarely collect price data but instead collect information on quantities purchased and expenditure values, it is still possible to derive a 'price' variable as a ratio between expenditure and quantity referred to as a unit value. While it is appealing to estimate price elasticities by regressing the logarithm of quantity on the logarithm of unit value as a proxy for price, two attendant problems arise. First, since the unit value is calculated from quantity, errors in measuring quantity result in a spurious negative correlation between quantity and unit value. Over-reporting quantity will underestimate the derived unit value. Second, unit values embody not just price but also quality. Higher prices, for instance, allow the consumers to alter not just the quantity but the quality purchased as well. Unit values represent both quality and price. The move towards lower quality when price increases causes the unit value to vary less than prices. Consequently, direct estimation of the consumption elasticity using the unit value overestimates that which is derived using actual prices *(Sadoulet & de Janvry, 1995).* Also, note that for the data set used in this research, unit values were derived and considerable differences were observed across households within the same province for the same commodity under the same time period.

To avoid the problems cited above, this empirical work uses the Frisch methodology instead for estimating a complete set of direct and cross price elasticities of demand[3]. Under this methodology,

[2]Draws heavily from Pinstrup-Andersen, de Londono, and Hoover (1976)

[3]Deaton (1988,1990) provided for a three-stage solution to this. However, since it is the objective of this research

price elasticities are obtained using three sets of information: (a) income elasticities; (b) budget proportions, and (c) flexibility of money. If the flexibility of money is known, the price elasticities can be derived from cross-sectional household survey data that allows for estimations of income elasticities and provides data on budget shares. This does not entail the use of unit values or observation of prices.

Direct and cross-price elasticities of demand for income stratum m are estimated as:

$$e_{ii(m)} = -E_{i(m)} \left[A_{(m)} - \frac{1 - A_{i(m)} E_{i(m)}}{\phi_{(m)}} \right] \tag{3.1}$$

and

$$e_{ij(m)} = -E_{i(m)} A_{j(m)} \left[1 + \frac{E_{j(m)}}{\phi_{(m)}} \right] \qquad i \neq j \tag{3.2}$$

where

e_{ii} = direct price elasticity of demand for good i

e_{ij} = cross price elasticity of good i with respect to good j

E_i, E_j = income elasticities for goods i and j

A_i, A_j = budget proportions spent on goods i and j

Under the assumption that consumers face the same market for any one commodity, the average per capita direct and cross price elasticities of demand for good i is the weighted average of the strata elasticities using quantity of good i consumed by stratum m using the relative proportion of total population found in stratum m as weights:

$$e_{ij} = \frac{\sum_{m=1}^{n} e_{ij(m)} Q_{i(m)} N_{(m)}}{\sum_{m=1}^{n} Q_{i(m)} N_{(m)}} \tag{3.3}$$

where

$e_{ij(m)}$ = direct or cross price elasticity of demand for stratum m

$Q_{i(m)}$ = quantity consumed per capita of commodity i in stratum m

$N_{(m)}$ = population in stratum m

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to minimize data requirements to computing nutritional impact, the Frisch method is used instead.

Income Elasticities

The income elasticity for each food is estimated for each of the income strata using data within each stratum. It is assumed that consumers generally face the same price for any given food commodity. Tastes and preferences are assumed to have little or no variation among consumers within a particular stratum. Income elasticities are estimated simply by regressing per capita real income on per capita quantity consumed within each stratum with the β coefficient as the income elasticity:

$$ln\left[\frac{Q_{i,h(m)}}{N_{h(m)}}\right] = \alpha + \beta\ ln\left[\frac{Y_{h(m)}}{N_{h(m)}}\right] \tag{3.4}$$

where

$Q_{i,h(m)}$ = total quantity consumed of good i by household h in stratum m

$N_{h(m)}$ = total family size of household h in stratum m

$Y_{h(m)}$ = total family income of household h in stratum m adjusted for inflation

Budget Proportions

Budget proportion spent on each commodity is computed as the ratio between total expenditure on a particular commodity and total food expenditure for each stratum m:

$$A_{i(m)} = \frac{C_{i(m)}}{F_{(m)}} \tag{3.5}$$

where

$A_{(m)}$ = budget proportion spent on commodity i

$C_{i(m)}$ = total expenditure on good i for stratum m

$F_{(m)}$ = total food expenditure of stratum m

Money Flexibility

The flexibility of money, ϕ, is estimated on the basis of the income elasticity and the direct price elasticity of one good and the budget proportion spent on that good. Solving (3.1) for ϕ, it is necessary to estimate e_{ii} for at least one good for each income strata using an alternative method:

$$\phi_{(m)} = \frac{E_{i(m)}\left[1 - A_{i(m)}E_{i(m)}\right]}{e_{ii(m)} + A_{i(m)}E_{i(m)}} \tag{3.6}$$

Money flexibility, by definition, is the elasticity of the marginal utility of income with respect to changes in income.

Changes in Calorie Intake

To estimate the distribution of among strata of additional supply of the commodity for which the supply curve is shifted and to calculate the resulting adjustments in the consumption of all other foods, a set of recursive equations that incorporate the price and income elasticities computed for each strata is employed. The model estimates the new equilibrium for prices and quantities for all commodities using an iterative procedure under the following assumptions:

(1) All consumers face the same market that operates under perfect competition.

(2) Prices and quantities for all commodities are in equilibrium before the shift in the supply curve.

No shifts in the demand curves are accommodated except those due to changes in prices of other goods brought about by the initial shift in the supply curve and subsequent adjustments. As such, consumer incomes, tastes, preferences and other possible demand shifters are held constant.

The new equilibrium price after shifts in the supply and/or demand curves is estimated in the spirit of the framework used by *Pinstrup-Andersen and Tweeten (1970)* in estimating the impact of decreased food aid on the world market[4]. If the initial market equilibrium price for commodity i is P_i^0, the new equilibrium price P_i^1 is estimated as:

$$P_i^1 = P_i^0 \left[1 - \frac{\Delta S_i - \Delta D_i}{(e_{si} - e_{ii})Q_i^0} \right] \tag{3.7}$$

where

ΔS_i = horizontal shift in supply curve of commodity i

ΔD_i = horizontal shift in the demand curve of commodity i

e_{si} = price elasticity of supply for commodity i

e_{ii} = market price elasticity of demand for commodity i

In a similar vein, the new equilibrium quantity of commodity i, Q_i^1, is estimated as:

$$Q_i^1 = Q_i^0 + \Delta D_i + \frac{\Delta S_i - \Delta D_i}{1 - (e_{si}/e_{ii})} \tag{3.8}$$

[4]In the article Conceptual Framework for Estimating the Impact on World Market Price, the price that would occur in the world market if all food aid programs were discontinued and the food exported under these programs were added to the prevailing commercial world market supply, market clearing price, was computed.

Using these two equations, the change in the price and quantity of the commodity i whose supply increased is estimated as:

$$P_i^k = P_i^{k-1}\left[1 - \frac{B}{(e_{si} - e_{ii})}\right] \tag{3.9}$$

and

$$Q_i^k = Q_i^{k-1}\left[1 + \frac{B}{\left(1 - \frac{e_{si}}{e_{ii}}\right)}\right] \tag{3.10}$$

where

$$k = 1$$

$$B = \frac{\Delta S_i}{Q_i^{k-1}} = \text{horizontal shift in the supply curve of } i \text{ as a proportion of initial quantity,}$$

k represents the number of rounds the impact of a supply shift is had in terms of price and quantity changes. The final equilibrium price and quantity of the commodity whose supply shifted is traced through a series of price and quantity changes working their way through cross price elasticities of demand. This occurs recursively. If $e_{ji} = 0$ or $e_{ij} = 0$ for all $j \neq i$ then the final equilibrium price and quantity for commodity i would be P_i^1, Q_i^1 respectively. Note that e_{ji} is the cross price elasticity of demand for j given the change in the price of i. If, however, $e_{ji} = 0$ for all $j \neq i$ then the equilibrium quantities and prices for all other commodities are unaltered. Neither e_{ji} or e_{ij} is expected to be 0. Thus, the initial change in P_i will impact on the demand for other commodities j and shift their demand curves. The new equilibrium prices,P_j^1 and quantities, Q_j^1 are:

$$Q_j^k = Q_j^{k-1}\left(1 + p_i e_{ji}\left[1 - \frac{1}{1 - \dfrac{e_{sj}}{e_{jj}}}\right]\right) \tag{3.11}$$

and

$$P_j^k = P_j^{k-1}\left(1 + \frac{p_i e_{ji}}{(e_{sj} - e_{jj})}\right) \tag{3.12}$$

where $k = 1$ and $p_i = \dfrac{P_i^k - P_i^{k-1}}{P_i^{k-1}}$, $j = 1, 2, \ldots, n$ excluding i and $j \neq i$.

