

“Green Taxes”: Impacts on National Income, Social Welfare, and Environmental Quality

by

Chyi-lyi (Kathleen) Liang, Stephen B. Lovejoy, and John G. Lee

Chyi-lyi (Kathleen) Liang is an Assistant Professor with Department of Community Development and Applied Economics, The University of Vermont, Burlington, Vermont. (Effective August 1998)

Stephen B. Lovejoy and John G. Lee are Professors with Department of Agricultural Economics, Purdue University, West Lafayette, Indiana.

ABSTRACT

Two taxation schemes were designed to be included in a multi-regional multi-sectoral General Equilibrium model for reducing the use of commercial fertilizers, with the goal of alleviating surface water pollution. Under the 500% tax rate, results showed that 0.1% of the national income was given up in order to exchange for a 3% reduction in the fertilizer application used as an intermediate input. Furthermore environmental quality would be improved by 3%, if a linear relationship existed between the changes in intermediate fertilizer use and the improvement in environmental quality.

“Green Taxes”: Impacts on National Income, Social Welfare, and Environmental Quality

INTRODUCTION

Many studies provided evidence that agricultural production, especially crop production, was a major contributor for nutrients runoff. The 1994 National Water Quality Inventory Report to Congress published by the USEPA indicated that “Agriculture is the leading source of impairment in the Nation’s rivers and lakes, affecting 60% of the impaired river miles and 50% of impaired lake acres ...”. The present federal administrative approach has been to attempt to reduce the overall quantity of chemical fertilizer applied in agriculture. Although the correlation between quantity applied and quantity entering surface water is not direct, federal agencies and environmental groups are assuming that reduction in quantity applied will lead to *some* improvement in water quality.

Restricting agricultural chemicals is one of several options policy makers consider to prevent further damage to water quality. Several studies have attempted to capture the effect of the complete bans on certain chemicals on particular crops (Osteen and Kuchler, 1986 and 1987). At least thirty-seven States have their own laws regulating environmental quality (Rendleman, 1991). State policies include taxing fertilizer (Ribaud and Woo, 1991), regulating tillage practices, and restricting quantities of chemical use (Ribaud and Woo, 1991). Most of the previous studies focused on one-at-a-time, chemical-by-chemical, and site-specific regulating policies. The economic consequences of a general reduction in fertilizer use have not been thoroughly studied. The impacts of the federal level fertilizer taxes on the entire economy are unknown. Since fertilizer is the most important intermediate input to agricultural production, the

linkages and after-tax changes between fertilizer and other production factors (labor, capital, and land) still puzzle economists.

The purpose of this article is to determine the effects of the general fertilizer taxes on the fertilizer sector, national income, social welfare, and environmental quality. A Computable General Equilibrium (CGE) Model is applied to this study. The model structure, including benchmark data and how two tax schemes are incorporated into the CGE framework, is briefly described in the second section. By introducing two tax schemes (a uniform tax and a regionally differentiated tax), we would like to explore the changes in the quantity of the fertilizer produced and used as intermediate input in the third section. The fourth section discusses the impacts of the fertilizer tax on national income as well as social welfare. The fifth section discusses the linkages between the changes in the intermediate fertilizer use, the changes in the national income, and the changes in the environmental quality. Finally the last section provides conclusions and suggestions for future research.

MODEL STRUCTURE

In contrast to most previous studies which adapted partial equilibrium analysis (Huang and Lantin, 1993; Liapis, 1994; Taylor, et al. 1991; Barse, et al. 1988), a multi-sector, multi-regional Computable General Equilibrium (CGE) model is developed for this study in order to assess the tax impacts on the general economy. Agriculture is a relatively small sector compared to the overall economy in terms of factor/output relationship. However government programs targeted at agriculture constitute a large portion of government spending, and the potentially significant macro effects associated with agricultural chemical restrictions are still not clear. A

CGE model is more appropriate for analyzing linkages between industries, factor markets, government accounts, macro balances, and allows prices and quantities adjust to clear markets for products and factors. In this analysis, a fertilizer tax is introduced in the economy to increase the “user cost” for all fertilizer consumers (including producers and household). A CGE model is able to capture the changes in prices and quantities in each sector for domestic supply, domestic consumption, domestic intermediate use, export, import, and in factor markets.

