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Research Report 14

Multifunctional Agricultural Policy, Reduced Domestic Support and Liberalized Trade: An Empirical Assessment for Taiwanese Rice

Richard N. Boisvert and Hung-Hao Chang

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The Comprehensive Assessment (www.iwmi.cgiar.org/assessment) is organized through the CGIAR's Systemwide Initiative on Water Management (SWIM), which is convened by the International Water Management Institute. The Assessment is carried out with inputs from over 100 national and international development and research organizations—including CGIAR Centers and FAO. Financial support for the Assessment comes from a range of donors, including core support from the Governments of the Netherlands, Switzerland and the World Bank in support of Systemwide Programs. Project-specific support comes from the Governments of Austria, Japan, Sweden (through the Swedish Water House) and Taiwan; Challenge Program on Water and Food (CPWF); EU support to the ISIIMM Project; FAO; the OPEC Fund and the Rockefeller Foundation; Oxfam Novib and CGIAR Gender and Diversity Program. Cosponsors of the Assessment are the: Consultative Group on International Agricultural Research (CGIAR), Convention on Biological Diversity (CBD), Food and Agriculture Organization (FAO) and the Ramsar Convention.

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Acknowledgments: The authors wish to thank the Council of Agriculture (COA), Taiwan, the Asian Rice Foundation and the Department of Applied Economics and Management, Cornell University for financial support and for the assistance of the Agricultural Engineering Research Center (AERC) in collecting data on rice production and the nonmarket values for important non-commodity outputs.

The authors acknowledge also the assistance of Ranolph Barker, Gil Levine and David Blandford in the research and for comments on various sections of the report.

The authors accept responsibility for any errors or omissions. An earlier version of part of the empirical analysis was presented at the NAREA/CAES Workshop on International Trade and the Environment, Halifax, Nova Scotia, June 23, 2004, and appears in Chang et al. (2005).

Boisvert, R. N.; Chang, H. H. 2006. *Multifunctional agricultural policy, reduced domestic support, and liberalized trade: An empirical assessment for Taiwanese rice.* Colombo, Sri Lanka: International Water Management Institute. 44p. (Comprehensive Assessment of Water Management in Agriculture Research Report 14)

Agricultural policy / international trade / rice / assessment / groundwater recharge / Taiwan

ISSN 1391-9407
ISBN 92-9090-648-0
ISBN 978-92-9090-648-3

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Cover photograph by Lucy Fisher, which is from a slide collection of the Department of Plant Pathology Cornell University, Ithaca, NY, shows an area of terraced paddy fields in Asia.

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Summary

To meet the requirements of membership in the World Trade Organization (WTO) as specified in 2001, Taiwan must rely less on price supports and other traditional policies to support its agricultural sector. In addition, it must open its agricultural markets to increased imports. Central to this reexamination of agricultural policy is the potential conflict between domestic and international policy goals. For many, these so-called ‘non-trade’ concerns (NTCs) are captured in the concept of ‘multifunctionality’, which characterizes agriculture as a multi-output activity, generating both agricultural commodities and non-commodity outputs that are valued by society.

To address these new concerns, such as how food is produced and environmental issues, a new paradigm is needed in which policy instruments are oriented towards achieving the appropriate supply of both non-commodity and commodity attributes of agriculture. Such a paradigm must be consistent with trade iberalization and a distinction must be made between NTC’s that revolve around market failure in the production of multifunctional outputs, such as landscape amenities and environmental quality, and distributional issues, such as the level of farm income.

This report addresses the key elements of such a new policy paradigm and its empirical significance through an examination of changes in Taiwan’s rice policy required for the country’s admission to the WTO. Through empirical simulations based on a computable partial equilibrium model of the Taiwanese rice market, we examine the re-instrumentation of domestic policy to address both positive and negative environmental externalities, assess the implications of trade liberalization for optimal policy choice and examine some issues in farm income distribution. We model two of the multifunctional attributes that have figured prominently in the debate on the environmental impact of rice production in Taiwan and other Asian countries namely, groundwater recharge (a positive externality) and methane gas (a negative externality).

Through both our conceptual and empirical analyses, we have shown that a policy aimed at securing an appropriate supply of a major positive attribute – groundwater recharge – and containing a negative attribute – methane emissions – would require that the price and income support measures currently used be replaced by fees and compensations for the use of inputs used in rice production. Recognizing that the specific numerical results are sensitive to parameter values, we have also demonstrated the robustness of the qualitative conclusions on appropriate policy design under substantial variation in the valuation parameters for environmental attributes.

Net social welfare increases once the environmental externalities are internalized in this way, and the gains are higher under trade liberalization. This is consistent with the view that, overall, trade liberalization is welfare-enhancing. Furthermore, our results support early arguments by economists that trade policy should not be used to correct domestic distortions. In our context, the distortions created by the lack of markets for the positive and negative externalities associated with agricultural production are best addressed directly through domestic fees and compensations for the use of inputs. And, at the same time, these policies allow consumers to benefit from lower product prices resulting from reduced import protection.

Furthermore, because the multifunctional non-commodity outputs are not produced in fixed proportion with output, our results also underscore the fact that multifunctional objectives cannot be pursued efficiently through traditional price support policy. The compensation of producers associated with the income support objective implicitly values groundwater recharge below its social value, and underestimates the social cost of methane abatement.

There are direct policy implications for the distribution of water between agricultural and industrial uses in Taiwan. Achieving environmental objectives by replacing the current price support policies would require the payment of land and water subsidies and the imposition of a fee on fertilizer use. Under the valuations assumed for the environmental goods and trade liberalization, water use would expand by about 8 percent so that the value of groundwater recharge is increased by about 7 percent. Fertilizer use would decline by about 8 percent. Land in rice production would rise 5 percent, partly to foster the increase in groundwater recharge.

Contrary to what one might expect, this policy re-instrumentation reduces rice production by just less than 4 percent. This is due in large part to the fact that the pre-WTO support price was paid only on a fixed quantity of production per hectare. Thus, even prior to policy reform, the supply-inducing price at the margin was the domestic market-clearing price, rather than the support price.

Although there are gains in social welfare from the re-instrumentation of domestic rice policy in Taiwan, the efficiency gains are distributed toward consumers and away from farm households producing rice. Domestic payments to producers fall by 94 percent under trade liberalization. The imputed land rents decline substantially, by an estimated 42 percent under trade liberalization.

Because of their magnitude, there are undoubtedly political, economic and equity reasons to address these distributional issues to facilitate the process of adjustment to this new policy regime. However, these distributional issues fall outside our definition of multifunctionality. To address these distributional issues, some countries have used compensatory payments to producers to ease the adjustment process resulting from the reform of domestic agricultural policies. Therefore, to gain some perspective on the implications of providing adjustment assistance, we assume that Taiwanese rice farmers are compensated for nearly a 42 percent loss in land values due to the reduction in price supports and land set-aside payments. To do so, direct payments of about US$337/ ha. would be required. The total cost, if this payment is made only to land in production, is US$117 million, or 59 percent of the annual government outlays for price supports and land set-aside payments. If direct payments of this size were also made to the remaining set-aside land, the cost would rise to US$158 million or 79 percent of the budget outlays under the traditional support policies.

In conclusion, although the results obtained from this single empirical application may not be, generally, applicable to other countries and agricultural systems, the results of this empirical investigation into the effects of the re-instrumentation of an agricultural policy in Taiwan are extremely encouraging. They demonstrate that policy reform can contribute to optimal levels of multifunctional outputs, and it is also possible to address non-trade concerns that fall outside a workable definition of multifunctionality. Directions for additional research are also suggested in the efforts made to reconcile existing social values or costs of the multifunctional attributes of paddy. As is well understood in the environmental economic policy arena, many of the multifunctional attributes depend on local soil and water conditions and other factors that affect agricultural production. The values placed on these attributes can differ as well. Therefore, there is a need to extend this research by considering explicitly these regional differences. If they prove to be significant, then policy re-instrumentation may have to be implemented at the regional or local level. In addition, these types of policy analyses need to be extended to include additional multifunctional attributes. To the extent that policies recognize the contribution of farm production to a broader range of multifunctional attributes, the distributional consequences of policy reform may be diminished, thus reducing the need for adjustment assistance.

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Introduction

Rice is the primary food production industry in many Asian countries, especially in Japan, Korea and Taiwan. For years, the Taiwanese government has paid close attention to the rice industry and has employed several market-intervention strategies to promote farmers' welfare and protect the food supply for the public. Rice policy evolved substantially during the second half of the twentieth-century in response to changing domestic and international economic circumstances. Between 1946 and 1973, the goals of government rice policy were to stabilize prices and expand agricultural supply. After that period, the goals of government policy shifted dramatically—the primary focus was on increasing farmers' incomes through the adoption of a price support program and other policies (see annex A on page 24 for more details).

Since 1998, and as a condition for becoming a member of the World Trade Organization (WTO), the Taiwanese government has had to reexamine the goals of its agricultural policy. To meet the free trade objectives of the WTO, the government's efforts to support its domestic agricultural sector must rely less on price supports and other domestic policies that distort international trade. Furthermore, along with decreasing domestic support levels, the government must open agricultural markets to increased international trade.

Central to this reexamination of agricultural policy (as Taiwan joins the WTO) is the potential conflict between domestic and international policy goals. Since the conclusion of the Uruguay Round negotiations under the General Agreement on Tariffs and Trade in 1994,[1] the agricultural policy debate has increasingly been dominated by so-called 'non-trade concerns' (NTCs). These NTCs reflect a broadening of agricultural policy objectives beyond the traditional aim of providing price and income support to farmers. A range of concerns has been identified, extending from the relationship between agriculture and the environment to the standards under which food is produced, and the role of agriculture in ensuring a secure food supply (Blandford and Boisvert 2005). For many, these concerns are captured in the concept of 'multifunctionality', which seeks to reflect the broader contribution of agriculture to society. Multifunctionality characterizes agriculture as a multi-output activity, generating both agricultural commodities and non-commodity outputs that are valued by society.

The reevaluation of agricultural policies from the perspective of their impact on the supply of both commodity and non-commodity outputs raises important questions about the extent to which these NTCs can be addressed within the current disciplines on international agricultural trade. For example, it has been common to view

[1] Signed in 1994, the Agreement on Agriculture (AoA) contains provisions acknowledging the critical linkage between domestic agricultural policies and trade policies.

the supply of environmental attributes and other non-commodity outputs as secondary factors in the pursuit of traditional policy objectives, such as income support. If addressed at all, the focus would likely be on a single environmental attribute. It has been argued elsewhere that an approach that treats environmental aims and the production of other non-commodity outputs as subsidiary factors is an outdated policy paradigm (Blandford and Boisvert 2002). To address new concerns, such as how food is produced and environmental issues, a new paradigm is needed in which policy instruments are oriented towards achieving the appropriate supply of both non-commodity and commodity attributes of agriculture. It is also important that such a paradigm be consistent with the liberalization of international trade.[2]

Objectives

This report addresses the key elements of such a new policy paradigm and its implications. The empirical significance of such reforms is investigated through an examination of changes in Taiwan's rice policy required for the country's admission to the WTO. Through empirical simulations, we examine the re-instrumentation of domestic policy to achieve environmental objectives. We analyze policies that address both positive and negative environmental externalities, assess the implications of trade liberalization for optimal policy choice, and examine some issues in farm income distribution.

We focus on rice policy in Taiwan to illustrate the practical significance of these issues for domestic policy reform and trade liberalization. Prior to joining the WTO in January 2002, Taiwan operated an autarkic rice policy in which imports were prohibited. A price support program was in place, combined with a land set aside to control supply. As a result of its membership in the WTO, a tariff rate quota (TRQ) was introduced to permit limited imports of rice. Imports are made through a state trading enterprise (STE), which controls their release onto the domestic market. The price support/set-aside program continues to be used. Given that a degree of trade liberalization has recently occurred, we are able to explore the implications of a shift in domestic policy from price support to one in which environmental objectives are paramount under conditions of autarky, and when the economy is opened to limited international competition.

Since a primary objective of the report is to identify the policies that will lead to the production of the socially optimal levels of multifunctional outputs, one major difficulty in policy formulation is in determining appropriate social values for these nonmarket multifunctional goods. However, after a careful review of the empirical literature containing estimates of the several multifunctional attributes of paddy, it became apparent that there would be no way to reconsider the values for all multifunctional attributes for inclusion in our empirical analysis. Therefore, we model two of the multifunctional attributes that have figured prominently in the debate on the environmental impact of rice production in Taiwan and other Asian countries, and the potential impact of reforms in domestic and international agricultural policies (Yang 2000; Lin et al. 2002; Tsai 1993; APO 2001). These two multifunctional outputs are: groundwater recharge (a positive externality) and methane gas (a negative externality) generated by paddy production. Although we attempt to reconcile the existing wide range in estimates of the social value of these two externalities in the literature, methods for valuing jointly produced nonmarket goods are still under development. Therefore, in the empirical analysis, we do investigate the sensitivity of the results to a range in these environmental values.