These changes in prices and quantities of the affected commodities j ripple out several rounds of shifts in the demand for commodity i unless $e_{ji} = 0$ for all j. For subsequent rounds, the new equilibrium price and quantity for i is given by:

$$Q_i^k = Q_i^{k-1}\left(1 + \sum_{j=1}^{n} p_j e_{ij}\left[1 - \frac{1}{1 - \dfrac{e_{si}}{e_{ii}}}\right]\right) \tag{3.13}$$

and

$$P_i^k = P_i^{k-1}\left(1 + \sum p_j e_{ij}\left[\frac{1}{e_{si} - e_{ii}}\right]\right) \tag{3.14}$$

where $k = 2$ and $p_j = \dfrac{P_j^1 - P_j^0}{P_j^0}$, $j \neq i$, $j = 1, 2, \ldots n$ excluding i. This iterative process continues with k moving onto $k+1$ until a steady state is reached, $(k = F)$. That is, when the equilibrium price and quantity for all commodities is reached or simply the case when quantities and prices no longer change.

After the new market equilibrium is obtained, the distribution among strata of the quantity changes for each commodity is determined. The final quantity of commodity j obtained by stratum m,

$$Q_{j(m)}^F = \frac{N_{(m)}}{N} Q_j^0\left[1 + p_i e_{ji(m)} + p_j e_{jj(m)}\right] \tag{3.15}$$

where

j = $1, \ldots, n$ excluding i; m is equal to the number of strata

$N_{(m)}$ = number of consumers in stratum m

N = total number of consumers

$$p_i = \frac{P_i^F - P_i^0}{P_i^0} \tag{3.16}$$

The final quantity of commodity i obtained in stratum m denoted by $Q_{i(m)}^F$ is given by:

$$Q_{i(m)}^F = Q_{i(m)}^0\left[1 + \sum_{j=1}^{n}\left(p_j e_{ij(m)} + p_i e_{ii(m)}\right)\right], \quad j \neq i \tag{3.17}$$

The direct impact on calorie intake in stratum m, $C_{i(m)}$, is estimated as

$$C_{i(m)} = \left[Q_{i(m)}^F - Q_{i(m)}^0\right] c_i \tag{3.18}$$

where c_i is the calorie content per unit of commodity i.

Likewise, the indirect impact is

$$C_{j(m)} = \sum_{j=1}^{n}\left[Q_{j(m)}^F - Q_{j(m)}^0\right] c_j \tag{3.19}$$

Combining the direct and indirect impact gives the net impact

$$C_m = C_{i(m)} - C_{j(m)} \tag{3.20}$$

3.1.2 Caveats

It should be noted that this methodology only takes into account cross price effects and ignores totally any income effect derived from additional profits earned by producers of the commodity whose supply has increased. The results emanating from this methodology underestimates the total benefits and should be interpreted with caution.

Also, the advantage of this methodology its minimal use of data that can usually be derived from household surveys. As opposed to the methodology proposed by *Tun and Yetley* that requires actual values of the purchase price of commodities for the different households, cross price elasticities can be estimated without direct observation of prices. This comes at the expense of theoretical restrictions and assumptions.

In the Frisch methodology for estimating price elasticities, want independence is assumed in that the marginal utility of a good is independent of the quantity consumed of any other good. While want independence is not valid for all goods, the Frisch method can still be applied to estimate group elasticities if the bundle of goods available to the consumers can be grouped. Attempts were made to include commodity groups such as beef, chicken, pork and fish but unlike crop statistics which can be traced to specific provinces in different regions, poultry and livestock statistics are only available at the regional level. As such, price and production values necessary to compute for supply elasticites were unavailable. Also, since the primary purpose of this research is to test a methodology for estimating increases in caloric intake due to supply expansions, and not to estimate price elasticties as the end, with the use of minimum data, the Frish methodology was still applied even when the 12 commodities as specified below cannot be safely regarded as want independent. Should disaggregated data be made available later on, this research can be amended.

3.2 Proofs of Concept

3.2.1 Technology-oriented R&D: Eggplant Grafting in the Philippines

Bacterial wilt (*Ralstonia solanacearum*) is a destructive disease of eggplant in tropical and subtropical regions throughout the world. Most commercial varieties are moderately or highly susceptible to bacterial wilt. In the Philippines, these susceptible varieties are grafted onto bacterial wilt-resistant rootstocks as part of a host of IPM CRSP initiatives. This approach parallels work being done in the Bangladesh site and proves to reduce disease incidence and increase yield compared to the varieties grown without grafting.

Eggplant grafting implemented in two field sites in the Philippines, in Nueva Ecija and Pangasinan are used as case studies to serve as proofs of concept in pilot testing and developing a hierarchical framework for determining the nutritional impact of certain agricultural activities. In particular, it is instructive to trace through the nutritional impact of technology-oriented R&D such as eggplant grafting with the use of minimum data that will make the procedure or methodology replicable in a class of agricultural R&D initiatives.

3.2.2 Data Description

The above methodology was applied using cross-sectional household consumption and income data detailed in the Family Income and Expenditure Survey (FIES) of 2000 specifically those for the provinces of Nueva Ecija and Pangasinan together with partial budget results from farmers' fields in each province.

Scope and Coverage

Data gathered in the survey include sources of income in cash and in kind and the levels of consumption by item of expenditure. Related demographic variables such as family size, number of family members employed for pay or profit, occupation, age and educational attainment of household head, and housing characteristics form part of the survey.

These surveys were conducted every three years beginning in 1985, the most recent of which was done in 2000. While the surveys are large, they are not panels – there is no systematic effort to track the same households over time.

Geographical Classification

Several changes in the regional classification were made from 1985 to 2000. In 1985, there were only 13 regions. Then it became 14 in 1988, with the inclusion of the Cordillerra Administrative Region. The CAR comprises the provinces of Abra, Benguet, and Mountain Province, formerly of Region I, together with Ifugao and Kalinga-Apayao, then belonging to Region II. In 1991, another region was included – the Autonomous Region for Muslim Mindanao (ARMM). The provinces Sulu and Tawi-Tawi which were formerly part of Region IX, Lanao del Sur (excluding Marawi City) and Maguindanao (excluding Cotabato City), then part of Region XII, were made part of ARMM. Then in 1997, another region was named – CARAGA region, comprising of Agusan del Norte, Butuan City, Agusan del Sur, Surigao del Norte, and Surigao del Sur. The first 4 provinces were before part of Region X, while Surigao del Sur was before classified under Region XI. In 2000, a total of 16 regions were surveyed.

Relevant to this study are the surveys done for Pangasinan, which is one of the provinces that comprise Region I or the Ilocos Region, and those for Nueva Ecija, a province in Region III or Central Luzon.

Survey Design

The FIES Surveys adopts the "shuttle type" of data collection wherein respondents are interviewed on two occasions using the same questionnaire. The 1st interview is usually done in July of the reference year to gather data for the first 6 months of the year (January – June). The 2nd interview is done in January of the following year, to account for the last 6 months (July – December). The scheme is done to minimize memory bias and to capture the seasonality of income and expenditure patterns. Annual data is estimated by combining the results of the 1st and the 2nd visit.

The concept of "average week" consumption for all food items was utilized. Total expenditure for various commodities, total food expenditure and the quantities associated with them as well as household income were extracted from the whole survey for Nueva Ecija and Pangasinan. A total of 12 commodities belonging to different groups under food crops were selected for which reliable initial price data were available:

1. Rice
2. Onion
3. Ampalaya
4. Carrots
5. Eggplant
6. Tomato
7. Cabbage
8. Mongo (Mung Beans)
9. Camote (Sweetpotato)
10. Cassava
11. Gabi (Taro)
12. Potato

(1) is classified as a separate food crop while (2)-(8) fall under the vegetable category. (3)-(6) are fruit-bearing vegetables; (7) is a leafy vegetable while (8) is sorted as a legume. (9)-(12) are categorized as root crops and tubers.

Sampling Design

The FIES uses a 2-stage cluster sampling design. The primary sampling units are the barangays, while the households in the selected barangays comprise the secondary sampling units. The national sample increased from 16,971 in 1985 to 39,615 households in 2000 spread over 16 regions. In Nueva Ecija, a total of 658 households were surveyed as against 845 in Pangasinan. In this research, the households were stratified into income quintiles. Selected descriptive characteristics for each quintile are presented for both Nueva Ecija and Pangasinan in Tables 3.1 and 3.2.

