UNIVERSITY OF CYPRUS
ECONOMICS RESEARCH CENTRE

Economic Policy Papers

Optimal Tax Rates for Pesticides Usage in Cyprus Agriculture Production

Pandelis Kalaitzidakis
Department of Economics
University of Crete

Vangelis Tzouvelekas
Department of Economics
University of Crete

Theofanis P. Mamuneas
Department of Economics
University of Cyprus

Thanasis Stengos
Department of Economics
University of Guelph

Panagiotis Gregoriou
Economics Research Centre
University of Cyprus

No. 05-11

November 2011

Publication Editor: Sofia N. Andreou

ERC Sponsors (in alphabetical order)

Association of Cyprus Commercial Banks

Central Bank of Cyprus

Cyprus Tourism Organisation

Economics Department, University of Cyprus

Ministry of Finance

Ministry of Labour and Social Security

Planning Bureau

University of Cyprus

Optimal Tax Rates for Pesticides in Cyprus Agriculture Production

P. Kalaitzidakis, V. Tzouvelekas, T. P. Mamuneas,

T. Stengos and P. Gregoriou

Abstract

The aim of this paper is to empirically estimate the optimal tax price of pesticides which takes into account both their contribution into agricultural production as well as their negative side effects on the health of consumers, farmers and the quality of the environment. The optimal tax rate was derived from a dynamic macroeconomic model of pesticide use and was applied in two countries namely Cyprus and United Kingdom for comparison purposes. The results show that the tax rates range from 3.19% to 31.88% for the case of Cyprus and from 2.47% to 24.73% for the case of UK. Many factors have to be taken into consideration in order to design an effective tax and levy scheme for plant protection products mainly due to the complexities of pesticides and the multi-dimensionality of their effects. In addition, policy makers should be prepared that in order to achieve major reductions in pesticide use, high taxes may need to be applied.

CONTENTS

Βέλτιστη Φορολογία της Χρήσης Φυτοφαρμάκων στη Γεωργική Παραγωγή

Π. Καλαϊντζιδάκης, Β. Τζουβελέκας, Θ. Μαμουνέας,

Θ. Στέγγος και Π. Γρηγορίου

ΠΕΡΙΛΗΨΗ

Ο σκοπός της παρούσας μελέτης είναι να εκτιμήσει εμπειρικά τη βέλτιστη τιμή φορολογίας της χρήσης φυτοφαρμάκων στη γεωργική παραγωγή, καθώς επίσης και τις αρνητικές επιπτώσεις τους στην υγεία των καταναλωτών, των αγροτών και της ποιότητας του περιβάλλοντος. Το βέλτιστο ποσοστό φόρου προέρχεται από ένα δυναμικό μακροοικονομικό μοντέλο της χρήσης φυτοφαρμάκων και για τους σκοπούς της παρούσας μελέτης χρησιμοποιήθηκαν οι χώρες Κύπρος και το Ηνωμένο Βασίλειο για σκοπούς σύγκρισης. Τα αποτελέσματα δείχνουν ότι οι φορολογικοί συντελεστές κυμαίνονται από 3,19% έως 31,88% για την περίπτωση της Κύπρου και 2,47% έως 24,73% για την περίπτωση του Ηνωμένου Βασιλείου. Πολλοί παράγοντες πρέπει να ληφθούν υπόψη προκειμένου να σχεδιάσει κανείς ένα αποτελεσματικό φορολογικό σύστημα, κυρίως λόγω της πολυπλοκότητας των φυτοφαρμάκων και του πολυδιάστατου χαρακτήρα των αποτελεσμάτων τους. Επιπλέον, οι αρμόδιοι χάραξης πολιτικής πρέπει να είναι προετοιμασμένοι ότι οι υψηλοί φόροι μπορεί να χρειαστεί να εφαρμοστούν προκειμένου να επιτευχθούν σημαντικές μειώσεις στη χρήση των φυτοφαρμάκων.