In addition to ensuring that there are socially optimal supplies of these multifunctional attributes, the policy significance relates also to

[2]In contrast, and in an attempt to salvage traditional policy objectives, some have argued that the best way to sustain levels of these newly recognized jointly produced 'non-commodity' outputs is through a continuation of price supports. The research described in this report recognizes the critical need for an evaluation of these two alternative approaches.

the optimal allocation of land and water in the production of paddy relative to allocation of these resources to competing nonagricultural uses. Finally, we address some issues related to farm income distribution associated with this re-instrumentation of Taiwanese agricultural policy.

Outline of the Report

Since a critical feature of this new policy paradigm is to design policy instruments oriented towards achieving the appropriate supply of multifunctional, non-commodity attributes of agriculture, we begin by developing a working definition of multifunctionality. There can be little doubt that the characterization of agriculture as a multifunctional industry has helped to broaden international debate; it has stimulated analysis of the issues and their implications for domestic and international agricultural policy. In bringing greater clarity to the definition of multifunctionality, we make transparent how multifunctional issues differ from other important non-trade concerns (NTCs), and describe the implications for policy design in both cases. In the empirical analysis, we demonstrate how our policy solutions are not only correct for market inefficiencies associated with the supply of multifunctional non-commodity outputs, but also address the distributional consequences of another important NTC—the desire to support farm income or accommodate the adjustment process associated with the re-instrumentation of agricultural policy.

This discussion of multifunctionality is followed by the development of the theoretical and conceptual models needed for the empirical application. We first review some key conceptual issues relevant to policy design. These include the relationship between agricultural production and the supply of non-commodity attributes. In this regard, we pay particular attention to the fact that both commodity and non-commodity outputs are produced jointly, but not in fixed proportions. We use this review to develop an appropriate framework for the measurement and valuation of jointly produced goods, which in turn serves as a guide for reconciling and refining the current estimates of multifunctional values that appear in the literature. This valuation framework, as well as a discussion of important multifunctional outputs and other NTCs with a summary of existing value estimates, are described in greater detail in Boisvert et al. (2003) and Boisvert et al. (2004). We also discuss some conceptual issues and data requirements for specifying joint production function relationships.

Next, to be able to isolate the effects of this new policy paradigm, we specify an empirical model of the Taiwanese rice market, focusing on one positive externality—groundwater recharge and one negative externality—methane production, which are of particular policy significance to both rural and urban residents. In evaluating optimal policy choice, we give particular attention to instruments that are appropriate when it is difficult to observe and monitor the supply of environmental attributes associated with agricultural production.

The section that contains the empirical specification is followed by a discussion of empirical results. The final section draws important policy implications and outlines priorities for continuing research.

A Policy Framework for Multifunctional Agriculture and Other NTCs

From both technical and policy perspectives, it is important to distinguish between NTCs that relate directly to agricultural production (for example, environmental issues), and those that relate to the changing position of agriculture in the domestic economy (such as rural development or food security issues).[3] The policy problem surrounding any particular NTC stems largely from missing institutions or the failure of existing institutions. Failure to distinguish among different types of NTCs, or the use of an unduly inclusive definition of multifunctionality, blurs the logic of policy intervention and hinders the search for appropriate policy solutions. The real danger is the appearance that a 'one size fits all' policy approach is appropriate, when in reality, this is likely to result in a 'one size fits none' outcome.

A Workable Definition of Multifunctionality

To group the NTCs that result from similar institutional failures and for which there are common policy remedies, a workable definition of multifunctionality must be restricted to those non-commodity outputs of agriculture that satisfy two conditions. The first is that the non-commodity outputs must be jointly produced with the food, fiber and materials that are the commodity outputs of agriculture. The second is that these non-commodity outputs must provide social values (or impose social costs) that are not reflected in organized markets.

Joint Production

In a formal sense, jointness in production can arise in three distinct ways: (a) there are technical interdependencies in the production process; (b) outputs compete for an (allocable) input that is fixed at the firm level; and (c) outputs are produced from a non-allocable input (Boisvert 2001 a, b; Shumway et al. 1984; and Leathers 1991).

Case (a): Jointness due to technical interdependencies implies the presence of economies or diseconomies in production. An example is joint production of honey and fruit, where fruit trees depend on insects for fertilization but also provide food for honeybees.

Case (b): In this case, the amount of a factor used in the production of each output can be identified, but the total amount of that factor available to the enterprise is fixed in the short term. Another example that is illustrative of multifunctional agriculture would be the allocation of a fixed amount of land to several crops, as well as to one or more open-space land uses that provide wildlife habitat or other environmental benefits (e.g., acreage enrolled in the conservation reserve program in the United States). The outputs from these land uses are interconnected, because an increase in the amount of land devoted to one particular crop or to a particular conserving use reduces the amount of land available for the production of the other crops.

Case (c): This is the case where non-allocable inputs are used in the production of multiple outputs (e.g., outputs are obtained from one and the same input), and it may well be the most relevant of the three cases for the analysis of multifunctionality. The classical examples of joint production for agricultural commodities that fit this category are meat and wool from sheep, and oil and meal from soybeans. Multifunctional examples would include such things as the joint production of milk and landscape amenities by grazing cows on pasture and the joint production of grain and nitrate leaching and runoff from the

[3]This section, as well as others in the report, draws heavily on work by the senior author in collaboration with David Blandford. In several recent papers, they have articulated the need for a new agricultural policy paradigm that recognizes the social value of multifunctional outputs from agriculture. (e.g., Boisvert 2001a, b; Blandford and Boisvert 2002; Blandford and Boisvert 2005).

use of commercial fertilizer on cropland. Because we cannot separate the contributions of cows and pasture to milk production and amenities, production is joint. It is also impossible to disentangle the contribution of fertilizer to:a) the production of grain; and, b) to nitrate leaching or runoff.

To illustrate the complexity of multifunctional agriculture, if we count the pollution from animal waste, there is a third joint product in our livestock farming examples. Similarly, landscape amenities resulting from the use of cropland would add a third joint product to the grain farming example in that the land's contribution to grain production cannot be disentangled from its contribution to amenities.

Moreover, these examples also underscore another important feature of the joint, multifunctional production of commodity and non-commodity outputs—they are unlikely to be produced in fixed proportions with the agricultural commodities (OECD 2001). As is seen below, this characteristic of multifunctional agriculture has important implications for policy.

The Specific Case of Taiwanese Rice: In the case of Taiwanese paddy, important multifunctional attributes of rice production are also the result of non-allocable inputs used in the production of multiple outputs. In the current policy debate, a number of important multifunctional attributes of paddy have been identified. The most frequently mentioned relate to: (a) the recharge of underground aquifers; (b) the amelioration of land subsidence; (c) the reduction in flooding; the reduction in soil erosion; (d) change in water and air quality; and (e) landscape amenities.

As suggested by the detailed discussion of these multifunctional attributes in Boisvert et al. (2003 and 2004), the major emphasis is on those multifunctional attributes that have positive social value rather than those that impose costs on society. However, it is important to recognize both kinds of multifunctional attributes and, ideally one would include the entire list of multifunctional attributes in any agricultural policy analysis. To date we know of no attempt at such a comprehensive policy analysis. As is also apparent from the detailed discussion on the range of multifunctional attributes, such an analysis is also impossible here, partially because of a lack of information on agricultural outputs and inputs to the levels of these multifunctional outputs. Also there are inherent difficulties in assigning social values and costs to jointly produced nonmarket goods.

It is primarily for this reason that in our current examination of Taiwanese rice, we focus on one important positive multifunctional output —groundwater recharge, and one negative multifunctional output— the negative effects on air quality from green house gas emissions associated with the release of methane gas from paddy production. It is easy to see that these non-commodity outputs are indeed jointly produced with rice. Since groundwater recharge is directly related to total land planted to paddy rice and the intensity of the application of irrigation water, it is impossible to disentangle the contribution of these two inputs to the production of rice from their contribution to groundwater recharge. Similarly, the contributions of land, water and fertilizer to rice production cannot be separated from their effects on the release of methane. For example, methane released during rice production depends importantly on the water supply system; deepwater rice fields generate significant amounts of methane. Methane production also depends on soil quality, soil temperature, fertilizer practices and rice variety (e.g., Lin et al. 2002; Yang 2000).

Social Value or Cost

The second condition for a non-commodity output to fall within our definition of multifunctionality is that it must provide value to society (or impose a social cost) not reflected in markets. There are two reasons why such nonmarket outputs have no prices.

First, the joint non-commodity output may be what economists label 'public goods'—an individual's enjoyment (consumption) of such a good does not reduce the quantity available to others, and it is not possible to exclude someone from consuming the good once it is made available (Baumol and Oates 1988). Since the consumption of these goods is nonexclusive, consumers have no incentive to reveal the value placed on them. This public-good (nonexclusive) nature of multifunctional agriculture perhaps best characterizes landscape amenities, cultural heritage and the effects of CO_2 emissions on global warming.

Second, the joint non-commodity output could be in the form of a technical externality—defined in economic terms as a cost or benefit that is a by-product of economic activity (agricultural production in this case) allocated outside the market system (Baumol and Oates 1988). Unlike public goods, positive and negative externalities can be exclusive and depletable, but they are also un-priced. The environmental effects associated with agricultural production (such as nitrate leaching and runoff from the joint production examples above) are perhaps best characterized as negative technical externalities; they impose external costs on society. Alternatively, by raising the water table or increasing the outflow from aquifers to springs, streams, or the sea and reducing the threat of land subsidence, groundwater recharge from paddy production generates external benefits to society that are not captured in the market.

For both public goods and technical externalities, farmers have no incentive to take account of the external costs or benefits to society of jointly produced nonmarket goods in making production decisions. The consequence in both cases is that, from society's perspective, resources are misallocated. For example, by having no incentive to account for the 'positive' social value of landscape amenities, farmers may allocate too little land to farming activities for which such amenities are high. On the other side of the ledger, if farmers do not consider environmental implications of production decisions (for example, the contamination of water by agro-chemicals or animal waste or the release of methane to the atmosphere), crop or livestock production in certain areas may exceed the socially optimal levels.

The Optimal Policy Solution

By defining multifunctionality in this way, the optimal policy solution is to internalize the effects of the externalities or 'public' good attributes of the non-commodity outputs, i.e., to ensure that they are taken into account in farmers' resource allocation decisions. The standard economic prescription is to 'compensate' producers by an amount equal to the marginal social value of a positive externality and 'charge a fee' equal to the marginal social cost of a negative externality. In so doing, we obtain the social welfare maximizing levels of non-commodity outputs (Baumol and Oates 1988).[4]

In an earlier paper on the subject, Plott (1966) emphasized the importance of taxing or subsidizing the correct thing, as illustrated below. His observations are particularly significant in light of the belief held by some that appropriate levels of multifunctional outputs can be achieved through a continuation of traditional domestic price supports. Although not dealing with agriculture per se, Plott recognized explicitly that the environmental externality was produced jointly with another conventional output. He was also writing at a time when explicitly or implicitly through particular examples, many believed that the corrective fee or compensation should be placed on the production of the commodity. However, Plott demonstrated that such a policy (e.g., a price support on the commodity in the case of a positive externality) would be appropriate only under extremely restrictive

[4]While these are the well-known Pigouvian subsidies and taxes, Blandford and Boisvert (2005) argue that it is important to avoid referring to appropriate compensation and fees in terms that may have a pejorative connotation. Since the non-commodity outputs are of value to society, compensation is, in a very real sense, a payment to producers for services provided, rather than a means of redistributing income. In the case of a negative technical externality, producers are being charged a fee in lieu of the cost their production activities impose on society, rather than simply to generate government revenue. Throughout the report, the terms fees and compensations are used interchangeably with the terms taxes and subsidies when discussing Pigouvian policy instruments.

conditions i.e., there be only one input used in production and that the externality be produced in fixed proportions with the commodity output.[5] He went on to show that the fee or compensation should be assessed on the externality itself, or under certain conditions on the inputs used in the production of the externality. This latter observation proves critical in our empirical application.

Multifunctionality as a Basis for Policy

To understand why this definition of multifunctionality and the policy prescriptions above provide a sound basis for further discussions of agricultural policy formation, we must know what sets these multifunctional non-commodity outputs apart from other non-trade concerns such as food security, and rural development.

