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Abstract

This paper considers the problems related with excessive concentration of nitrates in inland waters. According to recent concerns about the level of nitrates in water, the British situation will be studied. Potential health and environmental problems are examined given new evidence for their linkage with nitrate concentrations. The paper will also consider the role that water companies play when treating polluted water and charging consumers for water supply. Current legislation dealing with nitrate pollution is also discussed. Moreover, the role of spatial variation and farmers' crop production is examined in order to distinguish what the key explanatory factors are, for nitrate pollution. The study focuses on the most important crops in terms of areas cultivated, aiming to indicate which inputs are more relevant for determining nitrate concentration in water. It concludes with a discussion of potential economic instruments to control nitrate pollution.

1. INTRODUCTION

Humans have been affecting environment since their existence. This relationship has been mainly of dependence because environment is the source for most basic goods, i.e. air, food. However, environment is also indirectly affected by humans' activities as steel production or car use. Changes in environment caused by these and other activities used to affect other agents that did not cause them. These effects are commonly known as externalities and represent the fact that agents do not bear all consequences of their actions, which could affect other agents' welfare, examples of these are noise derived from car driving or the positive effect that a museum has on the restaurants next to it.

For environmental problems, the uncertainty about their severity necessitates some environmental decisions being based on value judgments as the precautionary principle. This has two main viewpoints; on one hand it is possible that current view would be myopic whilst long run consequences will be important. On the other hand, it could be the case that the problem is overestimated and it will not be relevant in the long run. Therefore, data availability, quality and manipulation are crucial for making right decisions.

Additional problems for environmental decision-making are related with asymmetric information and idiosyncratic preferences problems. The former occurs when one agent has more information than the others do and he/she does not share it. The later arises when different groups have opposite preferences about the same thing so a social agreement is very difficult i.e. environmentalists and loggers.

Differences between collective and individual incentives can be part of the explanation for environmental problems. However, evidence from Soviet Union does not support this point of view [59b]. Nevertheless, it is clear that when dealing with public goods, i.e. air, individuals sometimes behave differently when making decisions as a group rather than as individuals, leading to free rider problems. For instance, although society could claim less car use to avoid air pollution in cities, an individual could overuse its car because he/she thinks that the effect will be negligible if the rest comply. Hence, if everybody free rides the problem persists. Consequently, governments have to deal with these problems and implement policies to avoid them.

This study discusses these difficulties and others encountered when trying to control agriculture pollution in the form of excessive nitrate concentrations in water. The principal problem is that nitrate pollution is typical nonpoint source pollution where polluters' identification is not possible or extremely costly. Additionally, it is difficult to know the level of nitrates in water that could affect humans' health or the relevance that site characteristics agricultural inputs and outputs have for increasing the level of nitrates in water.

The paper focuses on the main factors that related with this type of pollution. It is organised as follows: firstly, the nature of nitrate pollution and the reasons to take account of it is examined. Secondly, a description about the role of water companies and water charge structure is provided. The main objective is to test the hypothesis that prices of measured water demand could promote a more efficient use of water than unmeasured charges. Estimated results do not support this hypothesis and time or/and group effects invariant effects are more relevant for explaining water consumption. The former are related with effects that are the similar for all companies but that change over time, such as technological progress. The later are constant over time but vary over individuals, such as basic water consumption. Subsequently, nitrate legislation and other commonly employed pollution control measures are described. After this, the paper examines the role of crop production in UK for explaining nitrate pollution. Testing the hypothesis that mineral nitrogen fertilizer used for the most important crop in terms of area cultivated, i.e. wheat, is more relevant than for the second more relevant crop, i.e. barley. According to study characteristics, estimated results support the initial hypothesis so fertiliser applied for wheat production could be the variable to control. Finally the study concludes with an evaluation of alternative policy instruments to those currently used in the UK, these are economic instruments.

2. NITRATE POLLUTION

Nitrogen is an essential constituent of cells in all organisms. It is present in a wide variety of compounds in the atmosphere (NH_3, NH_4^+, NO_3^-, NO_x...), which go down to soils through rain, dust and gases. Lichens and free-living soil micro-organisms fix N_2 from atmosphere and convert it into organic N (nitrogen fixation). The organic N is transformed into inorganic forms as ammonium, nitrate, and little amounts of nitrite (mineralisation), that are used by lichens, plants and trees to grow. These inorganic forms can be leached, immobilised or sent back to the atmosphere converted in NO_2 or N_2, in what is called denitrification [10]. Therefore, nitrogen compounds are immersed in a continuous cycle that allows ecosystems conserve it efficiently. Notice, that during its cycle nitrogen interacts with compounds of other elements (carbon, sulphur), that could modify its cycle, however the most important reactions has been described above.

Human activities have been introducing reactive nitrogen into the biosphere in an increasing basis of approximately 150 tonnes each year, with the consequent distortion of the processes involved in nitrogen's cycle. Moreover, there is no sign of a relevant reduction in this tendency [38]. Power stations, motor vehicle engines and wash waters[1] coming from industrial and commercial activities are the main non-natural source for nitrogen compounds in the atmosphere where it contributes to ozone depletion and greenhouse effect [58, 59a]. Hence, this accumulation of nitrogen creates excessive deposition of nitrogen compounds into water and soil ecosystems resulting in their acidification, having associated biodiversity loss and reduction of forest among other negative consequences. Also, these effects could have an impact on human health and water recreational values indirectly. Nevertheless, the introduction of nitrogen fertilizer is partially responsible for the increase of food production, at global and regional scale, which allows fulfilling the increasing demand. However if the amount introduced exceeds crop optimum, its effects on crop could be negative. Hence, the environment has some assimilative capacity for nitrates, but over one determined level it becomes pollution, so they can be classified as fund pollutants [59b].

Usually, rainfall is the main responsible for transporting polluting substances related with nitrogen (ammonia, nitrate, nitrite and organic N) to inland waters, but the effectiveness of this transport depends on other factors as steepness and type of soil. In areas mainly dominated by forest, the main nitrate inputs come from atmosphere and its concentration in rain has been increasing as consequence of the global raise in reactive N [22]. In urban areas, municipal sludge and wastewater are the main sources for this kind of pollution [58]. However, the main problems associated with nitrate pollution used to happen in agricultural areas, where inefficient irrigation, excessive use of fertilizer and unmanaged livestock wastes were some of the key variables explaining nitrate transportation and the increase of its concentration in inland waters.

Nitrogen is important for agriculture practice because it is one of the key nutrients responsible of crop growth, yield and quality. Other nutrients, i. e. phosphorous, also influence the value of these variables, but usually not as much as N [1]. The main inputs of nitrogen to agricultural land are in the form of mineral fertilizer or present in animal wastes that at the same time could be employed as substitutes of fertilizers.

[1] These wash waters contain detergent residues, however nitrate pollution is minor compare to the other of their emissions.

Therefore, waste management could play a key role in explaining nitrate pollution. The main problem in defining amounts of fertilizer and waste management on soils is to determine the amounts that plants will uptake and how much is already in soils, given that these variables are not constant over time, so timing of fertilizer application is crucial. Thereafter, the presence of excessive amounts of nitrogen compounds in soils converts leaching as the main way to reach water sources. However, its importance depends on the proximity of water sources and intensity of rain or irrigation.

In this study the problem of interest is the excessive presence of nitrate in inland waters of England, Wales and Scotland. The peculiar characteristic of nitrates in water is based on its diffuse nature, being classified as nonpoint source pollution. Hence, the identification of the polluter is very difficult; because of its high degree of uncertainty or the extremely high costs associated. Consequently, the application of "The Polluter Pays Principle" is more complicated than with point source pollution. Therefore, policy making is very complex and it could be subject to a high degree of uncertainty about its potential outcome.

The main reasons to control nitrate concentrations in water are examined in the following sections. Traditionally they are related with ecological and health concerns: "blue baby syndrome", stomach cancer and eutrophication. However, actually the major concerns about nitrates concentration come from water companies, which have to assume the costs of removing nitrates from water.

3. ENVIRONMENTAL AND HEALTH CONCERNS

Most of environmental and health problems related with polluting substances have associated a high degree of uncertainty. For instance, it is difficult to know how much smoke is needed to increase the possibility of suffering lung cancer. The problem for the case of agriculture sector is similar; knowing what amount of pesticides or fertilizers applied could represent a health or environmental problem is also subject to a high degree of uncertainty. Part of this uncertainty is related with the interaction of other polluting factors and with individual characteristics. Nonetheless, examination of what are the potential harms and their justification should be present in any study related with environmental problems.

In this section I describe the main potential harmful effects derived from excessive nitrate concentrations in waters. These are "blue baby syndrome", stomach cancer and eutrophication. Special attention is paid to their origins, strength of their linkage with nitrates and how new findings affect old perspectives. These factors will be the basis for decision-making based on the precautionary principle that will be described in the following section.