1. INTRODUCTION

The use of pesticides in modern agriculture undoubtedly helps agricultural production. Pesticides protect plants against pathogens, insects, weeds and diseases. However, it is well known that the extensive and irrational use of pesticides in agricultural production may harm the health of both consumers and farmers, and may deteriorate environmental quality. Consumers are affected in terms of the quality of the products consumed, while producers are affected in terms of the negative health consequences to farm workers and changes in input combinations. On the other hand, the environment is influenced in terms of biodiversity loss arising from increased pesticide resistance and an altered plant-pest relation that result in ecosystem changes, which corrupt the overall environmental quality.

This paper focuses on the empirical estimation of the optimal tax on the price of pesticides which takes into account both their contribution into agricultural production as well as their negative side effects on the health of consumers, farmers and the quality of the environment. This estimation is made possible by utilizing the optimal tax rate derived from a dynamic macroeconomic model of pesticide use (Kalaitzidakis, Mamuneas, and Stengos, 2011). This socially optimum tax internalizes all three negative externalities from pesticide use introduced in our macroeconomic model. The estimation of the optimal tax rate is carried out for two country cases, namely Cyprus and the United Kingdom for comparison proposes.

There is a substantial body of literature attempting to produce solid policy recommendations that would help countries achieve safer use of pesticides, by minimizing their risks to health and the environment. Even studies that do not directly address issues of policy or regulation design can, nevertheless, be helpful insofar as they provide information which can be used for strategic planning and policy design. In Europe, for example, economic valuation has been integrated into environmental decision making, at both a pan-European and national level (Pearce and Seccombe-Hett, 2000).

At this point it would be helpful to outline some key issues pertaining to the design of pesticide taxes. The introduction of taxes on plant protection products (PPPs) can serve two purposes: First it discourages excessive use of PPPs and raises user awareness about their damaging effects, thus providing users with incentives to change their behavior. And second, Tax revenues may be used to finance national actions towards more sustainable use of pesticides (Zilberman and Millock, 1997a). At the same time a levy on PPPs may have several effects and an important part of achieving the desired ones lies on the decisions of governments as to how to utilise tax revenues. As Oskam et al. (1998) explain, if a levy on PPPs is successful, then the use and risks of PPPs are reduced. If, on the other hand, the levy proves to be ineffective in reducing pesticide use, then the tax revenues may be used for reducing the environmental effects of PPPs. Therefore, the targeting of funds generated from the imposition of a levy plays a very significant part on the overall effects of the levy.

Upon designing pesticide taxes, perhaps the most crucial implication arises because different types of pesticides have different levels of toxicity, or, put more generally, pose different levels of threats. Therefore, the application of a uniform tax across all agrochemical products may not be optimal, due to the large number of active ingredients composing the various types of pesticides, and the different levels of toxicity that these ingredients have. In these circumstances it would be more appropriate to design a scheme of differentiated tax rates, based on some measure of the hazards related to each agrochemical product (Falconer, 1998). This sort of taxation is not normally intended to stop farmers from using pesticides, but lead them away from using the more harmful types. In general, setting up an optimal tax scheme in terms of both applicability and effectiveness can be a hard task, because, there is a trade-off between economic efficiency and administrative simplicity (Falconer, 1998). Furthermore, the design and implementation of a differentiated tax involves higher costs due to higher information requirements and difficulties in enforcement (Sheriff, 2005).

Another choice faced by policy makers is whether to levy a tax on pesticide use or on pesticide price, as either way has its downsides (Falconer, 1998). For example, taxing the number of pesticide applications made can lead farmers to perform fewer but heavier applications. Similarly, a proportional tax on price may not have the desired effect when the most expensive agrochemicals are the ones causing less damage. In general, according to Falconer (1998), the key in designing environmental taxes is knowledge on the relationship between input-level and environmental damage. This relationship can be a very complicated one and, as argued by Pearce and Koundouri (2003) so can be the pesticide tax design. For example, the toxicity of pesticides varies not only by their chemical composition but also by the weather conditions during which the pesticides are applied. Furthermore, given the low price elasticity of demand for pesticides (Oskam et al.,

1992) taxes may have little effect in reducing their use, unless set at a very high rate. Complications in designing an optimal pesticide tax scheme can also arise from issues concerning the use of tax revenues. For example, recycling tax revenues back into agriculture may not be as effective as using them for developing pesticide alternatives or fixing damages already done from past uses. Other revenue limitations include the fact that ad valorem pesticide tax schemes result in lower revenues when the prices decrease; and users can avoid taxes by building up stocks prior to tax increases (Falconer, 1998).