Table 3.1: Selected Descriptive Characteristics of Households Surveyed, Nueva Ecija

	I	II	III	IV	V
Income range (P/family/year)	16087-67600	67736-95451	95462-126100	126180-192302	193089-890000
Average family income (P/year)	51180.92	80751.72	110127.5	154532	332238
Average per capita income (P/year)	13400.84	16386.21	21567.99	28194.56	59632.46
Average per capita food expenditure (P/year)	7129.29	7658.51	9127.10	9839.12	13081.32
Proportion of income spent on food (%)	53.2	46.7	42.3	34.9	21.9
Number of households interviewed	130	132	132	131	133
Number of persons in households surveyed	496.5	650.6	674	718	741
Distribution of persons in strata (%)	15.14	19.83	20.55	21.89	22.59

Table 3.2: Selected Descriptive Characteristics of Households Surveyed, Pangasinan

	I	II	III	IV	V
Income range (P/family/year)	12076-51770	52137-76303	76440-106224	106485-170021	170530-806390*
Average family income (P/year)	40041.26	62913.76	90273.59	134477.13	301159.38
Average per capita income (P/year)	9559.53	12841.09	16484.74	23256.47	49493.76
Average per capita food expenditure (P/year)	6154.09	7117.37	7808.74	9332.43	12935.54
Proportion of income spent on food (%)	64.38	55.43	47.37	40.13	26.14
Number of households interviewed	167	169	168	170	171
Number of persons in households surveyed	699.5	828	920	983	1040.5
Distribution of persons in strata (%)	15.64	18.52	20.58	21.99	23.27

Chapter 4

Empirical Results

The aim of this chapter is to present the two case studies that will serve as proofs of concept with the use of minimum data as to the functionality of the proposed framework.

4.1 Nueva Ecija

4.1.1 Background

Nueva Ecija is the largest of seven provinces that make up Central Luzon (Region III) covering an area of 550,718 hectares. It is richly endowed with some of the most productive agricultural lands in the Philippines. Agricultural lands devoted to various agricultural activities cover about 300,000 hectares out of the total provincial area. Apart from being conferred the Rice Bowl of the Philippines, Nueva Ecija grows a wide variety of field crops such as vegetables, legumes, root crops, corn and other fruit vegetables such as bitter gourd, squash, tomato and eggplant, among others.

In 2001, Nueva Ecija accounted for 4.5 percent of total eggplant production in the Philippines corresponding to 7,578 metric tons out of the total 169,819 metric tons of domestic production. For the same year, a total of 1890 hectares in the province were covered with eggplant or 9.3 percent of the total harvested area of eggplant in the country. In 2000, the yield per hectare of eggplant in the province is 3.97 metric tons. Below is a summary of production trends of eggplant for Nueva Ecija.

Table 4.1: Volume and Area of Production, 1990-2001

Year	Volume of Production (MT)	Harvested Area (ha)
1990	5349	1169
1991	5230	927
1992	5046	822
1993	5292	1093
1994	5384	1100
1995	6584	1171
1996	8882	739
1997	11761	1437
1998	8341	1019
1999	8211	1917
2000	7854	1980
2001	7578	1890

Sources: PIDS, BAS

4.1.2 Eggplant Grafting Site

Between 2000 and 2001, grafted and non-grafted eggplants were grown during the dry season (December to April) in Munoz, Nueva Ecija where the PhilRice experimental field infested with the potent Nueva Ecija strain of *R. solanacearum* is located. Two bacterial wilt-resistant varieties EG 203 and 89-002 were used as rootstocks while two commercial varieties Casino, Bulakena Long Purple (BLP), and a farmers variety Abar were used as scions.

The grafted and non-grafted seedlings were planted in 4×5 m plots with 4 replications. With the non-grafted resistant and susceptible varieties as controls, eggplant yields in each treatment were recorded at harvest. A total of 11 treatments were conducted. *Table 4.2* presents the yields of the grafted and non-grafted eggplant cultivars for each of the treatments.

The yield of Casino and Abar increased when grafted to EG 203 though no yield increase was observed on grafted BLP. In fact, the yield of BLP declined when grafted onto EG 203. In the same manner, all the varieties grafted onto 89-002 exhibited no yield increase but rather declines in yield were observed for all varieties. Only EG 203 + Abar significantly gave higher yield among all the varieties [5].

[5] Only project summary data for each treatment and not for each of the plots within each treatment were provided by the experimenting agency. This statement was taken from the Annual Report and from summary data provided.

Table 4.2: Yields of Grafted and Nongrafted Varieties

Treatment	Yield (kg)
T1 - EG 203 + Abar	7500
T2 - Eg 203 + Casino	7000
T3 - Casino	6250
T4 - BLP	6250
T5 - EG 203	5250
T6 - Abar	4750
T7 - 89-002	4500
T8 - 89-002 + Casino	4250
T9 - 89-002 + BLP	4000
T10 - EG 203 + BLP	3750
T11 - 89-002 + Abar	3750

Source: PhilRice

4.1.3 Partial Budget Results

Between Abar and Casino whose yields increased when grafted onto EG 203, it is only in grafted Abar where a per unit cost reduction is observed. From P9.082, the per unit cost dropped to P7.785, or a 14.28 percent decline. Using the elasticity of supply computed for eggplant of 1.3432, this translates to a yield change of 0.911 MT/ha. On top of the cost reduction, the increase in the yield of grafted Abar (2.75 MT/ha) is also higher than that for grafted Casino (0.75 MT/ha) reflected in the partial budgets.

Albeit the added harvesting cost that comes with higher yield, this overwhelming improvement in the yield of Abar of almost 60 percent more than covers for the additional cost.

In fact, this grafted Abar is the only grafted treatment that generates a positive net income. This strongly suggests that farmers are better off grafting Abar with EG 203.

4.1.4 Scaling Up of Experimental Field Data: Assessing Adoption

Survey data conducted in the dry season of 2003 on the incidence of bacterial wilt caused by *Ralstonia solanacearum* in three provinces in Luzon to include Nueva Ecija was used to assess the extent of adoption of the grafting method. Three fields were surveyed situated in 2 out of the 5 cities that comprise the province. In the three fields surveyed, wilt incidence ranged from 5 to 50 percent. This range serves as lower and upper limits in identifying the total area that will adopt the grafting method. In this research, problem domains instead of impact domains are identified. It is assumed that in Nueva Ecija, as little as 5 percent of total hectarage planted with eggplant are infected with bacterial wilt and can spread to as much as 50 percent. Out of the infected area, that portion which is planted with eggplant variety Casino is determined. It is this fraction whose yield will increase by 0.911 MT per hectare as shown in the partial budgets. Hence, the supply curve of eggplant in Nueva Ecija will shift by this much over the area planted with Casino. These initial shifts are considered for two cases: (a) 5 percent incidence of bacterial wilt as the lower base case, and (b) 50 percent bacterial wilt incidence as the high base case. Further, it is assumed that the Casino variety is grown in 40 percent of the total area infected with bacterial wilt. The remaining segment is planted with Abar (40%) and BLP (20%). Furthermore, it is assumed that farmers who grow Abar and BLP do not switch to Casino.

It is assumed in this study that data from the different farmers fields can be used to approximate the increase in yield for the entire province.

Research Evaluation Period

The impact of the eggplant grafting method in Nueva Ecija is evaluated over a period of 10 years beginning 2002 until 2011. It is assumed that the province follows an adoption profile of initially increasing adoption rate up to a maximum adoption. It is assumed that farmers are able to continue to adopt the technique until it becomes fully implemented in the field. In this case, until the technology is adopted in about 90 percent of the actual affected area. This assumption of seemingly high adoption rates accounts for the fact that eggplant grafting is not a hard technique to adopt unlike other technologies. The adoption and supply shift schedules for eggplant in both the low and high bacterial wilt incidence cases are shown in *Tables 4.3 and 4.4*

4.1.5 Baseline Data

Additional supply due to eggplant grafting is injected in the year 2002. While the household income and expenditure survey used was conducted in 2000, minimal variation in the elasticities derived from the survey is expected two years after. After all, the next survey occurs in 2003 and will not be available for public use until 2005. Initial values for volume of production and prices are for 2001 that are starting values for 2002 when the supply shock is introduced. After the shock is introduced in 2002, the new equilibrium price and quantity for all commodities become initial values for the

Table 4.3: Adoption & Supply Shift Schedule for Eggplant: 5% BW Incidence Case

Year	Hectarage alloted to Casino	Yield Change per ha (MT/ha)	Total Yield Change (MT)	Rate of Adoption (%)	Supply Shift (MT)
2002	37.8	0.911	34.4	0.7	24.1
2003	38.9	0.911	35.5	0.7	24.8
2004	40.1	0.911	36.5	0.7	25.6
2005	41.3	0.911	37.6	0.8	30.1
2006	42.5	0.911	38.8	0.8	31.0
2007	43.8	0.911	39.9	0.8	31.9
2008	45.1	0.911	41.1	0.8	32.9
2009	46.5	0.911	42.4	0.9	38.1
2010	47.9	0.911	43.6	0.9	39.3
2011	49.3	0.911	44.9	0.9	40.4

Table 4.4: Adoption & Supply Shift Schedule for Eggplant: 50% BW Incidence Case

Year	Hectarage alloted to Casino	Yield Change per ha (MT/ha)	Total Yield Change (MT)	Rate of Adoption (%)	Supply Shift (MT)
2002	378.0	0.911	344.4	0.7	241.1
2003	389.3	0.911	354.7	0.7	248.3
2004	401.0	0.911	365.3	0.7	255.7
2005	413.1	0.911	376.3	0.8	301.0
2006	425.4	0.911	387.6	0.8	310.1
2007	438.2	0.911	399.2	0.8	319.4
2008	451.4	0.911	411.2	0.8	328.9
2009	464.9	0.911	423.5	0.9	381.2
2010	478.8	0.911	436.2	0.9	392.6
2011	493.2	0.911	449.3	0.9	404.4

following year. In short, price and demand changes the previous year yield new equilibrium price and quantity values for a commodity. It is assumed that the transitory effect of a supply shock transmitted through cross price elasticities eventually peters out by the end of a year after which another wave of supply shock occurs.