3.1. BLUE BABY SYNDROME

The "blue baby" syndrome or methaemoglobinaemia was a serious problem during the 1940's in Hungary. This syndrome affects infants of less than 6 months. Its sequence is as follows: once nitrate is in human body it is reduced to nitrite and this reduces haemoglobin to methaemoglobin, which lessens the capacity of blood to carry oxygen. This makes the level of methaemoglobin in bodies go from normal values of less than 3% to more than 10%. In most cases, health deteriorates over a period of days causing a change in skin colour and shortness of breath, but rarely having death risk [25].

Comly discovered the link between nitrate in water and methaemoglobinaemia in 1945. He set drinking water levels above 45 mg/l as undesirable and above 100 mg/l as unacceptable [8]. This standard was spread worldwide, and in the 1970's the World Health Organization relaxed it recommending an acceptable range of 50-100 mg/l for Europe. However the current standard of 50 mg/l has been controversial since its establishment because of the scarce direct clinical evidence on the levels at which infantile methaemoglobinaemia is a real risk in Western Europe.

For Great Britain, there have been 14 cases[2] of blue baby since World War II, one of them causing death. Although, this tragedy was associated with water consumed from a private well [29], where is difficult for governments to implement any water quality standard. Moreover, most cases of blue baby were related with private water supply, where levels of nitrate well exceeded 100 mg/l. Though, there were other cases happening at concentrations in the range 50-100 mg/l from public supply, the Department of Health classified then as unconvincing, because of the probable presence of bacteriological pollution or their poor analysis. Furthermore, actually its occurrence in the UK is very rare and having the last case in 1972 [1]. Despite this uncertainty, the EEC established a maximum of 50 mg/l concentration of nitrate according to the precautionary principle, although British government argued that this value should be taken as an average and

[2] This number should be taken as an approximation because infantile methaemoglobinaemia is not notifiable disease in UK and there could be undiagnosed cases [31].

not as an absolute value. Even more, The European Chemical Industry Ecology and Toxicology Centre considered the limit too low and recommended to raise it until 100 mg/l [29].

The current situation in some developing countries is interesting. For instance, India has inland water with nitrate concentrations around 500 mg/l and there have been very few cases of methaemoglobinaemia. The explanation for this could be the effect of enzyme cytochrome-b_3 reductase that counteracts the effects of nitrate ingestion. However, its beneficial effect is very small for infants of less than one year whose stomach is not acidic enough to counteract potential effects of ingested nitrate [24]. Alternatively, there are cases of blue baby in China more associated with high concentrations of nitrates in certain food products and bacteriological contamination than with nitrates in water [7]. Furthermore, diarrhoeal illness, some gastrointestinal disturbances and a more than probable infectious origin could be important for explaining for blue baby syndrome [2].

Therefore, the evidence for nitrates having a key role in causing blue baby syndrome is weakening. It has been proved that there could be other factors having an important role for appearance of this illness. Moreover, people used to be concerned about all the products that babies consume and water is not an exception, so for instance is common to boil water before let babies consume it. However, this does not justify that authorities should not control nitrate pollution given that there is need for further research in accounting the importance of nitrates in these interactions.

3.2. STOMACH CANCER

The second potential health hazard related with nitrate ingestion from potable water is stomach cancer. The reaction of nitrate giving nitrite, and this last one with amine constituents in diet can produce nitrosamines that, given experiments with animals, are assumed to be carcinogenic to man [49, 29].

This relationship has linked lots of uncertainties because people can have nitrate in more ways than dissolved in water, for instance in potatoes, leafy and other vegetables or as an additive for cheese and cured meat. Nevertheless, consumption of vegetables could prevent cancer and food storage in refrigerators may inhibit conversion of nitrate in nitrite [62]; therefore, water consumption could be the key factor. Additionally, other health problems as anaemia encourage the propensity of stomach cancer. Moreover, salt intake has been denoted as other key factor interacting with nitrates to explain the occurrence of stomach cancer [33]. Another weak point of this relationship is that stomach is quite acidic and this makes more difficult the required reduction of nitrate to nitrite for having the potential risk of cancer [1]. An additional problem to determine this relationship is that cancers sometimes depend more in persons' genetic characteristics than in their habits. Furthermore, they could develop at different velocity according to this, hence people's current intake of nitrate could be reflected in their health in five, twenty or forty years time. So according to this, there is not much evidence of nitrate being the key factor in causing stomach cancer.

Additionally, there are studies that find a positive relationship between gastric cancer and concentration of nitrates in water, but others find a negative relationship with it [20, 3]. Moreover, some studies presented a positive relationship at first glance but a further examination of employed data did not support it [9]. For the case of UK the relationship between stomach cancer and nitrate intake seems even weaker because the areas where nitrate concentrations were higher, South and East, are the opposite to the areas where rates of stomach cancer are higher [6]. Moreover, a study for Netherlands [61], that is one of the countries with higher nitrate concentrations in their waters, has proved that there is an inverse relationship between gastric cancer risk and nitrate intake from foods and that there is no link between this illness and nitrate intake from drinking water.

However, given long-term behaviour of this type of illness, prudence should be present. Hence, as before further research is needed even though stomach cancer is the weakest justification for controlling concentration of nitrates in drinking water

3.3. EUTROPHICATION

The third harmful effect is a process denominated eutrophication. It can be natural or human caused, and happens when there are high concentration of nutrients in water, mainly nitrogen and phosphorous, which cause overgrowth of planktonic algae and aquatic plants. In the first phase of growth could be beneficial for the aquatic ecosystem but as it becomes relatively important it has negative effects on oxygen conditions, benthic vegetation, sediments and fauna; leading to fish kills and odour problems [48].

Eutrophication process has the following sequence; first, aquatic vegetation overgrowth restricts the abundance of light and oxygen to other organisms. Secondly, blue-green algae becomes the dominant in algal community (algal blooms), which may be unsightly and washed up at the shores but they can cause odour problems, unpleasant taste and increased bacterial growth in drinking waters. Therefore, recreational value of waters is directly affected. Additionally, large amounts of algae can block the filters of water treatment works, which implies the need for removing algae, closing the reserve until water can be properly treated and the subsequent increase in costs for providing potable water [25].

The Nature and Conservancy Council estimated the nitrate levels for eutrophication at 15 mg/l in rivers and 7.5 mg/l in lakes, but surface waters can reach these levels naturally [29]. However, the natural process of eutrophication is slower than when it is affected by additional inputs coming from farms or urban areas [59b]. Consequently, control of nitrates based on these levels would be stricter than for the levels related with blue baby syndrome.

Nevertheless, the relative importance of phosphorous for determining plant growth is more relevant because its presence in inland waters is comparatively smaller than nitrogen so it could limit algae growth. Conversely, in salt waters the proportion of phosphorous is higher, being nitrogen the restrictive factor [25, 29]. Therefore eutrophication needs a joint management of nitrogen and phosphorous. Furthermore, there are other factors apart from nutrients, which must be favourable to have eutrophication, i.e. temperature and physical movement of water [29].

Particularly, for United Kingdom there is no much evidence for nitrate as the key factor determining eutrophication. Nonetheless, the primary input of algae communities are nutrients, their management is key to avoid eutrophication. Hence, management proposals must target the nutrient that has the restricting potential, but they should not forget that other nutrients could have a complementary role and if their management is easier they should be the chosen alternative.

4. PRECAUTIONARY PRINCIPLE

The relationships between nitrates and the exposed problems have associated some degree of uncertainty; however as most of environmental issues they require management before there is precise proof that harmful effects will occur [18]. The main reason for this is that once the environment reaches a state of high degradation could be very costly or impossible to make it come back to its original status, and the consequences of this degradation could be fatal for humans and other species. Nevertheless, uncertainties related with nitrates are diminishing over time, however, there are strong enough for keeping in mind that there is no perfect knowledge about the consequences for future generations of polluted groundwater sources or how many species we will lose as a consequence from eutrophication. Therefore, is justifiable to use the precautionary principle to avoid these undesirable effects.

According to the 1992 Rio Declaration of Environment and Development [47], The precautionary principle should be applied if:

"there are threats of serious or irreversible environmental damage, lack of full scientific certainty shall not be used as a reason for postponing cost effective measures to prevent environmental degradation"

It plays an important role for environmental law because it helps environmental decision making of different organizations, as the European Union [37]. Its function could be divided in three although they usually overlap; these are standard setting, application and enforcement [19]. However, all of them are subject to criticisms.

Firstly, its definition is not concrete, because its application is subject to the possibility of harmful effects for human or environment and the confidence associated with scientific studies is little. However, it must be invoked without reticence when risk of harm affects those considered vulnerable, for example children [31]. Hence, its application is not simple and different countries use it with different criteria. A clear example of this is its diverse application between EU and USA when dealing with different environmental aspects as global warming, genetically modified organisms or nitrates in water. The underlying problem here could be that its application would have strong effects on the economy of countries and subsequently affect its competitiveness at global level.