Pearce and Koundouri (2003) suggest that pesticide taxes should be expressed as the sum per unit of toxicity-weighted ingredient. Such taxes, according to the authors, may result in farmers moving towards less toxic pesticides, thereby reducing the overall toxicity pesticide use, even when the level of pesticide usage remains unchanged. The problem with this type of tax system is that the real value of the tax is eroded by inflation, and so will be the effectiveness of the scheme to discourage the use of pesticides with highly toxic ingredients. The remedy to this problem is an inflation adjustment of all the taxes imposed on toxicity units.

Pretty et al. (2001), like most studies, suggest that the ideal pesticide tax would be one placing higher costs to products causing the most harm to people and the environment. Yet this can be difficult in the absence of a credible hazard ranking methodology. The authors suggest ways around this problem, including grouping pesticides into clusters with similar impacts, ad valorem taxes, or taxes imposed on the level of use. The question is, however, what effect these taxes would have in an environment where the price elasticity of demand for pesticides is generally low.1

In a more general context, another important question is what exactly the 'desired' level of PPP use is. Bürger et al. (2008) discuss this topic in an attempt to provide a theoretical framework for making decisions about the 'appropriate level of pesticide use', defined as the level necessary to control a pest on a crop.

---

[1] Some examples of the price elasticity of demand for pesticides are extracted from Rayment et al. (1998): Estimates for the Netherlands, Greece, France, Germany, Denmark and the UK are typically between -0.2 and -0.4 with some ranging up to -0.7 to -1.0.

Falconer and Hodge (2001) examine the linkages between the multi-dimensionality of ecological problems and the complexities associated with policy design. Pesticides present a difficult problem to trace in the sense that their hazardous effects are to a large degree uncertain in terms of extent, duration, and scale. Given this complexity, Falconer and Hodge (2001) argue that rather than eliminating and treating each aspect of environmental quality problems individually, it is best to consider them all jointly, by taking a multi-dimensional approach to policy formulation. To achieve sustainable use of plant protection products it is necessary to find a balance between, economy, ecology and social aspects (Bürger et al., 2008). It is therefore essential to accept the fact that there may have to be trade-offs between these aspects, and, consequently find some compromising solution.

Falconer and Hodge (2001) suggest that the ideal policy plan would be one which creates incentives for farmers to move towards more pesticide-free cultivation methods, rather than trying to adjust their application habits. Within this context, the authors propose that all policy schemes should have advice and education at the core of their strategies. Pacini et al. (2004) investigate the significance of evaluating the environmental performance of conventional and organic farming systems, towards the development of efficient agri-environmental schemes under the regulations of the Common Agricultural Policy (Agenda 200). To do this, the authors design an ecological-economic model of farmer behaviour using the linear programming method, and apply the model under current EU regulations and different policy scenarios. More specifically, the authors estimate: (a) the loss of income that conventional farmers would suffer in order to produce the environmental benefits similar to the benefits generated by organic agriculture, and (b) the loss of income that farmers would suffer in order to reach various environmental sustainability thresholds, which correspond to society's demand for environmental benefits. This is applied to the case of Northern Tuscany. The results of this study show that (a) organic farming systems produce more environmental benefits than conventional farming systems, (b) if conventional farmers seek to produce environmental performances similar to those of organic farming, or if they comply with environmental sustainability thresholds then they will suffer an opportunity cost from adopting organic farming techniques or farming extensively (that is, using relatively fewer inputs, i.e. pesticides or fertilizers).