4.1.6 Income Elasticities and Budget Proportions

All commodities showed a declining trend of income elasticity for increasing income levels. Though some spikes are observed, the trend is downward. As expected, the lowest income group had the

Table 4.5: Income Elasticities of Selected Commodities by Income Strata, Nueva Ecija

Commodity	I	II	III	IV	V
Rice	0.3297	0.3365	0.1408	0.1801	0.1874
Potato	0.5666	1.1746	0.5334	0.6123	0.4876
Cassava	0.3180	0.7737	0.3664	0.6758	0.0835
Camote	0.8264	0.8567	0.3866	0.4651	0.2650
Gabi	0.6602	1.0908	0.5699	0.7826	0.5413
Cabbage	1.1686	0.8766	0.5135	0.7564	0.4697
Ampalaya	0.8975	0.6642	0.4103	0.4677	0.4073
Eggplant	0.7958	0.6580	0.3927	0.5798	0.2084
Tomato	0.7752	0.9616	0.4907	0.7428	0.3255
Mongo	0.5852	1.3700	0.6592	0.6512	0.1666
Carrot	1.0054	1.0002	0.9332	0.5626	0.4117
Onion	0.8522	1.0147	0.6227	0.7499	0.2875

highest income elasticity across most of the commodities whereas the highest quintile had the lowest income elasticity across all the commodities. Rice, which is the staple food in the Philippines and certainly in Nueva Ecija had the lowest income elasticity among the commodities.

The largest single food expenditure among the commodities for all quintiles is rice which accounts for 20-33 percent of the total food budget. As expected, the budget proportion spent on the food items decreases with increasing incomes.

Table 4.6: Average Budget Proportions of Selected Commodities, Nueva Ecija

Commodity	I	II	III	IV	V
Rice	0.3319	0.3063	0.2618	0.2537	0.1925
Potato	0.0043	0.0050	0.0051	0.0044	0.0047
Cassava	0.0017	0.0007	0.0007	0.0012	0.0003
Camote	0.0035	0.0027	0.0024	0.0024	0.0015
Gabi	0.0057	0.0051	0.0055	0.0046	0.0041
Cabbage	0.0028	0.0035	0.0042	0.0040	0.0035
Ampalaya	0.0065	0.0062	0.0055	0.0046	0.0039
Eggplant	0.0084	0.0086	0.0078	0.0064	0.0059
Tomato	0.0086	0.0078	0.0076	0.0061	0.0059
Mongo	0.0053	0.0041	0.0039	0.0037	0.0019
Carrot	0.0023	0.0016	0.0024	0.0020	0.0020
Onion	0.0074	0.0063	0.0059	0.0058	0.0044

4.1.7 Money Flexibility

No estimates of money flexibility are available for the province of Nueva Ecija. Hence, to estimate ϕ by income quintile, it was necessary to estimate e_{ii} for at least one good or a composite of goods. The direct price elasticity was computed by simply regressing the price of the commodity as well as the price of other commodities on the per capita quantity consumed. This was done using weekly data on the estimated per capita consumption by region of selected commodities from a survey conducted during the months of May, August and November 1999 and February 2000. This included rice, ampalaya and eggplant. The survey, *Consumption of Selected Food Commodities in the Philippines*, was conducted by the Bureau of Agricultural Statistics (BAS) and was released in January of 2001. Though the survey was conducted in between 1999 and 2000, there was no other data available that will yield per capita consumption values. Direct price elasticities were computed for eggplant, ampalaya and rice and using equation (3.5). Correspondingly, three different estimates for money flexibility were computed. The simple average of the three was obtained to get an overall measure of money flexibility for each income strata. The estimated coefficients are shown in Table 4.7.

Table 4.7: Estimated Money Flexibility Coefficients by Income Quintile

Quintile	Money Flexibility
I	-1.6785
II	-1.7803
III	-0.5353
IV	-0.6173
V	-0.7514

In general, there is no way to verify whether the above money flexibility coefficients are appropriate in the absence of studies done for the Philippines. However, the estimates are consistent, to an extent, with Frischs conjecture that the absolute value of ϕ decreases as the level of income increases if we note the disparity between the lowest and the highest income levels; a downward trend is also observed. The estimates fall below the range of -3 for countries with low levels of per capita income as in Chile and Argentina and -1.1 for high-income countries such as the United States [6].

[6] De Janvy and Sadoulet, p. 37.

Table 4.8: Estimated Direct Price Elasticities by Strata

	I	II	III	IV	V	Average
Rice	-0.2844	-0.2726	-0.2902	-0.3242	-0.2765	-0.2894
Potato	-0.3392	-0.6618	-0.9965	-0.9919	-0.6498	-0.7505
Cassava	-0.1899	-0.4349	-0.6846	-1.0946	-0.1112	-0.5407
Camote	-0.4938	-0.4824	-0.7225	-0.7537	-0.3530	-0.5684
Gabi	-0.3956	-0.6149	-1.0645	-1.2668	-0.7210	-0.8146
Cabbage	-0.6972	-0.4939	-0.9594	-1.2246	-0.6258	-0.8417
Ampalaya	-0.5374	-0.3756	-0.7670	-0.7581	-0.5428	-0.5959
Eggplant	-0.4776	-0.3732	-0.7344	-0.9395	-0.2783	-0.5563
Tomato	-0.4654	-0.5436	-0.9169	-1.2023	-0.4343	-0.7051
Mongo	-0.3506	-0.7708	-1.2308	-1.0547	-0.2220	-0.7460
Carrot	-0.5999	-0.5625	-1.7417	-0.9114	-0.5482	-0.9068
Onion	-0.5108	-0.5727	-1.1626	-1.2138	-0.3834	-0.7608

4.1.8 Price Elasticities

A price elasticity matrix was estimated for each of the income strata using equations (3.1), (3.2) and (3.3). The average was obtained using total quantity consumed by strata as weights. As the income level increases, the direct price elasticity also increases for almost all commodities as underscored by the substantial difference between the lowest and highest income quintiles. For most commodities, the elasticity values dip from I to II and then go back up until income level V.

The average direct price elasticities for most commodities are within close range from estimates done in previous studies except for carrot, gabi and cabbage. Estimates for leafy vegetables and vegetables fall within -0.6 and -0.8 [7].

4.1.9 Changes in Calorie Intake

Equilibrium Price and Quantity

The cumulative change in calorie intake was evaluated over a ten-year period, 2002-2011. In each year, the supply of eggplant is shifted out by the increase in the yield per hectare over the total area allocated to Casino, the variety that will be grafted to the resistant rootstock EG 203. This is adjusted for the rate of adoption each year. Subsequent demand and price changes by the end of the

[7] Ferre-Guldager (1977) estimated the own-price elasticity of leafy vegatables in the Philippines to be 0.6 and fruit vegetables as 0.75. Kunkel et al (1978) estimated that for vegetables as 0.71 in rural areas and 0.78 in urban areas. Goldman and Ramade (1976) had it as 0.67 for vegetables in both rural and urban areas.

year, conveyed through cross price elasticities generate new equilibrium values that are then used as initial values the following year and so on and so forth. The change in calorie intake was taken for two cases, the low base case of 5 percent bacterial wilt infection and the high case of 50 percent bacterial wilt infection. Tables 4.9 and 4.10 show the equilibrium prices and quantities. Price and quantity data for 2001 are actual values faced by the province for that year. It is assumed that in each of the next ten years, farmers will continue to graft Casino onto EG 203 every planting season, thus the shock occurs every year.

