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Simulating a Market for Tradable Greenhouse Gas Emissions Permits amongst Irish Farmers

Authors James P. Breen
Rural Economy Research Centre, Teagasc, Athenry, Ireland
e-mail: james.breen@teagasc.ie

Abstract

Research into Greenhouse Gas (GHG) emissions from Irish agriculture has focused on two main themes (i) projecting future emission levels and (ii) devising abatement strategies at the farm level such as changes in animal diet, better waste management and or changes in farm management practices. These abatement strategies will have costs associated with them some of which, such as capital investment or reducing livestock numbers, may be substantial. However economic theory indicates that market based solutions such as tradable emissions permits (TEP's) are the least cost means of achieving desired reductions in emissions.

To date within Europe a regulatory approach has been favoured when trying to curtail emissions from agriculture, the Nitrates Directive being a recent example. This paper seeks to compare the impact on farm incomes of a regulatory approach to emissions abatement with a TEP's approach. In order to do this data from the Irish National Farm Survey is used to construct a farm-level Linear Programming (LP) model for each farmer within the dataset. Firstly a baseline scenario with no constraint on emissions is run. We then enforce a 20 percent reduction in emissions and the impact on farm incomes is measured. The LP model is then used to determine each farmers shadow value for a TEP. These shadow values are then weighted up to estimate the supply and demand and used to simulate a market for TEP's and the farm income is re-estimated. Finally the implications for farm incomes of both abatement strategies are compared with the baseline scenario.

Keywords: Farm level modelling, greenhouse gas emissions, tradable emissions permits

JEL codes: Q12, Q52

Introduction1[1]

The increasing concern over climate change has led to a number of international agreements to control greenhouse gas (GHG) emissions, including the Kyoto Protocol and the Clean Air for Europe (CAFE) Act. More recently the EU have proposed to cut greenhouse gas emissions by 20 percent by 2020 and have offered to reduce emissions further if other developed regions will also commit to reducing their greenhouse gas emissions. Ireland occupies a somewhat unique position amongst western economies in that agriculture accounts for a very large proportion of its total greenhouse gas emissions. Agriculture currently accounts for over 25 percent of greenhouse gas emissions in the form of methane and nitrous oxide emissions. In comparison agriculture accounts for a far smaller proportion of total greenhouse gas emissions the EU approximately 10% of greenhouse gas emissions from the EU come from agriculture (Eurostat 2005). Australia and New Zealand are amongst the only developed countries with a proportion of total greenhouse gas emissions from agriculture that is comparable with Ireland. Agriculture, forestry and fishing accounted for approximately 23 percent of greenhouse gas emissions in Australia in 2005 and approximately 32 percent of total greenhouse gas emissions in New Zealand.

[1] The author would like to thank Pat Westhoff, Willi Meyers, Tom Johnson, Tony Prato and Douglas Miller of the University of Missouri-Columbia for their assistance to date on this project. He would also like to thank his Thia Hennessy, Trevor Donnellan and colleagues Kevin Hanrahan, of the Rural Economy Research Centre, Teagasc for their assistance to date on this project. The author would like to thank FAPRI-Missouri for the provision of financial support as well as the Irish Department of Agriculture, Food and Forestry. The author would like to acknowledge National Farm Survey for the provision of data. All remaining errors and omissions are the responsibility of the author.

Therefore within Ireland agriculture is likely to play an important role in reducing national GHG emissions. As a result targeted reductions in GHG emissions have been set in the past for the Irish agricultural sector, for example the National Climate Change Strategy called for a reduction in methane emissions from agriculture, equivalent to a 10 percent reduction in the livestock herd. If we are to assume that as part of the EU's proposal to cut emissions by 20 percent by 2020, each EU member state will have to cut its national emissions by 20 percent then it will be necessary for Irish agriculture to make significant reductions to its emissions levels given its current contribution to Ireland's total greenhouse gas emissions. Furthermore given its declining importance and its high level of greenhouse gas emissions relative to other sectors Irish agriculture could potentially be faced with a reduction in net emissions beyond the 20 percent target set by the EU. However current high prices and future agricultural policy reforms will potentially lead to an increase rather than a decrease in GHG emissions from Irish agriculture. For example the expansion of the EU milk quota is likely to lead to an increase in Irish dairy cow numbers and consequently an increase in GHG emissions. While high cereal prices along with the decision to allow farmers to take land out of set-aside is likely to lead to an increase in the area tilled within Ireland and the release of carbon dioxide currently stored within the ground.

Agricultural production in Ireland largely takes the form of pasture based livestock production with approximately 90 percent of the total agricultural area used in the production of milk, beef and sheep from grass. Methane released through enteric fermentation and manure management in the dairy and beef sectors account for over 50 percent of total greenhouse gas emissions from Irish agriculture (Donnellan and Hanrahan 2003). Therefore if Irish agriculture is to achieve meaningful reductions in its net greenhouse gas emissions, then significant changes in one or both of these sectors is required. However the prospect of milk quota abolition by 2015 presents a further complication as many of Irelands dairy farmers are looking to expand their herds significantly once quotas are abolished.

