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Modelling the Gross Cost of Transporting Pig Slurry to Tillage Spread Lands in a Post Transition Arrangement within the Nitrates Directive

Reamonn Fealy[1*], Cathal O'Donoghue[1], Kevin Hanrahan[1],

Michael Martin[2] and Rogier P.O. Schulte[3]

1. *Teagasc Rural Economy and Development Programme, Athenry, Ireland*

2. *Teagasc Pig Development Department, Athenry, Ireland*

3. *Teagasc Crops, Environment and Land Use Programme, Johnstown Castle, Wexford, Ireland*

*corresponding author: Reamonn.Fealy@teagasc.ie

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Abstract

The context of this paper is in the phasing out of the transitional arrangement under the Nitrates Directive. As there is relatively little grassland capable of taking significant amounts of pig slurry available in the vicinity of the main pig production areas, in this paper we attempt to quantify the cost of transporting this slurry to the nearest available tillage land. The approach taken was to examine the geographic structure underlying the pig sector in Ireland using Geographic Information Systems (GIS) technology. The study highlighted the differential cost with, amounting to 10% of gross margin on average and as high in major pig producing areas as 21.5% in Longford and 16.6% in Cavan, while lower at 7-9% in South Tipperary and Cork. Thus while the problem is significant, the impact is not constant across the country, highlighting the value of a spatial analytical approach. Future work should assess the existing cost of spreading manure in order to be able to ascertain the net cost of spreading on tillage lands. The robustness of the results also need to be tested to assess the implications of changes in the prices of fossil fuels and fertilisers, both in terms of the cost function and in terms of the cost of substitutable mineral fertiliser

- Corresponding Author: Email: reamonn.fealy@teagasc.ie

1. Introduction

The context of this paper is in the phasing out of the transitional arrangement under the Nitrates directive, whereby pig producers could spread slurry on farm land up, subject only to maximum available nitrogen (N) application rates, but were not bound by phosphorus (P) limits. As there is relatively little grassland capable of taking significant amounts of pig slurry available in the vicinity of the main pig production areas, in this paper we attempt to quantify the cost of transporting this slurry to the nearest available tillage land.

Economic Structure of the Pig Sector

The pig sector is a relatively important part of the Irish agricultural economy. The share of total goods output value at producer prices that is accounted for by the sector varies from one year to the next but has generally been in excess of 6% (Central Statistics Office (CSO)). This means that, when measured in output value terms, pig production is the third most important sector of Irish agriculture after cattle and milk production.

As noted by Fealy and Schroeder (2008), a characteristic of Irish pig production has been the structural change that has occurred in recent decades. The CSO data shown in Figure 1 illustrate that the proportion of pig farms with in excess of 1000 pigs has climbed as the number of pig farms has fallen. In 2007 there were approximately 800 hundred farms with pigs in Ireland. However over 90 percent of pigs are found on farms with in excess of 1000 pigs which in 2007 accounted for approximately 40% of pig farms (approximately 320 farms).

The importance of pig production varies considerably by region. The most up to date regional dis-aggregation of Irish agricultural output value is that contained in the CSO (2008) *Regional Accounts for Agriculture*. In 2008 the share of pig output in total agricultural output at producer prices varied from less than 2% in the West to over 11% in the Border region. The economic impact of the pig farming sector relates not only to the pig output, but also to its upstream linkages to suppliers and downstream linkages to processors. For pigs domestically processed according to Miller et al (forthcoming), each euro of pig production results in a further 2.95 euro of output in the processing sector. As these businesses are located primarily in rural towns around the country, they provide an important contribution to the rural economy. Overall the input, production and processing sectors account for 7500 jobs.

The Border region accounts for the largest share of the Irish pig herd (32%) while the South East, South West and Midlands region account for between 16% and 19% of the herd. In 2009 there was a dramatic decline in the number of pigs in the South West Region. This decline is most likely due to the precautionary culling of 170,000 pigs in 2009 in response to the dioxin crisis (DAFF, 2010). In recent years the South-West region has had second largest share of the national pig herd.

Information on the relative importance of pig farming at the level of county is published in the Census of Agriculture. Two counties dominate pig production in terms of sow/pig numbers. Both Cavan and Cork have just over 28,000 sows each out of a total herd of 149,400 (Table 2). The most recent data that are available are from the 2000 Census. At a national level the ratio of the number of pigs to ruminants (cattle and sheep) is equal to 0.12. Only 4 counties have a ratio of 0.2 or more, with

Cavan having a ratio of over 1. This illustrates the importance of the pig sector to the county of Cavan in the border region as well as its unusual dependence, in an Irish context, on the pig sector.

The profitability of pig farming, like all other farming activities, depends on the relative levels of output value to input costs per unit of output. Martin (2010) reports that a margin after accounting for feeding costs of 50 cent per kg deadweight is needed to cover non feed costs, provide a minimal return on investment and provide resources with which to meet increased welfare and environmental compliance costs.

The average margins over feed that have been earned by the Irish pig farms surveyed by the state Agriculture and Food Agency, Teagasc's have been at or below the 50 c per kg threshold, around 48c per kg in recent years (Martin, 2010), suggesting that, on average, the levels of profitability per kg of meat produced are low. The low levels of profit per kg explain the large concentration of Irish pig production that has occurred in the last 30 years. Lara, Kelly and Lynch (2002) found that Irish pig production was competitive relative to the UK, Denmark and the Netherlands on the basis of lower non-feed costs. However they pointed to increases in non-feed costs that would arise from compliance with environmental and animal welfare regulations that would likely erode the competitive position of Irish pig production.

