Economic Impacts of the IR-4 Project and IR-4 Project Programs

December 28, 2011

Steven R. Miller
&
Andrea Leschewski

Center for Economic Analysis
Michigan State University
88 Agriculture Hall
East Lansing, MI 48824

This is a corrected version of the September 30, 2011 report that corrects Tables 4 and 5 in the text. In both tables, erroneous industry direct effects were reported that do not impact the overall findings of this report. The direct effect numbers previously reported in Tables 4 and 5 were not used in the calculations of overall impacts. The corrected tables in this document do reflect the estimates, as described in the text of the original report.

October 22, 2012

Executive Summary

The Interregional Research Project Number 4 (IR-4 Project) has been a pivotal resource in providing U.S. residents a plentiful and low-cost array of vegetables, fruits, berries and tree nuts since 1963 by facilitating the registration of newer, lower-toxic pest control products with the EPA for application on specialty crops. Specialty crop growers often are at a disadvantage relative to program crop growers in having access to effective crop loss mitigation options against common agricultural pests. Specialty crops make up about 40 percent of the total value of U.S. crop production and include both food and ornamental crops that afford insufficient economic incentive for a pesticide companies to support initial or continuing registration of commercial pesticides. As all agricultural uses of pesticides are regulated by the EPA, each use must be registered or exempted before applied. Such registration is costly, making only registration for uses on any but large acreage crops unprofitable for pesticide companies. The IR-4 Project leverages resources to pursue registration for such uses. Along with supporting the use of reduced-toxicity pesticides, with its Biological and Organic Support program, the IR-4 Project is able to direct necessary resources to meet the U.S. goal of substantially decreasing the environmental and health impacts of agricultural pesticide use following the passage of the Food Quality Protection Act of 1996.

This report assesses the economic impact of the IR-4 Project on the U.S. economy. The assessment assumes a long-run presence of the IR-4 Project, such that relevant decision makers recognize and plan for the continued efforts of the IR-4 Project. Because this report limits research to private transactions, and hence returns to expenditures, it does not purport to measure the true social costs of pesticide usages that include public health and environmental quality aspects. In addition, the report does not purport to measure the true cost of allocated public and private funds to IR-4 activities in terms of the value of foregone uses of such funding.

Well-established methods of measuring direct and secondary economic impacts are used to gauge the contributions of the IR-4 Project and its three primary programs, including the Food Crops, Ornamental, and Biological and Organic Support programs in terms of sales, employment and gross domestic product. It should be noted that estimated economic impacts do not take into consideration health or environmental impacts, or associated economic outcomes of such impacts. Economic impact estimates do measure the direct and secondary effects of IR-4 registered pesticides' contribution to increased agricultural output of minor use crops and associated impacts of IR-4 expenditures for research and pesticide registrations. The findings suggest that each program posits real economic benefits to growers and the economy as a whole. Specifically, growers benefit in higher yields with higher quality output, consumers benefit by higher varieties and lower costs to food and ornamental crops, and the industry benefits through better global competitiveness of U.S. output. Including all secondary impacts, the IR-4 Project is anticipated to support research and industry sales sufficient to support 104,650 U.S. jobs and bumps annual gross domestic product by $7.3 billion. The findings support public investment in the IR-4 Program in alleviating an economic market failure should the pesticide industry for minor-uses be left to its own devices under the regulation of the Food Quality Protection Act of 1996.

Table of Contents

Introduction

The Environmental Protection Agency (EPA) and the U.S. Department of Agriculture (USDA) recognize that a variety of pest management tools are needed in order to maintain a safe and dependable supply of fruits and vegetables while allowing U.S. crop producers to compete in global markets. Access to such pesticide tools also enables the management of pest resistance, reduces the risk of pest-borne diseases and enables more effective integrated pest management practices. However, pesticide use poses risk to health and environment. To reduce risks, federal law requires that pesticides must be registered or exempted by the U.S. EPA to assure that prescribed uses pose no threat to human health and no unreasonable risk to the environment if used in accordance to label directions. As stipulated under the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA), the EPA examines the ingredients of a pesticide; the site or crop on which it is to be used; the amount, frequency and timing of its use; and storage and disposal practices to ensure that it will not have unreasonable adverse effects on humans, the environment and non-target species before registering or exempting labeled pesticide applications. More than 140 different studies on a chemical's toxicology, crop residues and environmental effects may be required before the EPA determines the conditions by which the pesticide meets health and environmental safety guidelines (National Agricultural Chemicals Association 1993). Food and feed-grain applications require additional testing to ascertain whether chemical residues at harvest meet EPA-established tolerances (maximum pesticide residue levels). Through extensive testing, those applications that demonstrate compliance with all federal health and environmental safety restrictions will receive EPA clearance for prescribing such use on the pesticide label. Uses and rates not listed on the label are strictly prohibited without special exemption under Section 18 of the Federal Insecticide, Fungicide and Rodenticide Act of 1947 (FIFRA). Pesticide labels specify directions for safe use, storage and disposal based on rigorous testing and off-label uses of pesticides are strictly illegal (USDA: National Agricultural Statistics Services 2007). The costs of research necessary to develop data to support labeled uses are generally borne by chemical companies.

The registrant is responsible for providing the EPA field test studies conducted under strict EPA regulations. Such field testing is expensive and can require years of research. For large acreage crops such as corn, wheat and soybeans, the registrant generally assumes the costs of registration, as the cost is easily recovered through high sales volumes. However, agrichemical firms seldom assume the full expense of registering for minor-use crops, where the expected returns from sales will not cover the registration expense. For minor uses, the relative high cost of registration against limited sales potential and the potential liability provide an unfavorable risk-reward relationship for pursuing pesticide registrations for minor uses. Minor-use crops include both food and ornamental crops where total production is less than 300,000 acres, or those crops for which there exists insufficient economic incentive for a registrant to support initial or continuing registrations (USDA: National Agricultural Statistics Services 2007).[1] Such crops are generally high-value but occupy low acreage compared to program crops. They occupy multiple minor-use registrations in isolation but account for about 13.7 million acres of U.S. farmland, about $67 billion in sales and approximately

[1] The easiest way to discern what is a specialty crop is by listing what is not a specialty crop. The following crops do not meet the acreage definition of a minor crop: almonds, apples, barley, beans (snap and dry), canola, corn (field, sweet and pop), cotton, grapes, hay (alfalfa and other), oats, oranges, peanuts, pecans, potatoes, rice, rye, sorghum, soybeans, sugar beets, sugarcane, sunflower, tobacco, tomatoes, turf and wheat.

40 percent of all U.S. crop sales according to the 2007 and 2002 Agriculture Censuses (USDA: National Agricultural Statistics Services 2002, 2007).

While specialty crop production makes up a large component of total U.S. agricultural sales, such crops would be susceptible to prohibitive risk of economic loss from common agricultural pests without access to many of the same pesticides used by large acreage crop producers. If the market was left to its own devices, insufficient financial incentives for the agrichemical industry to invest in the research required to register pesticides for the plethora of minor uses would restrict consumer access to a wide spectrum of minor-use food crops that make up USDA guidelines to a healthy diet. The USDA and state agricultural experiment stations (SAES) recognized this problem in 1963 when they organized the Interregional Research Project Number 4 (IR-4 Project) to facilitate the registration of existing and newer pest control products. The IR-4 Project is the only program that conducts research and submits petitions to EPA to establish new tolerances and labeled uses for specialty crop growers.

This report assesses the economic impact of the IR-4 Project on the U.S. economy. The assessment assumes a long-run presence of the IR-4 Project, such that relevant decision makers recognize and plan for the continued efforts of the IR-4 Project. With its rich history in supporting specialty crop growers, such an assumption is reflected in historical relationships used to model the fiscal impacts of the IR-4 Project.

The structure of the report is as follows. First is an overview of the IR-4 Project, the Biological and Organic Support and the Ornamental Horticulture Programs. This is followed with a general overview of the methodology used to assess the economic impacts. Next is a section on empirical estimates of direct and total macroeconomic impacts. The report concludes with a summary of findings.