To date there has been a considerable volume of research into the impact on emissions from changing farm practices in Ireland. O'Mara et al. (2007) conducted a review of strategies to reduce enteric methane emissions. Lovett et al. (2006) have looked at a range of alternative greenhouse gas abatement strategies that would reduce emissions per litre of milk. While Lovett et al. (2005) and O'Mara (2006) explored the impact of changes in animal type and feeding practices on agricultural emissions. These alternative abatement strategies have been shown to help in the reduction of greenhouse gas emissions. However in many cases the cost of achieving that reduction is quite high relative to the reduction in emissions achieved. Therefore it is likely that while these abatement strategies will help to reduce emissions they would be unlikely to achieve a reduction of 20 percent in emissions from Irish agriculture. Secondly if these emissions abatement strategies were to be used it is possible that the inventory process currently being used may not capture fully their effect on greenhouse gas emissions.

Alternatively policy can be used to reduce greenhouse gas emissions, the simplest way being a command and control approach that would place a flat reduction of 20 percent on each farmers total greenhouse gas production levels. While such a system is simple it would also be quite rigid and more importantly it would be very inefficient as it does not consider the marginal abatement costs of individual farmers. Economists have proposed a number of alternative cost-minimizing emissions abatement strategies. One such approach is tradable emissions permits or permit trading, the idea was first conceived by Crocker (1966) and Dales (1968) and the concept was further refined by Baumol and Oates (1971 and 1988). Baumol and Oates (1988) argued that permit trading may be the most cost efficient means of cutting emissions. While De Cara et al. (2005) concluded that there was a wide variability across Europe in abatement costs of greenhouse gas emissions from agriculture. They concluded that there was potentially significant cost savings from market based mechanisms.

In this analysis the marginal abatement cost of emissions reduction is the income foregone from reducing your agricultural activity i.e. reducing livestock numbers. Considerable variability exists in the gross margins per livestock unit earned in alternative agricultural enterprises. A significant difference also exists in the marginal abatement cost of an intensive dairy farmer who must reduce his dairy cow numbers in order to reduce his greenhouse gas emissions and the marginal abatement cost of a beef farmer who for example must reduce his number of steer animals or suckler cows. Therefore if we were to create a market and allow the dairy farmer to purchase emissions permits from the beef farmer the cost of achieving the emissions reduction could be minimised.

This paper compares the cost of achieving a targeted reduction in emissions by allowing farmers to trade permits with a command and control approach or emission standards approach.

2. Background

The impact on farm incomes of two strategies, emissions standards and tradable emissions permits, both of which could be applied to reduce greenhouse gas emissions from Irish agriculture is analysed. An emissions standard or command and control approach would require a regulatory body to set an acceptable environmental standard for polluters and to monitor their levels of emissions and if necessary to enforce the standard. Such a strategy is relatively simplistic and if successfully enforced will guarantee that total emissions do not exceed the acceptable level. However emission standards can be highly inefficient as marginal abatement costs will typically vary by emitter and may enforce inefficient levels of abatement on some polluters.

Figure 1 below outlines how an emission standard would work, in this example we have two sources x and y. A uniform emission standard is applied and both sources are required to reduce their emission levels to point A. Source x has a higher marginal cost of emissions abatement (MCA_x) than source y (MCA_y). Therefore the cost to x of reducing emissions by A is the area under the line MCA_x up to A and the cost to y of reducing emissions by A is the area under the line MCA_y up to A. As can be seen from Figure 1 the cost of reducing emissions to the level A will be greater for source x than for source y.

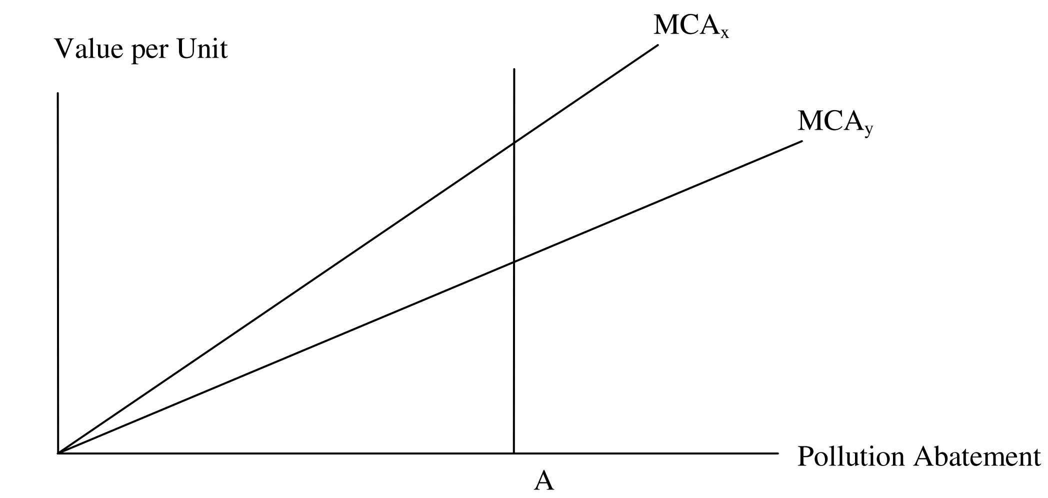

Figure 1: Emission Standards

Source: Prato (1998)

Figure 2 below outlines how a market for tradable emission permits would operate. In this example both sources have been issued with 0.5A tradable emission permits. As in figure 1, source x has a higher marginal cost of abatement than y. Therefore so long as x's abatement cost is greater than the cost of an emissions permit, x has an incentive to purchase, while y has an incentive to sell permits so long as the permit price is greater than their marginal abatement cost. Therefore source x will buy permits and increase its emissions from A – 0.5A to A – 0.25A, while source Y sells permits and will reduce its emissions from A – 0.5A to A – 0.75A. As a result the marginal cost of reducing emissions is equalized across the sources of emissions and the overall cost of reducing emissions is minimized (Prato 1998).