Zilberman and Millock (1997b) provide a detailed presentation aiming to clarify some of the issues involved with designing optimal pesticide taxes. They present the following case: a farmer grows a crop in a field. In doing so, the farmer chooses two things, (a) the level of pesticide use and (b) the level of effort he or she will apply. For simplicity reasons there are only two levels of farmer effort, high and low. High effort incorporates a fixed cost (scouts and equipment) but also reduces pesticide use and residue levels. Pesticide use has a short run productivity benefit but can produce negative secondary effects (pest resistance and loss of beneficiary pests) and externality costs (health and environmental damages). In this scenario, under the assumption of a given level of effort, the level of optimal pesticide use is found where the value of the marginal product of pesticide use (price of output times the marginal product of pesticides) equals the sum of pesticides price, the marginal externality cost and the marginal secondary cost. However, it may be the case that this optimal solution is not reached for several reasons (i.e. farmers ignore secondary and externality costs). Thus, a second case is considered where two application technologies are available, a high-effort technology and a low-effort technology, the former of which incorporates a lower social marginal cost. In this scenario, the authors again illustrate how an (differentiated by technology) optimal tax can be constructed which, when introduced, will encourage the adoption of high-effort technologies, thus reducing pesticide use.

2. THE MODEL

Kalaitzidakis et al (2011) have developed an aggregate economy model, which embodies the negative effects of pesticide use on the consumers, the producers, and the environment. On the production side, pesticide use has a negative effect on farmers' productivity through the negative effects of pesticide use on farmers' health. To the extent that farmers underestimate these health effects of pesticide use, a negative externality is introduced in the production side. As a result, the decentralized choice of pesticide use is greater than its socially optimum level. On the consumption side it is assumed that consumers care about the quality of the agricultural good consumed, and the quality of the environment, both of which are negatively affected by the use of pesticides. In a decentralized economy, farmers choose the amount of pesticides that maximizes profits without taking into account its negative externality on the utility of the consumers.

In order to reach a socially optimum solution, a tax on the price of pesticides was introduced in the decentralized economy. This socially optimum tax internalizes all three negative externalities from pesticide use introduced in our macroeconomic model. In addition, tax revenues must be transferred to the consumers in a lump sum manner, in order for the whole economy to reach its socially optimum outcome.

The optima tax on pesticides is given by:

$$\tau_B = \frac{-MRS_{B,C} + \frac{\varepsilon_2}{\rho} MRS_{E,C} + \frac{\left(\beta_2 - \tilde{\beta}_2\right)}{\rho} MPH}{p_B} \qquad (1)$$

where $MRS_{B,C}$ is the marginal rate of substitution between pesticide use and consumption, ε_2 is the marginal effect of pesticide use on the quality of the environment, ρ is the rate of time preference, $MRS_{E,C}$ is the marginal rate of substitution between environment and consumption, $\left(\beta_2 - \tilde{\beta}_2\right)$ is the underestimation in the marginal effect of pesticide use on farmers' health, *MPH* is the marginal product of health and p_B is the price of pesticides.

For model parameterization we assume that the utility function is of the following form:

$$U = (B^{-a}C)^{\beta} E^{\gamma} \qquad (2)$$

where E is the stock of the Environment, α captures the negative effect of pesticide use on the final (consumption) agricultural good, β relates to the effect of the consumption of the agricultural good on overall utility and γ relates to the effect of environmental quality on overall utility.

The production function is assumed to be of the form:

$$Y = (1 - D)(H^{\delta} L)^{\eta} \qquad (3)$$

where (1- D) is the damage function of pesticides , H is the farmer stock of health, L is labor effort of farmers, δ relates to the quality of labor which depends on health, and η relates to the productivity of labor,

The optimal tax rate on pesticide use is given by the following equation:

$$\tau_B = \frac{\alpha \frac{C}{B} + \frac{\gamma}{\beta} \frac{C}{E} \frac{\varepsilon_2}{\rho} + \frac{(\beta_2 - \tilde{\beta}_2)}{\rho} \delta\eta \frac{Y}{H}}{p_B} \qquad (4)$$

and the restriction on parameters $0 < \alpha, \beta, \gamma < 1$ applies..

3. DATA CONSRTUCTION AND SIMULATION

Data for Cyprus range from 2002 to 2007 and for the UK from 2001 to 2008.

- **Pesticide Use**

Data for the use of pesticides in the agricultural sector measured in Euros (and UK pounds for the case of the UK) proved to be the most troublesome to collect, as this variable is most commonly measured in tones or kilos of active substances. For the case of Cyprus, this data was collected from publications of the Cyprus Statistical Service[2] which report the money value of applied pesticides (in Euros) in current prices. Using price indices for pesticides from the same source, the values were thereafter converted in constant prices (2005=100). The same procedure was followed for the case of the UK.