Nineteen sectors were defined in the economy producing nineteen goods (for final consumption or intermediate use), including Livestock, Great Plains Food Grains, Midwest Food Grains, Southeast Food Grains, Rest of the US Food Grains, Great Plains Feed Grains, Midwest Feed Grains, Southeast Feed Grains, Rest of the US Feed Grains, Great Plains Oilseeds, Midwest Oilseeds, Southeast Oilseeds, Rest of the US Oilseeds, Other Agricultural Products, Agricultural Processing, Nitrogen and Phosphorus, Other Agricultural Inputs, Mining and Manufacture, and Services. Notice that Food Grains, Feed Grains, and Oilseeds are further disaggregated into four regions according to the different levels of the fertilizer application.

There is only one representative household and an explicit Government in the simulated economy. The household provides production factors to agricultural sectors and non-agriculture sectors. The household also purchases composite goods from domestic production and imports. Producers pay wages to the household, and produce nineteen goods for either domestic consumption (including final consumption and intermediate use) or exports. Both the household and producers pay taxes to the Government. They also receive transfers from the Government. Rest of the World industry directly links to domestic economy by import-export transactions. On the import side, our model incorporates the “small country” assumption: world prices are

exogenous. On the export side, we assume downward-sloping demand curves for some of the U.S. exports (including Livestock, all Food Grains, and all Feed Grains).

Technology for domestic production is represented by a Cobb-Douglas value-added production function with primary factors. Primary factors include agricultural labor, agricultural capital, agricultural land, non-agricultural labor, and non-agricultural capital. We assume no mobility among agricultural factors and non-agricultural factors. The usage of intermediate inputs in each sector are fixed by the constant Input-Output coefficients. There is no substitution between primary factors and intermediated inputs. There is also no substitution among intermediate inputs. A Constant Elasticity of Transformation (CET) function is used to describe how sectoral production is transformed into goods for domestic markets and export markets.

The household can choose between present consumption and savings (either purchasing domestic or foreign capital goods). The marginal propensity to consume is assumed to be constant. Consumer expenditures on different goods are a function of prices and income according to a simplified version of the Linear Expenditure System (LES). The minimum amount of food or non-food items for household consumption is set to be zero. Household expenditure shares among different goods are assumed to be fixed, so only income will affect the final consumption expenditure on each good. However, consumer demands for imports and domestic goods are distinct with separate sectoral prices by the assumptions about imperfect substitution and transformation between domestic market and world market. Further details about modeling structures and definitions of equations can be found in Liang (1996).

Benchmark Data

Benchmark data for the base year (1990) are from two sources: 1990 National Income and Product Accounts (NIPA), and 1990 Impact Analysis for Planning (IMPLAN) data. The intermediate demand between sectors are calculated by the IMPLAN program as constant input/output coefficients. Household consumption, Government consumption shares, employee compensation, capital income, indirect business taxes, labor income, returns to land, export volume by sector, and import volume by sector are all from 1990 IMPLAN data. The rest of the benchmark data are from 1990 NIPA, such as tariff, export subsidies, social security tax, business profit tax, business savings, capital depreciation, household income tax, household savings, government transfers to businesses and the household, government savings (usually negative), net foreign remittances, net foreign transfers, and net foreign savings. Other parameters which can not be found in 1990 NIPA or 1990 IMPLAN are estimated from parameters in the 1982 ERS/CGE model. All of the share parameters are in percentages, and the other values are in millions of dollars for 1990. All of the prices in the base year (1990) are set to one.

Uniform Tax Versus Differentiated Tax

Two tax schemes are designed in this research in order to provide an economic incentive for firms to reduce the consumption of Nitrogen and Phosphorus fertilizer: a uniform tax and a regionally differentiated tax.

The uniform tax is a single tax rate imposed on the domestic user price of fertilizer regardless of region, sector, and purpose of purchasing fertilizer. Whoever uses fertilizer must pay the tax, including intermediate input users, household, government, and capital investment. Tax rates vary from zero to 500%. The user price of fertilizer after including the uniform tax can be defined as: $User\ Price\ of\ Fertilizer = Producer\ Price \times (1 + Tax\ Rate)$