The average margins reported by Martin (2010) suggest that increases in costs associated with compliance with environmental and welfare regulations would, other things equal, lower the profitability of Irish pig production. Differences in the costs structures of pig farms will mean that the impact on profitability per kg of meat and production of compliance with environmental and welfare regulations will differ. The challenge for the average Irish pig farm is to reduce costs of production such that even with compliance with environmental and welfare regulations a sufficient margin over feed costs remains with which to remunerate labour and capital employed in the farm business.

The Nitrates Directive: impact on spreading of pig slurry on tillage spread lands

Of particular concern to the economics of the pig industry is the phasing out of of the transitional arrangements within the Nitrates Directive (91/ 676/ EEC). The Nitrates Directive was implemented in Ireland in Statutory Instrument (S.I.) 378 of 2006, and updated in Statutory Instrument 101 of 2009 (Government of Ireland, 2009). Referred to as the "European Communities (Good Agricultural Practice for Protection of Waters) Regulations 2009", these regulations gave statutory effect to Ireland's national Nitrates Action Programme. The regulations mandate the 170 kg organic nitrogen limit as set out in the Nitrates Directive (91/ 676/ EEC) but also regulate a range of additional farm practices including detailing minimum slurry storage capacity, closed spreading periods on a regional basis and introduce an upper threshold on land application based on P. The key principle in the regulations underlying the application of manures to land is based on crop requirements for nutrients. A restriction on spreading according to a P limit is primarily related to a soil P index system (Table 2) which is based on the measured level of available P in soil as determined by the Morgan's P test (Morgan, 1941).

A four year transitional arrangement that ended in December 31st, 2010 applied to pig and poultry manures and spent compost from the Mushroom industry (Schulte, et al., 2010). The transitional arrangement allowed the spreading of these waste products to be subject only to the Nitrogen part of the regulation that restricts the application of organic N to 170 kg per hectare and not the P limits of the Directive.

The ending of the transitional arrangement was likely to increase costs for pig farmers due to having to transport pig slurry to tillage farms, which have a relatively high absorption capacity for P and grassland farms that can import sufficient quantities of P under the P regulations. Of particular concern to the pig sector was the possible effect that the regulations would have on large producers and their requirements for handling annual slurry output. It was feared that the 170 kg N limit imposed by the Nitrates Directive would lead to a decrease in the availability of land to pig producers for slurry spreading. It could be argued that this fear has in the main been realised with many grassland farmers unwilling to engage with the perceived bureaucracy involved in securing approval for taking in pig manure. The licensing and recording requirements for these customer farmers have been the subject of protracted negotiations between the farmer representative organisations and the governmental agencies with statutory responsibility in this area.

A general response to the sector's concerns was that the pig sector could shift the focus of land spreading to arable areas (DAFF 2004). Farmers whose enterprise is exclusively tillage-based with no animals on farm have a natural advantage in their capacity to accept animal manure over those with mixed arable-livestock enterprises. The pro-regulatory argument for an arable land based solution to the issue of pig manure holds that with 10% of the national land area in crop production, there should be ample land available to take the national output from pig producers. In response the pig sector argued that the concentration of the industry in the Border area and the lack of arable land in this region could lead to the demise of the industry.

The Nitrates Action Programme was reviewed in 2010, and a second Action Programme has come into effect as S.I. 610 of 2010. In this second programme, the existing transitional arrangements for pig and poultry manure and spent mushroom compost (SMC) were extended until 31 December 2012. From 1 January 2013 onwards, spreading of pig and poultry manure and SMC will be subject to maximum available P application rates; from 1 January 2013, P in aforementioned organic materials may be applied at excess rates of 5 kg ha^{-1}; from 1 January 2015 this surplus will be reduced to 3 kg ha, and from the 1 January 2017 the transitional arrangements will come to an end, with no further P excess allowed for pig and poultry manure or SMC.

The short-term extension of transitional period effectively recognised the difficulties that implementing the regulations would have on the pig sector. However, with the imminent phasing out of the transitional arrangements, the difficulties arising from the location of enterprises geographically removed from arable lands remains to be resolved.

The phasing of the transitional period would pose significant restrictions to the use of grassland as recipient land for pig and poultry slurry. From 2013 onwards, slurry application rates will not only be limited by organic N loadings, but in addition by total P loadings. Where recipient grassland fields are assumed to be in the target Soil P Index 3, the annual ‘maximum fertilisation rate’ of P is restricted to between 15 and 29 kg ha^{-1}, depending on grassland stocking rate. This includes P inputs from bought-in concentrates and “home-produced” slurry. Once these P inputs are accounted for and deducted from the maximum annual total P input, the amount of P that may be brought onto the holding in the form of either fertiliser or externally produced slurry /

manure, amounts to less than 10 kg ha^{-1} for a wide range of farm scenarios up to 2015, 8 kg ha^{-1} up to 2017, and less than 5 kg ha^{-1} afterwards. This is considerably lower than the amounts that can be brought onto tillage land.

While other papers such as Fleming et al, (1998) have looked at the economics alternative pig slurry management methods, in this study we shall focus on the transport economics of moving pig slurry from pig farms to tillage farms and not grassland farms. The approach taken in this research is thus to examine the geographic structure underlying the pig sector in Ireland using Geographic Information Systems (GIS) technology. GIS has been used previously to examine the manure to arable land issue, perhaps most comprehensively by the USDA in their study on the Chesapeake Bay area (Ribaudo et al., 2003). While the USDA study provides a detailed modelling approach to optimising the economic aspects of slurry distribution, the underlying distance transport functions are based on straight line distances.