The IR-4 Project

The IR-4 Project was established in 1963 as a collaborative effort of the Agricultural Research Service (ARS) agency of the USDA, National Institute of Food and Agriculture (NIFA – formally called the Cooperative State Research, Education, and Extension Service) and state Agricultural Experiment Stations (SAES) at Land Grant universities in coordination with the Environmental Protection Agency (EPA) to assist in the collection of residue and efficacy data in support of the registration or reregistration of minor use pesticides. With headquarters at Rutgers University, and regional state university offices at the University of California, Cornell University, University of Florida and Michigan State University, the ARS coordinating office in Beltsville, MD, and research laboratories and field research centers located in twenty-five states, the IR-4 Project conducts the research necessary to support a wide variety of specialty crop pesticide applications necessary to maintain a stable and safe food supply for the nation and to deliver a diversity of ornamental crops that brings value to U.S. households and neighborhoods. The IR-4 Project works with various stakeholders to establish priorities in pursuing ample pesticide options for specialty crop pest control.

By leveraging its network of SAES and industry scientist, and through its correspondence with the EPA, the IR-4 Project provides the field trial and laboratory residue data necessary for EPA clearance of minor use tolerances. The IR-4 Project has provided the necessary field and residue data to account for about 50 percent of EPA's annual work plan and new clearances in recent years. In this role, the IR-4 Project closes the gap in pest management options between specialty crop and program crop growers.

Since its inception, the IR-4 Project has achieved over 10,000 pest control clearances on food crops (including biopesticide uses) and over 10,000 clearances on ornamental crops and is instrumental in curtailing substantial economic loss from pest-induced crop damage. In addition, the IR-4 Project preempted economic losses to the agricultural sector when stricter standards of food safety were imposed with the passage of the Food Quality Protection Act of 1996 (FQPA). FQPA imposed added protections from pesticide exposure on food, especially for infants and children, and forced several critical pesticides off the market or substantially restricted their use. The IR-4 Project reduced the potential impact of FQPA on specialty crop growers by proactively pursuing the registration of new and safer alternatives for minor use pest management prior to the passage of FQPA. More so, about 70 to over 80 percent of IR-4 Project's effort supports the registration of reduced-risk pesticides that substantially reduce the risk to human and environmental health relative to existing or recently de-registered products (Viray and Hollingworth 2009; U.S. Environmental Protection Agency 2001a).

The IR-4 Project operates three distinct programs; the Food Program, the Ornamental Horticulture Program, and the Biological and Organic Support Program. Within each program area, the IR-4 Program operates several initiatives to further streamline the pesticide registration process that build on existing synergies across its network of scientists, crop protection industry, and national and international regulatory agencies. For example, following the passage of the Pesticide Registration Improvement Act of 2003 (PRIA), the IR-4 Project and the EPA have increased coordination efforts to streamline the EPA registration process and clear backlogs of IR-4 petitions (Kunkel 2008). The project also facilitates research and registration standards across national boundaries (Kunkel 2010) that not only expedite the registration process with international residue and tolerance data collaboration, but also facilitate international trade through adoption of global research standards and by aligning international maximum residue levels (MRLs). Further efforts have led to U.S. and international capacity building efforts like the launch of the IR-4 Project Global Minor Use Information Portal found at http://ir4.rutgers.edu/GMUS/GMUSportal2.htm, and classification schemes that increase the scope of field trials across similar crop applications. Through such efforts, the IR-4 Project has decreased the domestic and international research costs of collecting pesticide residual and efficacy data, increased agricultural trade opportunities and reduced the economic costs of pesticide registrations. Such synergistic outcomes are not likely to occur in the absence of the IR-4 should industry be left to its own devices for meeting minor-use growers' needs.

The IR-4 Project is funded by the USDA in partnership with the SAES. The majority of USDA funding for the IR-4 Project comes through the National Institute of Food and Agriculture (NIFA-formerly called Cooperative State Research Education and Extension Service). The Agriculture Research Service (ARS) established a companion minor use program in 1976 to provide further program support. Recently, USDA-Foreign Agriculture Service (FAS) has provided IR-4 additional funding to coordinate the development of international standards that support specialty crop exports. The SAES contributes financial resources through Hatch Multi-State Research Funds and a significant amount of in-kind contributions by housing IR-4 Field Research Centers, analytical laboratories and management offices throughout the United States. The crop protection industry also contributes direct financial resources as well as significant in-kind resources. There are three principal programs under the IR-4 Project: the Food Program, the Ornamental Horticulture Program and the Biopesticides and Organic Support Program. Each is discussed separately below.

The IR-4 Ornamental Horticulture Program

The IR-4 Ornamental Horticulture Project was founded in 1977 to provide agrichemical registration support for non-food, specialty crop growers that include ornamental horticulture plants grown in greenhouses and nurseries, landscape plantings, Christmas tree farms, sod farms and interiorscapes. This program directly contributes to the health of this industry by providing necessary research and EPA registration support for an industry that otherwise would have few resources to address agrichemical usage and research tools to form enlightened management decisions for controlling pests in an efficient and ecologically friendly manner.

The ornamental crop industry makes up an important component of specialty crop agriculture. Ornamental crops exclude plants intended for commercial food production. They include floriculture and nursery crops, where floriculture crops include bedding and garden plants, cut flowers, potted flowering plants, indoor foliage plants, and cuttings and other prefinished plants generally sold to other growers for further growing. In the U.S., non-food specialty crops make up over 15 percent of the total value of sales of all production crops and 36 percent of the value of sales of all specialty crops (National Agricultural Statistics Services 2004). According to the 2007 Census of Agriculture, the U.S. total value of sales of non-food specialty crops were nearly $13.7 billion as shown in Table 1. As in indication to the total value of ornamental crops, Jarardo (2006) estimates that sales per U.S. Households are about $147 at wholesale based on 2005 estimates.

Table 1: Value of Specialty, Non-Food Crops Sold: 2006 (1,000s)

Crop		Sales
Aquatic Plants	$	35,193
Bulbs, corms, rhizomes and tubers-dry	$	90,304
cuttings, seedlings, liners and plugs	$	440,933
Floriculture crops	$	6,466,886
Flower seeds	$	35,995
Nursery stock	$	6,568,563
Other nursery crops	$	48,476
Total	**$**	**13,686,350**

Source: Table 37 of the 2007 Census of Agriculture

Consumer desire for cosmetically unblemished ornamental plants demands substantial investment in agrichemical solutions. Presentation is a vital component in the value of ornamental crops. Consumer perception of the quality of ornamental crops rests wholly on external attributes, such as absence of defects, uniformity of size, and shape. Ornamental growers must contend with demand for blemish-free ornamentals. To address customer demand, growers have a small portfolio of options to support unblemished ornamental crop production that include integrated pest management approaches, environmental controls in greenhouses, pesticides, and growth regulators. However, regulatory oversight of pesticide usage and unfavorable agrichemical industry risk-reward relationships for ornamental crop registration creates a market failure condition for ornamental crop growers; reducing access to agrichemicals available to other growers. This known issue was addressed in the creation of the IR-4 Ornamental Horticulture Project to coordinate and sponsor research for data generation required for registering floriculture uses.

Over the Ornamental Horticulture Program's history, the primary focus has been to generate crop safety information and to add new crops to labels. This changed during the 2003 Annual Workshop where attendees established high priority projects to focus the research efforts on key issues in each discipline. At that workshop attendees selected Phytophthora Efficacy, Scale & Mealybug Efficacy, and Herbaceous Perennial Tolerance to Select Herbicides. Since then, the program has also conducted research on several high priority projects such as efficacy for Borers, Beetles, Pythium, Q biotype Whiteflies, Thrips, and White Grubs, and crop safety on a number of herbicides. The 2008/2009 research priorities include efficacy for Armored Scale, Downy Mildew, and Borers, and crop safety for Freehand, Tower, among other herbicides.

High priority project selection starts with growers, landscape care professionals, extension agents or researchers identifying a need – an area where current management tools are not registered, such as for a newly introduced pest or for crops where little phytotoxicity information is available. Research has been sponsored on most active ingredients registered for ornamental horticulture since 1977.

The IR-4 Biopesticides and Organic Support Program

The IR-4 Biological and Organic Support Program were initiated in 1982 to assists in the EPA registration of biopesticides for pest management systems for specialty crops or for minor uses on major crops. Two classes of biopesticides are biochemical (naturally occurring substances) and microbial (consisting of microorganisms). The EPA defines biopesticides as those chemicals that "include naturally occurring substances that control pests (biochemical pesticides), microorganisms that control pests (microbial pesticides), and pesticidal substances produced by plants containing added genetic material (plant-incorporated protectants) or PIPs" (U.S. Environmental Protection Agency 2001b). This definition excludes biologicals like arthropod parasites and predators or predacious nematodes (Braverman et al. 2006).