- **Output and Consumption of Agricultural Products**

Following the assumption that Y=C, that is, agricultural output (Y) equals the total consumption of agricultural products (C), we use the gross value added of the agricultural sector (in constant, 2005, prices) as a proxy for these variables. The source of the data for Cyprus is EUROSTAT and for the UK is DEFRA UK.

- **Stock of the Environment**

We also use a variable measuring environmental quality (stock of the environment). This is a variable constructed by the authors. We assume that the quality of the environment improves due the environment's ability to "self-clean" but worsens due to the use of pesticides. Thus, we assume that the following relationship applies:

$$E_t - E_{t-1} = \varepsilon_1 E_{t-1} - \varepsilon_2 B_t \qquad (5)$$

[2] Cyprus Statistical Service, Agricultural Statistics 2005 (2007) and Agricultural Statistics 2007 (2009).

Where E_t and E_{t-1} is the stock of the environment in the current and previous year, respectively, B_t is the use of pesticides in the current year, ε_1 is the self-cleaning rate of the environment and ε_2 is the damage rate of the environment from the use of pesticides. To calculate the stock values for the current year (0) we employ the following equation:

$$E_0 = \frac{\varepsilon_2 B_1}{\varepsilon_1 - g_E} \quad (6)$$

where g_E is the growth rate of the environment which we proxy using the growth rate of each country's GDP.

- **Farmer's Stock of Health**

The stock of health of the farmers is also constructed. The latter, is a variable that proxies the level of health that the farmers are in, as health influences their ability to produce. In similar fashion to the stock of the environment, we assume that the health condition of farmers is positively related to their expenditure on health and negatively related to the application of pesticides. Thus the relationship we follow is:

$$H_t - H_{t-1} = \beta_1 A_{Ht} - \beta_2 B_t \quad (7)$$

where H_t and H_{t-1} is the current and previous year stock of health of farmers, AH_t is farmers' health expenditure in the current year, B_t corresponds to the pesticides used in the current year, β_1 is the efficiency rate of investment in health protection, and β_2 is the health damage rate of pesticide use.

To calculate the stock values for the current year (0) we employ the following equation:

$$H_0 = \frac{\beta_1 A_{H1} - \beta_2 B_1}{g_H} \quad (8)$$

where g_H is the growth rate of the farmers' stock of health, approximated by the growth rate of each country's GDP.

For the farmer health expenditure data, A_H , the following procedure was followed. Data on each country's total household expenditure on health was retrieved from EUROSTAT. In addition, the percentage of each country's farmer population was constructed using EUROSTAT data. Farmer health expenditure was thereafter calculated by applying the estimated farmer's population percentages on the total health expenditure data.

Descriptive statistics of our key variables are presented in the Appendix. In all cases we assume that $\rho = 1\%$, $\varepsilon_1 = 4\%$, $\varepsilon_2 = 1\%$, $\beta_2 - \tilde{\beta}_2 = 0.1\%$, $\beta = 90\%$ and $\eta = 70\%$, and estimate the tax based on various combinations of the parameters α, γ and δ, taking values of 0.1%, 0.5% and 1%.

4. RESULTS

The base year results of the simulations made for the optimal tax rates on the price of pesticides are presented in Tables 1 and 2 for Cyprus and UK respectively. The data used in all estimations are those described in the previous subsection. Depending on the specification of the model parameters the tax rates range from 3.19% to 31.88% for Cyprus and from 2.47% to 24.73% for the UK. For the latter country case we remain skeptical as to the credibility of the results because of the aforementioned difficulties in retrieving the data for pesticide use.

In addition, as a simulation exercise we extent the values of parameters α, γ and δ to 1.5%, 2% and 2.5% and retrieve the resulting tax rates. These results are reported in Tables 3 and 4 for Cyprus and the UK respectively. The results range from 47.83% to 79.71% for Cyprus and from 37.09% to 61.82% for the UK.

As a final simulation, we provide tax estimations by fixing parameter δ to the value of 10%. These estimations are presented in Table 5. The results range from 17.04% to 44.48% for Cyprus, from 33.26% to 52.72% for the UK.