In view of the cost of hauling and applying manure there are varying opinions on whether the enterprises producing significant quantities of manure in Ireland are within economic distance of suitable arable land or not, with a generally argued belief that they are not. Evidence suggests that the national distribution of these pig enterprises places some at least close to tillage land, which is considered potentially suitable for spreading. However, a comprehensive analysis has not previously been completed to describe this national distribution or the spatial relationships with available arable land. Given the low incidence of tillage farms in the border area where the pig sector is disproportionately located, this is likely to impost a significant cost, albeit this cost is an upper bound as some pig slurry is likely to be spreadable on grassland farms willing and able to take pig slurry.

2. Materials and Methods

Due to data limitations, we focus in this study on the gross cost of transporting pig slurry and not the net cost. The gross cost relates to the costs of transporting pig slurry from a pig farm to a tillage farm. If one were to model the net the cost, one would need to know the current cost of spreading slurry on existing spread lands and also whether there is fee to spread pig slurry on a tillage farm which would increase the net cost, or conversely, given the rising cost of mineral-based P fertiliser, whether a fee may be received for spreading the pig slurry, which would result in a reduced net cost.

Modelling the transport cost to a pig farm of spreading slurry on a tillage farm requires a number of components. We require both the location of the pig farm and potential location of all parcels of tillage land that might accept the slurry, the probability of acceptance, data on the road network to determine the distance between pig farm and tillage farm, the quantity of slurry produced by each farm to determine the demand for spread land, an algorithm to locate the closest tillage parcel and a transport cost algorithm to estimate the total cost per farm.

In this study, we draw upon the earlier work of Fealy and Schroeder (2008) who developed a methodology for modelling the distance between pig farms and tillage farms and McCutcheon and Lynch (2008) who produced estimates of potential transport cost per kilometre. In this paper drawing upon these methodologies, we model the total cost associated with moving pig slurry to the closest possible tillage farm.

The research reported here was undertaken using the most highly resolved geographic location data available nationally for each of the key datasets. The research has utilised an advanced GIS technique to provide a network analysis of mapped roads data. Using such an approach a high definition transport distance dataset has been developed which approximates the real along-road distances between the major pig producing enterprises and arable land in Ireland.

The Location of Pig Farms

In Ireland the primary source of geographic data for the agriculture sector is the Central Statistics Office (CSO). The main reference product from the CSO is the Census of Agriculture which is undertaken on an approximate ten year interval. The latest census was taken in 2000. These data are augmented by surveys on an annual or biannual basis for various parts of the sector. The geographic unit of distribution of the CSO data is the Electoral Division (ED) which is the smallest legally defined administrative unit in Ireland equivalent to the NUTS5 level as determined by Eurostat (Council Regulation (EC) No. 1059/ 2003). (Recent modifications to the Eurostat coding would place EDs in Ireland in the Local Administrative Unit 2 category). There are 3,440 defined EDs in Ireland and with an average area of approximately 3,000 ha the ED geographic unit can prove challenging for high resolution analysis.

The location data for pig holding facilities was obtained from the Teagasc database on pig production facilities was used. With production details of approximately 400 of the largest enterprises this was deemed suitability representative of the higher output end of the production spectrum in Ireland.

To locate the enterprises accurately for GIS analysis, an address matching completed successfully. This required the cross matching of 3 databases: the Teagasc Pig Development Unit enterprise database which contained address information and herd structure details; a database of NPITS herd number and spatial location information and a database of NPITS and address information. As with all address databases there were a significant number of anomalies in these databases which required substantial intervention to resolve address coding conflicts. In some cases reference to underlying historical 1:2,500 raster mapping where original district names were visible and were absent from more modern mapping was employed. In one particular case a reference to a Dáil debate contained in the Oireachtais archives enabled the resolution of an addressing conflict. The resolution and finalisation of 400 addresses to a very high level of geocoding accuracy and resolution (estimated 98% accuracy) took almost 4 weeks.

Geographic data required on available arable land.

The most spatially resolved and detailed data available on enterprise location in Ireland are contained in the Land Parcel Identification System (LPIS) dataset. The LPIS data are a major constituent of the mandated control systems for agriculture payments in Ireland administered under the Integrated Administrative Control System (IACS) rules. In Ireland the LPIS data are managed by the Department of Agriculture Fisheries and Food. The spatial data were created by digitising aerial-derived ortho-photographs captured at 1:40,000 scale and are updated manually every year based on farmer applications for the Single Farm Payment. The data are held in an Oracle database with distribution provided through export to a spatial data format such as ESRI Shapefile. In general the LPIS data are maintained on a restricted access basis, primarily in deference to farmer confidentiality concerns. LPIS parcel polygon midpoints were determined using the GIS and assigned to the vector linework of the digital roads dataset. This was to facilitate the determination of loading along the network dataset and to enable the allocation analysis.

Geographic data required on road networks.

The adequate spatial representation of a national roads network is of particular importance to the research presented here. A key consideration is the requirement that any such roads data would be topologically correct. In GIS, topology has been defined as referring to the connectivity of spatial entities (Burrough and McDonnell, 1998). In vector entities such as those that define a roads network the presence of arc and node topology is required where arcs constitute the road vector with a directional attribute and nodes represent junctions. Arc-node topology permits analysis across a network as the nodes and arcs are comprised of directional and connectivity pointers. In effect each element of the network is attributed in such a way that it contains data describing each of the other elements of a network to which it is connected.