Biopesticide use in the US has consistently grown since 1997 (Bailey, Boyetchko, and Längle 2010). While, their use has not reached the level of conventional pesticides – making up only about one percent of the global pesticide market (Copping and Menn 2000) – their growth in use exceeds that of chemical pesticides (Hall and Menn 1999). The biopesticide market is also diversifying products. While *Bacillus thuringiensis* comprised about 90 percent of total biopesticide applications in 1990s, its share of the biopesticide as dwindled to about 57 percent by 2007 (CPL Business Consultants 2010). According to the EPA there were 195 registered biopesticide active ingredients and 780 products at the end of 2001 (U.S. Environmental Protection Agency 2010).

Biopesticides offer several advantages over conventional pesticides (Joshi 2006, pp. 12). They are generally considered safer and more environmentally friendly alternatives to highly toxic chemical pesticides and make up an important component of an integrated pest management (IPM) system (Copping and Menn 2000). Biopesticides generally offer much more targeted activity against a desired pest than conventional pesticides, which often affect a broad spectrum of pests including desirable, beneficials and human workers. Biopesticides often are effective in very small quantities; thereby offering lower exposure. They also decompose more quickly than conventional chemical pesticides and often supplement the conventional pesticides when used in integrated pest management (IPM) programs for reducing pest resistance. Additionally, biopesticides are often consistent with certified organic food production, which has seen significant growth in the U.S. market (Dimitri and Greene 2002). But this is not to suggest that all biopesticides meet the National Organic Program guidelines.

The popularity of biopesticides has increased substantially in recent years with enhancements in effectiveness and with consumer preferences toward healthier food products and elevated environmental concerns (Thakore 2006; Joshi 2006). Extensive research over the past 20 years has enhanced the effectiveness of biopesticide use, while techniques for mass production, storage, transport, and application of biopesticides have reduced production and operational costs of adopting biopesticides (Uri 1998). However their adoption is largely restricted to niche markets (Gaugler 1997) and most IR-4 Project registration assistance is sought for biopesticides produce by small businesses and individual scientists (Braverman et al. 2006).

The EPA encourages the development and use of biopesticides. Because biopesticides are naturally occurring, they pose fewer risks than conventional pesticides, and the EPA generally requires much less data for registration. However, the EPA always conducts rigorous reviews of any pesticide, as mandated under FQPA to ensure that pesticides will not have adverse effects on human health or the environment. For the EPA to be sure that a biopesticide is safe, the agency requires that registrants submit the relevant data on the composition, toxicity, degradation, and other characteristics required of chemical pesticides. The IR-4 Biological and Organic Support Program provides assistance in meeting EPA data requirements for registering biopesticide solutions across most agricultural crops and advances the development and implementation of biological solutions.

In addition, the IR-4 Biological and Organic Support Program, along with additional support from NIFA and Agricultural Research Service, encourage the development of biopesticide solutions through competitive grants for biopesticide research. The program also partners with the EPA to provide funding for demonstration projects using biopesticides. The awards are extremely competitive as only about 40 percent of requested funds are awarded each year (The IR-4 Project 2008).

The IR-4 Food Program

When established in 1963, the IR-4 project was established to include specialty crops on pesticide labels. At the time, there was no distinction between food and horticulture directives. In 1977, the IR-4 established a program that focuses on horticulture needs and one that focuses on food agriculture needs. The later became the IR-4 Food Program, where priorities and issues specific to minor-use food crops can be addressed. With this focus, the Food Program has evolved over time to keep pace with grower needs and facilitates the registration of and adoption of new, reduced-risk pesticides to replace older pesticides pulled from the market.

According to the 2007 Census of Agriculture, vegetables, melons, fruits and tree nuts – the largest component of minor-use food crops – make up about 25 percent of total production of agricultural food crops, or about $33 billion annually. While the total value of sales is significant in the aggregate, many crops make up this category, such that any one crop makes up a small component of total sales. This limits the attractiveness of pesticide companies to pursue registration for each specialty crop. The Food Program works with growers to establish minor-use, food crop priorities that instruct the Food Program on which commodity-pesticide registration projects to pursue.

Despite the establishment of the Ornamental Horticulture and Biopesticides and Organic Support Programs, the Food Program makes up the largest component of the IR-4 annual operating budget. Of the total 2009 IR-4 budget, approximately 80 percent can be accounted for pursuing registration under the Food Program. However, the delineations across programs are not easy to make as field trials and laboratory work may be shared across food and horticulture programs and many efforts, such as IPM and educational projects, transcend program boundaries.

Estimating the Economic Impacts of the IR-4 Project

The economic impact estimates in this report follow well-established economic modeling practices for estimating all private transactions associated with IR-4 activities. Such transactions include all direct expenditures of the IR-4 Project, which also include in-kind industry and SAES expenditures for the administration and research around pesticide registration in pursuit of the program objectives. Additionally, estimated industry productivity impacts that arise through access to pesticide solutions that would logically be restricted in the absence of the IR-4 Project are estimated. Industry productivity impacts are limited to farm-level direct effects in terms of added output and revenues attributed to pesticide access.[2] Because this report limits research to private transactions, and hence returns to expenditures, it does not purport to measure the true social costs of pesticide usages that include public health and environmental quality aspects (Headley 1975). In addition, the report does not purport to measure the true cost of allocated public and private funds to IR-4 activities in terms of the value of foregone uses of such funding.

Calculating the economic impact of the IR-4 Project follows a traditional expanded input-output (I-O) approach for impact assessment. I-O approaches of impact assessment have an enduring history in economic modeling since the 1930's and is the subject of extensive economic research. The presentation below provides a cursory description of the I-O approach and limitations. Appendix A of this document provides a more complete description of the I-O approach and the model used to estimate economy-wide impacts.

The I-O approach starts with a social accounting matrix (SAM), which represents a double-entry accounting system that tracks the transactions of industries and institutions within the study region. Industries represent productive activities defined along commodity types, institutions represent non-producing sectors such as households and governments within and outside of the region, and the region is defined as the whole of a nation or any sub-part of the nation. Transactions include the purchases of goods and services across industries as intermediate inputs to production and the purchases of goods and services for final use by institutions. The SAM also records trade transactions with other regions as imports and exports. The SAM is a true representative model of the national economy reflecting the exchange of funds across all industry sectors and institutions. This framework tracks transactions across all sectors of the economy via linear mathematical equations. Therefore, an increase in economic activity in one sector will result in changes in economic activities of all associated industries and institutions in fixed proportions. The SAM used in this analysis is adopted from estimated Benchmark Input-Output Accounts reported by the Department of Commerce, Bureau of Economic Analysis (Bureau of Economic Analysis 2010; Minnesota IMPLAN Group Inc. 2004).

---

[2] As noted below, the modeling framework explicitly assumes no price effect of added or restricted industry output.

Several implicit and explicit assumptions are inherent in the I-O framework. First, the I-O model employs strictly linear relationships across industries and institutions. While such linear relationships simplify the modeling design and solution, it implicitly assumes no externalities, constant returns to scale, and no capacity constraints. An externality occurs if benefits or costs are incurred by parties that are not directly engaged in direct or secondary transactions. Constant returns to scale imply fixed productivity of all sectors regardless of the change in scale of operations. It seems plausible that scale economies should exist in shared resources across IR-4 research projects. However, the loss of precision due to the assumption is likely to be minor. The last potentially restrictive assumption maintains that land, labor, capital, and intermediate inputs[3] are not constrained by availability that would otherwise result in price changes. However, for relatively small impacts, this assumption is generally not an issue. Other restrictive assumptions of this framework exist but do not necessarily pertain to the analysis at hand. For an introductory treatment of the assumptions of I-O modeled impacts, see Coughlin and Mandelbaum (1991). A more complete, textbook, treatment can be found in Richardson (1972).

Total economic impacts are generally calculated as the sum of three components. The change being modeled itself is termed the direct effect. The direct effects set into motion a chain of secondary transactions across the economy including indirect and induced effects. Indirect effects are all the transactions necessary to supply the inputs to accommodate the new direct sales. Induced effects are new expenditures from income. These include consumer spending associated with increased wages and government expenditures from added tax revenues. The induced effects also lead to purchases that give rise to additional indirect effects, as households and government increase the demand for final goods and services sets off a second chain of transactions across. The total effect can be characterized by the following equation,

$$Total\ Effect = Direct\ Effect + Indirect\ Effect + Induced\ Effect.$$

- *Total effect* is the total change in economic activity and can be measured in terms of income, employment, output or gross domestic product.
- *Direct effect* is the measure of the force of change postulated to cause the total change in economic activity. It represents an exogenous infusion to or drain on the economy.
- *Indirect Effect* is the measure of changes in inter-industry transactions resulting from the direct effect.
- *Induced Effect* is the measure of changes in transactions of households from changes in income resulting from the direct and induced effects.