Compared to uniform taxes, differentiated tax rates can be charged to fertilizer users depending on fertilizer pollution levels and cropland areas. Previous studies (Ribaud, 1989) have indicated that cropland is a much greater contributor for suspended sediment, Nitrogen, and Phosphorus in some regions than in others. We calculate a “differentiated tax parameter” based upon total Nitrogen and phosphorus runoff weighted by cropland shares in four regions (Great Plains, Midwest, Southeast, and Rest of the U.S.) (Table 1). Non-crop producers (household, government, and capital investment) still need to pay a general level tax. However crop producers in each of the four regions are paying different prices (higher than non-crop producers) since the tax rates are not the same across regions. For example, if the tax rate for non-crop producers is T , then the tax rate for crop producers in Great plains is $T(1+0.0563397)$, tax rate for crop producers in Midwest is $T(1+0.110915)$, tax rate for crop producers in Southeast is $T(1+0.006526)$, and tax rate for crop producers in the Rest of the U.S. is $T(1+0.072487)$. T varies from zero to 500%, and we totally created 5 levels of differentiated taxes in the economy.

Table 1. Differentiated Tax Parameters for Four Regions

Region	TN+TP ¹ Shares	Cropland Shares ²	Differentiated Tax Parameter ³
Great Plains	0.176276	0.319935	0.056397
Midwest	0.326194	0.340029	0.110915
Southeast	0.035643	0.183099	0.006526
Rest of the U.S.	0.461887	0.156937	0.072487

Note 1: TN = Total Annual Discharge of Nitrogen; TP = Total Annual Discharge of Phosphorus
Source: Ribaud, 1989

Note 2: Source: Agricultural Statistics, 1990

Note 3: Parameter = $\text{TN+TP Share} \times \text{Cropland Share}$

DIRECT AND INDIRECT IMPACTS ON THE FERTILIZER INDUSTRY

The fertilizer industry directly and indirectly links to other sectors in the economy.

Fertilizer becomes more expensive after taxes. Any distortion in the fertilizer user price will affect everyone who uses fertilizer, especially Food Grains and Feed Grains (Food Grains and Feed Grains utilize 36% to 44% of the total produced fertilizer in the economy). Let's consider two extreme cases where the uniform tax rate is 500% versus no tax. Domestic fertilizer users' price increases by more than 500% (548.54%), and the producer price increases by 8.09%. This result contradicts what we expect from a partial equilibrium analysis. When the uniform tax rate is 500% or differentiated tax is at the 5th level, our study shows that Food Grains and Feed Grain prices increase by between 13% and 14% for domestic buyers in four regions. This reflects the increasing costs to producers in Food Grains and Feed Grains sectors. Domestic outputs of Food Grains and Feed Grains drop by between 10% and 24%. Domestic sales for Food Grains and Feed Grains (including domestic and foreign) drop by between 5% and 14%, while exports for these two sectors fall by 25% to 30%.

However, Food Grains and Feed Grains producers receive an 17% to 19% increase in prices, returns to agricultural factors drop substantially as we are going to discuss in the next section. This means that the windfall profits from producing Food Grains and Feed Grains must be distributed to intermediate inputs. Since fertilizer has the largest share among all of the intermediate inputs to Food Grains and Feed grains, it receives a higher profit and fertilizer producers gets a slightly higher price than the market clearing level.

When the uniform tax rate is at 500% or the differentiated tax is at the 5th level, domestic output of fertilizer falls by 6.5%-6.6%. Domestic sales of fertilizer drops by about 5%, and

intermediate use drops by about 3.3%. A greater proportion of fertilizer is used as intermediate input when the tax is added to its price. When there is no tax, 82% of the fertilizer produced is used as intermediate input. When the uniform tax is at 500% or the differentiated tax is at the 5th level, 85% of the produced fertilizer is used as intermediate input. This result relates to a major assumption made in the model: there is no substitution between intermediate inputs.

WHAT HAPPENS TO THE NATIONAL INCOME AND SOCIAL WELFARE?

National income is defined as the sum of the returns to labor, capital, and land, and plus the transfers from government and foreign sectors. Results from this study show that returns to agricultural labor, agricultural capital, and land decline significantly given an increasing tax rate, while there is no significant changes in non-agricultural factors. When the tax is set to be at the highest level, rents to agricultural factors drop by between 34% and 47%. The most dramatic reduction in rents happens to agricultural land, which decreases by almost 50%.