5. CONCLUDING REMARKS AND POLICY RECOMENTATIONS

In this paper we utilize an aggregate economy model, which embodies the negative effects of pesticide use on the consumers, the producers, and the environment, in order to estimate the optimal tax rate for pesticide usage in Cyprus agriculture production.

On the production side, pesticide use has a negative effect on farmers' productivity through the negative effects of pesticide use on farmers' health. To the extent that farmers underestimate these health effects of pesticide use, a negative externality is introduced in the production side. As a result, the decentralized choice of pesticide use is greater than its socially optimum level.

On the consumption side it is assumed that consumers care about the quality of the agricultural good consumed, and the quality of the environment, both of which are negatively affected by the use of pesticides. In a decentralized economy, farmers choose the amount of pesticides that maximizes profits without taking into account its negative externality on the utility of the consumers.

In order to reach a socially optimum solution, a tax on the price of pesticides is introduced in the decentralized economy. This socially optimum tax internalizes all three negative externalities from pesticide use. This paper presents estimations of the optimal tax rate on the price of pesticides for Cyprus and the UK . Based on the different specifications of the model parameters, the tax rates range from 3.19% to 31.88% for Cyprus and from 2.47% to 24.73% for the UK.

Designing an effective tax and levy scheme for plant protection products entails several difficulties and requires many factors to be taken into consideration, primarily because of the complexity of pesticides (given that they are composed of active ingredients of various toxicity levels), and the multi-dimensionality of their effects. Therefore, in search of an optimum policy to bring down their use to an optimal level, one must first carefully chose what that level is, and then keep in mind that in order to reach it, compromises may have to be made and trade-offs will occur between aspects such as economy, ecology, or other social aspects.

In addition, the literature addressing the demand for pesticides documents that it is generally inelastic. If this is truly the case, then a mild tax rate on the price of pesticides may have little effect on farmer practices. Thus policy makers should be prepared that in order to achieve major reductions in pesticide use, high taxes may need to be applied.

.

Table 1: Optimal Tax Rates: Cyprus

(A) Tax rates when α=0.1%

	δ=0.1%	δ=0.5%	δ=1%
γ=0.1%	3.19%	3.75%	4.45%
γ=0.5%	6.04%	6.60%	7.30%
γ=1%	9.60%	10.16%	10.86%

(B) Tax rates when α=0.5%

	δ=0.1%	δ=0.5%	δ=1%
γ=0.1%	12.53%	13.09%	13.79%
γ=0.5%	15.38%	15.94%	16.64%
γ=1%	18.94%	19.50%	20.20%

(C) Tax rates when α=1%

	δ=0.1%	δ=0.5%	δ=1%
γ=0.1%	24.21%	24.77%	25.47%
γ=0.5%	27.06%	27.62%	28.32%
γ=1%	30.62%	31.18%	31.88%

Table 2: Optimal Tax Rates: The United Kingdom

(A) Tax rates when α=0.1%

	δ=0.1%	δ=0.5%	δ=1%
γ=0.1%	2.47%	3.72%	5.27%
γ=0.5%	7.53%	8.77%	10.33%
γ=1%	13.85%	15.09%	16.65%

(B) Tax rates when α=0.5%

	δ=0.1%	δ=0.5%	δ=1%
γ=0.1%	6.06%	7.31%	8.86%
γ=0.5%	11.12%	12.36%	13.92%
γ=1%	17.44%	18.68%	20.24%

(C) Tax rates when α=1%

	δ=0.1%	δ=0.5%	δ=1%
γ=0.1%	10.55%	11.80%	13.35%
γ=0.5%	15.61%	16.85%	18.41%
γ=1%	21.93%	23.17%	24.73%

Table 3 : Cyprus (Additional Tax Rate Estimates)

(A) Tax rates when α=1.5%

	δ=1.5%	δ=2%	δ=2.5%
γ=1.5%	47.83%	48.52%	49.22%
γ=2%	51.39%	52.09%	52.79%
γ=2.5%	54.95%	55.65%	56.35%

(B) Tax rates when α=2%

	δ=1.5%	δ=2%	δ=2.5%
γ=1.5%	59.50%	60.20%	60.90%
γ=2%	63.07%	63.77%	64.47%
γ=2.5%	66.63%	67.33%	68.03%