However, the main argument against the precautionary principle is that it is based on assumptions about likelihoods of consequences. Hence the level of uncertainty plays a double role, against and in favour of its application. To avoid this uncertainty, its application has not got a permanent validity and it should be reviewed as soon as there is more information about the issue where it is functional. Simultaneously, it must be present that policy makers should never underestimate the potential damage associated with absence of its application [18].

Therefore, according to the evidence for the linkage of nitrate with health and environmental problems, it seems clear that is easier to justify regulation according to health concerns than with environmental ones. However, further research is needed in both areas for measuring nitrate influence according to the different interactions involved.

5. WATER & WATER COMPANIES

Nitrates in water are also important because water is a replenishable but depletable resource. However, replenishment could be costly because water availability and quality is not constant over time. Moreover, water is associated with humans' basic needs; but it also has an aesthetic and recreational value because it is linked with activities as tourism, fishing or swimming. Therefore, to know water value is a complex task given that usually there is no exact market measure for all of these characteristics. However, contingent valuation methods and other valuation techniques try to estimate this value, although results from these studies are subject to a high degree of discussion and they are away from the scope of this study[3].

Common people assess water quality by its odour, taste and colour. Nevertheless, there are circumstances, as with nitrates, when is not easy to observe deterioration of these factors and they have linked a potential health risk. In these situations, people assume that their governments or water companies are responsible of providing water of good quality. Governments have to establish and make sure that standards are achieved by water companies, which at same time have to collect, treat and distribute water [56]. This should be done efficiently so water companies try to minimise leakage from their pipes that could have relevant values [40a]. However, the controversial issue is that they take account of pollution from other agents, which is contrary to the theoretical approach because polluters should be the ones working under the standards internalising the externalities. But, given the difficulty of identifying some polluters, water companies assume the costs of cleaning up waters to meet standards.

Households are also concerned about water prices, given that water quality is a public good[4] and its price directly affects their disposable income. Nevertheless, there could be contradictory behaviour among consumers as individuals and as members of the society because they could claim higher standards of water

[3] See [25]

quality for society as a whole, but as an individual they do not contribute to avoid water pollution or inefficient use of it, arising free rider problems. Moreover, consumers' perspective could be based in short term and when dealing with resources of the importance of water, a long-term perspective is needed.

Additionally, British water companies used to be natural monopolies at regional level and government completely managed them [28]. However, the possibility of efficiency gains and superior capital investment coming from private markets were the main reasons for privatisation of water companies in 1989 [56]. However, given that market forces affecting private companies could "forget" about environmental damages or health concerns, government regulated this privatisation, establishing different management roles among different organisms as Environmental Agency or Drinking Water Inspectorate, which are in charge of key issues as protection of environment and drinking water quality respectively.

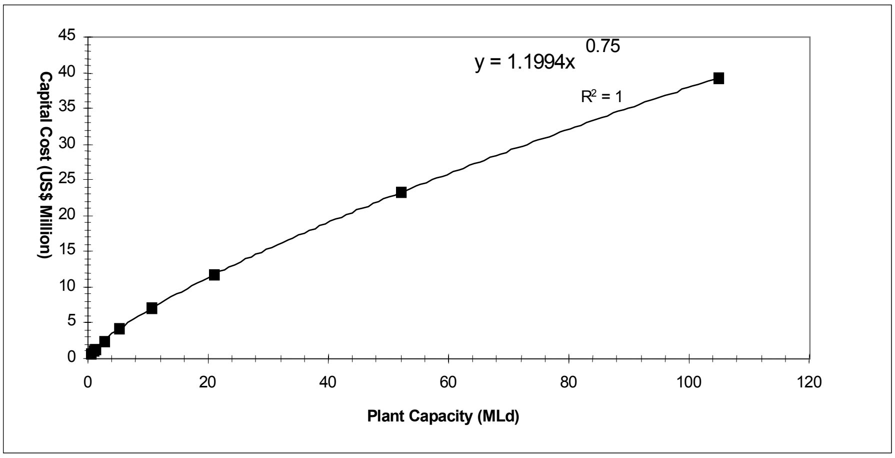
An important fact is that the Director General of Water Services sets water companies' charge regulation. This regulation accounts for water companies' operational and fix costs, annual inflation, service quality, costs of increasing environment protection and costs of efficiency improvements [56]. Furthermore, the potential deadweight loss should be minimized. This is a tough task because is difficult to know the precise values for all these variables, and water prices directly affect the amount of funds available for investment from water companies and other factors related with the whole economy, for example inflation.

For the case of nitrates legislation, water companies have tried to keep within the normative by blending water supplies and by chemical treatment [43]. However, nitrates are not easily removed from waters when applying conventional methods as coagulation, ozone treatment, filtration and chlorination. The best techniques to remove it are ion exchange, reverse osmosis and biological denitrification, although they may create a disposal problem and their costs are high [54]. Nevertheless, biological denitrification is the only process that does not shift the concentration of other ions, though it requires very intensive post treatment processes to control compounds produced during its application, raising the issue of adding suitable carbon source that could cause problems for drinking water quality; so it's more commonly used for sewage treatment. Alternatively, metals can remove nitrates at a reasonable cost, and immobilised enzymes can convert nitrate to nitrogen without residues [54]. Moreover, ion exchange was the cheapest option when water companies started to treat underground water, so is not rare that is one of the most commonly used methods

[4] Pure public goods are those with non-rival and non-excludable consumption. Notice that water has associated rival-consumption [62].

[11]. Hence, these two methods are superior to reverse osmosis that has associated high operating costs due to energy needed to achieve the necessary pressures involved in the process. One advantage of water treatment is that there is a possibility for large economies of scale [59b], however capital depreciation weakens this positive effect in the long run. Moreover, the costs of removing nitrates from water for UK are £24 million per year and they have been on the top of water treatment measures since 1986 [44]. Part of the explanation for this could be because treatment costs are related with the amount of water treated and level of pollution in water, so the increase in consumption implies an increase in costs (**Figure 1**)

Figure 1: Capital costs from water treatment

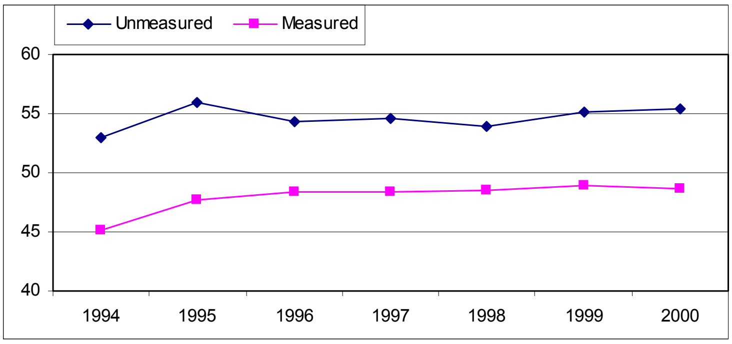


Source: The Chartered Institution of Water and Environmental Management (CIWEM)

5.1. EFFICIENT USE OF WATER

Water use could be one of the variables that governments and water companies would like to use for avoiding nitrate pollution. Water companies have to promote efficient[5] use of water and measured charges could do this and also represent an alternative way of payment [40a]. Thus, as shown in **Figure 2** water consumption is lower under measured supply. Nevertheless, most of water companies install meters at no charge and this is costly, so their global implementation has to be gradual. Moreover, its effects on consumers vary according to some especial needs that households could have, as families with many members, or according to their income levels. Hence, this has to be taken into account when establishing tariffs, which usually have associated a fix charge or a standing fee plus a volumetric one [14]. Additionally, total water demand also increases because the growth of population, however explanations for population growth problem are beyond the expectative of this study[6].