Table 4.9: Price and Quantity Schedule for Eggplant: 5% BW Incidence

	P (P/kg)	Q (MT)
2001	26.72	7578.00
2002	26.68	7585.06
2003	26.63	7592.33
2004	26.58	7599.82
2005	26.53	7608.63
2006	26.47	7617.71
2007	26.41	7627.06
2008	26.35	7636.69
2009	26.28	7647.85
2010	26.21	7659.35
2011	26.14	7671.19

Table 4.10: Price and Quantity Schedule for Eggplant: 50% BW Incidence

	P (P/kg)	Q (MT)
2001	26.72	7578.00
2002	26.27	7648.58
2003	25.82	7721.28
2004	25.37	7796.16
2005	24.86	7884.30
2006	24.34	7975.09
2007	23.83	8068.60
2008	23.32	8164.92
2009	22.74	8276.53
2010	22.18	8391.48
2011	21.61	8509.89

Net Impact on Calorie Intake

The direct, indirect and net impacts for the low incidence case are shown in Tables 4.11 to 4.13. Increases in calorie intake from increased eggplant consumption are negligible in the low incidence case. However, increased consumption of the other commmodities is observed, with the biggest increase in the lowest income levels. Taking out rice from the indirect impact, it is still the lowest income level that purchased more of the other vegetables and root crops relative to the highest income level. The same is observed if rice is included. Apparently, both the rich and the poor consume more of both rice and vegetables given an extra income due to lower eggplant prices. In some cases, the poor would tend to buy more rice and a little more of vegetable to augment their food and the rich would tend to increase their consumption of other vegetables more than increase their intake of rice. This is the case that will be observed in the case of Pangasinan.

Table 4.11: Direct Impact by Income Strata: 5% BW Incidence

(*kcal/capita/day*)

	I	II	III	IV	V
2002	0.0033	0.0025	0.0054	0.0062	0.0021
2003	0.0035	0.0026	0.0057	0.0066	0.0022
2004	0.0033	0.0025	0.0055	0.0062	0.0021
2005	0.0045	0.0033	0.0073	0.0084	0.0028
2006	0.0047	0.0035	0.0078	0.0088	0.0030
2007	0.0050	0.0037	0.0082	0.0094	0.0032
2008	0.0039	0.0029	0.0064	0.0072	0.0025
2009	0.0044	0.0032	0.0072	0.0082	0.0028
2010	0.0044	0.0033	0.0072	0.0082	0.0028
2011	0.0044	0.0033	0.0072	0.0082	0.0028

Table 4.12: Indirect Impact by Income Strata: 5% BW Incidence

(*kcal/capita/day*)

	I	II	III	IV	V
2002	0.6232	0.4910	0.2429	0.3233	0.0931
2003	0.6251	0.4925	0.2438	0.3246	0.0934
2004	0.6329	0.4986	0.2466	0.3283	0.0945
2005	0.7295	0.5747	0.2850	0.3793	0.1092
2006	0.7352	0.5792	0.2875	0.3826	0.1102
2007	0.7410	0.5838	0.2901	0.3859	0.1112
2008	0.7235	0.5701	0.2820	0.3754	0.1081
2009	0.8160	0.6429	0.3180	0.4234	0.1219
2010	0.8178	0.6443	0.3187	0.4244	0.1221
2011	0.8196	0.6457	0.3195	0.4253	0.1224

Table 4.13: Net Impact by Income Strata: 5% BW Incidence

(*kcal/capita/day*)

	I	II	III	IV	V
2002	0.6265	0.4935	0.2483	0.3295	0.0952
2003	0.6286	0.4951	0.2496	0.3311	0.0957
2004	0.6362	0.5011	0.2521	0.3346	0.0966
2005	0.7340	0.5781	0.2924	0.3877	0.1121
2006	0.7400	0.5827	0.2953	0.3914	0.1132
2007	0.7460	0.5875	0.2983	0.3952	0.1144
2008	0.7274	0.5729	0.2883	0.3827	0.1105
2009	0.8203	0.6461	0.3252	0.4316	0.1246
2010	0.8222	0.6476	0.3259	0.4326	0.1249
2011	0.8240	0.6490	0.3267	0.4336	0.1252
Total	7.3051	5.7536	2.9020	3.8500	1.1124

Likewise, the direct, indirect and net impacts in the high incidence case are shown in Tables 4.14 to 4.16.

Table 4.14: Direct Impact by Income Strata: 50% BW Incidence

(*kcal/capita/day*)

	I	II	III	IV	V
2002	0.0331	0.0246	0.0544	0.0620	0.0211
2003	0.0347	0.0258	0.0570	0.0650	0.0221
2004	0.0333	0.0248	0.0548	0.0624	0.0212
2005	0.0436	0.0324	0.0716	0.0816	0.0277
2006	0.0456	0.0339	0.0749	0.0854	0.0290
2007	0.0477	0.0355	0.0784	0.0893	0.0304
2008	0.0387	0.0288	0.0635	0.0724	0.0246
2009	0.0436	0.0325	0.0717	0.0817	0.0278
2010	0.0438	0.0326	0.0720	0.0821	0.0279
2011	0.0440	0.0327	0.0723	0.0824	0.0280

Table 4.15: Indirect Impact by Income Strata: 50% BW Incidence

(*kcal/capita/day*)

	I	II	III	IV	V
2002	6.2318	4.9099	2.4286	3.2335	0.9306
2003	6.1990	4.8840	2.4181	3.2189	0.9266
2004	6.2237	4.9034	2.4256	3.2295	0.9296
2005	7.1113	5.6025	2.7784	3.6976	1.0649
2006	7.0953	5.5898	2.7747	3.6921	1.0635
2007	7.0779	5.5759	2.7706	3.6860	1.0620
2008	6.8419	5.3905	2.6693	3.5532	1.0229
2009	7.6351	6.0154	2.9794	3.9658	1.1417
2010	7.5607	5.9568	2.9512	3.9280	1.1309
2011	7.4855	5.8975	2.9226	3.8898	1.1199

Table 4.16: Net Impact by Income Strata: 50% BW Incidence

($kcal/capita/day$)

	I	II	III	IV	V
2002	6.2649	4.9345	2.4830	3.2954	0.9517
2003	6.2337	4.9098	2.4751	3.2838	0.9487
2004	6.2570	4.9282	2.4804	3.2920	0.9508
2005	7.1549	5.6349	2.8500	3.7792	1.0926
2006	7.1409	5.6237	2.8496	3.7775	1.0925
2007	7.1256	5.6114	2.8490	3.7753	1.0924
2008	6.8805	5.4192	2.7328	3.6256	1.0475
2009	7.6787	6.0479	3.0511	4.0476	1.1695
2010	7.6045	5.9894	3.0232	4.0101	1.1588
2011	7.5295	5.9302	2.9948	3.9721	1.1479
Total	69.8703	55.0292	27.7890	36.8585	10.6523

The same explanation holds for this high incidence case except that this time the net impact is positive and considerably more significant.

4.2 Pangasinan

4.2.1 Background

Pangasinan is the largest of four provinces that make up the region of Ilocos (Region I) covering an area of 5,368 square kilometers. The province's economy is mainly agricultural due to its vast fertile plains. More than 44 percent of its agricultural area is devoted to crop production. Aside from being one of the Philippine's rice granaries, Pangasinan is also a major producer of coconut, mango and eggplant. The province has two distinct seasons: dry from November to April and wet during the rest of the year. Average temperature is 27.6 degrees centigrade; humidity averages 87.3% and average monthly rainfall is 153.77 millimeters.

In 2001, Pangasinan accounted for about a third, 32.5 percent, of total eggplant production in the Philippines corresponding to 55,151 metric tons out of the total 169,819 metric tons of domestic production. For the same year, a total of 3,974 hectares in the province were grown with eggplant or 19.5 percent of the total harvested area of eggplant in the country. In 2000, the yield per hectare of eggplant in the province is 13.29 metric tons which is way above the national average of 8.31 metric tons per hectare. Below is a summary of production trends of eggplant for Pangasinan.

Table 4.17: Volume and Area of Production, 1990-2001

Year	Volume of Production(MT)	Harvested Area(ha)
1990	29582	3620
1991	29004	3480
1992	30675	3754
1993	31029	3881
1994	39528	3900
1995	43042	3994
1996	43913	3361
1997	45282	3361
1998	49531	2558
1999	50063	3810
2000	51567	3880
2001	55151	3974

Sources: PIDS, BAS

4.2.2 Eggplant Grafting Site

During the dry season from November 2001 to April the following year, grafted and non-grafted eggplant seedlings were transplanted into five 3×4 plots in Asingan, Pangasinan. A total of nine treatments were conducted, each replicated four times. The eggplant breeding line EG 203 was used as root tock and was grafted onto the high-yielding but bacterial wilt-susceptible farmers Abar and commercial Casino and Nueva Ecija Green (NE Green) varieties of eggplant. In addition, the non-grafted eggplant variety Mara was the ninth treatment.

