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The Impact of EC Nitrogen Taxes on Agricultural Competitiveness and Welfare: Simulations with the World Trade Model TEPSIM

Abstract: In this paper the attempt is made to estimate the trade and welfare effects of nitrogen taxes in the European Community. The world trade simulation model TEPSIM was developed for this purpose. TEPSIM differs from conventional agricultural trade models in that it is not limited to agricultural output markets but explicitly considers 12 agricultural inputs. Thus, the model is not only suitable for the simulation of environmental policies in agriculture but also gives valuable insights into the intensification and specialization effects of current agricultural policy reforms. The results of the study reveal that the implementation of nitrogen taxes in the EC would lead to a loss in comparative advantage for agriculture in Europe. At the same time this policy would induce conventional welfare gains in the EC if the tax level did not exceed 44 percent. However, at that tax level the relative change in mineral nitrogen demand would be very low (13.5 percent). Higher nitrogen taxes, on the other hand, would induce net welfare losses in the Community. While these losses would increase exponentially with the tax rate, the decline in nitrogen use is not even linear. Thus, the implementation of extreme taxes would have high economic costs without inducing profound improvements in the ecological area.

INTRODUCTION

There is a growing concern in the European Community (EC) and in many other industrialized countries about the ecological consequences of current production and consumption structures. In the past the blame for environmental deterioration was laid primarily at the door of the industrial sector. However, as more is learned about the environmental impact of modern farming practices, agricultural producers also find themselves sitting in the dock. Farmers are accused of polluting ground and surface water with minerals, such as nitrogen and phosphorus and pesticides. Soil erosion and salinization are increasing problems, especially in Southern Europe. Air pollution due to intensive animal husbandry, manure spreading and crop spraying is a growing nuisance. Farming practices are also blamed for the accelerating rate at which species are disappearing. An important reason that farming places this increasing stress on the environment arises from the intensification and specialization of agricultural production, particularly to the increasing use of chemical inputs such as nitrogen and pesticides. This new awareness has led to the demand for environmental regulations, such as input taxes. Coinciding with these claims is a concern over the potential effects of these policies on agricultural production, farm income and agricultural trade. Producers in the EC fear that they might lose their competitiveness in world agricultural markets, especially in the case of unilateral EC implementation of environmental regulations.

While there is a vast literature on the economic effects of an agricultural trade liberalization, there are only a few empirical studies analyzing the trade and welfare effects of taxes on agricultural inputs¹.

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Given this background the paper attempts to step into this breach. The Multi-Output Multi-Input World Simulation Model TEPSIM has been developed for this purpose. In the paper attention is confined to the analysis of taxes on nitrogen, as one of the environmentally most damaging chemical inputs. To examine the sensitivity of the production, trade and welfare effects to the level of nitrogen tax, four different simulations are compared.

MODEL DESCRIPTION

To determine the trade and welfare effects of taxes on agricultural inputs, a partial analytical framework is not sufficient. Rather, an approach is needed which is able to capture the various horizontal and vertical interdependencies between agricultural outputs and farm inputs. The policy simulation model TEPSIM (Trade and Environmental Policy Simulation Model) was created to analyze the national and international impact of EC nitrogen taxes.

Economic Structure of TEPSIM

The Trade and Environmental Policy Simulation Model is a three region world trade model, covering; the European Community (EC-12), the United States of America (US) and the Rest of the World (RW)². The basic structure of TEPSIM is borrowed from the SWOPSIM (Static World Policy Simulation) modeling framework developed by Roningen and others (Roningen, Sullivan and Dixit, 1991) at the USDA. Like all SWOPSIM variants, TEPSIM is of comparative static nature. These models can be solved to determine changes from the base year due to endogenous shocks such as changes in demand, supply or policy. Given the non-spatial character of the model, transport costs and product heterogeneity are neglected in the analysis. TEPSIM is based on constant elasticity functional forms for agricultural output supplies and consumer demand. The elasticities are not estimated endogenously in the model, but were taken from the literature.