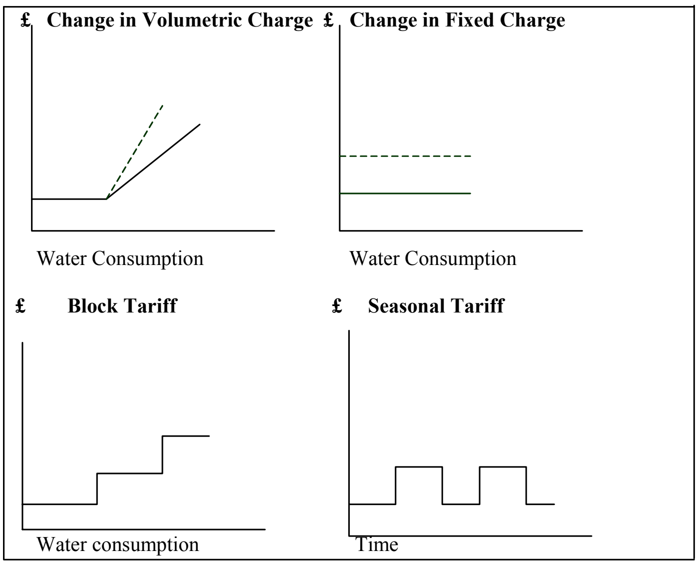
Figure 2: Average Household Water Consumption (m3 per year)



There are several tariff options that have being studied to account for different problems related with water use. For instance, block tariffs or tariffs with a seasonal element that could account for specific water uses. Alternatively, modifying the unit charge or fix charge, as shown in **Figure 3,** could have efficiency improvements from households and non-households [27, 40b]. Notice that for nitrate pollution, irrigation technique is a crucial factor when explaining leaching from farmland to waters, therefore increase of water charge could work as an incentive for efficient irrigation techniques and at the same time avoid pollution of water sources. However it could happen that demand for water is inelastic so consumers do not diminish water consumption until charges increase substantially.

[5] Efficiency is reached when marginal price of water is equal to long run marginal cost.

Figure 3: Examples of tariff options



In the following section the hypothesis that measured charges will promote a more efficient use of water, is tested. This is undertaken by estimating the demand for water according to charges for measured and unmeasured supply from different British water and sewerage companies. Potential efficiency gains will be measured by analysing the sign and absolute value of the estimated coefficient for water charges. This coefficient is expected to be negative and higher for the case of measured demand, indicating that if it increases the reduction in water consumption and in sewage discharge will be more important for measured consumption than for unmeasured ones. Therefore, if results support the hypothesis water charges could become part of some environmental policies.

[6] See [12]

5.2. WATER CONSUMPTION MODEL

I estimate water demand for most of the water and sewerage companies to know the influence of charges in households' consumption. This could be used as a proxy for farmers' consumption. The analysis was done using panel data with a total of eight companies and the time period was 1994-2000 for measured supply and 1992-2000 for unmeasured. Companies supplying only water were not included because their charges will exclude sewerage services that are an important part of total water charges.

The model used is the individual effects one with the typical form [34, 30]:

$$Y_{it} = X_{it} B + \alpha_i + \lambda_t + \varepsilon_{it}$$

ε_{it} ----- Independently identically distributed $(0,\sigma^2)$

Where Y_{it} is a vector of household's water consumed per year in cubic meters, for water company i (i=1... N) in time t (t=1...T). X_{it} is a vector of total water charges[7] in pounds per year, including the constant term. B is a vector of constants having as a first element a common intercept[8] and the second the coefficient for water charges. Additionally, α_i stands for unobserved variables constant over time but not over individuals, for example capital, and is called fixed group effects. Period effects are represented by λ_t, that is the influence of factors constant over individuals and not time, which are not observed, as technological progress. If they are correlated with explanatory variables, the fixed effects model should be chosen and if not, random one should be. This is known calculating the Hausman test that when is relatively high supports fixed effects model.

Given sample characteristics it is expected that fixed effects model will be chosen, moreover according to economic theory the coefficient of our explanatory variable, charges, should be negative because if charge increases household water consumption should decrease.

[7] Water charges are regulated, so inflation does not affect them as other goods [42].

[8] These variables will change according to the model: measured or unmeasured.

5.3. RESULTS AND DISCUSSION

Results for unmeasured consumption (**Table 1**) show a high value for Lagrange Multiplier test implying that individual effects are relevant therefore OLS without dummy variables is rejected. Hausman test, for the model without dummy variables does not reject random effects model at the 5% level of significance. But, in the case with period effects fixed effects are chosen with a 5% level of significance. Thus, if I employ random effects model estimates will be inconsistent. Moreover, given the small number of companies, their particular characteristics and the fact that fixed effects produce consistent estimates, I use fixed effects model[9] even though it could be less efficient and introduces lots of variables with the potential multicollinearity problem [45]. Results show an estimated negative sign for the coefficient of charge. However, it has very small value and it's not significant at 10% level. Nevertheless, adjusted R^2 is 0.884 that is very high, but this could be a sign of multicollinearity given the high number of variables introduced.

Table 1 Unmeasured Demand for Water.

	OLS without Group Dummies		**Fixed Effects Model**		**Random Effects Model**	
	Coefficient	**Pvalue**	**Coefficient**	**P value**	**Coefficient**	**P value**
Charge	.005	.555	.055	.000	.043	.001
Constant	53.46	.000			50.63	.000
Adjusted R^2	-.009		.703		-.224*	
LM Test	121.7	.000	**Hausman Test**		3.17	.074
	LS with Group Dummies and period effects			**Random Effects Model (Period Effects)**		
	Coefficient		**P value**	**Coefficient**		**P value**
Charge	-.004		.696	.007		.466
Constant	54.23		.000	53.29		.000
Adjusted R^2	.884			.737*		
LM Test	124.75	.000	**Hausman Test**	4.82		.028

* Not adjusted

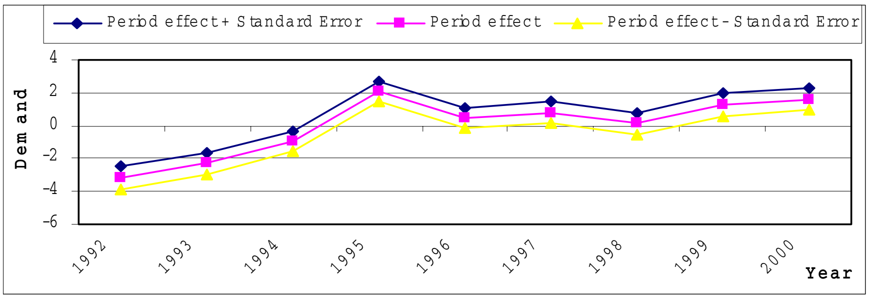
Thus, most of the explanation is based on the fixed effects (**Table 2 and Figure 4)**. Group effects are significant[10] for most of the companies indicating a higher consumption for South West, Southern and Thames water companies and a lower consumption for Wessex and Yorkshire. This is related with time invariant factors, which affect water companies and are not established in the model, for example basic consumption. Nevertheless, period effects show an increasing tendency for water consumption. These effects are constant over companies and could be related with population habits.

[9] Fixed effects model with period effects refers to LS with group dummies and period effects.
[10] The t-ratio for 5% level of significance and 54 degrees of freedom is 1.673

Table 2: Group Effects

Group	Coefficient	t-ratio
Anglian	.985	1.498
Dwr Cymru	-.732	-.396
Northumbrian	-.849	-1.169
South West	1.982	3.369
Southern	3.290	4.652
Thames	3.389	3.853
Wessex	-2.988	-2.853
Yorkshire	-5.077	-5.952

Figure 4: Period Effects



For the case of measured supply, I expected a negative relationship between charges and quantity supplied as well. However, results (**Table 3**) support random effects model, which has a coefficient for charge significant at 5% level, positive and with a very small coefficient of determination. Additionally, its value is more relevant than for the previous case, which is contrary to the fact that volumetric charge will promote efficient consumption. The explanation for these results could be related with data quality or omitted variables bias; as household income, individual characteristics of consumers, capital differences between companies... which is data not easily accessible, and less when doing a macroeconomic study as the current. Furthermore, if I look at the results for fixed effects model that produces consistent estimates at the same time that drops all time or individual invariant effects, the results do not change too much. Period effects are mostly estimated insignificant (**Annex 1**) therefore just looking at fixed effects model where most group dummy variables are significant at the 5% I cannot conclude too much because the value is very similar among different companies. These estimates of individual time invariant effects explain water consumption of approximately

30 m^3 per year, more than a half of average water consumption per year (47.95 m^3) that could be related with basic needs.

Table 3 Measured demand for water

	OLS without Group Dummies		Fixed Effects Model		Random Effects Model	
	Coefficient	**P value**	**Coefficient**	**P value**	**Coefficient**	**P value**
Charge	.076	.001	.140	.000	.122	.000
Constant	38.38	.000			32.63	.000
Adjusted R^2	.162		.712		.113*	
LM Test	65.55	.000	**Hausman Test**		1.21	.271

	LS with Group Dummies and period effects		Random Effects Model (Period Effects)	
	Coefficient	**P value**	**Coefficient**	**P value**
Charge	.155	.000	.128	.000
Constant	28.59	.000	31.94	.000
Adjusted R^2	.768		.097*	
LM Test	65.78	.000	**Hausman Test** 1.41	.235

* Not adjusted

Additionally, volatility measures computed as the standard deviation over mean show higher values for charge when taken into account the measured sample; Thus, they could be part of the explanation for these results that do not support the use of prices as control of water consumption (**Table 4**). Moreover, as shown before this market is no purely competitive and regulator's task is very important. It could be argued that non-households demand should also be included, however this demand responds to other factors different to households' ones; for instance irrigation techniques; additionally some farmers have their own supply from water sources in their land. Therefore, these results are just a proxy of what could be farmers' behaviour.