All effects are measured in terms of output (sales). However, more common measures of economic activity include the value of gross domestic product (the value of all final goods and services produced in an economy), employment and wages. A simple transformation converts output into other economic measures using baseline ratios to total output by industry.

The IMPLAN Pro Version 2.0 (IMPLAN) software environment is used to provide the I-O economic impact modeling framework of the IR-4 Project research activities. The model is specified using economic and demographic measures from a host of government statistical reporting agencies including the Bureau of Economic Analysis, Bureau of Labor Statistics, and the U.S.

[3] Purchases by businesses from businesses for the production of goods and services

Census Bureau (Minnesota IMPLAN Group Inc. 2004). The structure of the model relies on the social accounting matrix that is a restatement of the Annual Industry Accounts provided by the Bureau of Economic Analysis. This social accounting matrix is specified in terms of output which is the sum of all goods and services provided within the economy. The IMPLAN model provides the conversions from output to gross domestic product, employment and wages internally.

IMPLAN Pro has 440 industry sectors at its most disaggregate level. Such industry detail affords detailed analysis but is too expansive for forming economic impacts. Hence, industry sectors are aggregated along functional lines replicating NAICS industry aggregates at the three-digit level except for NAICS 54162 (Environmental Consulting Services) and NAICS 54169 (Other Scientific and Technical Consulting Services), which were aggregated into a single category; Environmental Consulting. This special category is necessary to isolate the direct effect of the IR-4 Project. A second special category, Specialty Crops, is established for the specialty or minor-use sector by combining vegetable and melon farming (NAICS 1112), tree-nut farming (NAICS 111335), fruit farming (NAICS 11131, 11132 & 11133 exc. 111335), and greenhouse and nursery production (NAICS 1114) sectors. A final special category, Pesticides, is isolated as NAICS 32532 (Pesticide and Other Agriculture Chemical Manufacturing) to measure pesticide inputs to minor crop production.

Direct Effects

The first task to estimating the macroeconomic impacts of the IR-4 Project is to define and estimate the direct effects. Direct effects are broken out into three distinct categories to isolate the impact of the Food, Ornamental Horticulture, and Biopesticides & Organic Support Programs. In addition to direct expenditures of the IR-4 Project, each program contributes to industry impacts through reductions in loses to pests, and increases in product value. These industry direct effects are estimated for each program and detailed below. The next sections discuss estimates of direct expenditure impacts, or effect, and then discuss direct industry impacts. These direct effects are then used to calculate economy-wide impacts using the IMPLAN economic impact model.

Direct Expenditure Effects

Direct effects of the IR-4 Project include all IR-4 direct expenditures, all budgeted and in-kind SAES expenditures for IR-4, and in-kind expenditures by industry and government and non-government agencies. Several funding sources contribute to the total IR-4 Project direct effects, where IR-4 Project administration estimates that every dollar they receive in direct funding supports an additional dollar of in-kind expenditures.

The total fiscal budget of the IR-4 Project, including the IR-4 Ornamentals Program and the IR-4 Biopesticides and Organic Support Program, exceeded $19 million in the fiscal year 2009. The FY 2009 USDA appropriations from USDA-NIFA were $12.0 million plus $650 thousand for biological control, while the USDA-ARS contributed $4.0 million and the USDA-Foreign Agriculture Service provided $500,000. The Directors of the state agricultural experiment stations, through the Multi-state Research Funds, provided the IR-4 Project with $481,182. The commodity and crop protection industries and other grant-generating activity collectively contributed an additional $1.36 million, while the EPA contributed $1.00 million. Direct funding is augmented with in-kind contributions at a ratio of 1:1 (The IR-4 Project 2009) that contribute over $18.75 million to total value. That is, SAES host institutions, the crop protection industry, and regulatory authorities leverage IR-4 funded research with in-kind contributions toward reaching mutually beneficial outcomes. For example, SAES host institutions contribute indirect and direct costs of carrying out field testing and technical assistance, while commodity and crop protection industries provides non-pecuniary test substance and analytical and technical assistance to help in the registration of pesticides for minor use. When combining the IR-4 Project total funding and in-kind contributions to research, total direct economic activity toward registering pesticides exceeds $38 million dollars, as shown in Table 2.

Table 2: IR-4 Project 2009 Basis of Direct Effects (000's)

Source		Funding
USDA, National Institute of Food and Agriculture (NIFA)	$	12,650.00
USDA, Agricultural Research Service (ARS)	$	4,000.00
USDA, Hatch Grants (SAES)	$	481.2
USDA, Foreign Agricultural Service (FAS)	$	500
USDA, Animal and Plant Health Inspection Service	$	172
Industry and Other Grants	$	1,360.00
U.S. Environmental Protection Agency (EPA)	$	100
In-kind research expenditures	$	18,750.00
Total IR-4 expenditures	**$**	**38,013.20**

Includes the IR-4 Ornamentals Program and the IR-4 Biological and Organic Support
Source: IR-4 2009 Annual Report

The total fiscal budget of the IR-4 Project, including the IR-4 Ornamentals Program and the IR-4 Biopesticides and Organic Support Program, exceeded $19 million in the fiscal year 2009. The FY 2009 USDA appropriations from USDA-NIFA were $12.65 million, while the USDA-ARS contributed $4.0 million and the USDA-Foreign Agriculture Service provided $500,000. The Directors of the state agricultural experiment stations, through the Multi-state Research Funds, provided the IR-4 Project with $481,182. The commodity and crop protection industries and other grant-generating activity collectively contributed an additional $1.36 million, while the EPA contributed $1.00 million. Direct funding is augmented with in-kind contributions at a ratio of 1:1 (The IR-4 Project 2009) that contribute over $18.75 million to total value. That is, SAES host institutions, the crop protection industry, and regulatory authorities leverage IR-4 funded research with in-kind contributions toward reaching mutually beneficial outcomes. For example, SAES host institutions contribute indirect and direct costs of carrying out field testing and technical assistance, while commodity and crop protection industries provides non-pecuniary test substance and analytical and technical assistance to help in the registration of pesticides for minor use. When combining the IR-4 Project total funding and in-kind contributions to research, total direct economic activity toward registering pesticides exceeds $38 million dollars, as shown in Table 2.

The total IR-4 Project expenditures shown in Table 2 can be broken down into expenditures on each of the following three IR-4 Programs: the Food Crop Program, the Ornamental Horticulture Program and the Biopesticides and Organic Support Program. Of the $38 million dollars in total IR-4 Project expenditures, 83 percent, or $31 million dollars, is allocated to the Food Crops Program. The Ornamental Horticulture Program's expenditures total over $5 million dollars and account for over 13 percent of total IR-4 Project Expenditures. The remaining 4 percent of total IR-4 Project Expenditures is accounted for by the Biopesticides and Organic Support Program, whose expenditures total $1.5 million dollars. Table 3 shows the IR-4 Project Expenditures by Program.

Table 3: IR-4 Project Expenditures by Program
2009 Basis of Direct Effects (000's)

Expenditure Program	2009
Food Crops Program	31,337.20
Ornamental Horticulture Program	5,176.00
Biopesticides & Organic Support Program	1,500.00
Total Direct Effects	**38,013.20**

Source: A Strategic Plan for the IR-4 Project (2009-2014)

Industry Productivity Direct Effects

A review of the academic literature on the returns to cost of pesticides provides industry impacts that arise from productivity outcomes of access to pesticide solutions for specialty and biopesticide options. To keep the analysis manageable, the impact is measured in terms of production changes only; therefore avoiding the enumeration of price impacts. Shifting prices have the potential to transfer the impacts of greater productivity to various economic sectors including pesticide manufacturers, land owners, farmers, wholesalers, and consumers to name a few. Generally such distributional effects only establish the allocation of the aggregate impact, not the aggregate impact.[4]

The productivity impact section of this study estimates the anticipated economic gains to crop producers as a result of IR-4 Project-assisted registrations. The IR-4 Project provides data to support new EPA clearances and/or new tolerances for specialty crops that either enhances the productivity of crop farmers or mitigates losses to crop farmers. In this effort, the IR-4 Project contributes to the availability of newer, less toxic, pesticide products for minor use that affords producers more effective ways of mitigating economic losses from pests and for managing pest resistance.