The yield of Casino and Abar decreased when grafted onto EG 203 though grafted NE Green posted higher yields. Notice that EG 203 and A-300 produced the highest yields among the nine treatments (refer to Table 4.18).

4.2.3 Partial Budget Results

Per unit cost reductions are not observed for the grafted varieties except for NE Green grafted to EG 203. From P4.45, the unit cost drops to P4.21, or equivalently a 5.47 percent reduction. This is a much smaller reduction compared to the 14 percent in Nueva Ecija. Again, using the computed

Table 4.18: Yields of Grafted and Nongrafted Varieties

Treatment	Yield (kg)
T1 - EG 203 + Abar	8667
T2 - EG 203 + Casino	9188
T3 - Casino	13250
T4 - Eg 203	25417
T5 - Abar	12875
T6 - EG 203 + NE Green	17604
T7 - Mara	6375
T8 - NE green	12917
T9 - A-300	27229

Source: PhilRice

supply elasticity of eggplant of 1.3432, this unit cost reduction translates to a yield change of 0.095 MT/ha.

The increase in the cost of grafted treatments against non-grafted ones is of similar magnitude across the three varieties. The pivotal factor in determining the net effect on income is the magnitude of the yield change. Since NE Green is the only variety whose yield increased when grafted to EG 203, it is the only variety that generated positive net income with grafting.

4.2.4 Scaling Up of Experimental Field Data: Assessing Adoption

To assess the extent of adoption of the grafting method in Pangasinan, survey data on the incidence of bacterial wilt caused by *Ralstonia solanacearum* conducted in the dry season of 2003 that includes the province was used. Unlike in the case of Nueva Ecija with only three fields surveyed, 38 fields located in 3 cities (out of the 4 that comprise the province) were surveyed. In the 38 fields surveyed, wilt incidence ranged from 0 to 95 percent with a mean of 22.4 percent.

Similarly, problem domains instead of impact domains are identified. It is assumed that for Pangasinan, as much as 95 percent of the total area planted with eggplant is infected with bacterial wilt. Out of the infected area, the fraction planted with the NE Green variety is determined. As derived from the partial budgets, this portions yield is assumed to increase by 0.095 metric tons per hectare. Hence the supply curve of eggplant in Pangasinan is expected to shift by this much over the area sown with NE Green. Due to the fact that grafted NE Green is the only treatment that delivers positive net income compared to other grafted treatments, this research is extended to the case where farmers switch to using NE Green from other varieties. Among the dominant varieties that farmers grow in Pangasinan are the commercial variety Casino and the high-yielding but bacterial wilt-susceptible farmers Abar.

Thus, two cases are considered. In the first case, 95 percent of the total area devoted to eggplant is infected with bacterial wilt. Of the resulting hectarage, 40 percent is planted with Casino and the remaining split between Abar and NE Green. This segment allocated to NE Green is assumed to increase its yield per hectare by 0.095 metric tons. In the second case, it is further assumed that farmers will switch from growing Casino and Abar to NE Green and as such, a considerable segment of the area grown with Casino and Abar will be shifted to growing NE Green. It is assumed that 50 percent of these areas are shifted to NE Green.

Research Evaluation Period

The impact of the eggplant grafting method in Pangasinan is evaluated over a period of 10 years beginning 2002 until 2011. It is assumed that the province follows an adoption profile of initially increasing adoption rate up to a maximum adoption. It is assumed that farmers are able to continue to adopt the technique until it becomes fully implemented in the field. In this case, until the technology is adopted in about 90 percent of the actual affected area. This assumption of seemingly high adoption rates accounts for the fact that eggplant grafting is not a hard technique to adopt unlike other technologies. The adoption and supply shift schedules for eggplant in the two cases are in Tables 4.19 and 4.20.

Table 4.19: Adoption & Supply Shift Schedule for Eggplant: Without Switching Case

Year	Hectarage alloted to NE Green	Yield Change per ha (MT/ha)	Total Yield Change (MT)	Rate of Adoption (%)	Supply Shift (MT)
2002	1132.6	0.095	107.6	0.7	75.3
2003	1166.6	0.095	110.8	0.7	77.6
2004	1201.6	0.095	114.1	0.7	79.9
2005	1237.6	0.095	117.6	0.8	82.3
2006	1274.7	0.095	121.1	0.8	96.9
2007	1313.0	0.095	124.7	0.8	99.8
2008	1352.4	0.095	128.5	0.8	102.8
2009	1392.9	0.095	132.3	0.9	105.9
2010	1434.7	0.095	136.3	0.9	122.7
2011	1477.8	0.095	140.4	0.9	126.3

Table 4.20: Adoption & Supply Shift Schedule for Eggplant: With Switching

Year	Hectarage alloted to NE Green	Yield Change per ha (MT/ha)	Total Yield Change (MT)	Rate of Adoption (%)	Supply Shift (MT)
2002	2454.0	0.095	233.1	0.7	163.2
2003	2527.6	0.095	240.1	0.7	168.1
2004	2603.4	0.095	247.3	0.7	173.1
2005	2681.5	0.095	254.7	0.8	178.3
2006	2761.9	0.095	262.4	0.8	209.9
2007	2844.8	0.095	270.3	0.8	216.2
2008	2930.1	0.095	278.4	0.8	222.7
2009	3018.0	0.095	286.7	0.9	229.4
2010	3108.6	0.095	295.3	0.9	265.8
2011	3201.8	0.095	304.2	0.9	273.8

4.2.5 Baseline Data

Additional supply due to eggplant grafting is injected in the year 2002. While the household income and expenditure survey used was conducted in 2000, minimal variation in the elasticities derived from the survey is expected two years after. After all, the next survey occurs in 2003 and will not be available for public use until 2005.

Initial values for volume of production and prices are for 2001 that are starting values for 2002 when the supply shock is introduced. After the shock is introduced in 2002, the resulting final prices and quantities for all commodities are carried over to the next year as starting values. For each year, the corresponding initial price and quantity for a commodity are the final price and quantity values in the prior year after adjusting for the changes that occur in the same prior year. In short, price and demand changes the previous year impact on the initial price and quantity values for a commodity. It is assumed that the transitory effect of a supply shock transmitted through cross price elasticities eventually peters out by the end of a year after which another wave of supply shock occurs.

4.2.6 Income Elasticities and Budget Proportions

All commodities showed a declining trend of income elasticity for increasing income levels. Though there is a notable increase in elasticity as one moves from I to II, a downward trend is observed henceforth, and the trend is downward. As expected, the lowest income group had the highest income elasticity across most of the commodities whereas the highest quintile had the lowest income elasticity across all the commodities. Rice, which is the staple food in the Philippines and also in Pangasinan had the lowest income elasticity among the commodities.

Table 4.21: Income Elasticities of Selected Commodities by Income Strata, Pangasinan

Commodity	I	II	III	IV	V
Rice	0.2369	0.2557	0.2985	0.1302	0.1141
Potato	1.0516	1.1238	0.8763	0.8987	0.7109
Cassava	0.5956	1.1545	1.0946	0.8246	0.8797
Camote	0.6411	1.1611	1.0939	0.6506	0.3171
Gabi	0.6578	1.1230	1.0988	0.8651	0.6866
Cabbage	1.0376	0.9429	0.9498	0.8356	0.5877
Ampalaya	0.8149	1.0028	0.8200	0.7720	0.5436
Eggplant	0.7635	0.8817	0.6625	0.5917	0.4504
Tomato	0.8922	1.0538	0.9069	0.7773	0.5199
Mongo	0.4737	0.9070	0.3906	0.4171	0.0615
Carrot	0.9311	1.2701	1.0172	0.8560	0.6896
Onion	0.7476	1.1577	0.9454	0.8818	0.4227

The largest single food expenditure among the commodities for all quintiles is rice which accounts for 18-36 percent of the total food budget. As expected, the budget proportion spent on the food items decreases for decreasing incomes.