Table 4: Volatility

VOLATILITY	UNMEASURED DEMAND		MEASURED DEMAND	
	Charge	**Quantity**	**Charge**	**Quantity**
Anglian	0.294	0.025	0.047	0.076
Dwr Cymru	0.103	0.021	0.056	0.055
Northumbrian	0.216	0.026	0.107	0.064
South West	0.161	0.049	0.067	0.059
Southern	0.159	0.036	0.069	0.034
Thames	0.101	0.047	0.080	0.026
Wessex	0.491	0.047	0.033	0.030
Yorkshire	0.082	0.034	0.055	0.035
Total	0.581	0.063	0.169	0.080

The high value of the volatility index for Wessex charges for unmeasured demand could be explained by differences in the way companies recover surface and highway drainage costs because they are the main reason why standing charges vary between companies. Specifically, for Wessex its prices do not include the costs associated with provisions of surface water [40ab]. Furthermore, this could be the reason for the high total volatility unmeasured charges.

Therefore, results do not support policies affecting prices as a way to promote efficient water consumption; nevertheless there are studies that do it [63]. Hence, further research accounting for the importance of all the mentioned factors is needed. Moreover, a microeconomic analysis could be more helpful to measure how consumers respond to changes in charges. Nevertheless, current policy for nitrates in water is based on the regulatory approach and some voluntary instruments that will be described in the following sections.

6. WATER QUALITY REGULATION

Since the beginning of European Economic Community in 1957, agriculture played a key role because its function in the potential case of war and as one of the key economic sectors[11]. State Members concerned mostly about increasing production without accounting with the environment. At the same time the first cases of blue baby and its relation with nitrate concentrations in water were discovered. However, until 1970 the European Commission (EC) lightly managed this problem, and was during this period when it started to be concerned about nitrate pollution, implementing some environmental policies [21]. However, in the 1980s European countries realized that this approach was not achieving the expected objectives. The EC established a maximum nitrate concentration in 50 mg/l for water supplies, which was World Health Organization's recommended limit having 100 mg/l as a maximum. The former was also the level adopted in Britain and there were few water supplies that exceeded it [52]. Notice that the economic consequences of these different standards are big because they make the percentage of possible arable cropping land to go from 27% to 58% with the consequent restriction for management practice [1].

These regulatory measures usually represent the best available economic technology at their time, but they do not completely avoid environmental damage. Nitrate standards used to involve restrictions in number of farm animals, amount and timing of manure applications [53]. Therefore, standards could stipulate the performance without accounting for technology according with reasonable deadlines. However, they do not have associated too many incentives for technological innovation. In addition, authorities should review laws periodically and provide technical advice to potential polluters of how to avoid environmental damage [49]. Furthermore, given the diffuse nature of nitrate pollution regulatory measures have focussed on indirect instruments, as input use or management practice because emissions regulation has associated very high costs [35].

Farmers' response to regulations in fertilizer could be by applying crop mix, tillage practices, reducing number of hectares planted and fertilizer rates; having different consequences according to their actions. However, if it is less costly to pay the penalty than to implement pollution abatement procedures, farmers will just pay. Hence, policy makers should have this in mind when designing strategies to avoid pollution. Nevertheless, if both costs are excessive, the farmer could run out of business. Moreover in the case of nonpoint source pollution, the policy implemented could affect non-polluters or lightly affect polluters, because of the information lack.

In 1991 a new policy was announced to members of the EU, this was the Nitrate Directive (council directive 91/676/EEC). This legislation is more focused in organic (from animals, plants and fertilizers) than in mineral nitrogen fertilizer and required EC governments to identify Nitrate Vulnerable Zones (NVZs) [48]. Being these areas, the most likely to have nitrate levels higher than 50 milligrams per litre in their inland waters and also where there is a potential for eutrophication. Additionally, governments have to establish uncompensated measures in these NVZs to reduce concentrations of nitrates [41, 43], for which, the EC provides some guidance about how and when should apply these measures. The designation of NVZs will have economic effects on farmers as the ones coming from costs of implementation or land devaluation [41]. Moreover, countries could have other measures at national, regional or local level to control nitrate concentrations; for instance the Netherlands, Germany, Belgium and Denmark designated their whole territory as NVZs. This variation does not take into account that regulating a small number of fertilizer producers is less costly and information intensive than regulate all potential agricultural polluters. Nevertheless, the establishment of NVZs based on local areas could not prevent the occurrence of new polluted areas and if it pretended to do it, the costs involved would be much higher. The explanation for this

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[11] Economic relevance of agriculture, in terms of proportion of total GDP and employment, has decreased because of technological change and trade internationalisation.

could be related with problems of coordination, disputes regarding the potential subsidies from some measures and the uncertainties associated with nitrate pollution.

Other common measures applied were voluntary ones, i.e. Codes of Good Agricultural practice, which have associated potential benefits as: reduction of conflicts between the targeted sector and the environmental agency because they encourage cooperative solutions; more propensity to find a cost-effective solution, given the flexibility for negotiation; and they could meet environmental targets more quickly, because of the small implementations lags associated to them [51]. Therefore their transaction costs should not be high. Another characteristic of voluntary measures is that their effectiveness depends on the number of farmers applying them. Another problem related with this type of instrument is how long will take for farmers to get used to new management techniques which should take into account weather conditions or market characteristics among other factors.

Voluntary measures used to have associated informative instruments for controlling nitrate pollution by restricting agricultural area and promoting green management techniques. Examples of these instruments are telling farmers that the incorporation of straw over winter and the use of slow release fertilizer will reduce nitrogen leaching or that soil should not be bare during winter, and if necessary, farmers should sow catch-crop; moreover they should avoid applying nitrogen fertilizer during autumn and they must plough-in old grassland but not in young grassland because it enhances microbial mineralisation. Having the potential for reducing potential costs from policies targeting their activities.

Informative instruments are the most liked by potential polluters, however they only follow them when there is benefits in doing so [13]. Nevertheless, some of these practices will need more expenditure and/or hours of work from farmers than the normal amount, therefore to make their use real they should be subsidized. Hence, the conventional wisdom for adopting voluntary measures is that subsidies should cover all adoption costs and that farmers' net benefits do not decrease [39]. So, the key problem for governments is to find the way to encourage farmers in adopting these measures when there is absence of economic incentives. However, this becomes even more complicate when farmers expect the implementation of engineered measures[12], which make more difficult to encourage environmentally friendly management from farmers.

[12] Engineered measures used to reduce the generation of nonpoint pollution at the source, to impede the transport of pollutants to waters or to treat resultant water [48]

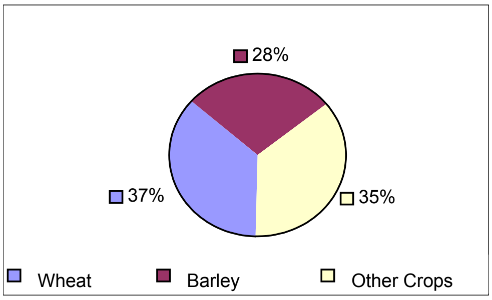
Moreover, in the case of nonpoint source pollution, sometimes farmers do not perceive the damage caused. However, for nitrates the linkage could be found in that their family would suffer health problems if they consume water from their wells. Therefore, this could justify the absence of subsidies to tackle nitrate problems given that farmers obtain benefits from their application at the same time that avoid pollution. Although the linkage between nitrates and health is weak, most of farmers use water from their wells just for irrigation because of other potential health risks associated with pesticides or other nutrients and the few costs associated with water supply from water companies [1, 58].

Another interesting fact of the regulatory approach is the different perspective between United States and Europe, because in the United States the limit is set to 10 mg per litre that is much lower. This is based on similar facts as health concerns rather than technological constraints and as shown before it is more close to standards needed to control eutrophication than European legislation. Moreover, American regulation establishes that authorities should communicate to television and radio stations the areas where the nitrate level is not satisfied, so population will be widely informed in a short period of time. Hence, parents have the chance to use alternative drinking water sources for their children. According to this different interpretation of the problem, the tighter legislation in United States could be justified by a more strict interpretation of the precautionary principle [17].

7. CROP PRODUCTION AND NITRATE POLLUTION MODELS

Agriculture is assumed to be the main responsible of nitrate pollution in waters. Therefore, knowing which activities are relevant for explaining nitrate pollution is an interesting matter. Panel data is used from eight different areas[13] of United Kingdom over the period 1990-2000. Panel data analysis is applied to estimate the importance of total nitrogen fertilizer applied per region for crop production and nitrate pollution; and to know how important spatial variation could be. Firstly the influence of fertilizer in crops production function is studied. Data availability and the fact that wheat and barley represent more than a half of total crop production (**Figure 5**) are the reasons to choose these crops as the object of study.