TEPSIM belongs to the group of synthetic models. To ensure that the model is economically plausible, the elasticities in the EC and US model were chosen to be consistent with profit maximizing behaviour of producers and utility maximizing behaviour of consumers (elasticities are discussed further below). Given data limitations, a similar procedure was not possible for the 'Rest of the World' sector of the model. An important distinction between TEPSIM and traditional agricultural trade models arises from the Multi-Input Multi-Output nature of TEPSIM. Traditional trade models are Multi-Output equilibrium models. One limitation of these models is that they consider the effects on agricultural product markets, exclusively. Prices and quantities of farm inputs are assumed constant in this framework. To analyze the effects of taxes on nitrogen or other chemical inputs on production, trade and welfare, an extension of the model is necessary. For that reason TEPSIM covers 2 agricultural input markets in the EC and US, as well as 15 farm products³. These are: nitrogen fertilizer; other mineral fertilizers; pesticides; the feeds, wheat, corn and other coarse grains; soyabeans and other oilseeds; hired labour, arable land, pasture land and other inputs⁴.

Data

Most prices and quantities for agricultural products were taken from the 1989 database of the USDA (Sullivan, Roningen, Leetmaa and Gray, 1992). However, modifications to the consumer prices seemed necessary. Valuing all products considered in TEPSIM at the database prices would account for only about 50 percent of food expenditure in the EC and the US. Those commodities actually account for about 75 percent of food expenditure (Hertel, Peterson and Stout, 1993). Thus, the marketing margins in the EC and US model were adjusted, using the calculations of Dunham (1991) (see also Hertel, Peterson and Stout, 1993).

To complete the output matrix, additional data were required for the aggregate 'Other agricultural products'. These were calculated from value data for the year 1989, assuming a producer price of 100 (Kommission der Europäischen Gemeinschaften 1992; United States Department of Agriculture, 1991; Putman and Allshouse, 1992; Bundesministerium für Ernährung Landwirtschaft und Forsten, 1991). Given the lack of information with respect to the trade activity for the aggregate Other agricultural products, no trade activity was considered on this product market in the reference scenario⁵. Information about the demand for and the prices of the newly integrated inputs was collected from different sources (Kommission der Europäischen Gemeinschaften, 1992; United States Department of Agriculture, 1991 and 1992; Barse, 1990; Food and Agriculture Organisation of the United Nations (FAO), 1991a and 1990b; Price, Seely and Tucker, 1991).

ELASTICITIES

Of utmost importance in creating a policy simulation model is the construction of a consistent and economically plausible elasticity matrix for product supply/input demand as well as for product demand. In TEPSIM the information in the USDA database was used as a starting point (Sullivan, Roningen, Leetmaa and Gray, 1992). However, considerable modifications and extensions to the EC and US sectors of the model were necessary, since the USDA database does not include any input markets. Thus, additional information was collected from various other published and unpublished sources. While a wide range of values for the own price elasticities of nitrogen demand are presented in the literature (Burrell, 1989 and the references therein), few estimates of elasticities for other inputs have been published. Information about the relationship between the input demand and producer prices for agricultural products is scarce as is that for consumer prices for other agricultural inputs. Additionally, the estimates in the literature often refer to a different country and/or product aggregation (for example, Anker and Schmitz, 1987; Boyle and O'Neill, 1990; Glass and McKillop, 1989; Michalek, 1988; Dubberke and Schmitz, 1993; Denbaly and Vroomen, 1991; Antle, 1984; Fernandez-Cornejo, 1993; Rendleman, 1993; Ball, 1989).

Given the limited applicability of the data in the literature to the present model it is important to secure the consistency of the chosen elasticities with profit maximizing behaviour of producers and utility maximizing behaviour of consumers. For that reason symmetry and homogeneity conditions were imposed on the product supply/input demand elasticity matrix as well as on the product demand elasticity matrix (Gardiner, Roningen

and Liu, 1989; Haley, 1988). In TEPSIM separability of the utility function with respect to food and other consumer goods is assumed⁶.

In the model, the supply of chemical inputs, hired labour and the aggregate other inputs is assumed to be perfectly elastic⁷. This implies that input supply equals input demand at constant prices. The own price elasticity of land supply is set equal to 0.2. Changes in the demand for land are thus reflected in its rental value.