A number of roads datasets are available. Companies such as Navteq and TeleAtlas are global suppliers specialising in the development and supply of PNDs, particularly for the on-board vehicle market segment. A key advantage of these datasets is that, by definition, they have inbuilt network topology. In Ireland, Navteq have created a national roads dataset and this has been used for the research reported here.

Willingness to accept slurry.

In modelling the location of potential tillage farms, we required not only the location of tillage farms, but also the likelihood of the tillage farm accepting the pig slurry.

There are a number of challenges to the acceptance of pig manure as a fertiliser replacement. While some of these could be perceived as deriving from possible inertia and lack of experience in handling pig manure as a fertiliser, other more justifiable concerns centre on the actual fertiliser value and the variability in nutrient content arising mainly from variability in the dry matter content of slurry. This variability influences both the utility of pig manure from a nutrient point of view but also has a significant impact on the transport costs per unit of available nutrient.

The negative sentiment towards the acceptance of slurry has been highlighted by a survey conducted by the National Farm Survey (NFS). The NFS is responsible for delivering Ireland's statutory data on farm output, costs and incomes on an annual basis to the EU-Farm Accountancy Data Network (FADN) in Brussels. The main aim of the National Farm Survey is to determine the financial situation across the broad spectrum of Irish farms by system and size. In 2006 additional questions were posed in the formal survey with the purpose of elucidating the willingness of the broader farming community to accept pig slurry onto their land. The results, weighted to national farm population level, showed 63% of all farmers across all farming systems would not accept pig slurry on-farm. However, only 37% of tillage farmers said they would not accept pig slurry. The majority of tillage farmers were willing to accept pig slurry but subject to certain conditions such as slurry being made available for free (35%); slurry freely available but would pay transport (23%) and 4% expressing a willingness to pay for both slurry and transport costs.

Modelling the Quantity of Slurry Produced

Manure production per pig livestock unit as determined legislatively by SI 101 (2009). Slurry production for each of the enterprises was estimated based on the pig numbers and the type of unit which was classed as either breeding, finishing or integrated (both breeding and finishing taking place on-site) units. The values used here for manure production per sow/pig place and associated P output are provided by Teagasc and closely approximate the values contained in S.I. 378 of 2006. The total P output per facility was determined by multiplying the production factors for P output by the number and type of pigs and the associated manure output value.

Locating the Closest Tillage Parcels

Identifying the location of the closest tillage parcel to each pig farm uses a GIS technique known as Network Analysis. Fischer (2004) and Curtin (2007) have argued that network analysis is one of the most significant and expanding research areas in geographic information science. While there are a number of references in the wider literature that report the use of network analysis for transport distance assessment in a GIS framework, most of these applications have tended to focus on resource allocation, and on issues in the health and education areas (e.g. Barbyn and Skelly, 2002; Dummer and Parker, 2004; Kalogirou and Foley, 2006).

The aim of the current research was to provide a network-based analysis of the location of large pig-producing enterprises in relation to potential arable land. Allocation-modelling, which is considered to be the most useful for this research, is the modelling of supply and demand through a network system. Supply represents a quantity of some resource or commodity that is located at a facility called a centre. Demand is the potential for the use of the resource or commodity. Allocation is the process bringing together demand and supply at one or more locations in space. Moeller-Jensen (1998) provides a description of location-allocation analysis as applied to the supply and demand of education facilities in Copenhagen.

While locating the closest tillage farm to each pig farm is not necessarily overly complex using Network Analysis tools, the computational requirement of this analysis is rather more complicated. As some of the pig enterprises are very large with significant volumes of slurry produced, they may require more than one parcel or farm to spread slurry. Again this is not necessarily complicated as it simply requires the area of spread land required. However the complexity rests in doing this simultaneously for all pig farms at the same time.

Fealy and Schroeder (2008) describe the algorithm used in some detail. Here we summarise the method. The algorithm used is essentially based on matching demand with supply. To match demand with supply, transportation or movement through the network must be modelled. The demand must be brought to the supply, or the supply must be brought to the demand through the network. In this case the network analysis is run in a form analogous to a population demand for a centrally available service where the demand point is assigned to the supply centre for the purposes of appropriate resource allocation.

The pig producing enterprises are considered as centres and have a supply term associated with them. The supply in this case is the amount of slurry and P produced annually. This supply term is calculated based on the amount of available P per unit of manure produced. In order to create demand across the road network, the centroids (broadly similar to the geometric midpoints) of tillage parcels in the LPIS dataset were assigned to the closest arcs representing the road network based on a minimum distance method. The demand term associated with tillage parcels was initially determined by the cropped area. This area was then multiplied by the legislatively determined maximum application rate of P as determined by S.I. 378 to provide a total demand term by parcel.

A conservative approach was taken in establishing the various terms required for this modelling exercise. Therefore the amount of P allowed to be spread to land was set according to the situation which will pertain post the 'transitionary period' determined in the legislation which expires in 2011. From January 2011 the default soil P index value will be set at Index 3 in the absence of up-to-date soil testing which shows the appropriate index level to be otherwise. According to S.I. 101, the annual maximum rate of P application to cereal crops with soil P Index 3 is 25 kg available P /ha. Under S.I. 378, pig slurry is deemed to contain 0.8kg P per m3 of which 100% is considered to be available. Notwithstanding other conditions, under these guidelines the statutory maximum rate of slurry application is therefore 31.25m3/ ha. Multiplication by LPIS parcel area of this value is then used to derive a total maximum value of slurry which can be spread per tillage parcel.