These other non-trade concerns relate primarily to whether freer trade undermines the ability of a country to guarantee a sufficient supply of safe food or to promote the economic and social development of rural areas. They are also qualitatively different from technical externality issues associated with multifunctionality. The changes in response to policy reform that give rise to these NTCs do not involve missing markets. Instead these concerns are reflected through the effects of the levels of activity and prices in other markets (e.g., rural labor markets, agricultural input markets, etc.).

Accordingly, these non-trade concerns fall under the heading of pecuniary externalities—the effects of production or transactions on outside parties through resulting changes in other markets and prices (Baumol and Oates 1988; Kolstad 2000). Although other market outcomes are affected, pecuniary externalities do not lead to a misallocation of resources, but there may be redistributive effects associated with transfers among different segments of society. These types of non-trade concerns may also be affected by the impact of freer trade on domestic agricultural production. While not requiring any public action because there is no resource misallocation, there may be political incentives to address the distributional consequences. Such concerns should not be addressed through the price system, but rather through institutions put in place to ensure appropriate distributional outcomes (for example, domestic decoupled payments to maintain farm household incomes and a viable rural economy; government stocks to provide security in the availability of food; food standards and inspection systems to protect food safety). To underscore the differences in institutional solutions for these NTCs and multifunctionality, policies to deal with the distribution of farm income under policy re-instrumentation are also addressed in the empirical analysis below.

Challenges to Implementing Multifunctional Policies

Although the standard economic prescriptions to multifunctional policy, to ‘compensate’ producers by an amount equal to the marginal social value of a positive externality and ‘charge a fee’ equal to the marginal social cost of a negative externality, appear simple enough on the surface, there are three major challenges to deal with when implementing. The first relates to valuation of jointly produced non-commodity outputs. The second relates to difficulties in observing or monitoring the levels of multifunctional outputs, while the third relates to establishing an unambiguous relationship between commodity production, agricultural input use and the production of non-commodity outputs. We discuss each of these issues below, and their practical solutions with respect to Taiwanese rice are discussed as part of the empirical specification.

[5] If these very restrictive conditions are not met, a tax or compensation on output could well make matters worse, rather than better.

Valuing Nonmarket Goods

Assigning monetary measures to the benefits or costs associated with nonmarket goods is always a challenge and, environmental economists have used both direct and indirect methods to do so.

There are three basic indirect methods that rely on observed choices: (i) the hedonic price approach exploits the notion that the price of goods, such as a house or a job, can be decomposed into the prices of the various attributes of the good (e.g., the air quality surrounding a house in addition to the size of the house, the number of rooms, etc.);
(ii) alternatively, the weak complementarity approach makes use of the fact that the consumption of some goods can be complementary to changes in environmental quality. For example, if an improvement in environmental quality results in an outward shift in the demand for visits to a lake, then the value of the improvement can be measured by the net addition to consumer surplus under the new demand curve; and (iii) the averting behavior approach is perhaps the most relevant for our purposes. This approach is based on the fact that in some cases expenditures on other inputs or goods and services can be used to mitigate the effects of pollution or other externality. If this is the case, then the value of a 'small change' in pollution can be measured by the value of the inputs (or other goods and services) used to compensate for the change in pollution. Variations on this approach might also be called the avoidance cost method (e.g., the water filtration costs avoided by a household because of a specific improvement in water quality), or the replacement cost method (e.g., placing a value on additional water catchment by calculating the cost of additional reservoir capacity to serve the same purpose). Using the costs of abatement, as is done for estimating the social cost of methane emissions in our empirical application, is yet another variation on this theme.

The alternative to these indirect methods is to gather direct evidence on the value of nonmarket goods through surveys based on the contingent valuation method (CVM) and discrete choice modeling based on conjoint survey responses, or through experiments conducted in a laboratory for experimental economics. Randall, one of the pioneers of the CVM methods, summarizes the intuition behind these methods in the following way. Paraphrasing, if we design questions with enough care, perhaps people can provide reliable evidence of amenity values by telling us their (willingness to pay) WTP or (willingness to accept) WTA directly; or by telling us what they would do (e.g., buy or not buy) given well-specified choice situations that we construct for them (Randall 2002).

Measurement Issues

Regardless of whether a direct or indirect approach is taken, the valuation process is particularly difficult in the case of agriculture's supply of jointly produced multifunctional outputs. The challenges begin with what to include in the list of nonmarket goods and how to measure or articulate the characteristics to be valued. These challenges are easily illustrated using some of the multifunctional benefits of paddy listed above.

The measurement issues are really difficult with respect to items such as landscape. For example, although the public may be willing to place a subjective value on landscape, what exactly are the characteristics of landscape that are valued? Is it a particular pattern of land use, small fields for example? Is it that there are particular crops in the fields or that the fields are interspersed with wooded areas that provide wildlife habitat?

There are also some measurement issues related to groundwater recharge and methane emissions, etc., but for these multifunctional outputs, the critical factors are perhaps more related to identifying the physical relationships between agricultural inputs and the 'joint' production of the commodity and non-commodity outputs. A second concern relates to difficulties in observing or monitoring the levels of non-commodity outputs.

Some of these relationships are currently based on sound engineering and knowledge of biological processes, but empirical application is often difficult because of a lack of data needed to estimate or evaluate these relationships. These issues are particularly difficult to resolve in empirical analysis if the relationships depend on differences in soil, climate and other regional-specific factors.

By knowing these physical relationships, we are also able to circumvent much of the difficulty associated with the non-observability of the non-commodity externalities. We do so by targeting multifunctional policy intervention at observable variables that are correlated with the externality generating process such as the inputs used for agricultural production (e.g., Rude 2001; Romstad 2004). In the absence of market distortions, the first-best welfare scenario can still be achieved if the appropriate fees (compensations) are applied to ‘all' inputs contributing to the production of the non-commodity externalities or ‘public’ goods (Plott 1966; Holtermann 1976; Griffin and Bromley 1982).

Valuing Jointly Produced Nonmarket Goods

Regardless of whether the multifunctional policies target the multifunctional outputs directly or the inputs essential to their production, our optimal policy design relies on individual values for each of the multifunctional outputs. And, regardless of whether these values are estimated using direct or indirect methods, problems can arise in using separate values when the several non-commodity outputs are 'jointly produced'. Hoehn and Randall (1989) and Carson et al. (1998) caution that problems can arise in this case if the net social benefits are derived by adding together the individual values of the separate nonmarket goods (e.g., non-commodity outputs in our case), each being derived independently and individually using conventional valuation procedures. By implicitly ignoring the effects of ‘joint production’ and policy interactions, such procedures will systematically overstate the benefits or understate the costs. Some proposed strategies for addressing this issue within the context of multifunctional agriculture are described by Randall (2002), but to date, no empirical work has been attempted. To facilitate the empirical analysis at hand, this issue is also addressed specifically by Boisvert et al. (2003) in modifying the use of existing values of groundwater recharge based on contingent valuation estimates of several multifunctional outputs for use in this study.

Conceptual Market Model Incorporating Multifunctional Policy Design

To conduct the empirical analysis of multifunctional policy for Taiwanese rice, a number of these challenges mentioned above had to be addressed to the extent possible, given time and other resource constraints and some limitations on the availability of data. The resolution of each issue is described as part of the empirical specification.

The optimal policy formulation built into this empirical model is based on a conceptual model incorporating multifunctional policy design. The complete formulation of this conceptual model is in annex B. Before moving on to a description of the empirical model of the ‘Taiwanese Rice Market,’ it is helpful to summarize the key features of the conceptual model and highlight the relationships between the social values and costs of the multifunctional outputs, and the levels of the policy instruments.

An essential component of this conceptual model needed to derive the optimal multifunctional policy design is the specification of a general transformation function for both rice production and the two non-commodity environmental outputs (equation 1B of annex B). As mentioned above, it is most appropriate in this case to think of the joint production being due to a non-allocable input. Therefore, one cannot disentangle the separate contribution of each input to each product, and the total input use is not determined by summing inputs used by each product as it would result in double counting.

Both characteristics of multifunctional agriculture affect modeling farm-level and market behavior. If markets are competitive and if we ignore the social value or cost of non-commodity outputs, a farmer would maximize profits by equating the marginal value product of each input with its price. If it is possible to observe the levels of production of the non-commodity outputs, then we also know that to maximize social welfare, the standard economic prescription is to 'compensate' producers by an amount equal to the marginal social value of a positive externality and 'charge a fee' equal to the marginal social cost of a negative externality.

However, it is difficult or impossible to monitor the levels of the two multifunctional outputs in this study (e.g., groundwater recharge and methane emissions). Therefore, following the theoretical results mentioned above, we derive socially optimal policies with appropriate fees (compensations) being applied to 'all' inputs contributing to the production of the non-commodity externalities.

In this report, we extend a similar conceptual model by Peterson et al. (2002) to the case where there are also market distortions due to traditional agricultural policies such as price supports and land set-asides. The appropriate modifications in the levels of the input fees (compensations), for what is now a second-best optimum due to the domestic or international policy intervention, are derived in a manner similar to that when the market distortion is in the form of imperfect competition.

Two-stage Approach to Policy Design

As discussed in annex B, it is convenient to design optimal policies either in two steps or in stages. In the first stage, the government implements the optimal policy design by taxing or subsidizing land and other inputs. Given the levels of the policy instruments announced by the government, the representative rice-farmer would make optimal decisions on the use of agricultural inputs in a second stage. Since a solution is derived through backward induction, it is convenient to begin with a discussion of the second stage.

Optimal Decisions of Producers

The representative rice-farmer is assumed to maximize profits (revenue minus costs, equation 2B in annex B). Revenue includes market sales of rice, and, under the traditional domestic support policies, rice sold to the government at the support price and payments for the set-aside land. Costs include the sum of the input quantities used multiplied by the input market prices. For purposes of accounting for the social costs or benefits of the multifunctional outputs, the farmer's profit equation also includes the compensations or fees for the use of inputs associated with the production of the multifunctional outputs.

It is well known in economics that to maximize profits, the farmer would use inputs up to the point where the additional revenue from the use of an additional unit of input is equal to the price of the input. This is no longer true, however, under an optimal multifunctional policy design. Under these conditions, the farmer equates the marginal revenue from the use of an additional input with the input price, adjusted for the marginal 'net' social benefit due to the use of another unit of the input. If the 'net' social benefit is positive (negative), input use under the policy will be higher (lower) than it would be under the private optimum, and the levels of the multifunctional outputs will also be higher (lower) than the levels associated with the private optimum.

Optimal Levels of Environmental Policy Instruments

The optimal levels of the compensations and fees for the use of inputs are, in turn, derived by maximizing a social welfare function, represented by the sum of consumers' and producers' surpluses, less governmental budget costs, plus the total benefit associated with the positive environmental externality and minus the total damage from the negative externality (equation 5B of annex B).

These optimal compensations and fees are derived from the optimality conditions for maximizing this social welfare function. The optimal input compensation (fee) is determined in part by the marginal contributions of each input to the production of the externalities multiplied by the marginal benefit or damage of each externality. If more than one input contributes to both externalities, it is impossible to determine 'ex ante' if the compensation (fee) is positive (negative). For example, the optimal fee for a non-land input may well be negative (for example implying compensation) if that input's marginal contribution to the benefits associated with the positive externality outweighs its marginal contribution to the cost of damage associated with the negative externality. Whether the compensation for land is positive or negative depends on similar considerations in our model, but, if the traditional policies are also still in place, the size of the land compensation depends in part on the distorting effect of the limited price support and the land set-aside payment. To underscore the effect of market distortions on the level of 'Pigouvian-type' policy instruments, the land compensation that ensures the optimal level of the multiple externalities will decrease if the level of domestic support (either the price support or the set-aside payment) increases (equation 10Bb from annex B). Without domestic support, the optimal compensation for land is equal to the net effect of land's net marginal contribution to both externalities, just as it is for other inputs.

Opening the Economy to International Trade

The optimal environmental policy design represented in equations (10Ba and 10Bb) from annex B applies to a closed economy, and was applicable to the rice market prior to Taiwan's admission to the WTO, which, in 2003, led to rice imports under a tariff rate quota (TRQ). For this reason, we must also determine how the optimal multifunctional taxes and subsidies are affected by the new policy regime.