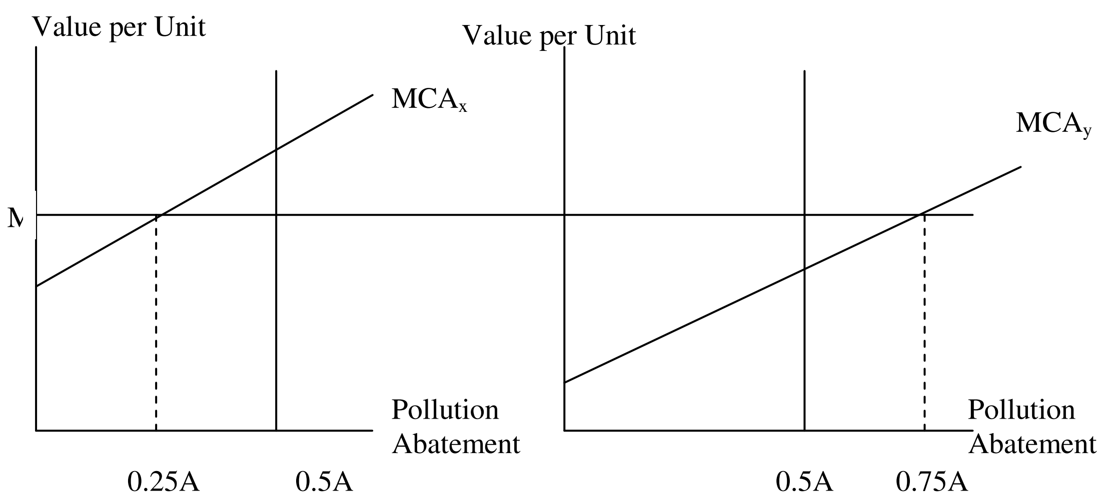

Figure 1: Market for Tradable Emission Permits

Source: Prato (1998)

Much of the research to date on tradable emission permits has been largely theoretical. While the majority of the applied literature has focused on trading permits for the following airborne emissions SO_2, CO_2 and waterborne nitrates emissions. De Cara et al. (2005) used a combination of mixed integer and linear programming to model the emissions of methane and nitrous oxide from regionally representative EU farms. They then examined the magnitude of emissions abatement costs. They concluded that there was a significant variability in abatement costs and that there was potential for emissions trading to reduce the cost of emissions abatement. Carlier et al. (2005) used simulation models of the Flemish pig finishing sector to compare the performance of a system of tradable permits with a command and control approach to achieve compliance with the EU Nitrates Directive. They found that the costs of satisfying the Nitrates Directive were 88 percent lower under the tradable permit system than under the most efficient command and control approach. Both analyses suggest that allowing farmers to trade emissions permits could provide the opportunity to reduce the cost of emissions abatement. Brannlund et al. (1998) examined the impact that allowing producer within the Swedish pulp and paper industry to trade permits and found that profits in the industry would have been 6 percent higher in 1989 and 1 percent higher in 1990 under a tradable permit system.

The EU's current preference is for command and control environmental policy as it relates to agriculture. Dietz and Heijnes (1995) argued that these policies in EU member states are neither effective nor efficient. This raises the question of whether or not market based policies would be more effective and efficient in reducing emissions. Advocates of emissions trading argue that it presents a least cost means of emissions abatement. Applied work such as Carlier et al. (2005) and De Cara et al. (2005) would appear to support this argument.

3. Data and Methods

The European Unions Greenhouse Gas Emission Trading Scheme (GGETS) began operating in January 2005; however this scheme does not allow farmers to trade emissions permits and to date no such tradable permits scheme has been introduced for Irish farmers. Therefore this analysis assumes that Irish farmers are restricted to trading permits of CO_2 equivalents with other Irish farmers and one emission permit is the equivalent of one tonne of CO_2. In the absence of any historical data on the value and volume of permits traded a normative modelling process was necessary. For this reason a linear programming approach was used and as noted by Jones (1982), such approaches are quite useful in modeling behaviour under conditions which are outside the range of past experience and which therefore cannot be modeled by more positive techniques such as econometric models.

A farm level linear programming model similar to those in Breen et al. (2005) will be constructed based on data from the Teagasc National Farm Survey (Connolly et al. 2007). The model will simulate the future behaviour of Irish farmers under a baseline scenario of no reduction in greenhouse gas emissions along with two scenarios where greenhouse gas emissions are constrained. In the first of these two scenarios farmers will have to reduce their greenhouse gas emissions by 20 percent and in the second scenario farmers will again have to reduce their greenhouse gas emissions by 20 percent however they will be allowed to trade emissions permits. We can then determine the impact of permit trading on future farm profit. The results of these two scenarios will then be compared with a baseline scenario where there is no restriction on greenhouse gas emissions. Models of this type have been used recently to analyze the impact of a number of agricultural policy scenarios on Irish farmers. Breen et al. (2005), Breen and Hennessy (2003) and Thorne (2004) used farm level modes to assess the impact of the 2003 CAP reforms on Irish farmers. Hennessy and Thorne (2006) and Hennessy et al. (2005) used similar approaches to look at the impact of WTO reforms and the EU Nitrates Directive respectively on the income of Irish farmers.