Table 4.22: Average Budget Proportions of Selected Commodities, Pangasinan

Commodity	I	II	III	IV	V
Rice	0.3643	0.3110	0.2838	0.2338	0.1830
Potato	0.0047	0.0055	0.0061	0.0062	0.0060
Cassava	0.0016	0.0019	0.0015	0.0012	0.0010
Camote	0.0023	0.0021	0.0025	0.0023	0.0018
Gabi	0.0017	0.0018	0.0023	0.0021	0.0023
Cabbage	0.0040	0.0043	0.0051	0.0056	0.0056
Ampalaya	0.0082	0.0080	0.0088	0.0080	0.0068
Eggplant	0.0102	0.0097	0.0098	0.0085	0.0075
Tomato	0.0092	0.0086	0.0085	0.0074	0.0065
Mongo	0.0085	0.0080	0.0070	0.0053	0.0044
Carrot	0.0015	0.0024	0.0025	0.0028	0.0030
Onion	0.0071	0.0061	0.0062	0.0055	0.0048

4.2.7 Money Flexibility

Similar to the case of Nueva Ecija, no estimates of money flexibility are available for the province of Pangasinan. Hence, to estimate ϕ by income quintile, it was necessary to estimate e_{ii} for at least one good or a composite of goods. The direct price elasticity was computed by simply regressing the price of a commodity on the per capita quantity consumed. This was done using weekly data on the estimated per capita c onsumption by region of selected commodities from a survey conducted during the months of May, August and November 1999 and February 2000. This included rice, ampalaya and eggplant. The survey, *Consumption of Selected Food Commodities* in the Philippines, was conducted by the Bureau of Agricultural Statistics and was released in January of 2001. Though the survey was conducted in between 1999 and 2000, there was no other data available that will yield per capita consumption values. Direct price elasticities were computed for eggplant, ampalaya and rice and using (3.5). Correspondingly, three different estimates for money flexibility were computed. The simple average of the three was obtained to get an overall measure of money flexibility for each income strata. The estimated coefficients are shown below.

Table 4.23: Estimated Money Flexibility Coefficients by Income Quintile

Quintile	Money Flexibility
I	-0.9335
II	-1.0539
III	-0.8628
IV	-0.8504
V	-0.5145

There is no way to verify whether the above money flexibility coefficients are appropriate in the absence of studies done for the Philippines. However, these estimates augur well with Frischs conjecture that the absolute value of decreases as the level of income increases. The fit is even better compared to that for Nueva Ecija if one moves from II to V. Notwithstanding this, Frischs conjecture is reinforced by the significant difference between the coefficients for the highest and lowest income quintiles. Again, these estimates fall below the range of -3 for countries with low levels of per capita income as in Chile and Argentina and -1.1 for high-income countries such as the United States.

4.2.8 Price Elasticities

A price elasticity matrix was estimated for each of the income strata using equations (3.1), (3.2) and (3.3). Again, the average was obtained using total quantity consumed by strata as weights. For almost all the commodities, the direct price elasticity increases as the income level rises. This is highlighted by the considerable difference between the lowest and highest income quintiles.

Table 4.24: Estimated Direct Price Elasticities by Strata

	I	II	III	IV	V	Average
Rice	-0.2192	-0.2289	-0.6127	-0.2224	-0.1891	-0.2939
Potato	-1.6894	-1.3648	-1.0700	-0.7147	-0.6474	-1.1366
Cassava	-2.1130	-1.2538	-1.3241	-0.7330	-0.3662	-1.1333
Camote	-2.1104	-0.9895	-0.4776	-0.7372	-0.3945	-0.9635
Gabi	-2.1201	-1.3151	-1.0336	-0.7130	-0.4045	-1.1567
Cabbage	-1.8310	-1.2696	-0.8851	-0.5998	-0.6385	-1.0781
Ampalaya	-1.5800	-1.1730	-0.8191	-0.6391	-0.5036	-0.9604
Eggplant	-1.2782	-0.9005	-0.6791	-0.5631	-0.4729	-0.7793
Tomato	-1.7463	-1.1812	-0.7834	-0.6715	-0.5515	-0.9886
Carrot	-1.9629	-1.3012	-1.0381	-0.8064	-0.5722	-1.1789
Onion	-1.8218	-1.3395	-0.6371	-0.7363	-0.4618	-0.9944
Mongo	-0.7554	-0.6352	-0.0929	-0.5785	-0.2936	-0.4761

The estimates are on the high side for most of the commodities relative to computations done in previous studies that range from -0.6 to -0.8.

4.2.9 Changes in Calorie Intake

Equilibrium Price and Quantity

The cumulative change in calorie intake was evaluated over a ten-year period, 2002-2011. In each year, the supply of eggplant is shifted out by the increase in the yield per hectare over the total area allocated to NE Green, the variety that will be grafted to the resistant rootstock EG 203. This is adjusted for the rate of adoption each year. Subsequent demand and price changes by the end of the year, conveyed through cross price elasticities are imbedded in the new equilibrium price and quantity carried over to the next year and so on and so forth. The change in calorie intake was taken for two cases: (a) without switching case, and (b) with switching case. Tables 4.25 and 4.26 show the final prices and quantities for eggplant.

Table 4.25: Price and Quantity Schedule for Eggplant: Without Switching Case

	Price (P/kg)	Quantity (MT)
2001	26.20	55151
2002	26.19	55187
2003	26.17	55224
2004	26.16	55262
2005	26.14	55301
2006	26.12	55347
2007	26.11	55395
2008	26.09	55444
2009	26.07	55494
2010	26.04	55553
2011	26.02	55613

Table 4.26: Price and Quantity Schedule for Eggplant: With Switching Case

	Price (P/kg)	Quantity (MT)
2001	26.20	55151
2002	26.17	55229
2003	26.14	55309
2004	26.11	55391
2005	26.07	55477
2006	26.04	55577
2007	26.00	55680
2008	25.96	55786
2009	25.91	55895
2010	25.87	56022
2011	25.82	56152

Net Impact on Calorie Intake

The direct, indirect and net impacts for the low incidence case are shown in Tables 4.27 to 4.29. Note that lower eggplant prices lead to relatively more eggplant consumption, reflected in the direct effect, in the highest income class relative to the lowest income class. However, the opposite is observed for the indirect effect or the increase in consumption of other vegetables and root crops. The extra income derived from lower prices is spent by the poor to buy more rice and a little bit more of both eggplant and other vegetables. Indirect effects, without rice, are bigger for the higher income levels but with rice, the opposite occurs. Hence, the poor is likely to spend extra income on augmenting rice intake that could go well with small increases in vegetable intake, both eggplant and other vegetables. The rich, on the other hand, will buy more of both types of vegetables and less of rice.

Table 4.27: Direct Impact by Income Strata: Without Switching Case

(*kcal/capita/day*)

	I	II	III	IV	V
2002	0.0123	0.0133	0.0125	0.0147	0.0161
2003	0.0123	0.0134	0.0125	0.0147	0.0161
2004	0.0124	0.0134	0.0125	0.0148	0.0162
2005	0.0124	0.0135	0.0126	0.0148	0.0163
2006	0.0142	0.0155	0.0144	0.0170	0.0187
2007	0.0143	0.0155	0.0145	0.0171	0.0187
2008	0.0144	0.0156	0.0145	0.0172	0.0188
2009	0.0144	0.0157	0.0146	0.0172	0.0189
2010	0.0163	0.0177	0.0165	0.0194	0.0213
2011	0.0163	0.0177	0.0165	0.0195	0.0214

Table 4.28: Indirect Impact by Income Strata: Without Switching Case

(*kcal/capita/day*)

	I	II	III	IV	V
2002	0.1146	0.1130	0.0666	0.0672	0.0462
2003	0.1149	0.1134	0.0669	0.0674	0.0463
2004	0.1153	0.1137	0.0671	0.0676	0.0465
2005	0.1156	0.1141	0.0673	0.0679	0.0466
2006	0.1326	0.1308	0.0771	0.0778	0.0535
2007	0.1330	0.1312	0.0774	0.0780	0.0536
2008	0.1334	0.1316	0.0776	0.0783	0.0538
2009	0.1338	0.1320	0.0778	0.0785	0.0540
2010	0.1509	0.1489	0.0878	0.0886	0.0609
2011	0.1513	0.1493	0.0881	0.0889	0.0611

Table 4.29: Net Impact by Income Strata: Without Switching Case

($kcal/capita/day$)

	I	II	III	IV	V
2002	0.1268	0.1264	0.0791	0.0819	0.0623
2003	0.1272	0.1268	0.0794	0.0822	0.0625
2004	0.1276	0.1272	0.0796	0.0824	0.0627
2005	0.1281	0.1276	0.0799	0.0827	0.0629
2006	0.1468	0.1463	0.0916	0.0948	0.0721
2007	0.1473	0.1467	0.0919	0.0951	0.0724
2008	0.1477	0.1472	0.0922	0.0954	0.0726
2009	0.1482	0.1476	0.0924	0.0957	0.0729
2010	0.1672	0.1666	0.1043	0.1080	0.0822
2011	0.1677	0.1670	0.1046	0.1084	0.0825
Total	1.4345	1.4292	0.8949	0.9267	0.7050

The net impact of eggplant grafting on per capita calorie intake per day, though positive is negligible in the no switching case. This is due in part to the fact that in this framework, income effects are ignored. Only price effects working their way through cross price elasticities are considered.

Likewise, the direct, indirect and net impacts in the high incidence case are shown in Tables 4.30 to 4.32. Like the no switching case, the poor are likely to buy more rice with the extra purchasing power due to lower eggplant prices and buy a little bit more of all vegetables while the rich are likely to buy more of all vegetables but rice. In fact, the diet of the poor in the Philippines consists more of rice and a little amount of vegetable or sometimes fish.