To understand the TRQ, for a small importing country, (e.g., the situation for rice in Taiwan), we discuss three possible outcomes in annex B. Under the first outcome, where imports equal the minimum access commitment, the TRQ acts like a quota in which a tariff is also levied. As is evident in the empirical analysis below, it is this case that is applicable to Taiwanese rice. Accordingly, the optimal environmental policy for this small open economy is similar to that from above, except that the domestic price is now determined by the sum of domestic production plus imports, rather than by just domestic production as in the closed economy case.

Empirical Model

To illustrate the economic impact of policy changes, a computable partial equilibrium model is used to represent the Taiwanese rice market. This framework has been widely used for analyzing the effects of agricultural policies (e.g., Floyd 1965; Maier 1991; Gardner 1987). A special feature of the approach is that the various market levels in the vertical production/consumption chain are considered simultaneously. The approach is adopted primarily because agriculture represents only about 2 percent of Taiwan's domestic product—thus it would be unlikely that there would be noticeable general equilibrium effects from changes in rice policy. Furthermore, similar partial equilibrium models have been used elsewhere to examine

TABLE 1.

The equations for the model of the Taiwanese rice market.

$$(1)\ L=g_l(p_l)=k_l P_l^{\varepsilon_l}$$

$$(2)\ Z=g_z(p_z)=k_z P_z^{\varepsilon_z}$$

$$(3)\ FP=g_{fp}(P_{fp})=K_{fp}P_{fp}^{\varepsilon_{fp}}$$

$$(4)\ W=gw\ (pw)\ =kwPw^{\varepsilon_w}$$

$$(5)\ \alpha PF_l+\alpha\bar{Q}(\bar{P}-P)+(1-\alpha)\ P_s+\alpha s_l=P_l$$

$$(6)\ PF_z=P_z$$

$$(7)\ PF_{fp}=P_{fp}+t$$

$$(8)\ PF_w+s_w=P_w$$

$$(9)\ \beta F\ (\alpha L,Z,FP,\ W)=\beta k\ (\alpha L)^{C_l}Z^{C_z}FP^{C_{fp}}W^{C_w}=Q^d$$

$$(10)\ PP=k_p P$$

$$(11)\ PP=a-b\ (Q^d+M)$$

$$(12)\ GW=k_{gw}WTP\log\ \{W^{d_w}(\alpha L)^{d_l}\}$$

$$(13)\ ME=k_m rW^{e_w}FP^{e\,fp}(\alpha L)^{e_l}$$

the effects of TRQs and the reduction in domestic agricultural support (e.g., Abbott and Paarlberg 1998; Boughner and de Gorter 1999). Finally, as demonstrated above, the optimal environmental policies can be analyzed in conjunction with the adoption of a TRQ by making some rather straightforward changes in the partial equilibrium framework. In order to isolate the impact of trade liberalization, we examine scenarios for both a closed economy and an open economy. We benchmark our empirical model assuming a closed economy with the domestic policies in place as in 2001. The essential features of the Taiwanese rice market are captured in 13 equations (table 1).

Because data to estimate the parameters of input supply equations and other such relationships are not readily available, we employ reasonable estimates of the parameters derived from the literature, relying particularly on studies from Japan, other Asian countries and the United States of America. Since a primary focus of the report is on optimal environmental policies, we focus our sensitivity analysis of the empirical results on the range in estimates of environmental values.

Input Supply Equations

Equations (1) through (4) represent input supplies: farmland (L), farm labor (Z), fertilizer (FP) and irrigation water (W), respectively. Research for the Japanese rice industry (Ohba 2001) is the basis for the value used for the supply elasticity of land, 0.55. The value is towards the low end of the range of 0.0 to 2.0 found in previous literature (Floyd 1965; Gardner 1987). Since individual irrigation associations have control over the allocation of irrigation, and the transfer of land in and out of agriculture has to be approved by a government sponsored, county-level farmers' organization, we believe it is appropriate to assume the supply of land is relatively inelastic.

In past studies for the United States of America, estimates of the elasticity of labor supply to agriculture have ranged from 1.0 to 3.0 (Gisser 1971; Rosine and Helmberger 1974). A study by Tyrchniewicz and Schuh (1969) found labor supply elasticities ranging from around 0.7 in the short term to around 1.5 in the long term. We assumed a value towards the low end of this range, 0.8, for the Taiwanese rice industry.[6]

Supplies of purchased inputs, such as fertilizer, are usually much more elastic than those of other agricultural inputs. The range of fertilizer supply elasticities found in the literature is from 0.5 to 10 (Gardner 1987). We assumed a supply elasticity of 2.0 for the Taiwanese rice industry.

We found no studies that provide empirical estimates of the supply elasticity of water for irrigation, but irrigation associations control most of the irrigation water used in Taiwan's rice production. Therefore, it seemed appropriate to assume that the supply of irrigation water would be quite unresponsive to the imputed value of water for rice production—an elasticity of 0.3 is used in our analysis.

Input Demand Equations

Equations (5) through (8) are the derived input demand equations for farmland, labor, fertilizer and water, respectively. Each variable is as defined in the theoretical model, and the additional term, F_i, is the partial derivative with respect to input *i* of the Cobb-Douglas production function, which is embedded in the market clearing equation (9). Three of the inputs (fertilizer, land and water) contribute to the production of the two environmental externalities. Demands for these factors are affected by fees or compensations assigned to them by the government (t, s_l and s_w, respectively). The demand for land is also affected by the level of price support, the set-aside payment and the proportion of land that is set aside. Based on data published by the Council of Agriculture (CoA 2002), the proportion of land suitable for rice that is actually allocated to rice production (α) is around 0.7. The government's purchase price for rice (p) was US$621/ton; the maximum amount that the government would purchase at this price was 1.26 ton/ha. The set-aside payment per hectare (P_s) was US$1,213/ha. (CoA 2002). These policy parameters and environmental fees and compensations are set at various levels, or eliminated altogether in the policy scenarios described below. In calibrating the model, the domestic policy variables are set at their 2001 levels and the environmental fees and compensations are set to zero.

The Production Function, Rice Demand and the Market Equilibrium

Equation (9) is the market clearing condition for rice production (the terms on both sides of the first equals sign) and consumption. We were somewhat limited in our choice of rice production functions because only time-series data on the cost of rice production were available. This is the primary reason for specifying that the production function for rice has a Cobb-Douglas form. However, the

[6] We recognize that these estimates of the supply elasticity of labor are dated, and we did search the literature for more recent estimates—to no avail. We did, however, perform some sensitivity analysis and determined that estimated changes in net social welfare and all other important variables from the model are extremely insensitive to changes in the supply elasticity for labor. There are two explanations for this result. The first, and perhaps the most important, is that all policy impacts are compared to a 2001 baseline. To be consistent with this baseline, the model is initially calibrated using the assumed values for factor supply elasticities. All policy impacts are measured relative to this calibrated baseline. The second reason for the relative insensitivity of the results is that, as is seen below, labor is the only factor that does not contribute to the production of the environmental goods, and thus it is neither taxed nor subsidized in the optimal environmental policy.

Cobb-Douglas form has performed well in other studies where production functions were estimated from Taiwanese rice data (Tsai and Wann 1995). We used time series data on the cost of rice production between 1952 and 2001 to estimate the parameters of the production function. Average cost shares over that period for farmland, labor, fertilizer and water were: 0.19 (c_l), 0.57 (c_z), 0.22 (c_{fp}), 0.02 (c_w).

In the market closing condition, we make the common assumption for the relationship between vertical market levels in the industrial organization literature (Tirole 1988) that there is a fixed proportional yield of table rice from raw rice. Based on the conversion rate published by the CoA (2002), the value of β in equation (9) is set at 0.7. Equation (10) defines a fixed relationship between the farm price and the consumer price for rice.

Equation (11) is the linear demand function for rice. The consumer price is determined by the amount of rice available in the domestic market—domestic production in the autarky case and the sum of domestic production and imported rice (M) released onto the domestic market in the with-trade case. Parameter b is calibrated based on the assumption that the consumer demand elasticity for rice is -0.1 (Yang and Chen 2000). The low demand elasticity reflects the fact that rice is the main staple food in Taiwan; given the relatively high level of consumer income, demand is insensitive to changes in the price of rice.

Modeling the Multifunctional Attributes

Although non-trade concerns have traditionally figured in the debate on agricultural trade policy, the range of non-trade concerns has broadened dramatically in recent years. Much of this has been associated with the characterization of agriculture as a multifunctional activity. In this regard, Taiwan's identification of non-commodity outputs in rice production is no exception. Some of the issues identified in Taiwan are common to the production system used to grow rice throughout monsoon Asia.

In the monsoon environment, rice is grown in saturated soil that is often flooded throughout most of the growing season. In addition to providing optimum growing conditions, the production system affects the natural environment. It may affect the frequency and intensity of flooding, groundwater recharge, soil erosion and the water and air quality. In addition, there may be important social and economic externalities relating to landscape and recreation.

There was certainly no way to model all multifunctional attributes of rice. To be able to demonstrate the interaction between environmental policy design within the context of domestic and international trade policy reform in agriculture, it was necessary to focus on a single important positive externality (groundwater recharge) and a single important negative environmental externality (methane emission) associated with rice production. These externalities are chosen not only because of their particular interest in Taiwan's agricultural research and policy circles, but also because it was possible to reconcile existing estimates of their nonmarket values.

The Positive Externality: Groundwater Recharge

One major consequence of the ponded conditions of paddy production is the percolation of water into the soil. The rate of percolation varies, depending upon soil type, but water moving downward has a recharge effect on groundwater. This will replace water withdrawn from the aquifer, raise the water table or increase the outflow from the aquifer to springs, streams, or the sea (Ohnishi and Nakanishi 2001). It may also reduce substantially the risk of land subsidence (Barends et al. 1995). Recharge is influenced strongly by the status of the underlying aquifer. If the aquifer is in overdraft, i.e., the phreatic surface is declining over time, the recharge water may, according to some, be considered to have a value equal to that of water stored above the ground. If the aquifer is not stressed by the rate of extraction, recharge may simply sustain the base flow of springs and streams fed from the aquifer. This may have significant environmental value, e.g., maintaining fish populations, but the value is likely to be lower than that for an aquifer in overdraft.

To model groundwater recharge, it was necessary to specify how recharge relates to input use. Based on an agricultural engineering study, groundwater recharge is assumed to be directly related to total land planted to rice and the intensity of the application of irrigation water (Matsuno et al. 2002). We model groundwater recharge as a semi-logarithmic function, equation (12); an increase in the intensity of the application of irrigation water per unit of land area will affect groundwater recharge, as will an increase in overall land use. We can see this by writing the term in braces { } from equation (12) as $\{(\frac{W}{\alpha L})^{2/3}(\alpha L)\}$, which is also equal to $W^{2/3}(\alpha L)^{1/3}$. Groundwater recharge increases with the use of both inputs (land and water), but at a decreasing rate. The value of groundwater recharge is reflected by multiplying the right-hand side of the equation (12) by an estimate of the nonmarket value, WTP.

The estimates for the value of groundwater (WTP) are derived from values reported by Chen (2001) and Chen et al. (2002). In both studies, CVM methods are used to estimate the value of groundwater recharge associated with Taiwanese rice production. However, while Chen et al. (2002) focus only on the groundwater recharge value, Chen (2001) estimates the value of groundwater jointly with the value of other multifunctional outputs of rice production. Thus, it is difficult to disentangle the effects of groundwater recharge in the latter study. To reconcile the two estimates of value, the total values were converted to marginal values. These estimates were weighted averages, the weights determined by the proportion of the population in households of different types and in different counties (Boisvert et al. 2003; and included references). The average willingness to pay for a one percent change in groundwater recharge was estimated to be US$844, with an upper bound of US$1,114 and a lower bound of US$574. The range of estimates of WTP for groundwater recharge is the basis for a sensitivity analysis.

The Negative Environmental Externality: Methane Emissions

Although nitrate residuals are among the most widely recognized sources of agricultural pollution, numerous test results (e.g., from data supplied by the Kaoshung Irrigation Association) suggest that current levels of nitrates in Taiwan’s drinking water are within acceptable levels of concentration. For this reason, we focus on another issue—methane emissions from rice fields.

Methane is produced during rice production by aerobic decomposition of soil organic material in flooded rice fields. Almost 90 percent of methane generated and oxidized by aerobic bacteria in the soil reaches the atmosphere, thus contributing to greenhouse gas emissions. In 1990, it was estimated that rice contributed 16 percent of total methane emissions worldwide (US EPA 1999). One important factor affecting methane generation from rice production is the water supply system. Deepwater rice fields generate significant amounts of methane. Some of the methane bubbles up through the water, but most reaches the atmosphere by traveling up the rice stalk through the plant’s vascular system (Hyman 2001). Other factors that affect methane emissions from rice production are soil quality, soil temperature, fertilizer practices and rice variety. For example, if farmers use biogas residues instead of barnyard manure in rice production, methane emissions can be reduced by 24 percent to 62 percent. If farmers use hybrid rice seed, methane emissions can be mitigated by 10 percent (ADB 1998).