The NFS is a member of FADN, the Farm Accountancy Data Network of Europe. It surveys approximately 1,200 farms nationally that are weighted to represent the total population of over 100,000 farms. A linear programming model is constructed for each individual farmer within the sample. Linear programming is an optimization tool in which we maximize or minimize an objective function subject to a given set of constraints. In this study it is assumed farmers are profit maximizers and will seek to maximize their gross margin each year for a nine year period. Figure 3 outlines how such a modeling system may operate. The model will include all of the main livestock and crop enterprises in Ireland. Farmers will be subject to a number of constraints including land, labour, capital, land type, milk quota, policy related constraints and environmental constraints. The input-output co-efficients used are those recorded in the base year and are assumed to remain fixed through time despite policy changes; in other words for any given production process only one combination of the factors of production is assumed. The model therefore will solve for the optimal mix of enterprises subject to the specified constraints. The model projects the gross margin for each farm as well as the level of emissions per farm and thus allowing the impact of emissions trading on these criteria to be assessed.

The model also uses aggregate projections from the FAPRI-Ireland model (Binfield et al 2007) this allows us to simulate farmer behaviour across a nine year time period and to model the impact of policy changes on emissions in the context of permit trading and no permit trading. The FAPRI-Ireland model is comprised of a set of individual econometrically estimated commodity models that are linked and solved simultaneously.

The farm-level linear programming model is represented by the central box in figure 3. The farmer's production decisions will be constrained by the existing supply of land, labour, and capital. Farmers' decisions will also be constrained by agricultural and environmental policy from the EU and Ireland and these are represented by the upper right and upper central box of figure 3. A number of likely farm activities are specified for each farmer based on their existing activities and other possible activities. However non dairy farmers will not be allowed to enter milk production, as they currently do not possess milk quota. The net revenue of each of these activities will be estimated and projected prices from the FAPRI-Ireland aggregate level model as represented by the box in the top left hand corner of figure one will be used in calculating the gross margin per enterprise across a nine year planning horizon. This will allow the linear programming model to be run each year for a nine year period and so changes in farm size, profit and farm numbers due to permit trading can be determined. The marginal revenue of carrying an additional livestock unit or growing an additional crop acre will be estimated and the optimal farm system for each farmer will be determined.

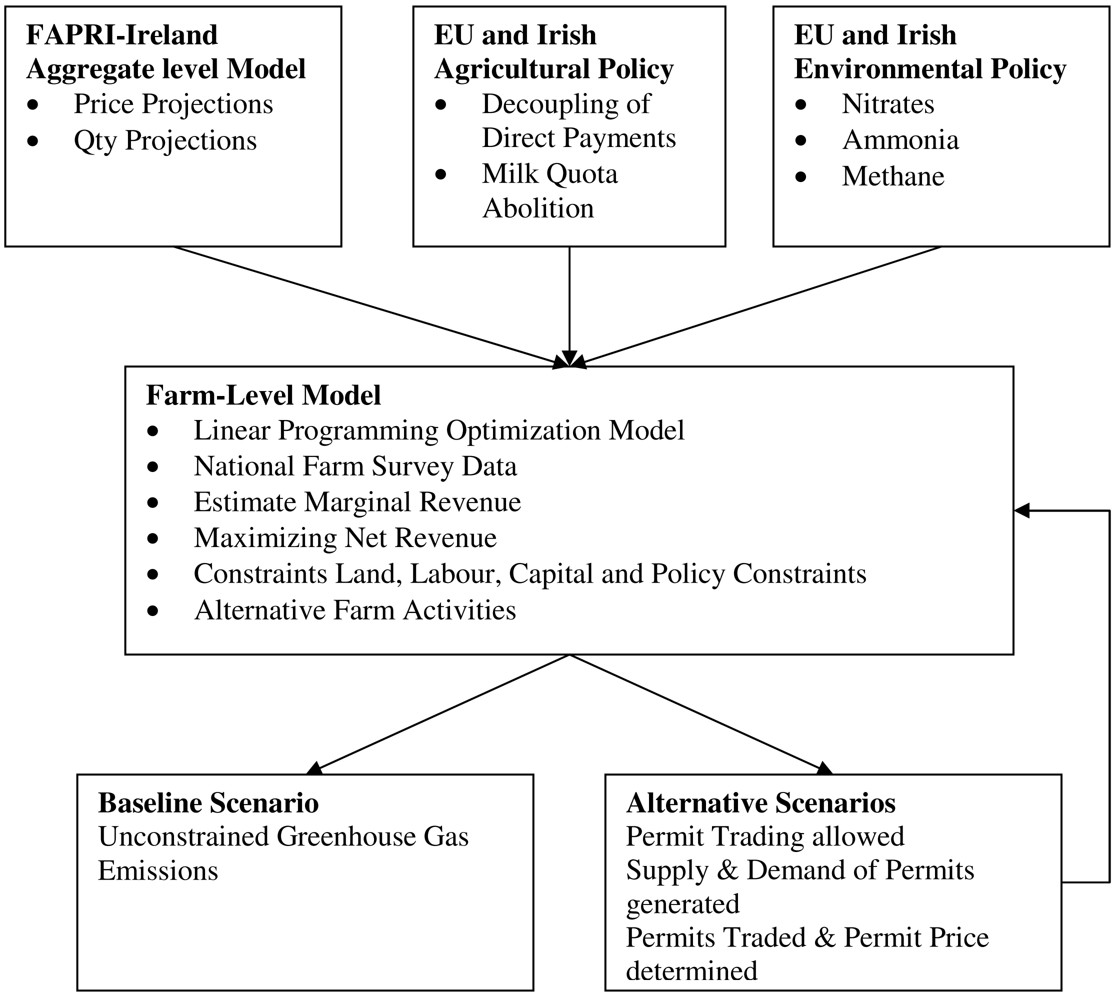

Figure. 3: Conceptual Framework for Model Irish Farm-Level Greenhouse Gas Emissions and Tradable Emissions Permit