The net impact is again positive though negligible in the with switching case for the same reasons cited above.

Table 4.30: Direct Impact by Income Strata: With Switching Case

(*kcal/capita/day*)

	I	II	III	IV	V
2002	0.0266	0.0289	0.0270	0.0318	0.0349
2003	0.0267	0.0290	0.0271	0.0319	0.0350
2004	0.0268	0.0291	0.0272	0.0320	0.0351
2005	0.0269	0.0292	0.0273	0.0322	0.0352
2006	0.0309	0.0335	0.0313	0.0369	0.0404
2007	0.0310	0.0337	0.0314	0.0370	0.0406
2008	0.0311	0.0338	0.0315	0.0372	0.0407
2009	0.0312	0.0339	0.0316	0.0373	0.0409
2010	0.0352	0.0383	0.0357	0.0421	0.0462
2011	0.0354	0.0384	0.0359	0.0423	0.0463

Table 4.31: Indirect Impact by Income Strata: With Switching Case

(*kcal/capita/day*)

	I	II	III	IV	V
2002	0.2482	0.2449	0.1444	0.1456	0.1001
2003	0.2488	0.2455	0.1448	0.1460	0.1003
2004	0.2494	0.2461	0.1451	0.1464	0.1006
2005	0.2500	0.2467	0.1455	0.1468	0.1009
2006	0.2865	0.2826	0.1667	0.1682	0.1156
2007	0.2871	0.2832	0.1671	0.1686	0.1159
2008	0.2877	0.2839	0.1675	0.1690	0.1162
2009	0.2883	0.2845	0.1679	0.1693	0.1165
2010	0.3250	0.3207	0.1893	0.1909	0.1314
2011	0.3256	0.3213	0.1896	0.1913	0.1317

Table 4.32: Net Impact by Income Strata: With Switching Case

(*kcal/capita/day*)

	I	II	III	IV	V
2002	0.2748	0.2738	0.1714	0.1774	0.1349
2003	0.2755	0.2745	0.1718	0.1779	0.1353
2004	0.2762	0.2752	0.1723	0.1784	0.1357
2005	0.2770	0.2759	0.1728	0.1789	0.1361
2006	0.3173	0.3162	0.1980	0.2051	0.1561
2007	0.3181	0.3169	0.1985	0.2056	0.1565
2008	0.3188	0.3176	0.1990	0.2061	0.1570
2009	0.3195	0.3184	0.1995	0.2067	0.1574
2010	0.3603	0.3590	0.2250	0.2331	0.1776
2011	0.3610	0.3597	0.2255	0.2336	0.1781
Total	3.0985	3.0871	1.9339	2.0028	1.5247

Chapter 5

Conclusion: Towards a Hierarchical Framework Using Minimum Datasets

Eggplant grafting implemented in two field sites in the Philippines, in Nueva Ecija and Pangasinan are used as case studies to serve as proofs of concept to illustrate and validate the feasibility of employing an impact assessment framework for determining the nutritional impact of technology-oriented agricultural activities. The implemented framework is illustrated to the specific case of eggplant grafting that increases yields and shifts the supply curve outward and is shown in *Table 5.1*. Two things may be noted as indicated by the arrows. First, in simple cases, economic surplus modelling may be passed over. Second, certain welfare indicators may be derived using other partial equilibrium models and not having to go through general equilibrium models. Hierarchical frameworks are not intended as recipes but rather as guidelines that can be easily altered. Evidently, there is a tradeoff between data intensity and rigor of results. The examples in this thesis suggest the use of minimum data.

In particular, nutritional impacts are assessed by disaggregating the market demand curve into demand curves by income groups and by using their separate price elasticities of demand. The methodology in this research only takes into account cross price effects and ignores totally any

Table 5.1: Hierarchical Framework for Minimum Datasets and Impact Indicators: Technology-oriented R&D (*Example: Eggplant Grafting*)

Impact Level		Typical Scale	Actual Impact	Data Needs		Model Needs			Indicator
				Minimum	Optional	Bio/PS	PE/ASM	GE	
Human Welfare	Human consequences of enhanced agricultural performance	Nueva Ecija and Pangasinan; can be extended to regions or the Philippines	Increase in calorie intake per income strata	Cross-sectional consumption and expenditure survey data for the scale intended; also family income survey	Existing calorie intake by household type, commodity prices.				Change in intake of kilocalories/capita/day
Economic Systems	Value of eggplant production, consumption, and/or trade		Economic benefits to eggplant producers and consumers in the area		Discount rate, time pattern of benefit and cost profile				Producer surplus Consumer surplus Agricultural GDP/capita
Markets and Trade	Market structure: domestic production of eggplant is mainly for domestic consumption	Nueva Ecija and Pangasinan	Initial values for production and consumption of eggplant in Nueva Ecija and Pangasinan. Actual *supply shift* when production is enhanced by eggplant grafting.	Total volume of domestic production. In this case all domestic production is consumed and is equivalent to total consumption for Nueva Ecija and Pangasinan					Increase in volume of eggplant production - MT/year.
Adoption Domains	Ex-ante adoption domains (two types: problem and impact domains)	Nueva Ecija and Pangasinan	Account for spatial variation in eggplant grafting across (a) bacterial wilt-infested areas or (b) areas with similar agroecological conditions. Upper and lower limits of adoption rate identified.	Experimental field data from 38 fields in 3 cities in Pangasinan, and from 3 fields in 2 cities in Nueva Ecija.	Adoption dynamics and probabilities. Variability in soil and climate conditions across different seasons.				Number of hectares that will experience increase in yields - out of the bacterial wilt infected area, that allocated to the variety that will be grafted.
Projects	Evaluation of eggplant grafting project	Towns of Munoz, Nueva Ecija and Asingan, Pangasinan	Recommended bacterial wilt-resistant rootstocks and corresponding appropriate scions	Known changes in yields and production cost of grafted and non-grafted eggplant varieties.					Changes in yield, labor and materials costs and revenue per hectare of grafted eggplants
Project Activity	Eggplant grafting	Experimental field plots in Munoz, Nueva Ecija and Asingan, Pangasinan	Testing of bacterial wilt-resistant rootstocks and scions combined	Experimental data on different eggplant varieties.	Geo-referenced experimental data.				Bacterial wilt incidence and changes in yields for different eggplant varieties

income effect derived from additional profits earned by producers of the commodity whose supply has increased. As such, the results emanating from this methodology underestimates the total benefits and should be interpreted with caution.

One advantage of this method is its minimal use of data that can usually be derived from household surveys. As opposed to other methods that require actual values of the purchase price of commodities for the different households, cross price elasticities can be estimated without direct observation of prices. This comes at the expense of theoretical restrictions and assumptions.

In the Frisch methodology for estimating price elasticities used in this study, want independence is assumed in that the marginal utility of a good is independent of the quantity consumed of any other good. While want independence is not valid for all goods, the Frisch method can still be applied to estimate group elasticities if the bundle of goods available to the consumers can be grouped. Attempts were made to include commodity groups such as beef, chicken, pork and fish but unlike crop statistics which can be traced to specific provinces in different regions, poultry and livestock statistics are only available at the regional level. As such, price and production values necessary to compute for supply elasticites were unavailable. Also, since the primary purpose of this research is to test a methodology for estimating increases in caloric intake due to supply expansions, and not to estimate price elasticties as the end, with the use of minimum data, the Frish methodology was still applied even when the 12 commodities as specified below cannot be safely regarded as want independent. Should disaggregated data be made available later on, this research can be amended.

The increase in yields due to eggplant grafting has positive effects on the daily caloric intake per capita in the different income classes with the greatest impact on the lowest income class; though negligible in most cases presented. For Nueva Ecija, under the 5 percent bacterial wilt incidence case, total daily per capita calorie intake increases by 0.09 to 0.60 kilocalories. Under the second case of 50 percent bacterial wilt incidence, the increase ranges between 0.9 and 6.0 kilocalories. Under the no switching case in Pangasinan, calorie intake increases between 0.07 to 0.22 and between 0.15 and 0.49 when switching is accommodated.

This methodology employed can be augmented by using additional optional data in the form of existing calorie intake of different household types with which to benchmark the magnitude of the increase in calorie intake.

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VITA

Maria Erlinda Mutuc was born in the Philippines on August 20, 1972. She obtained her B.S. in Business Economics in 1994 and her M.S. Economics degrees in 1998 from the University of the Philippines School of Economics (UPSE). She holds a certificate in Advanced Studies in International Economic Policy Research from the Kiel Institute of World Economics. She served as local consultant for the Asian Development Bank in Manila prior to attending Virginia Tech. She will join the graduate program of Texas Tech in the Spring of 2004.