Based on the nature of this aerobic process, we assume that fertilizer, water and land used in rice production contribute to methane emissions, as in equation (13). This specific formulation is based on estimates of total methane emissions by Yang (2000) and Lin et al. (2001). Average total emissions from rice production in these two studies were estimated to be 35,500 tons. Further, from a recent study of methane abatement in China (ADB 1998), it is estimated that a one percent change in rice production will change methane emissions by roughly 2 percent. By combining these sources of information with the input production elasticities from the production function, we can relate methane emissions to input use. The details are in Boisvert et al. (2004).

The negative value of methane emissions to society is estimated as the product of average abatement cost (r in equation [13]) and total emissions. Our estimates of average abatement costs depend on the available technology for the abatement and total decrease in the amount of methane. According to a recent study of rice production in China, the most efficient abatement strategy is through effective manure management, involving an abatement cost of US$86/ton; a much less efficient strategy is through the adoption of hybrid rice, with an abatement cost of US$1,342/ton. Another possible strategy is through the use of a dry nursery for which the abatement cost is US$402/ton (ADB 1998). Again, these values are used in evaluating the sensitivity of our results with respect to the social cost of methane emissions.

The Results of the Policy Analysis

Table 2 contains a summary of the values for the parameters and the exogenous variables used in the empirical model. After calibrating the functional constants, k_i, for each equation based on the observed data, we find the optimal levels of the 13 endogenous variables ($L, Z, FP, W, P_l, PZ, P_{fp}, P_w, Q^d, P, PP, GW, ME$) by solving equations (1) through (13) simultaneously.

Table 3 provides a summary of key results from the policy simulations. Columns A to C relate to simulations performed under the assumption of autarky, and columns D to F reflect limited imports whose allocation is controlled by the state trading entity.[7]

Columns A and D provide the bases for comparison under the closed economy and limited trade options, in that each relates to the 'current support' case—one in which the existing system of price and income support with a land set-aside is in operation. Columns C and F relate to the case in which price and income support objectives are abandoned, being replaced by a policy in which environmental objectives alone are pursued. To provide a further point of comparison, columns B and E show what happens if the government keeps its existing price and income support instruments, but also uses compensations and fees to address the environmental externalities.

The key conclusions that can be drawn from these results are:

1. Achieving environmental objectives by replacing the current price support policies would require the payment of land and water subsidies, and the imposition of a fee on fertilizer use (column C, table 1). Under valuations assumed for the environmental goods, water use would expand by about 10.4 percent (8.0 percent under trade liberalization) so that the value of ground- water recharge is increased by 9.5 percent (6.8 percent under trade liberalization). Fertilizer use would decline by about 2.4 percent (7.6 percent under trade liberalization). The amount of land in rice production would rise by 7.6 percent (4.6 percent under trade liberalization), in part to foster the increase in groundwater recharge.

[7]In all simulations where limited imports are allowed under the TRQ, the quota is binding (e.g., imports are equal to the minimum access commitment). Since the lower, in-quota tariff rate is set at zero in Taiwan, there are no tariff revenues collected.

TABLE 2.

Values for the parameters and policy variables of the model for the Taiwanese rice market.

Supply elasticity of land, $\varepsilon_l = 0.55$
Supply elasticity of labor, $\varepsilon_z = 0.80$
Supply elasticity of fertilizer, $\varepsilon_{fp} = 2.00$
Supply elasticity of water, $\varepsilon_w = 0.3$
Proportion of land for production, $\alpha = 0.71$
Ratio of raw rice to table rice, $\beta = 0.70$
Payment for land set aside, P_s = 41,000 (NT$/ha.)
Government purchase price, $\bar{P}$ = 21,000 (NT$/T)
Government purchase quantity, $\bar{Q}$ = 1.268 (T/ha.)
Production elasticity of land, $c_l = 0.19$
Production elasticity of labor, $c_z = 0.57$
Production elasticity of fertilizer, $c_{fp} = 0.22$
Production elasticity of water, $c_w = 0.02$
Contribution of water to ground water recharge, $d_w = 0.67$
Contribution of land to ground water recharge, $d_l = 0.33$
Elasticity of water to methane emissions, $e_w = 0.042$
Elasticity of fertilizer to methane emissions, $e_{fp} = 0.462$
Elasticity of land to methane emissions. $e_l = 0.40$

2. Contrary to what one might expect, this policy re-instrumentation would actually increase rice production slightly (0.3 percent) under autarky but would decrease it by only 3.5 percent under trade liberalization. As mentioned above, the relatively small changes in rice production are due in large part to the design of the pre-WTO price support policy. The support price was paid only on a fixed quantity of production per hectare. Thus, even prior to policy reform, the supply-inducing price at the margin was the domestic market-clearing price, rather than the support price.

3. The replacement of price and income support policies by environmental policies has significant redistributive implications. There is a substantial reduction in transfers to producers, since the current large payments to producers are not needed to achieve the environmental benefits and also reduce the environmental costs associated with rice production. The domestic payments fall by 93.6 percent (94.2 percent under trade liberalization).

4. The elimination of income support, in the form of set-aside payments and government purchases of rice, causes imputed land rents to decline substantially, by an estimated 38.9 percent (41.9 percent under trade liberalization).

5. The pursuit of environmental objectives is welfare enhancing. Producers lose, consumers gain, and government payments are reduced. Net social welfare increases once environmental externalities are internalized in the autarky case, but the gains are higher under trade liberalization. This is consistent with the view that trade liberalization is welfare-enhancing overall, and suggests that the pursuit of environmental aims is not inconsistent with freer trade.

TABLE 3.

Simulations for alternative agricultural, environmental and trade policies on the Taiwanese rice market.

	Autarky			Limited Trade Liberalization		
	Current Support	Support+ Env	Green Policy	Current Support	Support + Env	Green Policy
	(A)	(B)	(C)	(D)	(E)	(F)
Optimal Environmental Policy						
Land compensation (US$/ha)	0.0	-91.2	10.0	0.0	-126.6	10.5
Water compensation (US$/ 1,000 tons)	0.0	1.2	1.2	0.0	1.2	1.1
Fertilizer fee (US$/ton)	0.0	1.7	1.7	0.0	1.7	1.8
Resource Allocation		----------------	-Percent Change from Base (A)	-----------------		
Consumption (thousand tons table rice)	1,207.0	-0.1	0.3	0.5	0.3	0.7
Production (thousand tons raw rice)	1,724.0	-0.1	0.3	-3.7	-3.9	-3.5
Land planted to rice (1,000 ha)	332.0	0.0	7.6	-0.4	-0.4	4.6
Labor (1,000 persons)	231.0	0.5	-1.3	-3.9	-3.2	-4.8
Water (10^7tons)	804.0	11.1	10.4	-2.1	9.8	8.0
Fertilizer (1,000 tons)	829.0	0.3	-2.4	-5.9	-5.2	-7.6
Groundwater recharge	278.0	5.9	9.5	-1.5	4.4	6.8
Methane emissions (10^3 tons)	35.5	-0.9	2.3	-3.0	-4.3	-1.5
Prices and Revenue						
Imputed land rent (US$/ha)	23.8	-6.5	-38.9	-0.8	-9.9	-41.9
Wages (US$/person)	68.1	0.6	-1.6	-4.9	-4.0	-6.0
Fertilizer Price (US$/ton)	7.0	0.2	-1.2	-2.6	-3.9	-8.6
Water price (US$/1,000 tons)	0.1	41.9	39.1	-6.7	36.6	29.1
Farm price of rice (1,000 US$/ton)	0.5	1.3	-3.2	-5.2	-3.3	-7.3
Farm revenue (10^8 US$)a	11.3	-1.7	-18.9	-8.9	-25.2	-16.7
Welfare Analysis						
Consumer surplus (10^9US$)	5.8	-0.3	0.6	1.0	0.7	1.5
Producer surplus (10^9US$)	0.6	-1.9	-21.4	-5.7	-8.9	-27.6
Domestic payments (10^7US$)	19.9	-5.0	-93.6	5.5	-17.2	-94.2
Groundwater recharge value (10^7US$)	28	0.3	0.5	-0.1	0.2	0.3
Methane emission value (10^7US$)	0.3	-0.9	2.3	-3.0	-4.3	-1.5
Social welfare (10^9US$)	6.5	0.1	1.4	0.7	0.5	2.1

Notes: [a]Includes domestic policy payments.
All monitary values are in constant 2001 US dollars. The average NT$/US$ exchange rate in 2001 was 33.8 (GIO, 2004)

6. The joint pursuit of redistributive and environmental objectives is inferior, in terms of net social welfare, to a policy that attempts to achieve environmental objectives alone. Because the multifunctional non-commodity outputs are not produced in fixed proportion with output, the compensation of producers associated with the income support objective implicitly values groundwater recharge below its social value and underestimates the social cost of methane abatement. This is best seen by the magnitude of the environmental fees and compensations in the presence of domestic distortions created by existing policies. Given these distortions, environmental objectives can only be achieved through a land fee, rather than a land compensation, in conjunction with a water compensation.

TABLE 4.

Sensitivity of the policy simulations to alternative values for the environmental variables.

		Scenarios With Alternative Environmental Values				
	(A)	(C)	(G)	(H)	(I)	(J)
Parameter Value						
WTP (US$)	—	843.8	1,114.1	573.6	843.8	843.8
Me (US$)	—	85.5	85.5	85.5	402.4	1,341.9
Optimal Environmental Policy		0.0	0.0	0.0	0.0	0.0
Land compensation (US$/ha)	0	10.0	14.4	5.7	-2.9	-41.1
Water compensation (US$/1,000 tons)	0	1.2	1.4	0.7	1.0	0.8
Fertilizer fee (US$/ton)	0	1.8	1.8	1.8	8.3	27.5
Resource Allocation		- - - - - - - - - - - - - Percent Change From Base (A)- - - - - - - - - - - - -				
Production (thousand tons raw rice)	1,724.0	0.3	0.3	0.3	0.2	-0.1
Land planted to rice (1,000 ha)	332.0	7.6	7.9	7.4	7	5.1
Labor (1,000 persons)	231.0	-1.3	-1.4	-1.2	-0.8	0.4
Water (10^7tons)	804.0	10.4	11.9	6.5	9	8
Fertilizer (1,000 tons)	829.0	-2.4	-2.5	-2.2	-3.4	-6.4
Groundwater recharge	278.0	9.5	10.6	6.8	8.3	7.1
Methane emission (10^3 tons)	35.5	2.3	2.4	2.1	1.5	-0.7
Prices and Revenue						
Imputed land rent (US$/ha)	23.8	-38.9	-38.6	-39.1	-39.5	-41.4
Wages (US$/person)	68.1	-1.6	-1.7	-1.5	-1.1	0.5
Fertilizer Price (US$/ton)	7.0	-1.2	-1.3	-1.1	-1.7	-3.3
Water price (US$/1,000 tons)	0.1	39.1	45.5	23.2	33.3	29.4
Farm price of rice (1,000 US$/ton)	0.5	-3.2	-3.4	-2.9	-2.1	1.1
Farm revenue (10^8 US$)[a]	11.3	-18.9	-18.7	-19.2	-19.1	-19.3
Welfare Analysis						
Consumer surplus (10^9US$)	5.8	0.6	0.7	0.6	0.4	-0.2
Producer surplus (10^9US$)	0.6	-21.4	-21.1	-21.9	-21.6	-21.7
Domestic payments (10^7US$)	19.9	-93.6	-92	-96.5	-99.4	-114.3
Groundwater recharge value (10^7US$)	28	0.5	32.7	-31.8	0.4	0.4
Methane emission value (10^7US$)	0.3	2.3	2.4	2.1	377.5	1458.1
Social welfare (10^9US$)	6.5	1.4	2.8	0	1.2	0.6

Notes: [a]Includes domestic policy payments.
All monitary values are in constant 2001 US dollars. The average NT$/US$ exchange rate in 2001 was 33.8 (GIO, 2004)

Sensitivity Analysis

The results in table 3 were derived using the mean of the valuation for groundwater recharge (WTP = US$844) and with the cost of methane emissions associated with the most efficient management strategy (Me = US$86). In order to examine the robustness of our conclusions, we conducted a sensitivity analysis using the closed-economy scenario as a point of reference (table 4). Columns A and C in that table correspond to columns A and C in table 3. Columns G and H give the results obtained using the high and low valuations, respectively, from willingness to pay studies, as mentioned above. The abatement costs associated with methane emissions are unchanged from those used in generating the results in table 3 for these two simulations. This table also gives the results that are obtained when the alternative high (column I) and very high (column J) abatement costs associated with alternative management strategies are assumed (Boisvert et al. 2004)). The valuation attached to groundwater recharge is that used in deriving the results in table 3. The key points from the sensitivity analysis are:

1. As might be expected, a lower valuation on groundwater recharge results in a reduction in the land and water subsidies required to achieve environmental objectives; a higher valuation results in larger compensations.
2. As the economic costs associated with methane emissions increase, the optimal fee on fertilizer use rises, and land compensation is replaced by a land fee. These measures result in a reduction in both the amount of land under rice cultivation and the production of rice.
3. Although the net effect varies, social welfare is increased by the pursuit of environmental objectives in comparison to current policies. The substantial redistributive impact of the change in policy aims (as evidenced by the reduction in producers' surplus and land rents) remains.