Measuring productivity gains is complicated by the heterogeneous options for pest control, inconsistent growing environments across the U.S. variations of pest pressure, and the ability to assign proportional yield loss to various stresses. Such heterogeneity creates varying degrees of impacts across the spectrum of applications (Carpentier and Weaver 1996; Norwood and Marra 2003). Since the 1970s few researchers have attempted to measure the aggregate productivity gains afforded by pesticides. To circumvent these deficiencies, a meta-approach is employed that utilizes estimates across commodities, and across researchers to provide an average, or expected impact of pesticide availability on production with no accounting for the type of crop, geography, pesticide, method of application, or combined pesticide/crop interaction.

Despite this, there is sufficient evidence to suggest that pesticides play a significant role in securing U.S. supply of food, fiber and energy from agricultural production. The US National Research Council advocates that pesticides are irreplaceable in the production of agriculture (Anonymous 2000). In quantifying productivity growth of U.S. agriculture, Jorgenson and Gollop (1992) note significant declines in productivity growth following the recall of DDT (Gollop and Swinand 1998). Knutson *et al.*, (1990) estimated that a total ban on pesticide use in the U.S. would likely result in a cost of $41 billion per year in higher food costs and lower quality crops and livestock. Fernandez-Cornejo et al. survey a number of pesticide impact studies finding a broad range of impacts (1998).

[4] Some distributional impacts may result in slight distortions of aggregate impacts. However, within the I-O modeling framework, where prices are explicitly assumed constant, such distortionary effects are precluded from taking place.

Some authors attribute the variance in estimated productivity impacts to the econometric techniques employed across pesticide productivity studies (Carpentier and Weaver 1997; Saha, Shumway, and Havenner 1997). But no consensus has emerged as to the most appropriate econometric method for valuation. The question becomes more difficult to address in light of the heterogeneous production responses of plant/pesticide combinations, differences in active ingredients and approaches to measuring active ingredients and varying pesticide practices across regions and crops. A meta-analysis abstracts from such estimation issues by combining the empirics across a wide spectrum of research that, on average, is the best estimate of the potential impact of availability of a wide range of pesticide applications for specialty crops (Alston *et al.* 2000).

In their survey, Fernandez-Cornejo *et al.* found that the return per dollar spent on pesticide applications ranged from $11.90 to $0.11 with a mean and median of $3.66 and $2.50, respectively. We opt to use the more conservative measure of the median return of $2.50 for two reasons. First, where data is skewed, the median is the preferred measure of the expected impact because the median is robust to unusually large outliers. Second, where two options exist and there exists insufficient reason to favor one over the other, the most conservative value should be favored. Hence, the more conservative median meta-value of $2.50 return per dollar spent on pesticide applications will be used as the rate of return per dollar invested in pesticide application.

To apply the rate of return, and therefore identify the impact of the IR-4 Project on crop output, total expenditures for pesticides for use on specialty crops must be established. Market data of pesticide expenditures for minor uses are not tracked. Hence, an indirect method of estimation provides total minor-use pesticide expenditures. Using IMPLAN data, pesticide expenditures make up about seven percent of total value of specialty crop output, or $6.41 billion in 2007.[5] This compares conservatively to a 2001 EPA estimate of agricultural pesticide expenditures as a share of total sales of crops, nurseries and greenhouses in the 2002 Census of Agriculture (USDA: National Agricultural Statistics Services 2002; Kiely, Donaldson, and Grube 2004), which suggests that pesticide expenditures make up approximately 11.73 percent of total horticultural sales. The more conservative estimate that pesticides make up seven percent of total value of output in 2007 is used to estimate total pesticide purchases in 2007.

Direct and Economic Impacts of the IR-4 Food Program

The 2007 Census of Agriculture estimates the market value of specialty crops included under the IR-4 Food Program to be $53.38 billion (USDA: National Agricultural Statistics Services 2009). If seven percent of this value comprises pesticide expenditures, then pesticide expenditures make up $3.73 billion. Using the benefit cost ratio of $2.5 reported by Fernandez-Cornejo *et al.,* pesticides are estimated to contribute $9.34 billion dollars. A report by the EPA generally notes that the IR-4 Project has contributed to 50 percent of the total existing and new pesticide registrations for specialty crop applications (U.S. Environmental Protection Agency 2001a). Hence, only 50 percent of total industry expenditures on agrichemicals are attributed to the IR-4 Food Crop Program. The direct impact of food crops' productivity through the IR-4 Food Crop Program is therefore $4.67 billion dollars. These productivity estimates for the Food Crop Program are summarized in Table 4

[5] This is compared to 4.97 percent reported by the Bureau of Economic Analysis for the 1997 U.S. Input Output Account Benchmark (Bureau of Economic Analysis 1997). The USDA: NASS, places this value at 4.26 percent of all farm productive expenditures (USDA: National Agricultural Statistics Services 2004). However this also entails grain crops and other activities not tied to specialty crop production. Specialty crop production tends to support a higher concentration of pesticide applications. Total value of pesticide expenditures is valued in 2009 currency.

below. This is in contrast to a 2007 study (Miller 2007) that estimates industry impacts of $4.56 billion with industry sales of $60.02 billion. The relatively large industry impact from 2007 arises from two sources. First, the market value of specialty crops increased to more than $67 billion in 2007 – a $7 billion increase since the prior report. Second, for the U.S., pesticide expenditures share of total specialty crops' sales increased from five percent in 2004 to seven percent in 2007.

Table 4: IR-4 Food Crops Program Direct and Total Output Effects

	Effects ($ Millions)			
	Direct	**Indirect**	**Induced**	**Total**
Program Expenditures				
Food Crops Program	31.34	21.84	52.96	106.14
Industry Productivity				
Food Crops Program	4,671.16	3,672.96	5,305.59	13,649.71
Total	**4,702.49**	**3,694.79**	**5,358.56**	**13,755.85**

Two studies help to validate the productivity impact calculated here. Whittaker, Lin, and Vasavada (1995) find that restricting pesticide expenditures from $30 per acre to $6 per acre results in 13.7, 9.8, and 15.6 percent decline in farm profits for small, medium, and large farms respectively. Similarly, Pimentel et al. (1993) find that reducing pesticide use by 50 percent over 40 different crop groups would generally result in more than a ten percent reduction in yields compared to existing pest management practices. The current estimate of direct productivity impacts of 6.97 percent of total crop sales falls within this range and suggests that pesticide availability for minor uses contributes nearly 7 percent to total sector output annually.

Direct and Economic Impacts of the IR-4 Ornamental Horticulture Program

Similar to the IR-4 Food Program, the 2007 Census of Agriculture estimates the market value of specialty crops included under the IR-4 Ornamental Horticulture Program to be $13.68 billion (USDA: National Agricultural Statistics Services 2009). Using the more conservative estimate that pesticide expenditures make up seven percent of the market value, we find that pesticide expenditures comprise $0.95 billion. Again using Fernandez-Cornejo *et al.*'s benefit cost ratio of $2.5., we find pesticides are estimated to contribute $2.39 billion dollars. Taking into account that only 50 percent of total floriculture industry expenditures on pesticides are attributed to the IR-4 Ornamental Program, the direct impact of floriculture's productivity through the IR-4 Ornamental Horticulture Program is equivalent to $1.19 billion in floriculture sales annually over all U.S. producers. This increase in productivity manifests itself into measurable direct impacts through increased net revenue for producers, who in turn generate economy-wide impacts through transactions to expand production or expand household expenditures. Table 5 below includes the industry productivity estimate for the Ornamental Horticulture Program.

Table 5: IR-4 Ornamental Program Direct and Total Output Effects

	Effects ($ Millions)			
	Direct	**Indirect**	**Induced**	**Total**
Program Expenditures				
Ornamental Program	5.18	3.61	8.75	17.53
Industry Productivity				
Ornamental Program	1,197.56	941.64	1,360.21	3,499.41
Total	**1,202.73**	**945.25**	**1,368.96**	**3,516.94**

Direct and Economics Impacts of the Biological and Organic Support Program

Like estimating the industry productivity impacts of the IR-4 Food and Ornamental Programs, estimating the productivity impacts of the Biological and Organic Support Program presents challenges. Biopesticides are often associated with integrated pest management practices, organic farming and specialty crops. However, their application is not limited to such segments (Cao, Park, and McSpadden Gardener 2010; Rodgers 1993; Copping and Menn 2000). This makes establishing a basis of productivity impact in terms of sector sales difficult, and there currently are no comprehensive cost/benefit studies of biopesticide use in agriculture.