Tillage parcels on the network were allocated to the pig facility which was closest in distance. The allocation of parcels to a particular facility continued until the supply term of the facility - the total amount of P output from the pig production operation - was fully assigned.

The algorithm was run twice. Firstly, where it is assumed that all tillage farms accept pig slurry and secondly where only 63% of tillage farms accept, based upon the results of our NFS survey above. Parcels were chosen for acceptance on the basis of a Monte Carlo simulation.

Transport cost algorithm

Our network analysis determined the distance between pig enterprise and the closest available tillage parcels such that all slurry supply is disposed of. Our transport cost algorithm was based upon the work of McCutcheon and Lynch (2008) who generated a Manure Haulage Calculator for use by the industry.

Fundamentally, the transport cost algorithm decides the optimal mode of transport between tractor and truck. For short distances, it is cheaper to use a tractor and trailer to transport the slurry. Once a certain threshold distance is exceeded, then it becomes economically more efficient to use a truck to transport the slurry. We assume a dry matter percentage of pig slurry of 4.3%. This results in a threshold of 28km above which a truck would be the preferred mode of transport.

While the Manure Haulage Calculator is quite a complicated calculation, for the purposes of our simulation, we parameterise the calculator in a stylised model. The parameters in the model are

- The threshold beyond which a truck will be used. This is a function of the proportion of dry matter in the slurry.
- The distance parameter

Both models have separate functional forms. The tractor model is a power function:

$$\text{Cost} = 9.6073 \text{x} \text{Distance}^{0.6101} \tag{1}$$

The truck cost function model is linear:

$$\text{Cost} = 38.506 + 2.0425 \text{x} \text{Distance} \tag{2}$$

This cost will give us a total cost per farm and per sow. In order to convert this cost to a per kg dead weight, we convert the number of sows to the number of live offspring (21.5) and divide by the average dead weight of 78.4 kg (PigSys Report 2009).

3. Results

Running our network analysis optimisation algorithm, we found that it would take approximately 162000 tractor loads and 49000 truck loads to transport the slurry from the 440 commercial pig farms in the Teagasc PigSys database to Tillage spread lands. Approximately 59% of slurry would be transported via tractor and the remaining 41% by truck. The average distance a slurry load is transported is 21km.

While this is less than the 30km, i.e. the value above which the transport cost exceeds the nutrient value of the fertiliser (McCutcheon and Lynch, 2008), the average disguises a very significant variation in the distribution across counties. In Figure 2, we report the average distance per load travelled in each county. The second axis reports the cumulative proportion of sows per county.

We note the very significant difference in the average distance across counties. The counties in the East and South-East are close to potential tillage spread lands. However the counties with an average distance of less than 5km account for less than 7% of total sows. At the other extreme, the border and western counties have in general high average distances of over 20km an account for over one third of all sows. The counties Limerick, Clare, Kerry, Cavan, Longford, Roscommon, Mayo, Leitrim and Sligo have average distances of 30km or more. Of these counties, Cavan and Longford are the most significant producers accounting for about 26% of total sows.

In Figure 3, we rank instead by the largest producers. Here, we see that Longford, Tipperary South, Cork and Cavan account for over 50% of all sows. Cavan and Longford have average distances of 56km and 63km respectively, almost double the 30km threshold.

However, these averages in turn mask intra-county distributions. While there may be little tillage in parts of the country, there is some tillage in most parts of the country. Therefore, even in the border area, there are some tillage parcels that could potentially take pig slurry. In Figure 4, we report the proportion of pig slurry that could be transported less than 30km so that the nutrient value exceeds the transport cost. Of those with at least 3% of the national sow herd, there is a cause for concern (number in brackets indicates proportion that can be transported) in Limerick (41%), Westmeath (63%), Longford (5%), Cork (78%) and Cavan (15%). In Longford and Cavan it would not be economically viable to transport pig slurry, except for a very small proportion of farms to transport slurry to tillage farms.

Cost Analysis

The total gross transport of transporting the pig slurry to tillage farms for the 440 commercial farms in our dataset equated to €13.4m. This was equivalent to €91 per sow or 5.4c per kg deadweight.

However again as in the distance analysis, the average masks a very broad distribution. In Figure 5, we report the distribution of costs across counties, reported as the cost per sow. We note again of the counties with more than 3% of total sows, the cost per sow is over €100 (5.9c per kg dead weight) in Limerick, Longford and Cavan. Longford would experience the highest cost at €174 per sow or 10.3 cent per kg deadweight. In other large producers, the cost varies from about €50 to €70 per sow or 3c to 4.1c per kg. Therefore the cost of having to transport pig slurry to tillage spread lands would amount to over 10% on average of the deadweight price, as high as 21.5% in Longford and 16.6% in Cavan and 7-9% in South Tipperary and Cork, assuming an average margin of 48c.

Surplus Cost if Pig Slurry could be Sold

If it were possible to sell the pig slurry at a commercial value equivalent to the nutrient value of P-fertiliser, equivalent to the cost of transporting slurry 30km, then the cost would be €4m, equivalent to €27 per sow or 1.6c per kg deadweight. However as a pig slurry fertiliser market as its infancy in Ireland, it is unlikely that this volume of pig slurry could be sold. In addition given the uncertainty surrounding the nutrition value of the slurry, it is likely to incur a discount relative to mineral fertiliser.

In figure 6, we report the county distribution of surplus cost per sow if it were possible to sell the pig slurry at the fertiliser equivalent value. All of the top 4 counties, accounting over 50% of total sows, would incur additional costs, with significant extra costs in Longford and Cavan amounting to respectively 5.6c and and 3.8c per kg respectively.