Distributional Consequences of Policy Change

From these results, there are gains in social welfare from the re-instrumentation of the domestic rice policy in Taiwan. The efficiency gains from replacing price supports and land set-aside payments with policies aimed directly at providing optimal levels of multifunctional output and limited trade liberalization are distributed toward consumers and away from farm households producing rice. Therefore, to facilitate the process of adjustment to this new policy regime, there may be political reasons to address these distributional issues. Important though they may be, we have emphasized above that these distributional issues fall outside our definition of multifunctionality and, therefore, they must be addressed with a different policy approach. The objectives of a redistribution policy would be to ensure a smooth transition to a new long-term equilibrium number of rice farmers of appropriate size, and to address issues related to the economic viability of the affected farm households.

In some countries, policy strategies, such as compensatory payments to producers, have been used to ease the adjustment process resulting from the reform of domestic agricultural policies. Recently, Australia made payments to dairy farmers as part of the reform of domestic dairy policies (Harris and Rae 2006). Recognizing that trade liberalization and a reduction in traditional commodity support can reduce asset values in agriculture, steps have been taken recently by other countries to provide compensation to asset owners for such reductions. In the United States, for example, such payments were made to former holders of marketing quotas for peanuts as part of the introduction of a more market-oriented government support program for that commodity under the 2002 Farm Act (Dohlman et al. 2004).

To gain some perspective on the implications of providing adjustment assistance, we assume here that Taiwanese rice farmers are compensated for losses in land values due to the reduction in price supports and land set-aside payments. Focusing on the scenario from table 3 for the case where traditional policies are replaced with the multifunctional policies combined with trade liberalization, current annual returns to land are estimated to fall by nearly 42 percent (e.g., the change in imputed land rent, table 3). To compensate for this annual loss in land value, direct payments of about US$337/ha. would be required. The total cost, if this payment is made only to land in production (including the 4.6 percent increase in rice area) would be US$117 million, or 59 percent of the annual government outlays for price supports and land set-aside payments. If direct payments of this size were also made to the remaining set-aside land, the cost would rise to US$158 million or 79 percent of the budget outlays under the traditional support policies.[8]

[8] So as to not affect production, payments to this remaining set-aside land may well be necessary for the direct payments to meet conditions for inclusion in the WTO 'green box' provisions.

While a one-time payment of this size would compensate producers for a single year's reduction in returns to land, it would not account for losses in future years. To account for losses in future years, the government could make a much larger one-time payment, or make annual payments for a fixed number of years into the future. The one-time payment for the lost value of quota permits in the United States, for example, was equal to the loss in value discounted at 5 percent over a 24-year period (Orden 2005).

Policy Implications

The approach developed in this report demonstrates how optimal policies for the supply of non-commodity (environmental) attributes associated with Taiwanese rice production can be determined. We have shown that a policy aimed at securing an appropriate supply of a major positive attribute (groundwater recharge) and containing a negative attribute (methane emissions) would require policy re-instrumentation. Fees and compensations for the use of inputs used in rice production would need to replace the price and income support measures that are currently used. We have also shown that the modest liberalization of trade that has taken place since Taiwan joined the World Trade Organization, is not inconsistent with achieving key environmental objectives. Recognizing that the specific numerical results are sensitive to parameter values, we have demonstrated the robustness of the qualitative conclusions on appropriate policy design under substantial variation in the valuation parameters for environmental attributes.

Our results also have direct policy implications for the distribution of water between agricultural and industrial uses in Taiwan. When current domestic support is replaced by the optimal environmental policies, the demand of water in rice production increases, reflecting its value both in rice production and in producing a valuable non-commodity output of groundwater recharge. To put it differently, while the current domestic price support and set-aside policy do provide income support for agricultural producers, our analysis shows that the current policies understate the true (private plus social) value of water used in agricultural production. It is only through policies such as those examined here that one can be assured that important scarce natural resources can be allocated optimally between important sectors of the Taiwanese economy.

Although the results obtained from this single empirical application may not be generally applicable to other countries and agricultural systems, we believe that they shed some light on three important issues surrounding the debate on multifunctionality.

The first is that a policy approach that treats non-commodity attributes in agriculture as secondary objectives to existing aims, such as income support, may well result in sub-optimal outcomes. As the Taiwan case demonstrates, it does not follow that the pursuit of income support goals through the use of traditional policy measures will result in the desired supply of environmental goods. It may be possible to achieve that supply at far lower costs, both to the government and to society as a whole, if policy instruments are employed that are more suited for achieving environmental goals than the existing measures. If it is indeed the case, as some would argue, that agriculture's role in the supply of environmental goods is an increasingly important issue, it may not be appropriate or sufficient to make marginal adjustments in the settings of existing agricultural policy instruments to achieve the desired outcome; a more radical redesign of policy may be required.

The second issue illuminated by our analysis is that this more radical redesign of policy may have significant redistributive implications, particularly through reductions in farm asset values, that may have to be addressed for political and equity reasons and to help control farmers' entry and exit from agriculture. Our results indicate that the efficiency gains giving rise to increased social welfare, and the direct payments needed to compensate farmers for loss in annual returns to land can be achieved at a substantially lower cost to the government than the cost associated with traditional farm support policies.

The third issue illuminated by our analysis is that agricultural trade liberalization may not be inconsistent with the pursuit of domestic environmental objectives. Put differently, our results provide empirical evidence supporting the early arguments by Bhagwati and Ramaswami (1963), as well as others, that trade policy should not be used to correct domestic distortions. In the light of our findings, the distortions created by the lack of markets for the positive and negative externalities associated with agricultural production are best addressed directly through domestic fees and compensations for the use of inputs, while at the same time allowing consumers to benefit from lower product prices resulting from reduced import protection. The maintenance of high product prices through import protection seems an inefficient way to achieve environmental aims, and could run counter to achieving those aims.

In conclusion, the results of this empirical investigation into the effects of the re-instrumentation of agricultural policy in Taiwan are extremely encouraging. They demonstrate that policy reform can contribute to ensure optimal levels of multifunctional outputs, and that it also can address non-trade concerns that fall outside a workable definition of multifunctionality. Directions for additional research are also suggested in the efforts made to reconcile existing social values or costs of the multifunctional attributes of rice. As is well understood in the environmental economic policy arena, many of the multifunctional attributes depend on local soil and water conditions as well as other factors that affect agricultural production. The values placed on these attributes can differ too. Therefore, there is need to extend this research by considering explicitly these regional differences. If they prove to be significant, then policy re-instrumentation may have to be implemented at the regional or local level. In addition, these types of policy analyses need to be extended to include additional multifunctional attributes. To the extent that policies recognize the contribution of farm production to a broader range of multifunctional attributes, the distributional consequences of policy reform may be diminished, thus reducing the need for adjustment assistance.

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Annex A

Brief History of Taiwanese Rice Policy

Introduction

Rice is the staple crop in many Asian countries, especially Japan, Korea, and Taiwan. After Taiwan separated from Mainland China in 1946, the Taiwanese government began to intervene in the rice market both to ensure an ample food supply and for reasons of food security. As the economy has developed since that time, government policy has also evolved in response to different economic circumstances. Between 1946 and 1997, we can roughly divide this evolution of government rice policy into four periods (Fu and Chen 1995; CoA 1997). During the first two periods, encompassing the years 1946-1973, the goals of government rice policy were to stabilize prices and to help expand agricultural supply. During this time, the agricultural sector also supported other economic activity by supplying vital resources to the rest of the economy. During the latter two periods, encompassing the years 1974-1997, the goals of government policy shifted dramatically—the primary concern focused on increasing farmers' incomes through the adoption of a price support program and other policies. By the end of the twentieth century, agriculture had become a protected sector, supported by resources from other sectors of the general economy (Fu and Shei 1996).

Since 1998, and as a condition for becoming a member of the World Trade Organization (WTO), the Taiwanese government has had to reexamine the goals of its agricultural policy, effectively entering into the fifth period in the historical evolution of rice policy. In particular, to meet the free trade objectives of the WTO, the government's efforts to support its domestic agricultural sector will have to rely less on price supports and other domestic policies that distort international trade. Furthermore, along with decreasing domestic support levels, the government must also open agricultural markets to increased international trade.

These policy changes will have dramatic effects on the Taiwanese rice market and on the incomes of farmers. As Taiwan's agricultural economy is subjected to these significant internal and external pressures, government policy decision makers will be preoccupied with the issues surrounding structural policy adjustment for years to come. How will Taiwan's agriculture of small family farms survive? What are the barriers to future structural adjustments? What is the appropriate new direction of Taiwan's future agricultural policy after 1998?

To place these issues in proper perspective, the purpose of this annexure is to recapitulate the course of Taiwan's structural change in agriculture since 1946, including the discussion of the evolution of main agricultural policies. The history of agricultural policy initiatives is summarized in table A.1.

A Period to Encourage Production and Control of Rice Supply (1946-1968)

In 1946, immediately following the internal war between Taiwan and Mainland China, there was a serious shortage of manufacturing facilities to support the Taiwanese economy. The general price level was also high, caused by the scarcity of materials and food, including rice. Not surprisingly, the government was preoccupied with providing enough food and basic materials to support the national population and stabilize the general price level.

To increase the aggregate food supply, the Taiwanese government implemented a series of land reform policies to provide economic incentives for rice farming. These included policies such as the '37.5 percent farm land rent reduction program' in 1949, the 'sales of public farm land policy' in 1951, and the 'Tiller Act' in 1953. The government provided farm inputs, such as fertilizer and technical support for farmers. The government also facilitated the construction of irrigation systems. As a result of these policies, the number of rice farmers increased by one third, and the food supply increased rapidly as well.

To effectively control the food supply, policies known as the 'Taiwan Land Tax with Rice Quantity' and the 'Rice Fertilizer Barter' programs were also launched in 1946. Through these combined policies, rice farmers were allowed to pay the land tax with a portion of their rice production, and in turn, also received a fertilizer allocation. At that time, the government also restricted the numbers of private food stores that could sell rice to the general public.

The combined effect of these demand- and supply-side policies was a rapid increase in rice production, which helped to support the rest of the general economy and stabilize the general price level. Between 1946 and 1966, for example, rice production increased from 894 thousand MT to 2,379 thousand MT (an annual growth rate of 2.7 percent). Although these kinds of policies were effective in increasing the food supply, the government actually taxed rice farmers by forcing them to exchange production inputs at prices lower than the market price (Lin 2000). Under these policies, farmers had to increase rice production to survive financially.

Self-sufficiency and a Period of Export Difficulties (1969-1973)

During the 'Green Revolution' of the late 1960s and into the 1970s, world supplies of rice outstripped world demand, due primarily to the development and widespread adoption of high yielding varieties. Therefore, the world rice price dropped dramatically. The problems facing Taiwanese rice farmers became particularly acute as the major importers of Taiwanese rice, such as Japan, were among the widespread adopters of new varieties to promote food self-sufficiency and decrease their dependence of imported rice. The loss of these international markets for rice led to serious reductions in Taiwan's foreign exchange earnings.

Due to the rapid growth in Taiwan's industrial economy during this same period, agriculture's significance in the overall economy began to decline. Reflecting this structural change, agriculture's share of GNP had fallen to just under 16 percent by 1969. In response to these pervasive economic forces, the government reoriented its agricultural policy toward improving farmers' incomes and reducing costs of production. To achieve these objectives and reduce farmers' tax burdens, some policies, such as the 'Rice Fertilizer Barter' program, were abolished. By doing so, the government also lost much of its control over rice production.