Therefore, limited means exists for quantifying the contribution of biopesticides' impact on agricultural output. The approach used in this report is to assume an identical, aggregate benefit/cost ratio of biopesticides as that of conventional pesticides. Testing such an assumption is complex (Copping and Menn 2000; Gan-Mor and Matthews 2003) and is outside the scope of this study. Hence, we caution the reader to recognize such shortcomings of the estimated agricultural productivity impacts.

Because a recent report provides U.S. estimates of the sales of microbial biopesticide market, the calculation of the expected direct productivity effects is relatively straightforward. CPL Business Consultants provides global and national market reports and recently estimated the U.S. sales of microbial biopesticide to be about $101 million in 2007 (CPL Business Consultants 2010). According to this report, the market for biopesticide is seen growing by as much as 20 percent per year, while conventional pesticide usage has been in decline. We apply the same productivity factor of $2.50 for every dollar to estimate the direct productivity impacts of biopesticide access; suggesting that biopesticides contributes about $298.5 million to total sector output annually. Table 5 summarizes the productivity estimates of the Biological and Organic Support Program.

Table 6: IR-4 Biological and Organic Support Direct and Total Output Effects

	Effects ($ Millions)			
	Direct	**Indirect**	**Induced**	**Total**
Program Expenditures				
Biological and Organic Support	1.50	1.05	2.54	5.08
Industry Productivity				
Biological and Organic Support	101.00	83.43	109.03	293.46
Total	**102.50**	**84.47**	**111.57**	**298.54**

Macroeconomic Impacts

The direct effects specified above form the basis of the economic impact estimates. Total expenditure impacts represent the direct and industry productivity impacts of research and administrative expenditures of the IR-4 Project. Program expenditures are assumed to equal the total program budget of $38.01 million. This is separated into three components; the Food Crop Program, the Ornamental Horticulture Program, and the Biological and Organic Support Program. When taking account of secondary impacts – expenditures include indirect and induced effects, research expenditures from the Food Crops Program budget generates about $106.14 million in sales to the economy, while the Ornamental Horticulture Program and Biological and Organic Support Program generate $17.53 million and $5.08 million in sales to the economy respectively (See Tables 4 thru 6 above). However, program expenditures make up a small share of the total impacts of the IR-4 Project. Larger impacts accrue to growers afforded better tools for mitigating pest damage. Adding industry direct and indirect impacts from increased yields and produce quality, the overall program contributions to output is $13.8 billion, $3.5 billion and $299 million for the Food Crops, Ornamental, and Biological and Organic Support programs, respectively. Total program impacts are reported in Table 7, which summarizes Tables 4, 5 and 6.

Table 7: Aggregate Direct and Total Output Effects

	Program Aggregate Effects ($Millions)			
	Direct	**Indirect**	**Induced**	**Total**
IR-4 Food Crops Program	4,702.49	3,694.79	5,358.56	13,755.85
IR-4 Ornamental Program	1,202.73	945.25	1,368.96	3,516.94
IR-4 Biological and Organic Support	102.50	84.47	111.57	298.54
Total	**6,007.73**	**4,724.52**	**6,839.09**	**17,571.33**

When combining the research expenditure impacts and the agricultural productivity impacts across all three programs, the IR-4 Project generates over $17.57 billion in total U.S. output. This compares to $12.92 billion estimated in 2007 (Miller 2007) but takes into consideration recent increases in minor-use production and provides the first estimates of the impacts of the Biological and Organic Support Program. While total U.S. output provides an instructive gauge by which to measure the total impact of the IR-4 Project, output impacts can be misleading. Output represent the sales of not only the value of crop production, but also the value of seeds and other material that go into the production process, and the value-added transactions necessary to generate final goods and services for consumption. Other measures provide a more compelling assessment of the overall effect the IR-4 Project has on the U.S. economy. Tables 8 to 10 convert output sales into employment, earnings and gross domestic product (GDP) for each IR-4 Project programs.[6]

The IR-4 Food Crops Program provides the largest impact in terms of output and, hence, should produce the largest impacts in employment and GDP terms. Table 8 shows associated employment, labor income and GDP impacts of the Food Crops Program, suggesting that program expenditures and contributions to grower productivity generates nearly 30,000 jobs directly. Once accounting for secondary impacts, the Food Crops Program generates economic activity sufficient to support 87,792 U.S. jobs with labor income exceeding $3.5 billion. The IR-4 Food Crop Program and associated research is estimated to add nearly $6.1 billion to annual GDP.

[6] See Appendix A for methodology

Table 8: Economic Impacts of the IR-4 Food Crops Program

	Direct	Indirect	Induced	Total
Employment	29,595	24,862	33,335	**87,792**
Labor Income ($ mill)	986.61	992.96	1,544.69	**3,524.27**
Gross Domestic Product ($ mill)	1,943.91	1,641.61	2,507.50	**6,093.02**

Similarly, Table 9 shows employment, labor income, and GDP impacts of research expenditures and increased grower productivity impacts of the IR-4 Ornamental Horticulture Program. In total, this program generates a total of 14,501 full and part time jobs with wages of $582 million, and it is estimated to contribute $1.0 billion to annual GDP.

Table 9: Economic Impacts of the IR-4 Ornamental Program

	Direct	Indirect	Induced	Total
Employment	4,888	4,106	5,506	**14,501**
Labor Income ($ mill)	162.96	164.01	255.14	**582.11**
Gross Domestic Product ($ mill)	321.08	271.15	414.17	**1,006.39**

Table 10 reports employment, labor income, and GDP impacts of research expenditures and increased grower productivity impacts of the Biological and Organic Support Program. The estimated employment and GDP impacts reflect the relative size of this program relative to other programs. Regardless, the program is estimated to generate 2,358 jobs with annual earnings of $87 million. The program is also estimated to add just over $155 million to annual GDP.

Table 10: Economic Impacts of the IR-4 Biological and Organic Support

	Direct	Indirect	Induced	Total
Employment	888	641	828	**2,358**
Labor Income ($ mill)	22.61	25.95	38.44	**87.00**
Gross Domestic Product ($ mill)	48.09	44.67	62.30	**155.06**

Adding Tables 8, 9 and 10 provides estimated impacts of the IR-4 Project. Such estimated aggregate economic impacts are shown below in Table 11, where the IR-4 Project generates an estimated 104,650 jobs, with earnings just under $4.2 billion. In terms of gross domestic product, the IR-4 Projects is estimated to contribute $7.25 billion annually to GDP.

Table 11: Aggregate Economic Impact Summary of the IR-4 Project

	Direct	Indirect	Induced	Total
Employment	35,371	29,609	39,670	**104,650**
Labor Income ($ mill)	1,172.18	1,182.92	1,838.27	**4,193.37**
Gross Domestic Product ($ mill)	2,313.08	1,957.43	2,983.96	**7,254.48**

Section 18 impacts are shared-out to Biological and Organic Support and All other IR-4 Project Programs based on 2009 successful Section 18 petitions.

Summary of Findings

Specialty crop growers are at a disadvantage relative to their large-acreage crop counterparts in gaining access to pesticides. Because of the relatively small acreage employed for each specialty crop commodity, the added sales from pesticide registration for minor-use are often not sufficient to cover the cost of registering pesticides for such applications. The IR-4 Project supports growers and the pest control industry in developing the necessary data for registering minor-use application pesticides. As minor-use crops make up a substantial component of the USDA-recommended dietary intake, it is important that producers have sufficient pesticide resources for assuring low-cost access to such specialty food crops.

Additionally, effective pest management of our food and fiber production demands sufficient access to an array of pest management options for mitigating pest resistance while reducing environmental and health impacts. As about 70 to over 80 percent of project-supported registrations are for reduced-risk pesticides, the IR-4 Project's efforts have been instrumental in meeting the Food Quality Protection Act of 1996. With the Biological and Organic Support Program, the IR-4 Project is able to direct necessary resources to meet the U.S. goal of substantially decreasing the environmental and health impacts of agricultural pesticide use on 13.7 million acres of agricultural land.