(C) Tax rates when α=2.5%

	δ=1.5%	δ=2%	δ=2.5%
γ=1.5%	71.18%	71.88%	72.58%
γ=2%	74.75%	75.45%	76.15%
γ=2.5%	78.31%	79.01%	79.71%

Table 4: United Kingdom (Additional Tax Rate Estimates)

(A) Tax rates when α=1.5%

	δ=1.5%	δ=2%	δ=2.5%
γ=1.5%	37.09%	38.65%	40.20%
γ=2%	43.41%	44.97%	46.52%
γ=2.5%	49.73%	51.29%	52.84%

(B) Tax rates when α=2%

	δ=1.5%	δ=2%	δ=2.5%
γ=1.5%	41.58%	43.14%	44.69%
γ=2%	47.90%	49.46%	51.01%
γ=2.5%	54.22%	55.78%	57.33%

(C) Tax rates when α=2.5%

	δ=1.5%	δ=2%	δ=2.5%
γ=1.5%	46.07%	47.63%	49.18%
γ=2%	52.39%	53.95%	55.50%
γ=2.5%	58.71%	60.27%	61.82%

Table 5: Optimal Tax Rate Estimates (δ is fixed at 10%)

Cyprus

	δ=1.5%	δ=2%	δ=2.5%
γ=1.5%	113.89%	114.17%	114.46%
γ=2%	141.29%	141.57%	141.86%
γ=2.5%	168.69%	168.98%	169.26%

	α=0.1%	α=0.5%	α=1%
γ=0.1%	17.04%	26.38%	38.06%
γ=0.5%	19.89%	29.23%	40.91%
γ=1%	23.45%	32.80%	44.48%

The United Kingdon

	δ=1.5%	δ=2%	δ=2.5%
γ=1.5%	124.16%	124.45%	124.73%
γ=2%	151.56%	151.85%	152.13%
γ=2.5%	178.96%	179.25%	179.54%

	α=0.1%	α=0.5%	α=1%
γ=0.1%	33.26%	36.85%	41.34%
γ=0.5%	38.32%	41.91%	46.40%
γ=1%	44.64%	48.23%	52.72%

REFERENCES

Burger, J., de Mol, F., and Gerowitt, B.(2008), 'The "necessary extent" of pesticide use – Thoughts about a key term in German pesticide policy', *Crop Protection*, 27, 343-351.

Falconer, K. and Hodge, I. (2001), 'Pesticide Taxation and Multi-Objective Policy-Making: Farm Modelling to Evaluate Profit/Environment Trade-Offs', *Ecological Economics*, 36, 263-279.

Falconer, K. E. (1998), 'Managing Diffuse Environmental Contamination From Agricultural Pesticides: An Economic Perspective on Issues and Policy Options, with Particular Reference to Europe', *Agriculture Ecosystems and Environment*, 69, 37-54.

Kalaitzidakis P., T. P. Mamuneas and T. Stengos (2011), A Dynamic Macroeconomic Model on the Effects of Agricultural Supports on the Effective Pesticide Use, Mimeo

Oskam, A. J., Van Zeijts, H., Thijssen, G. J., Wossink, G. A. A., and Vijftigschild, R. (1992), 'Pesticide Use and Pesticide Policy in the Netherlands', WES 26 (Wageningen Agricultural University, Netherlands).

Oskam, A. J., Vijftigschild, R. A. N. and Graveland, C., (1998), 'Additional EU Policy Instruments for Plant Protection Products'. Wageningen Pers, Wageningen.

Pacini, C.; Wossink, A.; Giesen, G.; and Huirne, R., (2004), 'Ecological-economic modelling to support multi-objective policy making: a farming systems approach implemented for Tuscany', *Agriculture, Ecosystems and Environment, 102 (2004),* pp. 349-364.

Pearce, D. and Koundouri, P., (2003), 'Fertilizer and Pesticide Taxes for Controlling Non-point Agricultural Pollution', *Agriculture and Rural Development*, The World Bank Group.Available at :

Pearce, D. W., and Seccombe-Hett, T., (2000), 'Economic Valuation and Environmental Decision-Making in Europe', *Environmental Science and Technology*, 34 (8), 1419-1425.