Total emissions per farm will be calculated for each farm by multiplying livestock units by the equivalent emissions coefficients. Methane coefficients will be taken from the Intergovernmental Panel on Climate Change (IPCC) (1996) and the Department of the Environment (1997) as was done in Donnellan and Hanrahan (2003). There are five main types of greenhouse gas emissions from Irish agriculture and these include methane from enteric fermentation and manure management, nitrous oxide from manure management, nitrous oxide from agricultural soils and nitrous oxide from the use of chemical fertilizers. This analysis currently contains all of these emission sources with the exception of nitrous oxide from fertilizer. The incorporation of nitrous oxide from fertilizer will require the estimation of an econometric model to measure the relationship between fertilizer use, stocking rate and animal type and this will be the next stage in the analysis. However it should be noted that CO_2 from the breakdown of fertilizer accounts for less than 3 percent of total emissions from Irish agriculture.

Initially a baseline scenario where greenhouse gas emissions are unconstrained will be run as is shown by the box in the lower left corner of figure 3. The results of the permit trading scenario studied will then be compared against this baseline scenario. Once the gross margins and the optimum enterprise mix for each farmer has been estimated we can then determine the shadow value of an emissions permit. These shadow values will then be used to estimate the supply and demand curve for permits amongst Irish farmers and a market for emissions permits will be simulated. From this the quantity of permits traded and the equilibrium price for a permit will be determined, this is represented by the box in the bottom right of figure 3. Shrestha et al. (2006) used a similar approach to simulate a market of Irish milk quota. As shown in figure 3 the quantity of permits bought or sold by each farmer in year one will feed back into the farm level linear programming model and the farmers environmental constraint will then be adjusted by the number of permits they traded. The linear programming model will then be resolved and a new optimum farm mix based on maximizing gross margin subject to the new environmental constraints specified above. This process will be repeated for the remaining years. The impact of an emissions reduction on farm income can be compared with a baseline scenario where there is no enforced reduction in greenhouse gas emissions and the potential of permit trading to offset some of this loss in income can then be assessed.

Results

The model allows us to compare farmer gross margin under alternative policy scenarios. The results of three scenarios are presented the scenarios are called Unconstrained, 20% Reduction and TEP's. Firstly the "Unconstrained" scenario is run utilizing FAPRI-Ireland baseline projections in this scenario there is no constraint on individual farmers' greenhouse gas emissions. The "20% Reduction" scenario requires farmers to reduce their emissions by at least 20 percent of their historical level. In the "TEP's" scenario farmers are issued with a number of tradable emissions permits equivalent to 80 percent of their historical production which they are allowed to trade with other farmers. It is assumed that farmers emission levels are constrained under the 20% Reduction and TEP's scenarios from 2009 onwards. The impact of all three scenarios on average farmer gross margin is presented.

Figure 4 below illustrates the supply and demand curves for tradable emission permits in 2011. A supply and demand curve for tradable emissions permits was estimated from the farm-level LP model and a market for emissions permits was simulated for each year between 2009 and 2016. As can be seen from Figure 4 below the market clearing price in 2011 was €59.52 per permit and approximately 2.6 million permits would be traded at this price.