4. Discussion and Conclusions

The objective of the study has been to assess the economic cost to the Irish pig sector of the ending of the transitional arrangement within the EU Nitrates Directive, whereby pig farmers could spread pig manure on farm land, subject only to maximum available nitrogen (N) application rates, but not bound by phosphorus (P) limits. In practice this would require the availability of tillage spread lands for this purpose. Given the differential spatial pattern of pig production and tillage production, we have utilised a Geographical Information System based analysis to quantify the cost to the sector of transporting pig waste

The approach taken in this research was to examine the geographic structure underlying the pig sector in Ireland using Geographic Information Systems (GIS) technology. Slurry-producing enterprise and land cover type location were derived from GIS data. Network analysis was used to calculate road distances between pig and tillage farms, adjusted for volume of waste and combined with differential unit haulage costs to calculate the economic cost.

The study highlighted the differential cost with, amounting to 10% of gross margin on average and as high in major pig producing areas as 21.5% in Longford and 16.6% in Cavan, while lower at 7-9% in South Tipperary and Cork. Thus while the problem is significant, the impact is not constant across the country, iterating the need for a spatial analysis.

This issue has been highly contentious within national debates on the economics of the EU Nitrates Directive. It is anticipated that the establishment of these real distances will facilitate a fully informed national debate on the issues involved allowing all parties access to scientifically established facts on which to assess their relative positions. For example, drawing upon this analysis, agricultural advisory services are seeking to address this issue by highlighting to pig producers the benefits of controlling the liquid contents of slurry produced by focussing on improved feed processes and water management in slurry storage to reduce the cost of transport.

From a scientific point of view the key benefit is the development and testing of a methodology to assess real transport distances. Given the significance of the interaction between transport distances and costs in both monetary and energy budgetary terms the development of this method is a positive contribution to this field of research.

This study has focused upon transporting pig slurry to tillage spreadlands. Of course should a pig farm be able to source grassland capable of taking the pig slurry, then this cost is likely to be lower. However as noted above this possibility may be low due to the existing high P levels in areas of intensive pig production.

Another issue that may affect this analysis, particularly given rising fertiliser prices, is the development of a market for pig slurry for use as an alternative to chemical fertilisers. However as a pig slurry fertiliser market as its infancy in Ireland, it is unlikely that this volume of pig slurry could be sold. In addition given the uncertainty surrounding the nutrition value of the slurry, it is likely to incur a discount relative to mineral fertiliser.

Future work is also required to assess the existing cost of spreading manure in order to be able to ascertain the net cost of spreading on tillage lands. The robustness of the results also need to be tested to assess the implications of changes in the prices of fossil fuels and fertilisers, both in terms of the cost function and in terms of the cost of substitutable mineral fertiliser.

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Table 1. Annual maximum fertilization rates of P on cereal crops (kg/ha) as specified in SI 378 of 2006 and SI 101 of 2009

Soil P Index	Soil P range (mg/l) Grassland	Tillage	Description
1	0 - 3.0	0 - 3.0	Soil is P deficient; build-up of soil P required. Insignificant risk of P loss to water.
2	3.1 - 5.0	3.1 - 6.0	Low soil P status: build-up of soil P is required for productive agriculture. Very low risk of P loss to water.
3	5.1 - 8.0	6.1 - 10.0	Target soil P status: only maintenance rates of P required. Low risk of P loss to water.
4	>8.0	>10.0	Excess soil P status: no agronomic response to P applications. Risk of P loss to water increases within this Index.

Table 2. County Distribution of Sow Numbers

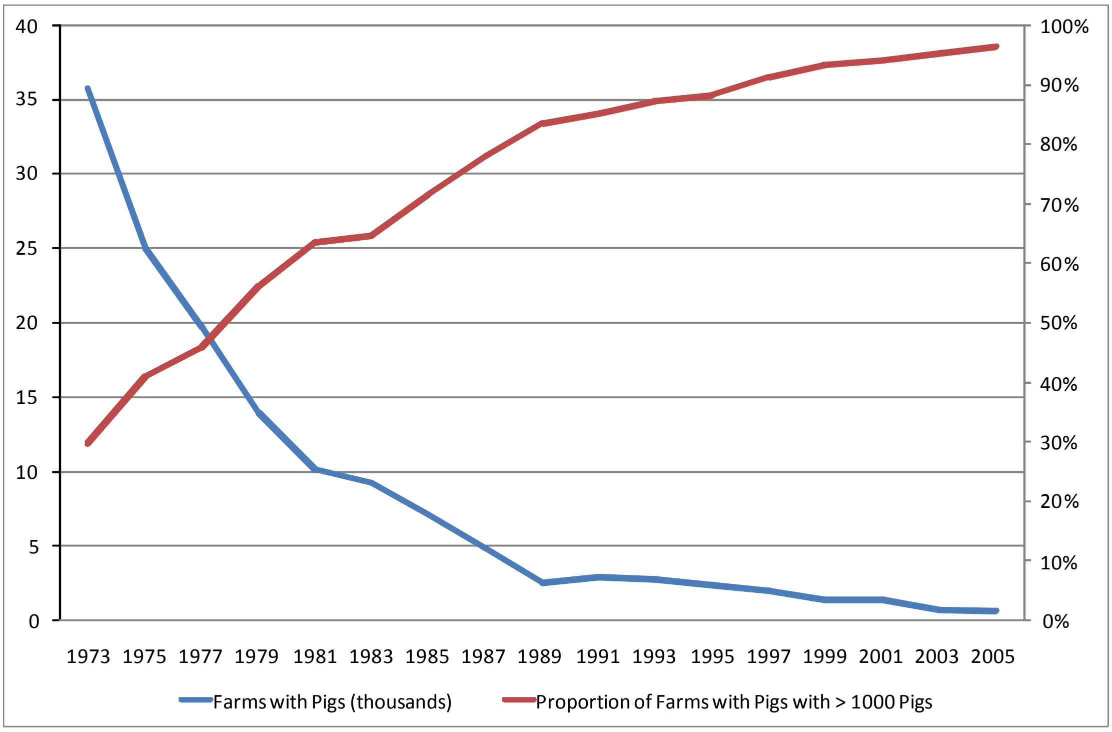
County	Region	Sow Numbers
Cavan	Border	28,377
Cork	South West	28,370
Tipperary	Mid-West & South East	15,095
Longford	Midlands	8,705
Waterford	South East	7,655
Others (21)		51,198
Total		149,400