Of considerable importance in world trade models is the determination of the world market price transmission elasticities for all countries/regions considered in the model. Given the price fixing policy in the European Community, the price transmission elasticity was set equal to 0 for all products but soyabeans and other oilseeds. Because of the deficiency payment system on these markets, consumer prices of these products will change with world market price changes. For the aggregate of other agricultural outputs a world price transmission elasticity of 0.7 was assumed. This parameter was set equal to 0.5 for all products in the Rest of the World model while in the US model product specific price transmission elasticities were used. The respective values were taken from the literature (Sullivan, 1990) and range from 0.2 for milk and sugar to 1 for grain, oilseeds and ruminant meat.

SIMULATIONS

Reference Scenario and Policy Options

The reference situation is characterized by the agricultural policies existing in 1989 in the three regions considered. Besides price intervention, the model takes into account quantity measures such as the quota policy on the EC milk market. Various policy options have been simulated with the Multi-Output Multi-Input model. In this paper the emphasis is on analyzing the effects of taxes on mineral nitrogen fertilizer in the European Community. Since it seems desirable to examine the sensitivity of the effects to the level of taxation, four different policy options are simulated which explore the impact of a 25 percent, 50 percent, 100 percent and 200 percent tax on nitrogen. In all scenarios the existing agricultural policies in the European Community are assumed constant. No policy changes are considered in third countries.

Quantity and Price Effects

The aim of imposing a nitrogen tax is to reduce the demand for this input and thus to lower the intensity of agricultural production. As expected, the relative change in nitrogen use depends heavily on the level of taxation (see Table 1). However, it is interesting to observe that a doubling of the tax leads to a less than proportional reduction in nitrogen use (see Table 1). Besides limiting nitrogen consumption, the taxation of this fertilizer induces a considerable decrease in the use of other chemical inputs, while the demand for feed, hired labour, land and other inputs is not very sensitive to this policy. Table 1 also summarizes the relative output supply changes in the European Community of the different simulations. Taxation of nitrogen use leads to a decline in crop and ruminant meat production, while the supply of pigmeat and poultry meat shows a slight increase. Apparently, the excrement from animal production becomes a valuable manure that is a

substitute for mineral fertilizer⁸. From an environmental point of view this effect is not desirable.

Due to the EC milk quota policy, taxation of nitrogen fertilizer consumption has no supply effects on this market, since the shadow price for milk lies far below the EC market price. It would need an unrealistically high tax level to shift the marginal cost curve on the EC milk market sufficiently upward for the quota equivalent price to reach the market price. In this case milk supply would start to decrease and the quota would no longer be binding.

Table 1 *Impact of an EC Nitrogen Tax on Product Supply and Input Demand in Agriculture*

Commodity, commodity group or input	Level of nitrogen tax			
	25%	40%	100%	200%
Beef	-0.03	-0.06	-0.10	-0.16
Pork	0.08	0.15	0.26	0.41
Mutton and lamb	-0.02	-0.04	-0.07	-0.11
Poultry meat	0.03	0.05	0.08	0.13
Eggs	-0.01	-0.01	-0.02	-0.03
Milk and milk products	0.00	0.00	0.00	0.00
Wheat	-1.15	-2.09	-3.54	-5.55
Corn	-1.12	-2.02	-3.43	-5.37
Other coarse grains	-1.16	-2.10	-3.56	-5.58
Rice	-1.24	-2.24	-3.80	-5.96
Soybeans	-1.02	-1.85	-3.13	-4.92
Other oilseeds	-1.24	-2.24	-3.80	-5.96
Cotton	-1.15	-2.08	-3.54	-5.54
Sugar	-1.15	-2.08	-3.53	-5.53
Other agricultural products	-0.62	-1.13	-1.92	-3.04
Mineral nitrogen fertilizer	-8.49	-14.89	-24.11	-35.43
Other mineral fertilizers	-5.66	-10.05	-16.57	-24.98
Pesticides	-1.99	-3.60	-6.07	-9.47
Wheat for feed	0.00	0.00	0.00	0.01
Corn for feed	0.00	-0.01	-0.01	-0.01
Other feed grains	0.01	0.01	0.02	0.03
Soybeans	-0.09	-0.17	-0.29	-0.46
Other oilseeds	-0.31	-0.57	-0.95	-1.50
Hired labour	-0.59	-1.06	-1.81	-2.85
Arable land	0.26	0.48	0.82	1.30
Pasture land	0.09	0.17	0.29	0.46
Other agricultural inputs	-0.09	-0.17	-0.29	-0.46

Source: Own calculation utilizing the TEPSIM model described in the text.