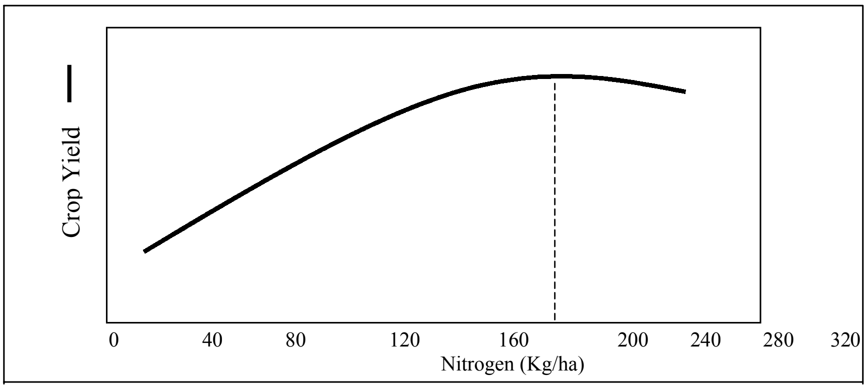
Figure 5: Percentage of Total Crop Area 2001



Source: Agriculture and Horticulture Census (2001)

Three types of mineral fertilizers are used as explanatory variables[14] for the two types of crop production: nitrogen, phosphate and potash. Variables are transformed into logs therefore the functional form is similar to traditional crop production function (**Figure 6**). I expect that nitrogen fertilizer will be the key explanatory variable in both functions. Moreover, fixed effects model with period effects is expected to be significant given missed variables as geographical characteristics, capital, labour and management techniques used by farmers.

Figure 6: Crop Yield



Source: MAFF (2000)

The model is analogous to the one presented for water consumption, but using matrix notation. The crop production function [42], is a common Cobb Douglas function with a log transformation:

$$Y_{it} = X_{k,it} B_k + \alpha_i + \lambda_t + \varepsilon_{it} \qquad \varepsilon_{it} \text{ ----- iid } [0,\sigma^2].$$

[13] North East, North West, Midlands, East, South West, Wales and Scotland.
[14] See **Annex 2** for notation.

Now there are several explanatory variables and therefore X and B are a matrix of k explanatory variables varying in time and by region and a vector of k constant coefficients, respectively. Notice that, for crop production, I did not introduce square terms of the dependent variables accounting for the possibility of inflexion points for crop production because they did not have expected signs and were insignificant at 10 % level.

The second part of the analysis tries to explain nitrate pollution according to the main characteristics of agricultural pollution in the form of nitrate concentrations in inland waters. These characteristics are that nitrate pollution use to occur over a wide area, it is not constant over time and space, and weather conditions can be crucial in explaining unusual levels of pollution. Moreover, geographical characteristics of the area are very important, as slope and soil type. Additionally, human activities also influence it, as for example land use, irrigation system, crop choice and fertilizer use [50, 49, 26]. For instance, nitrogen fertilizer efficiently applied to cereal crops, under Western European conditions; used to leave no unused fertilizer on soils [32]. Hence, the contribution of soils to nitrate concentrations in runoff should be less important than with other crops and fully explained by excessive use of fertilizer or nitrogen input from the atmosphere. It could happen that nitrate problems have their explanation more related with leaching from organic soils than from direct fertilizer losses. Moreover, in arable land the propensity of having nitrate problems caused by leaching is higher post harvest because plant uptake is zero and nitrogen release through mineralisation is high [6]. In the case of grassland, the source for nitrate pollution could be correlated with the existence of livestock, specifically intensive pig and poultry farms [36].

According to data availability the model is simplified to the relation between concentrations of nitrate in inland waters and total nitrogen fertilizer applied for wheat and barley production, numbers of livestock per region: sheep and lambs, total herd, pigs; rainfall, group and period effects[15]. Variables accounting for total nitrogen applied to wheat and barley production are in logs because their effect is expected to be positive and decreasing over time, given plant uptake and the retention of them by soil and crops. The rest of variables are assumed to be linear, expecting for all of them a positive sign, given their direct relationship with leaching and nitrogen compounds. Fixed effects model is expected to be significant given the effect of omitted variables as geographical characteristics, deposition of nitrogen compounds from

[15] It is assumed that variables fulfil ordinary least square assumptions in all the analysis [36], but here is pointed out because rainfall is stochastic but assumed uncorrelated with the error.

the atmosphere, cars and power stations. Moreover fertilizer use for wheat production is also expected to be the key explanatory variable.

7.1. RESULTS

7.1.1. CROP PRODUCTION

Estimated values for wheat production function are shown in **Table 5.** The values for Lagrange Multiplier and Hausman test support fixed effects model without time effects, however when these are included random effects should be used. Nevertheless, I choose fixed effects model without period effects because of the values of the coefficients for period effects are mostly insignificant (**Annex 3**) and because our initial expectations related with missed variables and the assumption that individual effects are correlated with explanatory variables. Having as only significant coefficient at 5% level, the estimated elasticity of wheat production with respect total nitrogen applied for wheat production. Interpreting its value, as if farmers increase a one per cent the use of nitrogen fertilizer it is estimated to lead to an increase in 1.13 % for the production of wheat. Thus, nitrogen mineral fertilizer is relevant for explaining wheat production. However, this value should be used cautiously given that this will imply that increasing fertilizer as much as farmers want, will increase production in a higher proportion. The explanation for this is that these variables are in terms of total cultivated area, which is part of the explanation in the total amount of fertilizer applied. The ideal would be to have fertilizer application rates per hectare, however data is only available for the whole nation and the way of distinguishing regions is by total use per cultivated area. Another problem is the extremely high value of adjusted R^2 given the low explanatory power of the estimated coefficients; that could be associated with multicollinearity problems.

Table 5: Estimated Wheat Production Function

OLS without Group Dummies			Fixed Effects Model		Random Effects Model	
	Coefficient	Pvalue	Coefficient	P value	Coefficient	P value
LTNW	1.18	.000	1.13	.000	1.18	.000
LTPW	-.102	. .544	-.107	.462	-.096	.499
LTKW	-.604	.793	-.054	.782	-0.067	.732
Constant	3.06	.000			3.370	.000
Adjusted R^2	.997		.997		.997*	
LM Test	26.09	.000	**Hausman Test**		13.01	.004

	LS with Group dummies and time effects			Random Effects (Period Effects)	
	Coefficient	Pvalue		Coefficient	P value
LTNW	.646	.088		1.09	.000
LTPW	.563	.089		.125	.554
LTKW	-.196	.573		-.197	.454
Constant	4.11	.000		3.49	.000
Adjusted R^2	.998			.997*	
LM Test	37.90	.0000	**Hausman**	3.23	.357

* Not adjusted

The same analysis is done for barley. Results without period effects (**Table 6**) support fixed effects model and when they are included the random one should be chosen. But, as before the higher relevance of group effects (**Annex 4**) and my assumptions about the model, fixed effects model without period effects is chosen. The only significant coefficient is the one related with total mineral phosphate fertilizer applied, moreover, its value is relevant and having the expected sign. Therefore, an increase of 1% in phosphate fertilizer used is estimated to increase 0.763% the production of barley for the whole region. As before, this value is very high and I suspect that the number of hectares cultivated must be taken into account. Moreover, high values for adjusted coefficient of determination are present as well with analogous explanation to the wheat model one.

Table 6: Estimated Barley Production function

	OLS without Group Dummies		Fixed Effects Model		Random Effects Model	
	Coefficient	Pvalue	Coefficient	P value	Coefficient	P value
LTNB	.407	.010	.168	.249	.383	.002
LTPB	.640	.000	.763	.000	.649	.000
LTKB	-.002	.983	-.055	.560	-.002	.974
Constant	4.26				4.317	.000
Adjusted R^2	.993		.995		.993*	
LM Test	26.40	.0000	**Hausman Test**		11.92	.007

Table6 (Contiued)

	LS with Group Dummies and Period effects		**Random Effects model (Period Effects)**	
	Coefficient	**Pvalue**	**Coefficient**	**P value**
LTNB	-.654	.351	.261	.291
LTPB	1.381	.008	3.032	.002
LTKB	.217	.676	-.027	.978
Constant	5.371	.000	4.423	.000
Adjusted R^2	.997		.997*	
LM Test	42.84	.000	**Hausman Test** 5.85	.119

* Not adjusted

Notice that group effects are significant in both models (**Annex 3 and 4**); however, their values among regions are not very different; therefore I cannot conclude that any of the regions has a comparative advantage in producing any of the studied crops. Although these results have to be used cautiously, it is clear that nitrogen fertilizer represents a much more important variable for wheat production than for barley one.