Source: Teagasc Pig Development: Survey of Commercial Pig Herds 2009

Source: CSO Census of Agriculture, 2000.

Note: Ratio is not based on livestock units but on numbers of animals only.

Figure 1. Structural Change in Irish Pig Farming, 1973-2005



Source: CSO Herd Size Survey

Figure 2. The Distribution of Average Distance per Load per County, Ranked by Distance

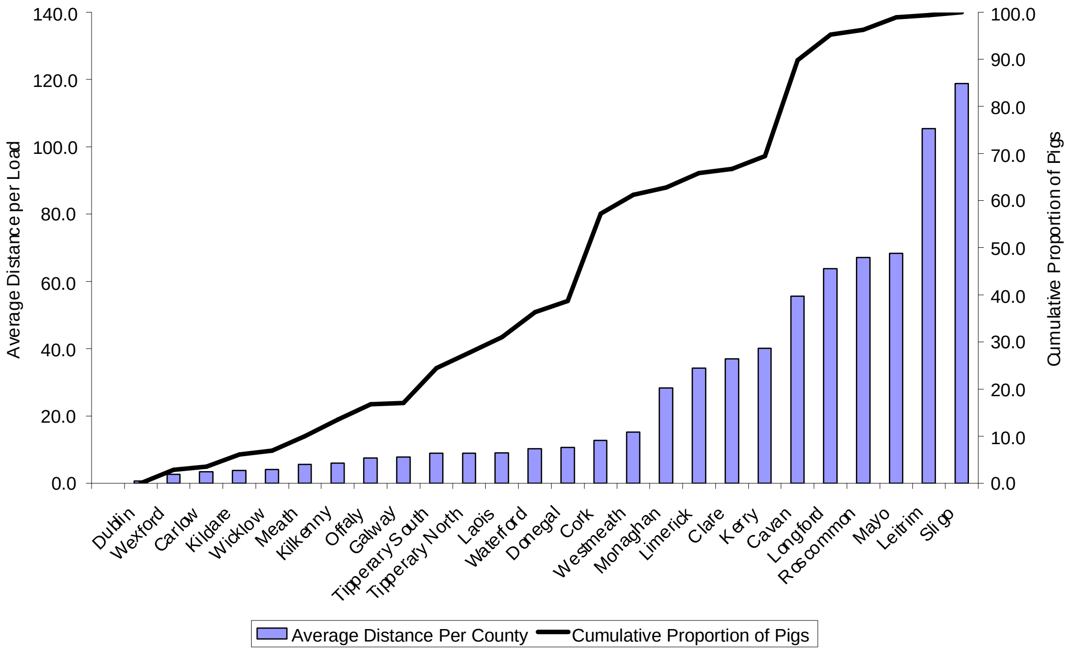


Figure 3. The Distribution of Average Distance per Load per County, Ranked by Proportion of Sows