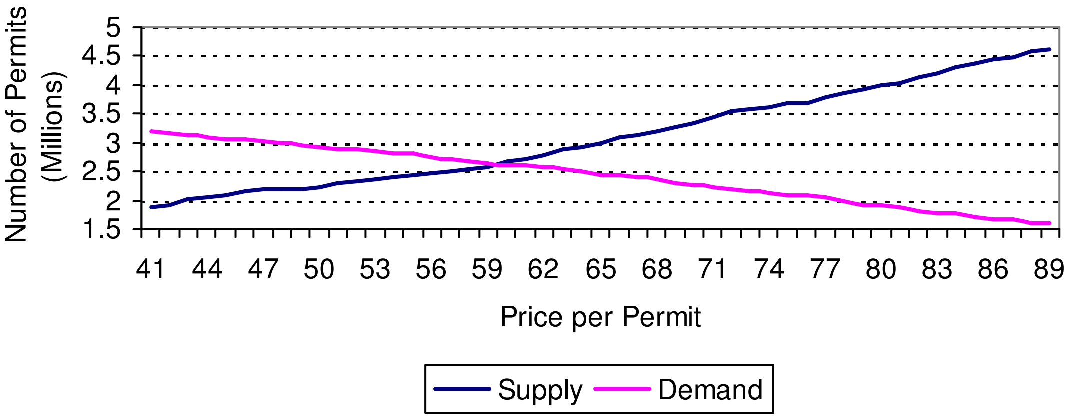

Figure. 4: Simulated Market for Tradable Greenhouse Gas Emissions Permits

Source: Authors Own Calculations

Figure 5 illustrates the market clearing price per year for permits over the period 2009 to 2016. The market clearing price for permits is at its highest in 2009 at approximately €67 per permit and declines gradually to approximately €55 per permit by 2016. The projected market clearing price under the simulated market is significantly higher than the market clearing price in the European Unions Greenhouse Gas Emission Trading Scheme (GGETS) in 2007, where the prices for permits did not exceed €20. The reason for this higher price in the simulated market is largely due to the fact that the restrictions being enforced are far more binding than those in the GGETS, secondly this analysis does not currently consider the potential of other abatement strategies such as improving the milk production per dairy cow. This reduction in the market clearing permit price over time is largely a result of the decline in gross margins to the dairy sector as a result of decreasing milk prices and increasing variable costs of production. This reduction in dairy gross margins causes the demand curve to shift downwards in later years.

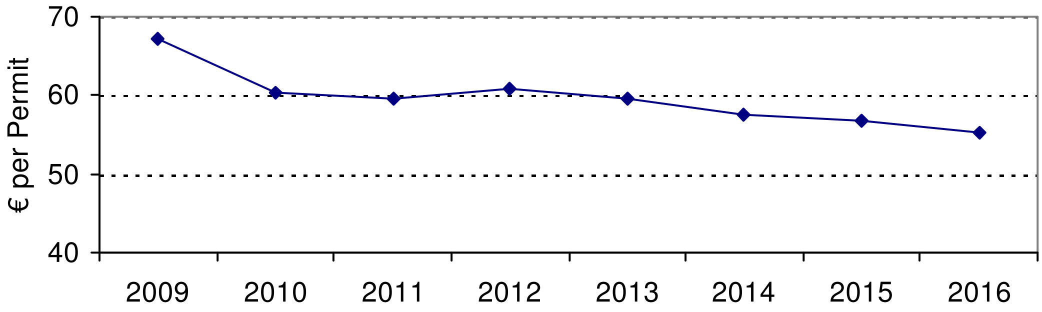

Figure. 5: Market Clearing Price for Tradable Greenhouse Gas Emissions Permits 2009-2016

Source: Authors Own Calculations

Figure 6 compares the impact of the three scenarios on dairy farm gross margin. As can be seen average gross margin per dairy farm under the unconstrained scenario declines from approximately €57,000 in 2008 to approximately €45,000 by 2016. This decline in dairy farm gross margin is largely a result of the decline in dairy prices that was projected under the FAPRI-Ireland baseline scenario. If farmers are forced to reduce their greenhouse gas emissions to 80 percent of the historical level then average gross margin on dairy farms will be approximately €9,000 below their level in the unconstrained scenario a reduction of 20 percent. The loss in average gross margin per farm is highest on dairy farms; this is to be expected given the high levels of methane produced by dairy cows and the high gross margin per cow. In comparison if farmers are allowed to trade permits the average gross margin on dairy farms is approximately 2 percent lower than under the unconstrained scenario or a reduction of approximately €1,000 per year.

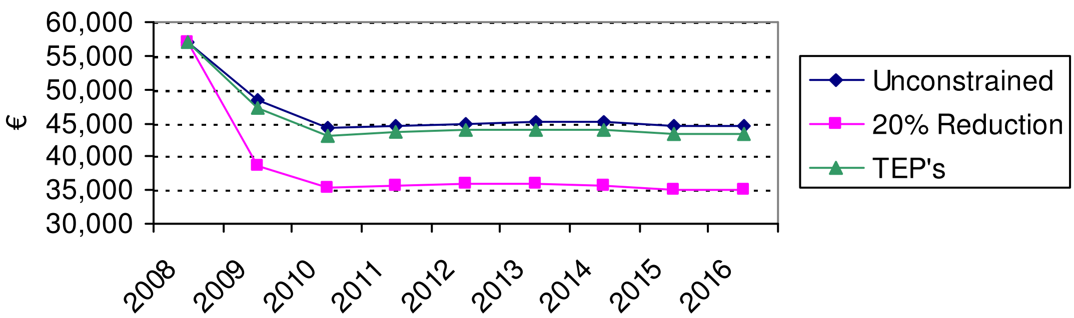

Figure. 6: Impact on Average Dairy Farm Gross Margin of Alternative Greenhouse Gas Emissions Scenarios

Source: Authors Own Calculations

Figure 7 projects the change in average gross margins on beef farms. The average gross margin on beef farms in 2008 is approximately €11,000 per farm and this average gross margin is projected to change very little under the unconstrained scenario. This is a result of a moderate increase in beef prices under the baseline scenario and increasing direct costs of production. When we compare the 20% reduction scenario we see that average gross margin is projected to decline by 44 percent to approximately €6,000. While the actual reduction in gross margin is lower than on dairy farms it is the largest percentage change in projected gross margin by farm type. Beef farms in Ireland are typically mixed farms while the principal enterprise is beef production they are also likely to have some sheep and/or tillage. As a result on the majority of beef farms their historical greenhouse gas emissions level is lower than if they had only kept beef animals. Therefore when the 20 percent reduction in greenhouse gas emissions is enforced these mixed beef farms find themselves to be more constrained than they would have been if they had only stocked beef animals in the historical reference period. This is the main reason for the large decrease in the average farm gross margin. When farmers are allowed to trade permits we see a significant increase in average gross margins on beef farms, the average gross margin in the permit trading scenario is approximately 84 percent of the average gross margin under the unconstrained scenario compared with 56 percent under the 20% reduction scenario. However it should be noted that over 50 percent of beef farmers become suppliers of permits to the market and this accounts for some of the increase in average gross margin.