7.1.2. NITRATE POLLUTION

Results for nitrate pollution model do not support fixed effects model with or without time effects (**Table 7**). Therefore, could be that there is no omitted variable with relevant effects, so the random effects model should be chosen. Given the higher R^2 for the model without period effects this is used, having associated only two significant coefficients at the 5% level, millimetres of annual rainfall and tonnes of nitrogen fertilizer applied for wheat production. The sign of the first one is negative, which was not expected but could be justified because as the volume of water sources increases the concentration of nitrates should not, thus its value is interpreted as if the number of millimetres increases in one unit the concentration of nitrates in water is estimated to decrease in 0.002. For the case of total nitrogen fertilizer applied for wheat production, the case is the inverse and its increase in one per cent is estimated to increase the concentrations of nitrates in 6.9 milligrams per litre. But, if as before I decided to use fixed effects model without period effects total herd becomes significant having, the expected sign but with small relevance, given that if the number of total herd increases in one thousand units that is estimated to increase concentrations of nitrates in water in 0.007 mg/l.

Table 7: Estimated Nitrates Concentration Function

	OLS without Group Dummies		Fixed Effects Model		Random Effects Model	
	Coefficient	**Pvalue**	**Coefficient**	**P value**	**Coefficient**	**P value**
RAIN	-.0064	.004	-.002	.055	-.002	.021
SL	.0006	.000	-.001	.078	-.0007	.160
HERD	-.005	.000	.007	.043	.004	.124
PIGS	-.012	.000	-.0003	.833	-.0004	.735
LTNW	17.48	.000	6.33	.007	6.90	.000
LTNB	-10.8	.000	-2.66	.166	-2.78	.111
Constant	18.06	.000			8.16	.146
Adjusted R^2	.873		.975		.587*	
LM Test	51.51	.000	**Hausman Test**		8.93	.177

	LS with Group Dummies and Period effects		Random Effects model	
	Coefficient	**Pvalue**	**Coefficient**	**P value**
RAIN	-.0002	.879	-.0002	.887
SL	-.001	.192	-.0009	.103
HERD	.007	.122	.461	.126
PIGS	-.0002	.859	-.0003	.827
LTNW	2.29	.549	4.896	.005
LTNB	-.93	.710	-.717	.709
Constant	13.57	.377	6.16	.316
Adjusted R^2	.980		.546*	
LM Test	51.52	.000	**Hausman Test**	7.88	.166

* Not adjusted

Nevertheless if I use fixed effects with period effects, none of the explanatory variables is significant at the 5% level. However, the estimated group effects (**Table 8**) for midlands is positive, relevant and significant at the 5% level[16] that could be expected given that is the region with highest average mean concentrations of nitrates in inland waters. The estimated coefficient for Scotland is also significant with a negative relevant value this could be expected given that with Wales are the two areas with lowest concentrations of nitrates. However, coefficients for Wales and the other areas are not significant at the 5% level. For time effects (**Table 9**) the significant coefficients are 1994, 1996 and 1998. The estimated sign is negative for the first one and positive for the last ones, all of their values are more than an unit in absolute terms and they reflect the estimated influence of variables that change over time but not over individuals as could be management techniques or regulations. Therefore, according to these estimated values regulations after 1995 have had a "positive" effect on the nitrate concentrations. Thus they are not promoting the reduction of nitrates in water.

[16] The t ratio for 5% level of significance and 53 degrees of freedom is: 1.674

Table 8: Fixed group effects.

Group	Coefficient	T-ratio
North East	-2.663	-.581
North West	-1.092	-.125
Midlands	13.985	1.840
East	11.864	1.156
South West	-9.502	-1.510
Wales	-1.949	-.126
Scotland	-10.641	-5.052

Table 9: Period effects

Period	Coefficient	T-ratio
1990	-1.204	-1.489
1991	-.200	-.255
1992	-.310	-.468
1993	-.032	-.037
1994	-1.386	-1.712
1995	-.395	-.542
1996	2.028	2.112
1997	.875	.804
1998	1.588	1.764
1999	.114	.135
2000	-1.077	-1.057

7.2. DISCUSSION

Results confirm the hypothesis that mineral nitrogen used in wheat production is a key variable to control, given its estimated value for explaining nitrate concentrations in water. Nevertheless, it is also estimated important for wheat production, therefore implementing a decrease in its use will have more important effects on farmers than if the targeted crop is barley, although the influence of nitrogen fertilizer applied for barley in nitrate pollution was estimated insignificant at 10% level. Additionally, group effects show that differences between some areas are quite important therefore regional policy could be more adequate for British situation.

Conclusions from this study should have data quality and limitations present. For instance, incrementing time period and disaggregating more the number of areas could give more robustness to this kind of study. Additionally, the collection of data at the current level of aggregation has to be revised and taken into consideration the different methodologies. This implies asking different organizations for this information, which sometimes they are not interested in making it public, or there is need for funds to buy it or there could be idiosyncratic preference problem between farmers, fertilizers producers and environmental organizations. Additionally, for groundwater, it could happen that effects of mineral nitrogen fertilizer on concentration of nitrates could have a lag of 40 years [15]. Moreover, given that in autumn is when most of the N leaching to ground water takes place [57], a seasonal study would be more appropriate.

The solution for some of these problems could be to undertake the analysis in a small area in a time series basis and collecting the data myself. This could take account of different management techniques; type of fertilizer used; or timings of applications among other factors. However this is time and money intensive and conclusions will be subject to the area of study. Therefore further research is needed trying to account for as many factors as possible but having in mind that policies could need a wide analysis for its national or regional application.

8. POLICY ALTERNATIVES

It has been shown that nitrate pollution is directly related with crop production. However, policies related to avoid this problem are not easy to implement given that polluters are not easily identified; thus it is very difficult to internalise externalities, because there is no chance for negotiation between polluter and affected agents. Additionally, it is hard to target nitrate polluters according to the level of pollution emitted, given the diffuse nature of their harmful effects and the high costs of identifying polluters. Hence, instruments should encourage prevention and not just focus in penalizing after the damage has occurred.

The heterogeneous characteristics of agriculture make that environment departments have to specify what agricultural activities, outputs or inputs, the policy instruments should target [60]. For instance, from results of the model, wheat production techniques should be monitored because of its higher relevance compared to barley. Nevertheless, other crops, as maize and potatoes, or livestock have been found relevant in other studies [58, 4].

Furthermore, notice that if the policy implies a transfer of one kind of crop production from one polluted area to other unpolluted, this could imply a transfer of pollution as well. This transfer is easy when areas are homogenous but presents lots of complications when they are not. Nevertheless, sometimes policy implementation could be more cost effective until some level of pollution and polluters involved, but beyond that point, restoring the environment could be a better alternative [46].

Regulatory and voluntary measures were described in preceding sections and they are the most common pollution control measures. However, recently more and more countries think about other instruments related with economic incentives. In the following sections I describe them, highlighting their weak and strong points.

8.1. NEGATIVE ECONOMIC INSTRUMENTS

Negative economic instruments used to be unwelcome by polluters because they could have associated high penalties [13]. Moreover they do not allow polluters to take too many decisions and they just penalize them. Nevertheless, these effects could work as incentive for innovation.

The most common economic instruments are taxes that discourage environmental harmful activities in different ways. The advantage of tax system is its low administrative cost compared to regulatory ones [48]. They could target, farm inputs or outputs related with nitrate pollution, emissions and ambient concentrations. Usually, only one of these alternatives is tested to check their individual effects given that if several are applied at the same time is more difficult to distinguish individual effects [53].

Emission taxes are very difficult to implement because they are information intensive. Leaching used to be the measure to impose them, however this is remote from the point at which damage occurs [43]. Alternatively, ambient taxes are based on concentrations of the polluting substance in a determined area, targeting all potential polluters at the same time. This implies a high efficiency loss, even though could be successful when characteristics of the area are homogeneous and only one type of pollution is the objective [53]. A controversial point of ambient tax is the way of measuring concentrations of nitrates in waters will have different results depending on the deepness, weather conditions, and place where the analysis is done. Therefore, calculation of nitrate concentrations should be made in different points, and it should be done under "normal" conditions, and reviewed as many times as possible.

Taxing inputs that increase nonpoint pollution could be more efficient than ambient taxes when accounting for transaction costs [35]. These costs are more important than for point source pollution given the spurious character of the polluting source. The main potential taxable inputs are fertilizers and water used for irrigation. However, given the results of our water demand model and the possibility of auto supply the later is more difficult to control. For the case of fertilizers, effectiveness depends on price elasticity. If this is high, fertilizer producers will suffer a reduction in their earnings and farmers will use substitutes with similar properties but with lower costs. Nevertheless, if elasticity is low, farmers will suffer the main economic consequences and fertilizer producers will have little consequences. Additionally, empirical evidence for elasticity measures is controversial, having analysis with high values and others with low ones [55, 5]. Sometimes this is associated with the presence of substitutes for the objective inputs. Therefore, the availability of environmentally friendly substitutes is crucial for the success of this policy. However, other risk for this kind of policy is that farmers could pass costs to consumers and continue with polluting activities. However this is very difficult given the degree of competition in food markets.