This report documents the estimated economic impact of the IR-4 Project's Food Crop Program, Ornamental Horticulture Program and Biological and Organic Support Program. Well-established methods of measuring direct and secondary economic impacts are used to gauge the contributions of the IR-4 Food Crop Program, the Ornamental Horticulture Program and the Biological and Organic Support program in terms of sales, employment and gross domestic product. It should be noted that estimated economic impacts do not take into consideration health or environmental impacts, or associated economic outcomes of such impacts, but rather quantifies the measurable contribution to economic output from program expenditures and grower productivity. These direct effects materialize into larger macroeconomic impacts once accounting for multiplier effects. The findings suggest that the IR-4 Project and associated programs contribute $7.3 billion to annual gross domestic product. Such economic activity is sufficient to support over 104,000 U.S. jobs with annual earnings that top $4.2 billion

The findings presented in this report illustrates the importance of the IR-4 Project in terms of contribution to U.S. specialty crop output that includes a multitude of food crops necessary for households to meet USDA dietary guidelines, and contribution towards reducing agriculture reliance on older, more toxic varieties of pesticides. Public investment in the IR-4 Project is small relative to its measurable economic returns. These returns are realized across agricultural producers in all 50 states from limited expenditures in correcting a market failure in the agricultural pesticide industry; thereby leveraging benefits across a $67 billion industry. In essence, there is strong evidence that public investment the IR-4 Project provides economic returns well in excess of program costs.

Appendix A: The IMPLAN Economic Impact Model

The Minnesota IMPLAN Group Inc. model for economic impact evaluation, IMPLAN Pro. 2 (Minnesota IMPLAN Group Inc. 2004) is a general application economic impact evaluation model based on a common economic construct known as a social accounting matrix (SAM). The SAM is a comprehensive accounting system that identifies all the monetary transactions between the sectors in an economy. The SAM is comprises a square matrix (number of columns equals number of rows) that represent individual sectors as both buyers and sellers. Each row represents the revenue earned by the corresponding sector while each column represents its expenditures (Isard et al. 1998, pp. 283). This construct builds a closed system that represents transactions within and amongst all sectors: inter-industry transactions; transactions between industries and government; transaction between industries and households; transaction between households and government; and the purchases and sales between the state economic sectors and the rest of the world.

IMPLAN provides industry detail to 440 different industry categories including agricultural, goods-producing, and service-providing industries. Institutions are broken out into households by income group, federal, state and local government sectors, and by import and export markets. The SAM also provides household and government purchases of goods and services. Additional transactions are recorded within the SAM including transactions across households, government transfers to households and household transactions to government in the form of taxes and fees. Because the social accounting system examines all the aspects of a local economy, it provides a comprehensive snapshot of the economy and its spending patterns.

The I-O framework was first described by Francois Quesnay in 1758 and developed by Wassily Leontief (1986). The structure supports demand-driven responses, where changes in output demand in one industry materializes in changes in the demand for production of other industries. For example, an increase in local demand for printing services will spur demand for feed paper, ink, printer repair services and other goods and services required by printing companies. The beneficiaries of these direct transactions will increase the demand for inputs used in their respective production processes. Households that enjoy enhanced employment opportunities earn and spend more on goods and services and taxes. Such household impacts generate additional direct and secondary transactions across the economy. The extent to which initial stimulus generates such secondary transactions is hindered by the degree of purchases made outside the modeled region. Industries that purchase inputs from local suppliers generate greater secondary transactions than industries that tend to purchase inputs produced outside the state, holding all else constant.

I-O models have become staple economic impact models for regional analysis (Blakely and Bradshaw 1989). I-O models provide a systematic and intuitive approach to estimating economy-wide impacts of a change in the local economy. This approach uses linear relationships to reflect production processes that equate industry inputs and outputs. The linear transactions that define a SAM are generalized in a set of multipliers that capture the full extent of transactions associated with any changes in the level of production in an industry. To exemplify, within the I-O analysis, the total impact is specified in value of transactions as,

$$Total\ Effect = Direct\ Effect + Indirect\ Effect + Induced\ Effect \qquad (1)$$

The I-O model takes changes in demand called direct effect and relates them to overall economic impact called total effect through a set of mathematical equations described above. The indirect effect is the value of secondary inter-industry transactions in response to direct effects. The induced effect is the value of transactions resulting from changes in income in response to direct effects.

Because the relationships are linear, the direct, indirect and induced effects can be specified as multiples of the direct effect and equation (1) can be restated as,

$$Total\ Effect = (1 + k_1 + k_2) \cdot Direct\ Effect, \qquad (1.1)$$

where k_1 and k_2 greater than or equal to zero. More simply, Equation (1.1) can be restated as,

$$\text{Total Effect} = \text{k} \cdot \text{Direct Effect}, \qquad (2)$$

where $k = (1 + k_1 + k_2)$. Equation (2) says that the economy-wide impact, Total Effect, is some multiple of the direct effect, where the multiplier takes a positive value equal or greater than one. The minimum value the multiplier can take, one, reflects the intuitive result that if the economy's output of agricultural products – for example – expands by $1 million dollars, the economy will expand at least by $1 million dollars. However, if the indirect and induced effects are not equal to zero, this $1 million increase in output will spur other industries to expand output of goods and services and will generate household income that are applied to the purchase of goods and services in the economy; generating a total economic impact greater than the initial $1 million expansion.

Generally, the economic multiplier is specified as a ratio of the total to direct effects. Rearranging equation (2) provides,

$$\text{k} = \frac{\text{Total Effect}}{\text{Direct Effect}}, \qquad (3)$$

where the multiplier, k encompasses all the direct, indirect and induced effects for a given industry and denotes the impact of a change in direct effects on the total economic system. Each industry in a region is characterized by its own multiplier k. Industries with expansive localized production chains will tend to have higher multipliers than industries that rely on suppliers outside of the modeling region. When there is adequate supply within the state, the state has more potential to retain the total effects of the industry. However, when producers have to depend on supplies outside the state, leakage occurs and part of the total effect is lost.

All effects are measured in terms of output (sales). However, more common measures of economic activity include the value of gross domestic product (the value of all final goods and services produced in an economy), employment and wages. A simple transformation converts output into other economic measures using baseline ratios to total output by industry. Sector values for gross domestic product, employment and labor wages per unit of output are derived using the following equations for industry *i*.

$$GDP_i = \frac{GDP_{i,0}}{Output_{i,0}} \cdot Output_i$$

$$Employment_i = \frac{Employment_{i,0}}{Output_{i,0}} \cdot Output_i$$

$$Wages_i = \frac{Wages_{i,0}}{Output_{i,0}} \cdot Output_i$$

The subscript 0 denotes baseline values not subject to change. These baseline ratios for each industry sector are used in conjunction with the social accounting matrix to provide impact measures on gross domestic product, employment, and labor wages.

The I-O impact evaluation model requires several restrictive assumptions. First, the model imposes constant returns to scale, such that a doubling of output requires a doubling of all inputs. Second, technology is fixed with no substitution. These two assumptions impose that an increase in industry output requires an equal and proportionate increase in all inputs. Additionally, supply is assumed perfectly elastic such that there are no supply constraints. This final assumption also asserts that all prices are fixed, such that an increase in demand for any commodity will not result in a price change for that industry. I-O models have been criticized on the grounds that some of these assumptions are overly restrictive and the magnitude of the bias generated by these assumptions are greater the larger the industry direct effects are relative the overall size of the industry (Coughlin and Mandelbaum 1991). Despite this criticism, I-O models have become a standard by which economic impact assessments are generated.

Bibliography

Alston, Julian M., Connie Chan-Kang, Michele C. Marra, Philip G. Pardey, and TJ Wyatt. 2000. A Meta-Analysis of Rates of Return to Agricultural R&D. In *IFPRI Research Reports*. Washington D.C.: International Food Policy Research Institute.

Anonymous. 2000. The Future Role of Pesticides in US Agriculture, edited by US National Research Council. Washington, D.C.: National Academy Press.

Bailey, K. L., S. M. Boyetchko, and T. Längle. 2010. Social and economic drivers shaping the future of biological control: A Canadian perspective on the factors affecting the development and use of microbial biopesticides. *Biological Control* 52 (3):221-229.

Blakely, E. J., and T. K. Bradshaw. 1989. *Planning local economic development*: Sage.