With the decrease in crop and ruminant meat supply, net exports are discouraged on these markets in all scenarios (see Table 2). The relative change in net exports is far more pronounced than the relative supply change. For instance, while the supply of other coarse grains decreases by only 5.6 percent with a 200 percent nitrogen tax, net exports of this

Table 2 *EC Net Exports of Agricultural Products due to a Taxation of Nitrogen Use in Agriculture*

Commodity or commodity group	Reference scenario	Level of nitrogen tax			
		25%	40%	100%	200%
(in '000 tons)					
Beef	574	572	569	566	562
Pork	791	802	812	826	847
Mutton and lamb	-199	-199	-199	-200	-200
Poultry meat	354	356	357	359	362
Eggs	69	68	68	68	67
Milk and milk products	10 578	10 578	10 578	10 578	10 578
Wheat	19 274	18 325	17 558	16 363	14 711
Corn	-2450	-2750	-2993	-3372	-3896
Other coarse grains	6145	5413	4822	3900	3625
Rice	-268	-285	-299	-321	-351
Soybeans	-13 045	-13 054	-13 061	-13 073	13 088
Other oilseeds	-2383	-2472	-2543	-2665	2809
Cotton	-965	969	-972	-977	-983
Sugar	2605	2427	2282	2058	1746
Other agricultural products	0	-5084	-9224	-15 729	-24 844

Source: Own calculation utilizing the TEPSIM model described in the text.

Table 3 *World Market Price Changes Due to a Taxation of Nitrogen Use in EC Agriculture*

Commodity or commodity group	Level of nitrogen tax			
	25%	40%	100%	200%
Beef	0.25	0.45	0.76	1.20
Pork	0.26	0.46	0.78	1.23
Mutton and lamb	0.19	0.34	0.58	0.91
Poultry meat	0.48	0.86	1.47	2.30
Eggs	0.26	0.48	0.81	1.27
Milk and milk products	0.49	0.89	1.51	2.37
Wheat	1.57	2.85	4.87	7.71
Corn	1.15	2.09	3.57	5.64
Other coarse grains	1.75	3.18	5.43	8.59
Rice	0.35	0.63	1.06	1.68
Soybeans	0.45	0.82	1.39	2.18
Other oilseeds	0.54	0.98	1.68	2.64
Cotton	0.30	0.55	0.94	1.47
Sugar	1.09	1.98	3.36	5.29
Other agricultural products	2.65	4.84	-8.34	13.38

Source: Own calculation utilizing the TEPSIM model described in the text.

product decline by 57 percent. The relative importance of the EC as an exporter declines and its role as a net importer increases, revealing the loss in international competitiveness, especially on the grain markets. A different development can be observed on the markets for pig and poultry meat. On these markets EC exports increase slightly.

The impact of an EC nitrogen tax is not limited to internal effects. Given the important role the EC plays on world agricultural markets, this policy also induces world market price changes and thus has an impact on third countries. Table 3 reveals that world market prices increase on all product markets considered. The prices for wheat, corn and other coarse grain show by far the largest change from 1989 base prices. The introduction of a nitrogen tax induces an increase in supply and a decrease in demand on almost all agricultural product markets in the USA and the Rest of the World. In addition the rise in world market prices for all commodities leads to a considerable increase in the demand for nitrogen and other chemical inputs in the USA. Use of arable and pasture land increases only slightly due to the low supply elasticity of this input.