Similarly, taxing outputs related with nitrate pollution could be part of the solution. However, this is very controversial given that sometimes pollution is more related with management techniques than with output. Additionally, the effectiveness of this policy will also depend on degree of substitutability for these goods.

A crucial problem when implementing these kinds of policy is to establish the tax rate. Theoretically its level should be equal to marginal social damage, though sometimes achievement of quality standards can suppose a very high cost and discharge control could be more cost-effective [43]. Another problem is that they affect agriculture sector, therefore its competitiveness could be lessened in comparison with other farmers from other regions and countries not subject to the same kind of measures. Although, sometimes the effects are negligible [16], they will depend on tax rate level. Nevertheless, distinguishing these effects is very difficult given the high level of policies affecting agriculture sectors in most countries. However, this does not excuse that taxes could be used to promote the use of environmentally friendly inputs and management techniques.

8.2. OTHER ECONOMIC INSTRUMENTS

Other potential economic measures to control nitrate pollution are: subsidies, liability rules, land use permits, pollution trading and fishing rights. Subsidies could be implemented as complement for other policies. They could promote the use of environmentally friendly activities or make more competitive some non-polluting inputs or outputs. In theory, the other instruments should be enough to control nitrate pollution, however, in real terms, competitiveness problems and lack of information about agents' performance justify the use of subsidies.

Liability rules consist in identifying and charging one or several polluters with the overall damage. Thereafter, any polluter has the right to sue other polluters for their contribution. The main problem for this measure is to have information to prove who is polluting. However, they could be based in features easy to check, as the existence of bare soils in farmland during autumn.

Land use permits consist in the assignation of some rights to pollute according to pollution levels of different areas. The level of information needed to know what should be the value of these rights is again one of its main problems. The problem could be avoided by pollution trading given that valuation of permits would be established in a market created by assigning to different agents with limited polluting rights. However, this will work only in small areas where identification of polluters is easier and the possibility of having free riders is small.

Another way to protect surface water quality, but only for the case of surface waters, is by establishing fishing rights. That as in the case of England and Wales, private angling associations can buy from landowners [59a]. Having associated an incentive to protect environment for making it appealing for fishermen, that will be charged for the recreational use of these water sources. Moreover, for this policy to work the standard of pollution for keeping biodiversity intact should be the same as for human health, and this seems the case of nitrate. However, notice that the weak point of this and the later measures is that they need high degree of information and they could be very costly depending on the number and characteristics of the affected areas.

9. CONCLUSIONS

This study highlighted the difficulties encountered when dealing with problems of excessive nitrates in water. It illustrated the reasons why nitrate pollution could cause health and environmental problems. It showed that there is no much evidence for the linkage of nitrates in water with stomach cancer and that the interaction of other factors such as bacteriological contamination or phosphorous, are relevant for explaining the blue baby syndrome and eutrophication respectively. Alternatively, the precautionary principle can justify actual legislation because of the uncertainties related with these interactions.

Additionally, the role of water companies was examined. They directly assume the costs of removing nitrates from water. However, given that they charge consumers for their services, households are also internalising the costs from nitrate pollution. Hence, the charging system was studied to know if charges could be an alternative for promoting efficient use of water. A panel data model distinguishing water demand under fixed and volumetric charges was employed. Estimated results did not find significant effects of charges for explaining water consumption. Moreover, for unmeasured charges fixed effects were significant, illustrating that time invariant effects, such as consumption habits could be important, and that there is an increasing tendency for water consumption.

The paper critically evaluated the current legislation for nitrate pollution and some of the instruments applied to avoid excessive concentrations of nitrates in water. Additionally, given the relationship of nitrates in water with agricultural activities, a panel data analysis for different areas of the UK was constructed in order to understand how important agricultural inputs and outputs are in determining nitrate concentrations. The main hypothesis was that fertiliser application for wheat is the most relevant factor to control. According to the model, estimated results confirmed the hypothesis, moreover group effects for some areas were relevant indicating that factors that not vary over time are relevant, i.e. geographical characteristics. The work concludes with a description of potential policy instruments that could be used as either alternatives to, or compliments to current policies.

This study highlighted some of the difficulties in avoiding nitrate pollution. However, there is need for further research accounting with differences in management techniques, site characteristics, polluter control costs, interactions which different policies could have when applied in the same area and the costs of data collection for policy implementation. These factors would help to choose which policy instrument will be more efficient. However, given the difficulty of having exact values for the importance of these factors, the precautionary principle should be applied if necessary.

Annex 1

Fixed Effects of Measured Demand for Water:

Group Effects:

Group	Coefficient	t-ratio
Anglian	29.99	7.04
Dŵr Cymru	30.46	7.38
Northumbrian	26.68	5.67
South West	32.90	9.850
Southern	26.51	4.78
Thames	37.09	8.37
Wessex	29.29	7.47
Yorkshire	30.31	8.30

Group and Period Effects:

Group	Coefficient	t-ratio
Anglian	-.423	-.578
Dŵr Cymru	.112	.150
Northumbrian	-3.928	-4.165
South West	2.899	2.089
Southern	-4.465	-2.444
Thames	6.607	8.598
Wessex	-.967	-1.148
Yorkshire	.164	.154

Period	Coefficient	t-ratio
1994	-2.163	-3.083
1995	.311	.450
1996	.952	1.373
1997	.435	.643
1998	-.248	-.348
1999	-.574	-.721
2000	1.287	1.853

Annex 2

RAINFALL[*]: Millimetres per year

POP: Thousands of People per Region

NITRATE: Annual average mean concentrations of nitrates per Region

HERD: Thousands of units per region

PIGS: Thousands of units per region

SL: Thousands of sheeps and lambs per region

WHEAT: Thousands of Tonnes Produced Per Region

BARLEY: Thousands of Tonnes Produced Per Region

TNW: Tonnes of Mineral Nitrogen fertilizer applied for Wheat Production per Region

TPW: Tonnes of Mineral Phosphate fertilizer applied for Wheat Production per Region

TKW: Tonnes of Mineral Potash fertilizer applied for Wheat Production Per Region

TNB: Tonnes of Mineral Nitrogen fertilizer applied for barley production per Region

TPB: Tonnes of Mineral Phosphate fertilizer applied for Barley Production Per Region

TKB: Tonnes of Mineral Potash fertilizer applied for Barley Production per Region

L: preceding variable name represents variables in logs

[*] Data was available from Digest of Environmental Statistics, DEFRA (2002), Agricultural and Horticulture Census: UK. DEFRA (2001) and different volumes of The British Survey of Fertilizer Practice DEFRA and Regional Trends, Office National Statistics.

Annex 3

Fixed Effects of Wheat Production

Group Effects:

Group	Coefficient	t-ratio
North East	3.63	9.10
North West	3.43	16.28
Midlands	3.60	8.18
East	3.63	7.71
South West	3.51	9.91
Wales	3.40	19.25
Scotland	3.62	11.60

Group and Period Effects:

Group	Coefficient	t-ratio
North East	.047	.338
North West	-.038	-.141
Midlands	-.003	-.017
East	.008	.031
South West	-.049	-.942
Wales	-.050	-.135
Scotland	.086	2.085

Period	Coefficient	t-ratio
1990	-.040	-.779
1991	-.056	-1.966
1992	-.074	-2.136
1993	-.058	-1.20
1994	-.020	-.678
1995	.006	.250
1996	.090	2.734
1997	-.056	-1.323
1998	-.010	-.296
1999	.115	1.203
2000	.104	1.649

Annex 4

Fixed Effects of Barley Production

Group Effects:

Group	Coefficient	t-ratio
North East	4.94	22.17
North West	4.58	31.46
Midlands	4.89	21.7
East	4.95	20.08
South West	4.77	23.01
Wales	4.53	30.84
Scotland	4.89	19.77

Group and Period Effects:

Group	Coefficient	t-ratio
North East	.121	3.597
North West	-.125	-1.248
Midlands	.069	1.876
East	.099	1.503
South West	-.026	-1.411
Wales	-.175	-1.790
Scotland	.036	.542

Period	Coefficient	t-ratio
1990	-.033	-1.006
1991	.043	.275
1992	-.039	-.788
1993	-.060	-2.041
1994	.049	.805
1995	.001	.052
1996	.073	1.611
1997	-.135	-1.083
1998	-.058	-.594
1999	.075	1.547
2000	.083	1.224

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