Pretty, J., Brett, C., Gee, D., Hine, R., Mason, C., Morison, J., Rayment, M., van der Bijl, G. and Dobbs, T., (2001) 'Policy Challenges and Priorities for Internalizing the Externalities of Modern Agriculture', *Journal of Environmental Planning and Management*, 44 (2), 263-283.

Sheriff, G., (2005), ‘Efficient Waste? Why Farmers Over-Apply Nutrients and the Implications for Policy Design’, *Review of Agricultural Economics*, Vol 27, No. 4, pp. 542-557.

Zilberman, D. and Millock, K., (1997a), ‘Pesticide Use and Regulation: Making Economic Sense out of an Externality and Regulation Nightmare’, *Journal of Agricultural and Resource Economics*, 22 (2), pp. 321-332

Zilberman, D.; and Millock, K., (1997b), ‘Financial Incentives and Pesticide Use’, *Food Policy*, Vol. 22, No. 2, pp. 133-144.

APPENDIX

Descriptive Statistics of Key Variables

CYPRUS

Variable	Gross value added of the agricultural sector (000s €)	Total pesticide Consumption in national currency (000s €)	Calculated stock of the environment (000s €)	Calculated stock of Health (000s €)
Year				
2002	345960	18488.37	51210.21	18750.42
2003	318400	16933.68	56779.96	17774.54
2004	307540	18775.43	43024.77	19692.46
2005	332330	14227.00	51825.05	16625.80
2006	299980	17136.99	49558.19	18961.24
Mean	320842	17112.29	50479.63	18360.89
St. Dev.	18581.02	1803.96	4961.40	1187.39

UNITED KINGDOM

Variable	Gross value added of the agricultural sector (000s £)	Total pesticide Consumption in national currency (000s £)	Calculated stock of the environment (000s £)	Calculated stock of Health (000s £)
Year				
2001	5600861.14	553684.21	475599.76	41824.76
2002	5227358.31	564893.62	453554.77	38115.17
2003	5697277.99	538709.68	494847.49	37474.05
2004	5227102.52	587755.10	460534.62	79905.90
2005	4912000.00	547000.00	431800.70	110564.40
2006	5256222.85	512871.29	466738.73	109562.12
2007	6046502.48	554368.93	553266.98	82551.85
Mean	5423903.61	551326.12	476620.44	71428.32
St. Dev.	378857.88	23031.25	38955.52	32456.26

RECENT ECONOMIC POLICY/ANALYSIS PAPERS

04-11 Pashardes P., A. Polycarpou, "Poverty and Labour Market Participation of Public Assistance Recipients in Cyprus", September 2011.

03-11 Pashourtidou N., A. Tsiaklis and Z. Kontolemis, "Consumers' opinions about macroeconomic variables", August 2011.

02-11 Zachariadis Th. and E. Shoukri, "Direct Effects from the Implementation of the EU Energy and Climate Package on Cypriot Economic Sectors and Households", July 2011.

01-11 Andreou A. and Th. Mamuneas, "Factors explaining productivity in Cyprus", May 2011 – in Greek.

10-10 Andreou E., A. Kourtellos and N. Pashourtidou, "Forecasting toolbox for Cyprus GDP growth", December 2010.

09-10 Pashardes P. and A. Polycarpou, "Taxation, Labour Supply and Welfare: A micro-simulation analysis for Cyprus", December 2010.

08-10 Andreou A. and P. Pashardes, "Distributional Effects of the Economic Crisis", December 2010 – in Greek.

07-10 Christofides L. N. and Maria Michael, "An application of the LIME Assessment Framework (LAF): The Case of Cyprus", November 2010.

06-10 Savva C. S., "Business Consumer Surveys: Do they help in predicting GDP growth? The case of Cyprus, November", 2010.

05-10 Pashardes P. and A. Polycarpou, "Labour Supply in Cyprus", October 2010.

04-10 Pashourtidou N. and A. Tsiaklis, "An assessment of business and consumer survey data for Cyprus", September 2010.

03-10 Zachariadis Th., "The Costs of Residential Water Scarcity in Cyprus", May 2010.

02-10 Andreou M., P. Pashardes and N. Pashourtidou, "Cost and Value of Health Care in Cyprus", April 2010.