Table 2 shows the changes in national income due to two tax schemes. National income reduces from 4429 (billions of 1990 dollars, no tax) to 4424 (billions of 1990 dollars, a 500% uniform tax), or to 4423 (billions of 1990 dollars, level 5 differential tax). The percentage change in national income is very small. Theoretically any tax is expected to reduce national income as well as social welfare. The CGE model used in this study assumed a linear relationship between national income and social welfare. The reduction in national income due to fertilizer tax directly implies the reduction in social welfare. This study shows that agricultural factors become much more worse off comparing to the non-agricultural factors. However national income only reduces by 0.133% given the highest fertilizer taxes. Fertilizer tax does not have a significant impact on

the national income because: (1) agricultural sectors have relatively small contribution to the overall economy; and (2) wage rates to agricultural factors are relatively lower than the non-agricultural factors.

Table 2. Changes in National Income Due to Two Tax Schemes (billions of 1990 dollars)

Uniform Tax		Differentiated Tax	
100%	4428.34 (- 0.02%)*	Level 1	4428.32 (- 0.02%)
200%	4427.22 (- 0.05%)	Level 2	4427.18 (- 0.05%)
300%	4426.05 (- 0.08%)	Level 3	4425.98 (- 0.08%)
400%	4424.82 (- 0.10%)	Level 4	4424.72 (- 0.10%)
500%	4423.53 (- 0.13%)	Level 5	4423.40 (- 0.14%)

* Note: numbers in the parentheses represent the reduction percentage. The base year national income without a tax is 4429.41 (billions of 1990 dollars).

TRADE OFF BETWEEN NATIONAL INCOME AND ENVIRONMENTAL QUALITY

Assuming that there is a relationship between the changes in fertilizer used as an intermediate input and that changes in environmental quality, the environmental quality should be improved when the quantity of intermediate fertilizer use is reduced. Table 3 shows the reduction in national income and fertilizer used as an intermediate input compared to base year (1990). When the tax rates are in the highest levels, national income reduces by about 6 (billions of 1990 dollars) and the volume of fertilizer used as an intermediate input reduces by about 0.21 (billions of 1990 dollars). This implies that we need to give up 0.133% of the national income in exchange for a 3.22% reduction in fertilizer application used as an intermediate input. If we assume that there is a

linear relationship between the reduction of the intermediate fertilizer use and the improvement of the environmental quality (i.e. one unit of the reduction in intermediate fertilizer use equals one unit of the improvement in environmental quality), then the nation has to give up 0.133% of the income in exchange for a 3.22% improvement in environmental quality. In both of the tax systems, there exists a very high correlation between “the reduction in the national income” and “the reduction of the intermediate fertilizer use”.

Although the trade off between “national income foregone” and “reduction in the intermediate fertilizer use” is significant, the percentage of the reduction in intermediate fertilizer use is not significant given a very high tax rate. Since the quantity of intermediate fertilizer use is not reduced significantly given a very high tax rate, fertilizer tax seems to have a small effect on improving environmental quality. Assuming that there is a linear relationship between “reduction in fertilizer use” and “improvement in environmental quality”, a 500% tax yields a 3.3% reduction in fertilizer use, which in turn, implies a 3.3% improvement in environmental quality for the whole society. This effect is much smaller than the experience in European countries (Dubgaard, 1990). At least in a very short term, to impose a fertilizer tax really might not help to reduce nutrient runoff very much.

Table 3. The Reduction in National Income and Fertilizer Used As An Intermediate Input Compared to Base Year (1990)

	National Income (Billions of 1990 dollars)	Fertilizer Usage (Billions of 1990 dollars)
Uniform Tax		
1	1.0731	0.0386
2	2.1906	0.0781
3	3.3622	0.1192
4	4.5924	0.1621
5	5.8853	0.2070
Differentiated Tax		
level 1	1.0922	0.0404
level 2	2.2322	0.0818
level 3	3.4292	0.1248
level 4	4.6892	0.1497
level 5	6.0152	0.2167

CONCLUSION AND IMPLICATION ON FUTURE POLICIES

While limiting pollution output would seem the direct avenue to environmental protection, the present political climate seems to prefer limiting inputs such as commercial fertilizers. Unfortunately, the methods for pinpointing the spatial location of these “nonpoint sources” of pollutants is beyond the scope of the current paper. However, if one assumes that input reductions is actually pollution prevention, this study provides an indication of the economic impacts of the resulting environmental improvement.

Our study provides an example of input restrictions at the federal level. Even though our model is only an abstract for the real world economy, the effects of “green tax” on the overall economy are not significant. The Fertilizer industry only reduces the output level by 7% to 8% when the fertilizer tax is set at the highest level. Intermediate use of fertilizer only drops by 3% at the similar situation.