Braverman, M. P., D. L. Kunkel, J. J. Baron, and R. E. Holm. 2006. The IR-4 Program for Registration and Development of Organic Products and Biopesticides. In *Crop Protection Products for Organic Agriculture*: American Chemical Society.

Bureau of Economic Analysis. 2007. *1997 Benchmark Input-Output Accounts* 1997 [cited May 1 2007]. Available from http://www.bea.gov/bea/dn2/i-o.htm.

———. 2010. *Benchmark Input-Output Accounts* 2010 [cited November 28 2010]. Available from http://bea.gov/industry/index.htm#benchmark_io.

Cao, Chunxue, Sunjeong Park, and Brian B. McSpadden Gardener. 2010. Biopesticide Controls of Plant Diseases: Resources and Products for Organic Farmers in Ohio. In *Fact Sheet*. Columbus, OH: Ohio State University Extension.

Carpentier, Alain, and Robert D. Weaver. 1996. Intertemporal and Interfirm Heterogeneity: Implications for Pesticide Productivity. *Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie* 44 (3):219-236.

———. 1997. Damage Control Productivity: Why Econometrics Matters. *Americn Journal of Agricultural Economics* 79 (1):47-61.

Copping, Leonard G., and Julius J. Menn. 2000. Biopesticides: A Review of their Action, Applications and Efficacy. *Pest Management Science* 56 (8):651-676.

Coughlin, C. C., and T. B. Mandelbaum. 1991. A Consumer's Guide to Regional Economic Multipliers. *Review-Federal Reserve Bank of St. Louis*:19-32.

CPL Business Consultants. 2010. The 2010 Biopesticides Market in North America. Oxfordhire, UK: Market Publishers: Market Report Database.

Dimitri, Carolyn., and Catherine. Greene. 2002. Recent Growth Patterns in the US Organic Foods Market. In *Agriculture Information Bulletin*. Washington, D.C.: Economic Research Service.

Fernandez-Cornejo, Jorge, Sharon Jans, and Mark Smith. 1998. Issues in the Economics of Pesticide Use in Agriculture: A Review of the Empirical Evidence. *Review of Agricultural Economics* 20 (2):462-488.

Gan-Mor, Samuel, and Graham A. Matthews. 2003. Recent Developments in Sprayers for Application of Biopesticides--an Overview. *Biosystems Engineering* 84 (2):119-125.

Gaugler, Randy. 1997. Alternative paradigms for commercializing biopesticides. *Phytoparasitica* 25 (3):179-182.

Gollop, Frank M., and Gregory P. Swinand. 1998. From Total Factor to Total Resource Productivity: An Application to Agriculture. *American Journal of Agricultural Economics* 80 (3):577-583.

Hall, Franklin R., and Julius J. Menn. 1999. *Biopesticides: Use and Delivery*. Totowa, NJ: Humana Press Inc.

Headley, J. C. 1975. The Economics of Pest Management. In *Introduction to Insect Pest Management*, edited by R. L. Metcalf and W. H. Luckman. New York: John Wiley & Sons.

Isard, W., I. J. Azis, M. P. Drennan, R. E. Miller, S. Saltzman, and E. Thorbecke. 1998. *Methods of Interregional and Regional Analysis*. Brookfield, VT: Ashgate.
Jerardo, Andy. 2006. Floriculture and Nursery Crops Yearbook: 2005, ed M. Evans. Place Published: Market and Trade Economics Division, Economic Research Service: USDA (accessed.
Jorgenson, Dale W., and Frank M. Gollop. 1992. Productivity Growth in U.S. Agriculture: A Postwar Perspective. *American Journal of Agricultural Economics* 74 (3):745-750.
Joshi, S. R. 2006. *Biopesticides: A Biotechnological Approach*. New Delhi: New Age International.
Kiely, Timothy, David Donaldson, and Arthur Grube. 2004. Pesticide Industry Sales and Usage: 2000 and 2001 Market Estimates. Washington DC: Office of Pesticide Programs: EPA.
Knutson, Ronald D., C. Robert Taylor, John B. Penson, and Edward G. Smith. 1990. Economic Impacts of Reduced Pesticide Use. *Choices* 5 (4):25-31.
Kunkel, Dan. 2008. IR-4 and EPA Registration Process: Reaching New Highs in 2008. *IR-4 Project Newsletter* 39 (4):2 & 8.
———. 2010. IR-4 International Activities. *IR-4 Project Newsletter* 41 (3):3 & 11.
Leontief, W. W. 1986. *Input-Output Economics*. New York: Oxford University Press, USA.
Miller, S. R. 2007. National Economic Impact of the IR-4 Project. East Lansing: Center for Economic Analysis.
Minnesota IMPLAN Group Inc. 2004. *User's Guide: IMPLAN Pro. Version 2.0.* Stillwater, MN.
National Agricultural Chemicals Association. 1993. From Lab to Label-The Research, Testing, and Registration of Agricultural Chemicals. Washington, D.C., .
National Agricultural Statistics Services. 2004. *2002 Census of Agriculture: United States: Summary and State Data*. Vol. Volume 1, Geographic Area Series Part 51. Washington D.C.: U.S. Department of Agriculture.
Norwood, F. Bailey, and Michele C. Marra. 2003. Pesticide Productivity: Of Bugs and Biases. *Journal of Agricultural and Resource Economics* 28 (3):596-610.
Pimentel, David, Lori McLaughlin, Andrew Zepp, Benyamin Lakitan, Tamara Kraus, Peter Kleinman, Favius Vancini, W. John Roach, Ellen Graap, William S. Keeton, and Gabe Selig. 1993. Environmental and Economic Impacts of Reducing U.S. Agricultural Pesticide Use. In *The Pesticide Question*, edited by D. Pimentel and H. Lehman. New York and London: Chapman & Hall.
Richardson, Harry W. 1972. *Input-Output and Regional Economics*. New York: John Wiley and Sons.
Rodgers, Paul B. 1993. Potential of Biopesticides in Agriculture. *Pesticide Science* 39 (2):117-129.
Saha, Atanu, C. Richard Shumway, and Arthur Havenner. 1997. The Economics and Econometrics of Damage Control. *Americn Journal of Agricultural Economics* 79 (3):773-785.
Thakore, Yatin. 2006. The Biopesticide Market for Global Agricultural Use. *Industrial Biotechnology* 2 (3):194-208.
The IR-4 Project. 2008. A Strategic Plan for the IR-4 Project (2009-2014). Princeton, NJ: The IR-4 Project.
———. 2009. The IR-4 Project: 2009 Annual Report. Princeton, NJ: The IR-4 Project.
U.S. Environmental Protection Agency. 2006. *New Approaches to Minor Uses* 2001a [cited April 23 2006]. Available from http://www.epa.gov/opp00001/minoruse/index.htm.
———. 2010. *Regulating Biopesticides* 2001b [cited December 1 2010]. Available from http://www.epa.gov/oppbppd1/biopesticides/.
———. 2010. *Types of Pesticides*, September 30, 2010 [cited December 1 2010]. Available from http://www.epa.gov/pesticides/about/types.htm.
Uri, Noel D. 1998. Development and Use of Biopesticides: Implications of Government Policy and Consumers' Preferences. *Technological Forecasting and Social Change* 59 (3):291-304.
USDA: National Agricultural Statistics Services. 2002. 2002 Census of Agriculture. Washington D.C.: United States Department of Agriculture.

———. 2004. 2004 Census of Agriculture. Washington D.C.: United States Department of Agriculture.
———. 2004. USDA-NASS Agricultural Statistics 2004. Place Published: U.S. Office of Printing. http://www.nass.usda.gov/Publications/Ag_Statistics/agr04/acro04.htm (accessed May 2007).
———. 2007. Agricultural Chemical Usage: 2006 Nursery and Floriculture Summary. Washington D.C.
———. 2009. 2007 Census of Agriculture: Specialty Crops. Washington D.C.: United States Department of Agriculture.
Viray, Faye Aquino, and Robert Hollingworth. 2009. The Use and Benefits of Reduced Risk Pesticides Since the Passage of the Food Quality Protection Act. *IR-4 Project Newsletter* 40 (4):1 & 10-11.
Whittaker, Gerald, Biing-Hwan Lin, and Utpal Vasavada. 1995. Restricting Pesticide Use: The Impact on Profitability by Farm Size. *Journal of Agriculture and Applied Economics* 27 (2):352-362.