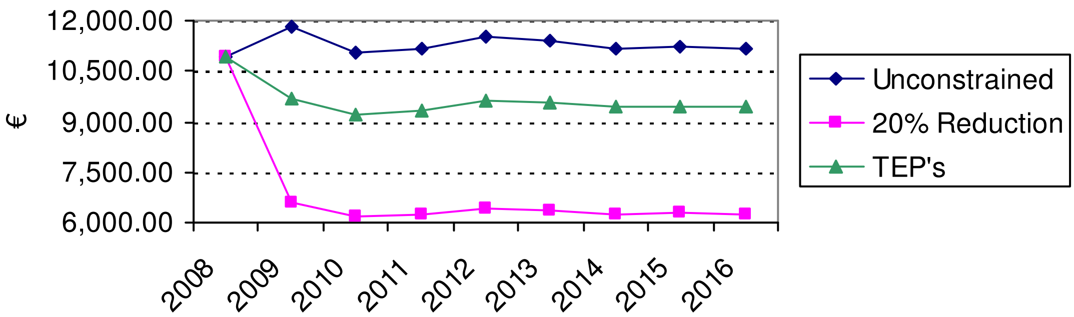

Figure. 7: Impact of Average Beef Farm Gross Margin of Alternative Greenhouse Gas Emissions Scenarios

Source: Authors Own Calculations

The story for sheep farms is to some extent the converse of what is projected to happen on beef farms. As with beef farms, the average gross margin on sheep farms is projected to change very little under the baseline unconstrained scenario. However in contrast to the beef sector the impact of the 20% reduction scenario on sheep farms is quite small. The reason being that many specialist sheep farms historically would have kept beef animals also and therefore when the reduction in emissions is enforced it is not binding on many of these farms. As a result average gross margin declines by only 6 percent compared with the unconstrained scenario, furthermore when farmers are allowed to trade emissions permits average gross margin on sheep farms would be largely unchanged when compared with the unconstrained scenario.

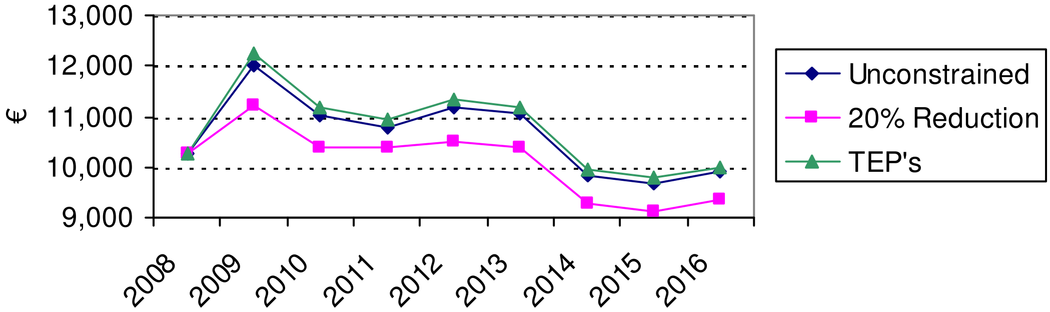

Figure. 8: Impact on Average Sheep Farm Gross Margin of Alternative Greenhouse Gas Emissions Scenarios

Source: Authors Own Calculations

The average gross margin per farm for cereal farms under the Unconstrained scenario is projected to decline from approximately €38,400 in 2008 down to €37,600 in 2016. Under the 20% Reduction scenario the average gross margin on cereal farms is projected to decline by about 10 percent. Many cereal farms would also have built up a substantial base emissions level by stocking beef animals and as a result the required reduction in emissions level from 2009 onwards is not binding for many of the cereal producers. Hence the impact that the necessary reduction in greenhouse gas emissions is projected to have on their average gross margin is moderate under the 20% Reduction scenario. Once again if farmers are allowed to trade permits we see a significant increase in the average gross margin. The average gross margin on cereal farms under the TEP's scenario is 99 percent of the level earned under the unconstrained scenario.

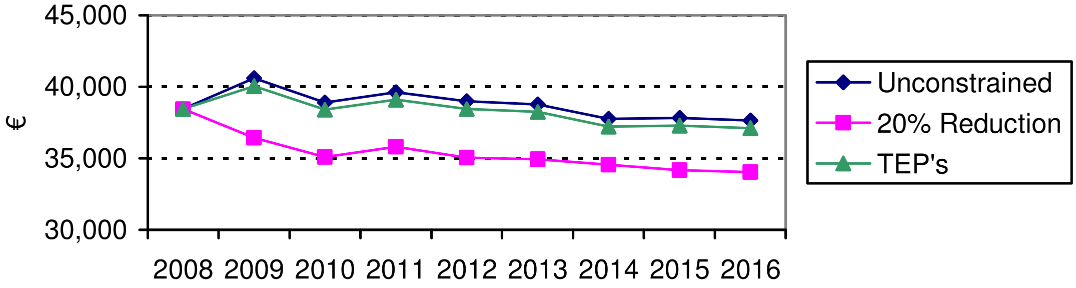

Figure. 9: Impact on Average Cereal Farm Gross Margin of Alternative Greenhouse Gas Emissions Scenarios
Source: Authors Own Calculations