When a “green tax” is targeted at the heavier fertilizer users such as crop producers, such effects will be passed on to all of the industries and factors associated with crop production. The net effects to the whole society’s welfare becomes weaker than expected.

The advantage of the tax policy is to internalize “environmental costs” or “user costs” directly. By adding the tax to user prices, no users will escape from the tax. Tax revenue can be directly collected by government agencies, then transferred to the public. There are also disadvantages associated with a tax. Any tax policy targeted at a specific group, such as farmers, has to be very careful about the distribution of the tax revenue. The welfare of farmers or fertilizer users will be reduced through the tax. How to distribute the tax revenue among fertilizer users and non-fertilizer users becomes a very important issue. On the other hand, political costs and operational costs are also major concerns before formulating the policy schemes. To impose the tax on one industry or one individual may be scary to the target. But if the taxed target can link to other operations and pass the effects to others, the net effects will not be significant to the individual any more. Such welfare and political issues need more studies in the future.

There are other instruments which can reduce the fertilizer use, and may improve environmental quality indirectly. Limiting fertilizer application on per acreage bases, restricting total fertilizer production, designing a transferable permit for fertilizer users, and introducing organic farming practices are just a few examples. To evaluate the effects of these policies on the economy is not easy. They deserve more detailed study in the future.

REFERENCES

- Barse, Joseph R., Walter Ferguson, and Robert Seem, *Economics Effects of Banning Soil Fumigants*, Resources and Technology Division, Economic Research Service, U.S. Department of Agriculture, Agricultural Economics Report, No. 602, December 1988.
- Dubgaard, Alex, Programs to Abate Nitrate and Pesticide Pollution in Danish Agriculture, pps 117-129 in John B. Braden and Stephen B. Lovejoy (editors) *Agriculture and Water Quality: International Perspectives*. Boulder, CO: Lynne Rienner Publishers. 1990.
- Hanson, Kenneth A., , Sherman Robinson, *Data, Linkages and Models: US National Income and product Accounts in the Framework of a Social Accounting Matrix*, Economic Systems Research, Vol. 3, No. 3, 1991.
- Huang, Wen-yuan, and Rhona M. Lantin, *A Comparison of Farmers' Compliance Costs to Reduce Excess Nitrogen Fertilizer Use Under Alternative policy Options*, Review of Agricultural Economics, Vol. 15, No. 1, January 1993.
- Kilkenny, Maureen, and Sherman Robinson, *Computable General Equilibrium Analysis of Agricultural Liberalization: Factor Mobility and Macro Closure*, Journal of Policy Modeling, 12(3), 1990.
- Liang, Chyi-lyi (Kathleen), *Environmental Policies and United States Agriculture: An Application of General Equilibrium Model*, PhD Dissertation, Department of Agricultural Economics, Purdue University, August 1996.
- Liapis, Peter S., *Environmental and Economics Implications of Alternative EC Policies*, Journal of Agriculture and Applied Economics, 26 (1), July 1994.

- Osteen, Craig, and Fred Kuchler, *Potential Bans of Corn and Soybean Pesticides: Economic Implications for Farmers and Consumers*, AER-546, Economics Research Service, U.S. Department of Agriculture, April 1986.
- Osteen, Craig, and Fred Kuchler, *Pesticide Regulatory Decisions: Production Efficiency, Equity, and Interdependence*, Agribusiness, Vol. 3, No. 3, 1987.
- Randleman, C. Matthew, *Agrichemical Reduction Policy: Its Effect on Income and Income Distribution*, The Journal of Agricultural Economics Research, Vol. 43, No. 4, Fall 1991.
- Ribaudo, Marc O., *Water Quality Benefits from the Conservation Reserve Program*, *Economic Research Service*, U.S. Department of Agriculture, Agricultural Economic Report, Number 606, 1989.
- Ribaudo, Marc, and Danette Woo, *Summary of Water Quality Laws Affecting Agriculture*, Agricultural Resource: Cropland, Water, and Conservation, Economic Research Service, U.S. Department of Agriculture, AR-24, Washington, D.C., September 23, 1991.
- Taylor, C. Robert, John B. Penson, Jr., Edward G. Smith, and Ronald D. Kuntson, *Economic Impacts of Chemical Use Reduction on the South*, Southern Journal of Agricultural Economics, July 1991.