A Period to Support Prices and Stabilize Food Supply (1974-1983)

The world energy crisis, beginning in the mid-70s, was accompanied by a serious worldwide shortfall in rice production in 1973. By 1975, the world price of rice had risen substantially, and the Taiwanese government's stocks of rice were nearly depleted. In 1974, the government established the 'Food Stabilization Fund' to regain control of rice production in the face of these shocks and to stabilize the price at a reasonable level. With a budget of US$89 million, the purpose of the fund was to purchase rice from farmers at prices exceeding world market prices. Between 1974 and 1976, the government placed no limit on its purchases. Rice production increased rapidly from 2,254 thousand MT in 1973 to its historical peak of 2,713 thousand MT in 1976.

By this time, the persistent rice surplus was beginning to put heavy pressure on government's storage capacity and budget outlays. To balance the budget and reduce government stocks of rice, the government adjusted the price support program by limiting planned purchases to 970 kg per hectare. To provide additional assistance to farmers, the government also launched the 'Guidance Purchase Program' in 1978, whereby farmers' associations in each county could also purchase rice from local farmers. Beginning in that year, rice farmers effectively had two ways to participate in the government's support price program (Yang 1993).

Rice Diversion and a Period of Demand-Supply Balance (1984-1998)

The government's support program for rice during the 1970s and early 1980s clearly protected farmers' incomes and controlled market supply, and it marked a significant change in the historical development of the government's rice policy (Sophia 1993). The government paid a heavy price (particularly in terms of budget outlays) to reach these policy goals.

With continued economic growth and increases in personal income during the 1980s, household consumption patterns (including food consumption) became more diverse. As per capita rice consumption began to decline, there was an ever-increasing excess supply of rice. In order to balance the demand and supply in the domestic market for rice and reduce the budget outlays for purchasing rice, the government launched the first 6 years of its 'Rice Diversion Program' in 1984.

Under the 'Rice Diversion Program', rice farmers were encouraged to plant high-valued grains and horticulture crops on land previously used exclusively for rice production. From 1984 to 1987, the incentive was an in-kind payment of 1.5 MT of rice per hectare converted to these other uses. Between 1988 and 1996, the in-kind payments were replaced by direct monetary payments. Unfortunately, these efforts met with little success, in part because the economic incentives were not sufficiently large (Huang 1992). There were other reasons for why rice farmers chose to keep land in rice production. First, and perhaps foremost, the price support program could still offer substantial income protection. Furthermore, farmers could still produce two crops of rice a year even in the northern-most counties of Taiwan. Finally, irrigation systems currently in place were designed primarily for rice production, thus, making rice less susceptible than other crops to drought and other natural disasters (Sophia 2001). By 1989, the government had recognized the limited success of these new policy initiatives, and it decided to continue its 'Rice Diversion Program'. This program continued until 1997.

Joining WTO: Decreased Supply and Government Support (1998-present)

Since 1998, the Taiwanese government has had to reexamine the goals of its agricultural policy as a condition for becoming a member of the World Trade Organization (WTO). To meet the free trade objectives of the WTO, the government had to agree to reduce domestic price supports and other domestic policies that distort international trade. Furthermore, along with decreasing domestic support levels, the government had to open agricultural markets to increased international trade. Thus, in discussing contemporary agricultural policy, we must deal with both domestic and trade policy.

Domestic Policy

To respond to the WTO requirements for decreasing the levels of domestic support for rice, the Taiwanese government launched a 4-year program called the 'Rice Paddy Utilization Adjustment Program' (RPUAP) in 1998. Under this program, rice farmers were paid a direct payment to set their land aside. Alternatively, they could also receive direct payments (but in different amounts) to plant green manure crops, or to rotate the rice crops with other crops (table A.2). To decrease further the Aggregate Measure of Support (AMS), the government also abolished the price support program for other grains in the same year.

Currently, the government is operating under a new 4-year RPUAP, launched in 2001. The special feature of this program was to enlarge the fallow area through higher direct payments than were allowed during the first RPUAP. The government's planned set-aside area is 32,000 hectares, and based on current yield estimates, the set aside of this area would reduce domestic production by an amount exactly equal to the amount of rice that Taiwan has agreed to import from other WTO members (144,720 MT). During this current 4 years of the RPUAP, the government also announced that for political and other reasons, it would also keep the current price support program. Thus, there are two remaining government policies affecting the domestic market for rice: a) price supports; and, b) a set-aside program with direct payments.

Trade Policy

In January 1998, Taiwan became an official member of WTO after 142-member governments formally endorsed the accession package. By the end of 2002, Taiwan had to allow rice imports through a minimum market access quota of an amount equal to 8 percent of domestic consumption during the base period, 1990-1992. This quota is set at 144,720 MT on a brown rice basis.[9] Although this condition is similar to what was required of Japan when it joined the WTO in 1995, the Taiwanese government has also promised that the imported rice from other WTO members would not be used for food aid or as exports to other countries. Hence, this affirmation forces imported rice to be sold in the domestic market, thus competing directly with domestically produced rice.

In return, Taiwan is allowed to control 65 percent of total imported rice with an additional markup of up to US$0.70/kg when it enters the country. Private traders account for the remaining 35 percent (Sophia 2001; Lin 2000). For this reason, Taiwan's government still has some power to control the rice market, but its effectiveness is diminished substantially from what it was under previous policy regimes.

Challenge for Current Rice Policy

In examining these changes in Taiwanese rice policy, it is important to note that the set-aside policy is different from the decoupled direct payment system adopted by the United States in their most recent farm legislation. Although not true of the U.S. decoupled payments, farmers in Taiwan must fallow some area to receive the direct payment. Accordingly, this regulation may still have some effect on farmers' production decisions, and it is an open question as to whether or not these payments will be classified as 'green box' by the WTO. Furthermore, some view the current set-aside policy as just a short-term adjustment policy to meet the 20 percent reduction in AMS required by the WTO (Chen and Chang 2002).

The minimum access quotas for rice imports for future years will be determined during the next round of WTO negotiations. There are perhaps advantages to minimum access quotas, one of them being that the domestic rice market can be affected by imported rice, not by the world rice market. This may contribute to stabilizing the domestic price of rice. But in 1999, Japan changed their rice import policy to a tariff-quota system. Thus, Taiwan may be disadvantaged in the next round of negotiations if it still insists on adhering to the minimum access quota system. If Taiwan follows Japan in adopting a tariff-rate quota system, the domestic price of rice will be set by the world price, and the government will not be able to exert much influence on the domestic rice market.

[9]According to the CoA, the minimum access quota for the following years will be decided during the new WTO negotiations.

TABLE A 1.

A history of Taiwanese rice policy since 1946.

Period	Year	Policy
1946-1968	1946	Control number of Food Stores
		Taiwan Land Tax with Rice Quantity & Rice Fertilizer Barter Policies
	1947	The Sales of Public Farmland Policy
	1949	37.5 percent Farm Land Rent Reduction Program
	1950	Quantity of rice production reached Pre-World War II level, government started to export rice
	1951	Legislative Yuan agreed to 37.5% Farmland Rent Reduction Program
		Executive Yuan agreed to The Sales of Public Farmland Policy
	1953	The Tiller Act program was enforced
	1960	Implement the farmland reforms
	1966	Implement Ten-year Economic Construction Program
1969-1973	1970	Program to increase miscellaneous grains
		Japan prohibited foreign rice imported
	1972	The Executive Yuan abolished Rice Fertilizer Barter program
	1973	The Executive Yuan decided not to export rice and fertilizer
1974-1983	1974	World energy crisis began
		The Executive Yuan allotted funds for the Food Stabilization Fund
		Implemented the Price Support Program with unlimited purchase
	1976	Quantity of brown rice was 2.71 million MT, the historical peak
	1977	Price support program has changed to planned purchase with 970 kg of rice/ha. since 1977
	1978	Implemented another program, Guidance Purchase, to price support program.
		From then on, the support of rice excess market demand
	1983	Abolished the “Food Store” system
1984-1997	1984	Implemented the first six years of the Rice Land Diversion Program to decrease the supply
	1987	Abolished the Taiwan Land Tax with Rice Quantity Program
	1989	Implemented the second six years of the Rice Land Diversion Program
	1995	The second six years of Rice Land Diversion Program supposed to end
		The Executive Yuan agreed to continue it through June of 1997
	1996	The Executive Yuan announced first four-year Rice Paddy Utilization
		Adjustment Program, which was implemented in January of 1998
1998-2002	1998	Abolished Price Support Program for Misc. Grains
		Implemented four-year Rice Paddy Utilization Adjustment Program
		Import U.S. rice through a Minimum Access Quota— WTO negotiations
	2001	The Executive Yuan agreed to continue Rice Paddy Utilization
		Adjustment Program, chose low quality and quantity county set aside
	2002	Rice Paddy Utilization Adjustment Program; increase direct payment

Source: Council of Agriculture (2002), Chang (1998), and Fu and Chen (1995)

TABLE A 2.

Direct payments associated with the RPUAP in 2002.

Item	Direct Payment US$/ha		
	Special Land	Set-aside Land	Plant Green Manure Crops
Basic Payment	799	799	799
Group Rewards		59	59
Additional Rewards (administration fee)		148	296
Upper Bound on Payment	799	1,006	
1998			1,213
2002			1,361

Source: CoA (1997 and 2002)

Note: Monitary values are in constant 2001 US dollars. The average NT$/US$ exchange rate in 2001 was 33.8 (GIO 2004)

Annex B

The Mathematical Formulation of a Market Model for Taiwanese Rice Incorporating Multifunctional Policy Design

Introduction

We begin to formulate a conceptual model of the Taiwanese rice sector by assuming fixed resource endowments of two inputs (L, Z), and by specifying a general transformation function for both rice production (q), and two non-commodity environmental outputs (E_1 and E_2). It can be represented as:

$$T(q, E_1, E_2; L, Z) = 0 \tag{1B}$$

In addition to the normal regularity properties, the representation of multifunctional agriculture requires that commodity and non-commodity outputs are produced jointly, and the non-commodity outputs must be 'public' goods or technical externalities that are not valued in organized markets.[10] In this case, it is easiest to think of the joint production in which the outputs are obtained from a non-allocable input.[11] One cannot disentangle the separate contribution of each input to each product. Total input use is not determined by summing inputs used by each product as such a practice would result in double counting.

Both characteristics of multifunctional agriculture affect modeling farm-level and market behavior. If we assume competitive markets and ignore the social value or cost of non-commodity outputs, a farmer would maximize profits by equating the marginal value product of each input with its price. If it is possible to observe the levels of production of the non-commodity outputs, then we also know that to maximize social welfare, the standard economic prescription is to 'compensate' producers by an amount equal to the marginal social value of a positive externality and 'charge a fee' equal to the marginal social cost of a negative externality.

Although the logic of this Pigouvian principle is particularly compelling at a theoretical level, its practical application is less straightforward. First, the levels of the externalities are difficult to observe and measure. For this reason alone, it would be difficult, if not impossible, to apply the Pigouvian principle directly. Furthermore, in countries where markets are distorted by domestic agricultural policy intervention to protect producers' income, or barriers to international trade, Baumol and Oates (1988) were among the first to show that the Pigouvian policy instruments would have to be set at levels different from their marginal social costs (benefits).[12] To do a comprehensive evaluation of these multifunctional policies, it is important to determine what levels of policy instruments ensure the socially optimal supply of

[10]In the empirical application above, the two jointly produced non-commodity outputs, E_1 and E_2, are positive and negative environmental externalities, respectively. Thus, throughout the report, the terms non-commodity outputs, multifunctional outputs, and environmental externalities are used interchangeably.

[11]The case of non-allocable factors could also be discussed within the context of technical interdependencies. See Shumway et al. (1984) and Leathers (1991) for rigorous mathematical definitions of jointness in production.

[12]For example, to compensate for the fact that the level of a negative environmental externality under imperfect competition is already below its level under perfect competition, the socially optimal tax must be set at less than the marginal social damage (e.g., Lee 1975; Barnett 1980). Lichtenberg and Zilberman (1986) examine the welfare impacts of revenue support programs (e.g., price support, marketing orders, and import quotas) in agricultural product markets.

non-commodity outputs in the presence of these distortions.

The issue of non-observability of the non-commodity externalities is addressed by targeting multifunctional policy intervention at observable variables that are correlated with the externality generating process (e.g., Rude 2001; Romstad 2004), such as the inputs used for agricultural production. Indeed, in the absence of market distortions, the first-best welfare scenario can still be achieved if the appropriate fees (compensations) are applied to 'all' inputs contributing to the production of the non-commodity externalities or 'public' goods (Holtermann 1976; Griffin and Bromley 1982).[13] Peterson et al. (2002) demonstrate this principle in the case where both positive and negative non-commodity externalities are jointly produced with agricultural commodity outputs.