Welfare Effects

Table 4 *Welfare Change Due to a Taxation of Nitrogen Use in EC Agriculture*
\$Billion

Countries/ regions scenarios	Change in producer welfare	Change in land owner revenue	Equivalent Variation	Change in government revenue	Change in net welfare
European Community					
25% N-tax	-293	279	-1874	1937	50
50% N-tax	-700	511	-3422	3585	-27
100% N-tax	-1702	882	-5894	6338	-375
200% N-tax	-4014	1419	-9441	10 651	-1385
United States					
25% N-tax	1739	334	-1740	-3	331
50% N-tax	3182	606	-3172	-5	612
100% N-tax	5501	1035	-5452	-8	1077
200% N-tax	8857	1638	-8707	-12	1777
Rest of the world					
25% N-tax	1553	0	-1668	-68	-182
50% N-tax	2818	0	-3024	-122	-329
100% N-tax	4803	0	-5152	-208	-557
200% N-tax	7580	0	-8124	-327	-871
World					
25% N-tax	2999	613	-5282	1867	198
50% N-tax	5299	1117	-9618	3458	256
100% N-tax	8602	1918	-16 498	6123	144
200% N-tax	12 423	3057	-26 272	10 313	-479

Source: Own calculation using the TEPSIM model described in the text.

For all 4 policy runs the conventional welfare effects for the 3 regions considered are calculated. Only the change in real income is considered in the welfare measure. Possible benefits of environmental improvement (for example, reduction in pollution of ground and surface water with nitrogen, phosphorous and pesticides) resulting from the introduction of a nitrogen tax are not considered in this analysis. The method used for the measurement of the conventional welfare change is the sequential approach based on the Hicksian compensated curves (Hartmann, 1991; Just, Hueth and Schmitz, 1982).

The distributional and efficiency effects of the implementation of nitrogen taxes in the EC are summarized in Table 4. The results reveal that EC producers and consumers have to bear welfare losses in all policy scenarios while, on the other hand, land owners are beneficiaries of such a policy change. Government revenue will increase in two ways. First, due to the introduction of the nitrogen tax, government gains an additional revenue source. Second, this policy leads to a reduction in supply of most agricultural products in the EC (see Table 1) and to world market price increases (see Table 3), thus leading to a decline in product subsidies and export subsidies.

The net welfare effects will be positive only if the EC introduces a moderate tax on nitrogen fertilizer. Table 4 reveals, that a 25 percent tax increases conventional welfare in the EC by \$50 million. This is due to the fact that the 'environmental policy' is implemented on already distorted markets. The input tax thus partly compensates for the price distortions on the product markets. The welfare gain reaches its peak at a nitrogen tax of 20 percent. If the tax level exceeds, 44 percent, the welfare effects become negative. Examination of Table 4 also shows that a linear increase in the level of the tax leads to an exponential rise in conventional welfare loss. The distributional and efficiency effects in third countries are also reported in Table 4. In common with land owners in the EC, those in third countries experience a welfare gain and consumers have to bear welfare losses in all policy scenarios considered. Producers in the USA and the Rest of the World will be beneficiaries from the implementation of a nitrogen tax in the EC while government revenues have to bear an additional burden in both countries/regions. In all simulations the net welfare change is positive for the USA but negative for the Rest of the World, reflecting the different net trade position of the two regions. The net welfare effects for the world as a whole depend on the level of the nitrogen tax. The world experiences real income gains in the case of a low 25 percent tax. Interesting enough these gains would increase if the tax level increases. World welfare is reduced by a 200 percent tax.

NOTES

¹ See, for example, Liapis (1990 and 1992), Lueck, Haley and Liais (1993), Hartmann and Matthews (1993), Hartmann (1993), Haley (1993) and Gunasekera, Rodriguez and Andrews (1992). In most of these nitrogen fertilizer is the only agricultural input considered. Thus, the interdependencies between nitrogen and other agricultural inputs are neglected in these papers. This is not the case for the studies of LIAPIS (1990 and 1992). The author considers 5 input sectors in his model. One limitation of the analysis is, however, the high degree of aggregation. The simulation of taxes on fertilizer or pesticide is not possible with this framework.

² In the EC-12, Germany is included in the borders before 3 October 1990.

³ The agricultural products considered in the analysis are: beef and veal; pork, mutton and lamb; poultry meat; poultry eggs; milk and milk products; wheat; corn; other coarse grains (barley, sorghum, mixed grains, oats, rye, and millet); soyabeans; other oilseeds (copra, cottonseed, flaxseed, palm kernels, peanuts, rapeseed, safflower, and sesame seed); cotton; sugar and other agricultural products.