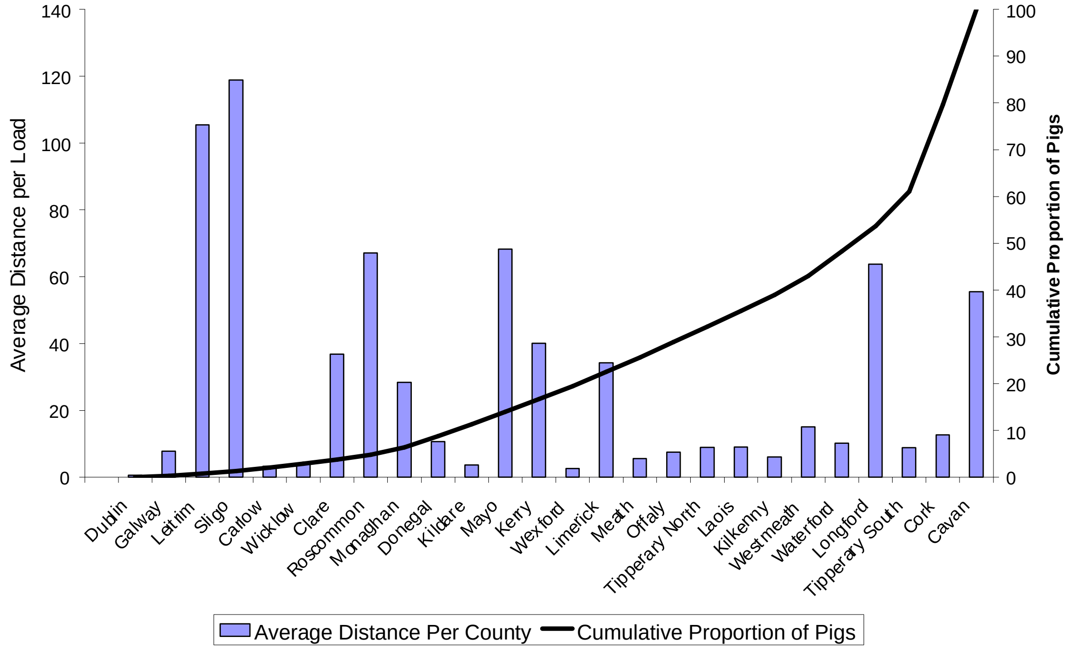


Figure 4. Proportion of Pig Slurry that can be transported 30km or less

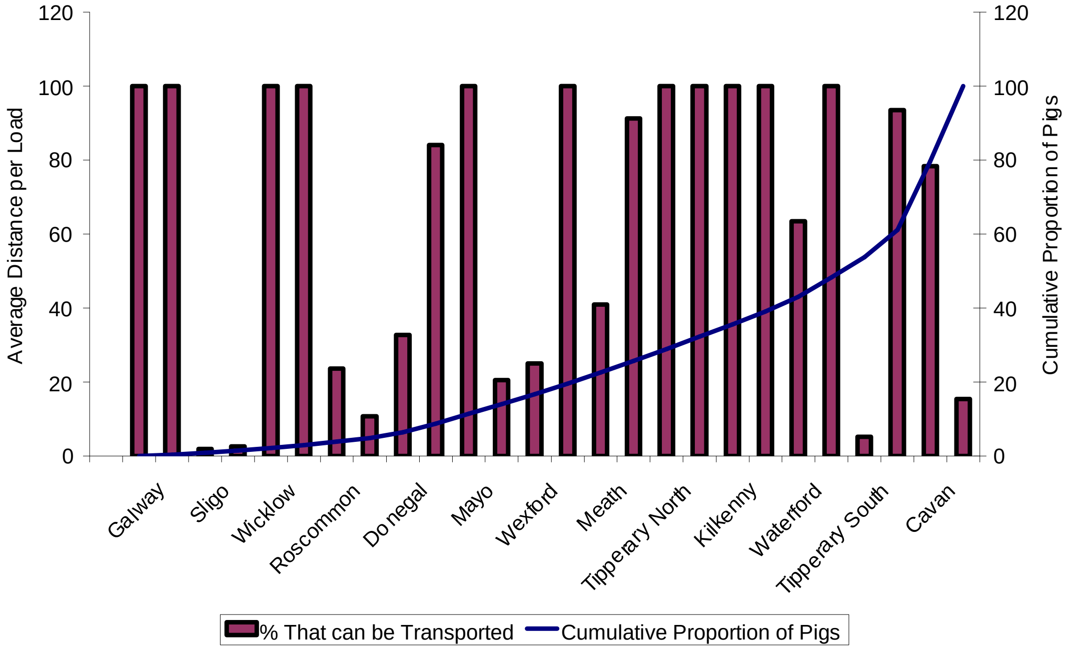


Figure 5. Distribution of the Transport Cost per Sow by county, ranked by proportion of Sows

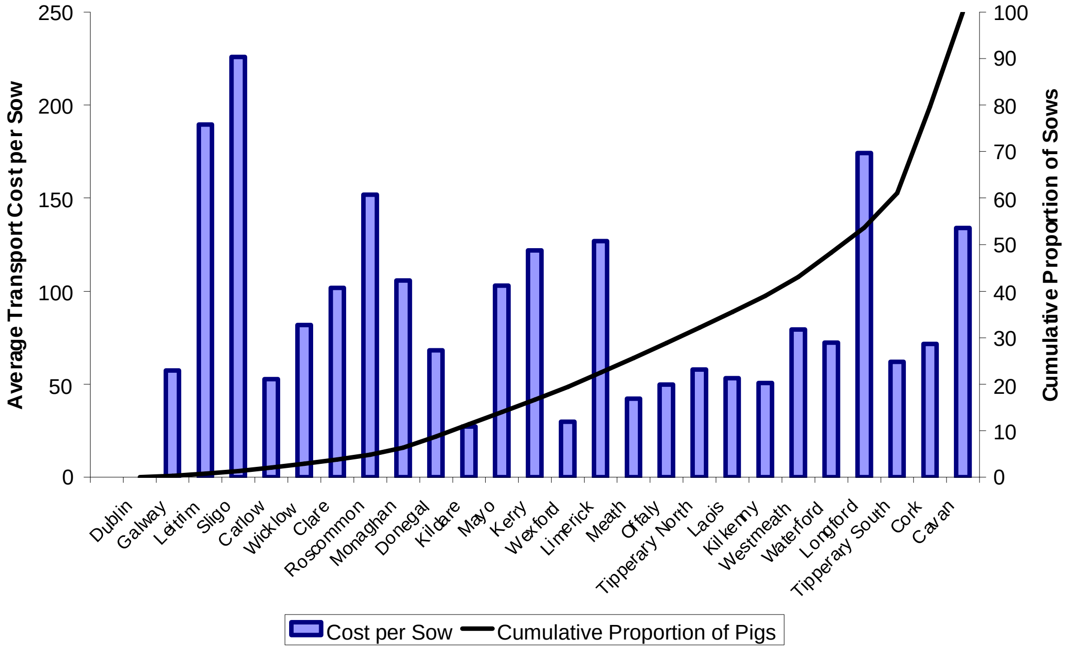


Figure 6. Distribution of Surplus Transport Cost per Sow by county, ranked by proportion of Sows