In this report, we extend that type of analysis to the case where there are also market distortions. The appropriate modifications in the levels of the input fees (compensations), for what is now a second-best optimum due to the domestic or international policy intervention, are derived in a manner similar to that when the market distortion is in the form of imperfect competition.

Two-stage Approach to Policy Design

To derive the optimal second-best multifunctional policy, we develop a two-stage approach around a partial equilibrium model of an agricultural market in which there are jointly produced non-commodity outputs. In the first stage, the government implements the optimal policy design by taxing or subsidizing land and other inputs (Peterson et al. 2002).[14] Given the levels of the policy instruments announced by the government, the representative rice-farmer makes an optimal decision on the use of agricultural inputs in a second stage. Since this two-stage problem is solved through backward induction (Tirole 1988), it is convenient to begin with a discussion of the second stage.

Optimal Decisions of Producers Under Domestic Support Policy

To understand the implications of domestic support for optimal multifunctional policy design, we must formulate the producer's 'decision-problem' within the context of the specific design of agricultural support policy for rice in Taiwan. The strategy we use at present is similar to what Fraser (2003) used in modeling the effects of a reduction in domestic support for agriculture in Europe.

Taiwan has both a price support program (the limited purchase support program) and a land set-aside program (Huang 2001). There is a payment for each hectare set- aside, but the government also limits purchases of rice at the support price to a fixed quantity per hectare. This is an important feature of the policy because it is likely that the supply-inducing price at the margin will be the domestic market-clearing price, rather than the support price. This characteristic of the price support program may reduce the level of the supply response as the support price is reduced.

The representative rice-farmer maximizes profits; revenue includes market sales of rice, rice sold to the government at the support price,

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[13]Shortle et al. (1998, pp. 574-575) also argue that these instruments provide the correct marginal incentives for input use, but do not guarantee that the set of firms left in the industry will be the efficient ones. Thus, they argue that an additional instrument, that does not distort input levels, may be needed to influence entry and exit of firms. This could be in the form of a lump sum tax on extra-marginal firms to ensure negative profits if they produce, or a compensation for not producing that would be larger than their after-tax profits. Further, while no such tax would be required for marginal or infra-marginal firms, a lump sum compensation may be necessary for those firms whose entry or exit is influenced by the input taxes or subsidies. The necessity for this lump sum tax or compensation clearly has implications for the re-instrumentation of government policy where there remains a desire to support the incomes of agricultural producers.

[14]For simplicity, we consider only two inputs in this conceptual analysis. The results extend in a straightforward fashion to the four inputs (fertilizer, labor, land and water) included in the empirical model of rice in Taiwan.

and payments for the set-aside land. The farmer's decision problem is:

$$\underset{L,Z}{Max}\pi = P\{F(\alpha L, Z) - \alpha L\overline{Q}\} + \alpha L\overline{P}\overline{Q} + (1-\alpha)LP_s$$
$$- P_l L - P_z Z + s(\alpha L) - tZ \qquad (2B)$$

where F(.) is the production function for rice, P is the equilibrium market price for rice, α is the mandatory proportion of total land, L, in rice production, (1-a) is the proportion of land enrolled in the set-aside program, Z is the other input used in rice production, $\overline{P}$ is the per unit government purchase price, $\overline{Q}$ is the government purchase quantity of per hectare, P_s is the per hectare set-aside payment, P_1 is the price of land, and P_2 is the price of a purchased input. Assuming that land contributes to the production of the positive externality, E_1 from equation (1B), and Z contributes to the negative externality, E_2 from equation (1B), s and t are the compensation and fee, respectively, on input use needed to ensure the appropriate production of the non-commodity environmental output variables.[15] The first term in the profit function is market revenue; the second term is the revenue from government purchases based on maximum per hectare quantity $\overline{Q}$; the third term is the revenue from the land set-aside program, and the last two terms are the compensation revenue and fee cost to the farmer associated with input use. Under the first-order, conditions necessary for an interior solution are:

$$\frac{\partial\pi}{\partial L} = \alpha P\frac{\partial F}{\partial L} + \alpha\overline{Q}(\overline{P} - P)$$
$$+ (1-\alpha)P_s + \alpha s - P_l = 0 \qquad (3B)$$

$$\frac{\partial\pi}{\partial Z} = P\frac{\partial F}{\partial Z} - P_z - t = 0 \qquad (4B)$$

The economic intuition behind equations (3B) and (4B) may be demonstrated by comparing the marginal cost and benefit of the use of each input.

For optimal land use, equation (3B), the first term is the marginal revenue from selling rice on the market; the second term is the marginal payment received through the price support program; the third term is the marginal payment for the land set aside; and the fourth term is the marginal compensation for the contribution of land in production to the supply of a 'positive' non-commodity environmental output. The solution of the farmer's optimization problem requires that these combined marginal (net) contributions of land to profit are equated to the price of land. Assuming that the marginal product of land is declining, and since the three terms involving policy instruments are positive, the optimal use of land will tend to be higher than under competitive market conditions in the absence of a price policy and an environmental policy that explicitly recognizes the social value of the positive non-commodity externality. In contrast, we can see from equation (4B), that the optimal level of the purchased input will tend to be below what it would be in a competitive market because of the assumed effect of the use of the input on the output of the negative non-commodity externality. The value of the marginal product of Z is equated to its price plus the fee on Z.

Optimal Levels of Environmental Policy Instruments

Given the solution to the rice-farmer's profit maximizing problem, second-best optimal environmental policies (given domestic policy distortions) can be derived by maximizing the social welfare function. Social welfare is represented by the sum of consumers' and producers' surpluses, less governmental budget costs and the net value of the non-commodity environmental externalities. Net social welfare can be expressed as:

$$SW = \int_0^{Q^c} p(h)\,dh - p(Q^c)Q + \pi\,(p, \overline{P}, \overline{Q}, P_s, t, s)$$
$$+ B(E_1[\alpha L, Z]) - D(E_2[\alpha L, Z]) - \alpha L\overline{Q}(\overline{P} - P)$$
$$-(1-\alpha)LP_s + tZ - s(\alpha L) \qquad (5B)$$

[15]The levels of these policy instruments are determined in the first stage of the 'policy design problem' described below.

where *p* (*h*) is the demand curve for rice, *P* (Q^c) is the equilibrium price, and π is the farmer's indirect profit function. *B* (.) is the total benefit function associated with the positive environmental externality and *D* (.) is the total damage function associated with the negative externality.[16] The first two terms of equation (5B) represent consumers' surplus; the third term is the profit of the representative rice-farmer, the fourth and fifth terms are the benefit and damage functions associated with the positive and negative non-commodity externalities. These non-commodity outputs are supplied jointly with a given level of inputs in rice production. The remaining two terms represent government fees and compensations, respectively, on the two agricultural inputs.

We apply Shephard's lemma to determine the optimal levels of the two new policy instruments by partially differentiating equation (5B) with respect to *t* and *s*. The first-order necessary conditions for an interior solution to the maximization of social welfare are:

$$\frac{\partial SW}{\partial t} = \frac{\partial L}{\partial t}\{\alpha(B'\frac{\partial E_1}{\partial L} - D'\frac{\partial E_2}{\partial L} - s - [\overline{P} - P]\overline{Q}) - (1-\alpha)P_s\} + \frac{\partial Z}{\partial t}\{B'\frac{\partial E_1}{\partial Z} - D'\frac{\partial E_2}{\partial Z} + t\} = 0 \qquad (6B)$$

and

$$\frac{\partial SW}{\partial s} = \frac{\partial L}{\partial s}\{\alpha(B'\frac{\partial E_1}{\partial L} - D'\frac{\partial E_2}{\partial L} - s - [\overline{P} - P]\overline{Q}) - (1-\alpha)P_s)\} \quad + \frac{\partial Z}{\partial s}\{B'\frac{\partial E_1}{\partial Z} - D'\frac{\partial E_2}{\partial Z} + t\} = 0 \qquad (7B)$$

Making the reasonable assumption that the partial derivatives of the input levels with respect to the fee and the compensation are nonzero, the levels of *t* and *s* that satisfy these first-order conditions also satisfy:

$$\alpha\,(B'\frac{\partial E_1}{\partial L} - D'\frac{\partial E_2}{\partial L} - s - [\overline{P} - P]\overline{Q}) - (1-\alpha)P_s = 0 \qquad (8B)$$

and

$$B'\frac{\partial E_1}{\partial Z} - D'\frac{\partial E_2}{\partial Z} + t = 0 \qquad (9B)$$

Solving equations (8B) and (9B) for *t* and *s*, we have:

$$t = D'\frac{\partial E_2}{\partial Z} - B'\frac{\partial E_1}{\partial Z} \qquad (10Ba)$$

and

$$s = B'\frac{\partial E_1}{\partial L} - D'\frac{\partial E_2}{\partial L} - (\overline{P} - P)\overline{Q} - \frac{1-\alpha}{\alpha}P_s \qquad (10Bb)$$

The intuition behind these two equations (10Ba and 10Bb) is straightforward; the optimal input compensation (fee) is determined in part by the products of the marginal contributions of each input to the production of the externalities and the marginal benefit or damage of each externality. Since both inputs contribute to both externalities, it is impossible to determine 'ex ante' if the compensation or fee is positive or negative. For example, the optimal fee for the non-land input may well be negative if that input's marginal contribution to the benefits associated with the positive externality outweighs its marginal

[16]Two issues must be addressed in specifying these environmental benefit and cost functions. The first has to do with the difficulties associated with the valuation of jointly produced nonmarket goods that are discussed in detail by Boisvert et al. (2004). Although, Randall (2002) has proposed a strategy for addressing these issues, no empirical work is available. Therefore, in our empirical analysis, it is necessary to assume that the cross derivative between E_1 and E_2 in the social value function for the externalities (V [E_1, E_2, I], where I is real income), is small. Further, our policies are likely to have only a small effect on the national income. Thus, we approximate the value function as $V \cong B(E_1) - D(E_2)$. The second issue relates to the Es being unobservable. If we assume that they are stochastic and contingent on both L and Z, B (.) and D (.) can be replaced by their expected values; appropriate fees and compensations applied to all inputs affecting the Es are preferred to taxes and subsidies applied to forecasts of the Es (Shortle and Dunn 1986).

contribution to the cost of damage associated with the negative externality. Whether the compensation on land is positive or negative depends on similar considerations, but, in addition, the amount of the land compensation depends in part on the distorting effect of the limited price support and the land set-aside payment. To underscore the effect of market distortions on the level of 'Pigouvian-type' policy instruments, the land compensation that ensures the optimal level of the multiple externalities will decrease if the level of domestic support (either the price support or the set-aside payment) increases (equation [10Bb]). Without domestic support, the optimal compensation for land is equal to the net effect of land's net marginal contribution to both externalities.

Opening the Economy to International Trade

The optimal environmental policy design represented in equations (10Ba and 10Bb) applies to a closed economy, and was applicable to the rice market prior to Taiwan's admission to the WTO, which, in 2003, led to rice imports under a tariff-rate-quota (TRQ). For this reason, we must also determine how the optimal multifunctional fees and compensations are affected by the new policy regime.

To understand the TRQ, we follow the argument developed both algebraically and graphically by Abbott and Paarlberg (1998) for a small importing country, (e.g., the situation for rice in Taiwan). To model the TRQ regime, we must recognize that there are three possible outcomes. Under the first, where imports equal the minimum access commitment, the TRQ acts like a quota in which a tariff is also levied. Accordingly, the optimal environmental policy for this small open economy is similar to that in equations (10Ba and 10Bb), except that the domestic price is now determined by the sum of domestic production plus imports, rather than by just domestic production as in the closed economy case. Second, if desired imports are less than the minimum access commitment, then the below quota tariff would be effective. The TRQ acts like a pure tariff in this case, and the domestic price is the world price plus the within in-quota tariff. For the third outcome, imports can exceed the minimum access level—in which case the higher out-of-quota tariff would apply.[17] As is seen in the empirical analysis above, it is the first outcome, where imports equal the minimum access commitment and the TRQ acts like a quota in which a tariff is also levied, that is applicable to the Taiwanese rice.

[17]Both Krutilla (1991) and Peterson et al. (2002) demonstrate that effects of these types of trade policies are slightly different for the large country case; the government can exploit the terms-of-trade effect of policy intervention.

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ISSN 1391-9407
ISBN 92-9090-648-0
ISBN 978-92-9090-648-3