Under the Unconstrained scenario there were almost 5,000 farmers with a negative gross margin. These farmers who are operating a market loss would find their Single Farm Payment being eroded by their loss making enterprise and so their optimal solution is to cease production while retaining their land in order to draw down their Single Farm Payment. However by doing this the only incomes to these farms are payments and subsidies such as the Single Farm Payment. Therefore under both the Unconstrained and 20% Reduction scenarios the average market based gross margin earned on these farms would be zero if they cease production. However if these farmers are allowed to trade the permits that they would have based on their historical production then they would provide an additional source of income. Figure 10 below projects the increase in income earned by these non-productive farmers from 2009 to 2016. In 2009 the average income earned is almost €5,700 compared with almost €6,800 by 2016. The income earned has increased over time despite a decrease in the market equilibrium price for permits. The reason for this change in income earned is due to changes in the number of those farmers who are earning a negative gross margin.

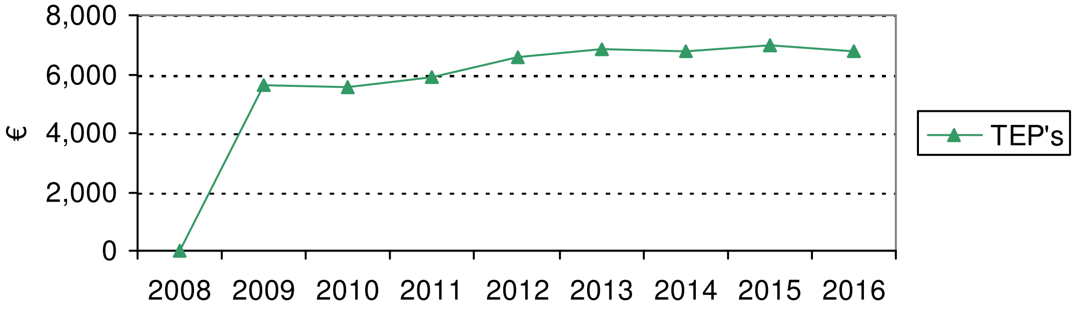

Figure. 10: Increase in Income of Non-Productive Farms from Tradable Emissions Permits

Source: Authors Own Calculations

Conclusions

The analysis presented above outlines the potential impact of a restriction in greenhouse gas emissions from agriculture. If a 20 percent reduction in greenhouse gas emissions relative to their historical base emissions was enforced at the farm level, the dairy sector would face the greatest reduction in average gross margin. This is to be expected given that firstly dairy cows are amongst the largest producers of greenhouse gas emissions and secondly the gross margin per livestock unit is higher on dairy farms than on other farms. The average gross margin on beef farms is projected to decline by €5,000 or 44 percent as a result of the 20 percent reduction in greenhouse gas emissions. This would appear to be a disproportionately large effect given the reduction in emissions that is enforced. However this reduction in gross margin reflects the fact that historically beef farmers in Ireland devoted some of their land to the production of sheep and/or cereals both of which have relatively lower emissions coefficients than beef production. As a result many of Irelands beef farmers will have a historical level of emissions that is much lower than the level they would have if they had only stocked beef animals. In comparison the projected percentage decrease in average gross margin on sheep and cereal farms is much smaller at approximately 6 and 10 percent below the unconstrained gross margin respectively. The reason for this relatively small impact is that many of these farmers will have kept beef animals in the reference year and as a result they have acquired more emissions permits than they would have if they devoted their land entirely to the production of sheep or cereals. As a result an enforced emissions reduction of 20 percent would have little impact on many of those farmers whose optimal solution is to specialise in the production of sheep or cereals.

The results suggest that permit trading can lower the cost of reducing greenhouse gas emissions from Irish agriculture. For all four farm types the average gross margin is higher when the agriculture sector is allowed to achieve its greenhouse gas emissions reductions by allowing farmers to trade permits. The most significant gains are seen on dairy and beef farms where the percentage decrease in average gross margins is much smaller when they are allowed to trade permits. If farmers are allowed to trade emissions permits then the average gross margin on dairy farms falls by approximately 2 percent in the permit trading scenario compared with a 20 percent reduction in the average gross margin when no permit trading is allowed. The percentage decrease in average gross margins for beef farms would be 16 percent if they are allowed to trade permits compared with 44 percent if they are not allowed to trade permits. The change in average gross margins on sheep and cereal farms is negligible as a result of allowing farmers to achieve their emissions reductions by trading permits. Finally the other significant gain from allowing farmers to trade permits is made by those farms with a negative market gross margin the income on these farms would be almost €7,000 higher in 2016 if they were allowed to supply permits to a greenhouse gas emissions market.

As stated the next stage in this analysis is to incorporate the production of CO2 emissions from the breakdown of chemical fertilizer. In order to do this an econometric model will be used to estimate the relationship between fertilizer application and stocking density and animal type. This will allow the model to adjust individual farmer’s fertilizer use as the farmer changes his stocking rate and the type of animals kept on the farm. This model will be estimated using a pooled dataset from the NFS collected over the years 2002 to 2006. Once this is completed the impact of alternative abatement strategies such as improving the genetic merit of the animal, changing animal diet and minimum tilling will be included in the analysis and the permit market will be re-simulated.

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