⁴ In contrast to the procedure in other SWOPSIM variants, the demand for wheat, corn, other coarse grain, soybean and other oilseeds is defined by two separate equations; one equation for the final demand for human consumption and one equation for feed demand.

⁵ The consumer expenditures on the aggregate 'other agricultural products' are equal to all food

expenditure in the EC and the USA minus the expenditure for the products considered in the model.

⁶ Interdependencies in input supply are not considered in the model.

⁷ See also the discussion of this issue in Hartmann and Wiegand (1993).

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DISCUSSION OPENING — Consuelo Varela-Ortega (*Polytechnica University, Madrid, Spain*)

This paper presents a method of estimating the trade and welfare effects of levying/applying different levels of nitrogen taxes in the EU agriculture. A trade simulation model is used (TEPSIM) in which the usual scope of agricultural trade models has been enlarged by introducing not only agricultural outputs but also agricultural inputs. (Multi-input, multi-output trade equilibrium model). This permits one to simulate different scenarios of input use (prices and/or quantities) valuable for policy analysis.

The model is a non-spatial aggregated three-regional static model (EU, US and the rest of the world) in which product and intra-regional heterogeneities are not considered. Elasticities are exogenous and the agricultural policy frameworks for the three regions is the one existing in base year 1989.

A sensitivity analysis is then carried out by simulating the impact of four different levels of taxation to mineral nitrogen fertilizer in the EU: 25 percent; 50 percent, 100 percent and 200 percent. The EU agricultural policy is assumed constant in all four scenarios. The welfare effects are measured as changes in real income using the approach based on Hicksian compensated demand curves.

My comments to this paper (aimed to stimulate the discussion from the floor) can be summarized in the form of 5 remarks.

With respect to policy analysis as referred to in the paper, I would say that this research focusses more on sensitivity analysis rather than on policy simulations. The EU policy has been held constant when envisaging a clear change in agricultural policy represented by the CAP reform. Thus no comparisons between pre- and post-CAP reform have been made. Also, for policy analysis the introduction of some dynamics into the model will surely enhance its simulation capacity.

With respect to the ecological benefits commented on in the paper (after all, the goal of reducing nitrogen use is environmental in nature), the estimates of environmental benefits cannot be conclusive due because this is an aggregated model without a spatial dimension. The effects on the environment of the reduction in mineral nitrogen fertilizer use are highly spatially specific. So we cannot conclude that any given reduction in nitrogen fertilizer use in the EU will necessarily lead to environmental benefits.

So, I think that it will be enhancing to integrate this analysis into a more comprehensive one that will integrate both the economic and environmental effects of such a measure of reducing nitrogen fertilizer use through taxing nitrates assumption. This will necessarily have to be spatially specific and thus have a lower level of aggregation.

With respect to the levels of taxation simulated (ranging from 25 percent to 200 percent), the upper bound appears to be too high and may cause problems with the consistency of elasticity measures, which in turn can lead to non-concluding results over that range of price variation.

The analysis of the land market, I think, needs further specification. When looking at the results, the ZUC column on Table 4 'Change in Land Owner Revenue' is confusing. If it refers to a change in the value of land for the land owner, the positive sign is realistic. The land value increase results from an increase in the demand for land as a response to the intensification process that results from a lower input use. However, the land supply elasticity is referred to in the text (0.2 percent) but no reference has been found to the demand response. Thus figures of land owner revenues have to be further explained.

Also, an increase in land prices for land owners will result in an increase in the value of their assets of land equity but cannot be considered a rental value (to add up). If this column refers to land rents (see page 6) the reduction of the producers' incomes will lead to a decrease in the demand for renting land and will induce a reduction in land rents received by land owners hiring out their plots. So, this column should have a negative sign and the positive sign shown will not be realistic.

As a general comment, I would conclude that based on the results of this research, a unilateral EU environmental policy of taxing nitrogen fertilizer use leads to net welfare losses for the EU as well as for the NGW, whereas it induces clear welfare gains in the USA. Thus, for an environmental policy (nitrate pollution reduction) to be well balanced and not a source of welfare disequilibria, it will have to be designed following a unilateral agreement scheme.