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Estimating the Elasticity of Demand and the Production Response for Nitrogen Fertiliser on Irish Farms

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Abstract

The application of artificial fertiliser continues to be a vital component of the production system on the bulk of Irish farms, accounting for approximately nine percent of total costs on dairy and cattle farms (Hennessy et al. 2011). However, the average application of artificial nitrogen fertiliser per hectare of grassland has been in decline recently. This reduction in use is likely due to a number of factors including better on-farm grassland management, as well as better management and utilisation of organic manures, the introduction of the Rural Environmental Protection Scheme, the Nitrates Directive, and more recently higher fertiliser prices. Changes in the level of artificial nitrogen usage are likely to have significant implications for agricultural productivity and the environment, both in terms of nitrate emissions and greenhouse gas emissions. Therefore, a better understanding of the factors affecting fertiliser demand, as well as the relationship between fertiliser use and agricultural production levels is required. In this study an unbalanced panel dataset was constructed using data for the period 2000 to 2010 from the Irish National Farm Survey (NFS) and used to estimate two fixed effects models. The first model estimated the elasticity of demand for artificial nitrogen fertiliser applied on grassland. A second fixed effects model was developed to estimate the relationship between stocking rate and the level of artificial nitrogen applied on grassland.

Keywords Fixed Effects Model, Fertiliser, Elasticity of Demand

JEL code Q12

Estimating the Elasticity of Demand and the Production Response for Nitrogen Fertiliser on Irish Farms

Introduction

The application of chemical fertiliser in agricultural production dates back to the mid 1800's, when sulphuric acid was combined with phosphate of lime in bone meal to create the chemical fertiliser superphosphate. Since their first use in agriculture, chemical fertilisers have been viewed as synonymous with increased production levels through higher crop yields and higher stocking rates. Throughout the 1980's and 1990's the price of chemical fertilisers in Ireland increased at a relatively low rate in nominal terms. The rate of increase in Irish fertiliser prices accelerated from 2000 onwards peaking in 2008, when the price of most chemical fertilisers increased to a level that was 50 percent higher than the 2007 average (see Figure 2). Although fertiliser prices declined in 2009 and 2010, they increased substantially once again in 2011 but did not return to the record levels observed in 2008. This has raised concerns that we might be heading towards a future of increasingly volatile fertiliser prices. Fertiliser is one of the largest individual cost items on Irish farms along with concentrate feed, machinery hire charges and fuel costs. The expenditure on artificial fertiliser accounted for nine percent of total costs on Irish dairy and cattle farms in 2010 (Hennessy et al. 2011), and as can be seen from Figure 2 below the average fertiliser price in 2010 was relatively low compared with 2008, 2009 and 2011.

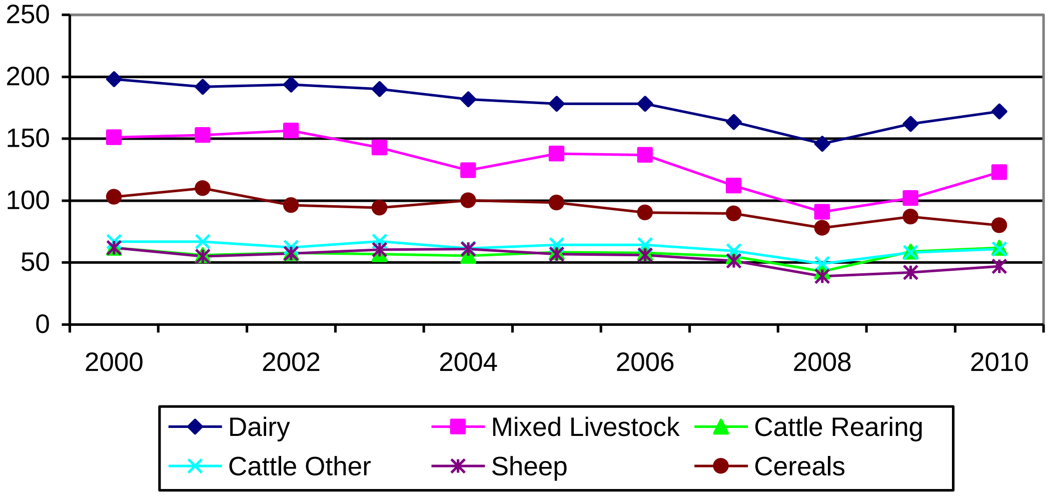
In the presence of volatile fertiliser prices, it is important to quantify the relationship between fertiliser demand, fertiliser prices and other factors that determine the level of fertiliser usage for a number of reasons. Firstly, as a significant component of the costs of production, understanding the relationship between fertiliser prices and usage levels is important in understanding the influence of fertiliser prices on the costs of production and, in turn, farm income. Furthermore, the demand for fertiliser should depend not only on the price of fertiliser but also the price of other inputs and the price of outputs produced. Secondly, the application of chemical fertilisers can have significant environmental consequences, for example nitrogen fertiliser is an important source of greenhouse gas (GHG) emissions from agriculture. Therefore, a better understanding of the relationship between fertiliser price and usage is required to model future emissions of GHG by Irish farms and also to better understand the potential impact of a tax on fertiliser to restrict its usage. In this paper we use data from the Teagasc Irish National Farm Survey (NFS) to estimate the price elasticity of demand for a nitrogen fertiliser amongst dairy farmers and the agricultural supply response due to changes in fertiliser application on dairy farms. The agricultural supply response with respect to fertiliser application is captured in terms of the relationship between fertiliser usage and stocking rate per hectare.

The paper is structured as follows: the next section contains an overview of fertiliser price movements and usage rates by farm type in Ireland, while also examining the literature in this area. A subsequent section describes the modelling approach used in estimating the elasticity of demand and production response for nitrogen fertilisers on Irish farms. Following this, the results of the analysis are detailed and discussed, with the final section concluding.

Background

Nitrogen, phosphorous and potassium are the most commonly used elements in the production of artificial fertilisers. Given the predominance of grass-based livestock production in Ireland, nitrogen is the most widely applied chemical element. Much of the nitrogen applied is in the form of calcium ammonium nitrate (CAN) and urea, which are composed of 27.5 and 46 percent of nitrogen respectively. In 2010 farmers within the NFS applied a total of 1.27 million tonnes of fertiliser on grassland, 548,000 tonnes of which was CAN making it by far the most widely applied fertiliser on grassland (Hennessy et al. 2011). The second most widely used fertiliser on grassland in 2010 was 18-6-12 and 143,000 tonnes of which was applied on grassland in 2010. As shown in Figure 1, the average application rate of artificial nitrogen per hectare of grassland in Ireland is highest on specialist dairy farms (farms whose main output is milk) with mixed livestock farms (these farms generally also include a dairy enterprise as a minor activity of the farm) having the next highest level of usage per hectare. The high rate of nitrogen application on these types of farms is largely due to their higher average stocking rate compared with drystock farms and the larger dietary requirements of dairy cows when compared with drystock animals. The average nitrogen application on specialist dairy farms and mixed livestock farms in Ireland has generally been decreasing since the turn of the century, by 2008 average application rates on both farm types were approximately 50 kg per hectare lower than in 2000 (a decrease of more than 25 percent). In contrast to the rates of application on dairy farm types, the reduction in average application rates since 2000 on drystock farms was substantially smaller in both absolute and percentage terms. However, all three drystock farm types (cattle rearing, cattle other, and mainly sheep) showed a sizable reduction in nitrogen use in 2008 when compared with previous years.

Figure 1: Average Artificial Nitrogen Application on Grassland by Farm System. (kg/ha)

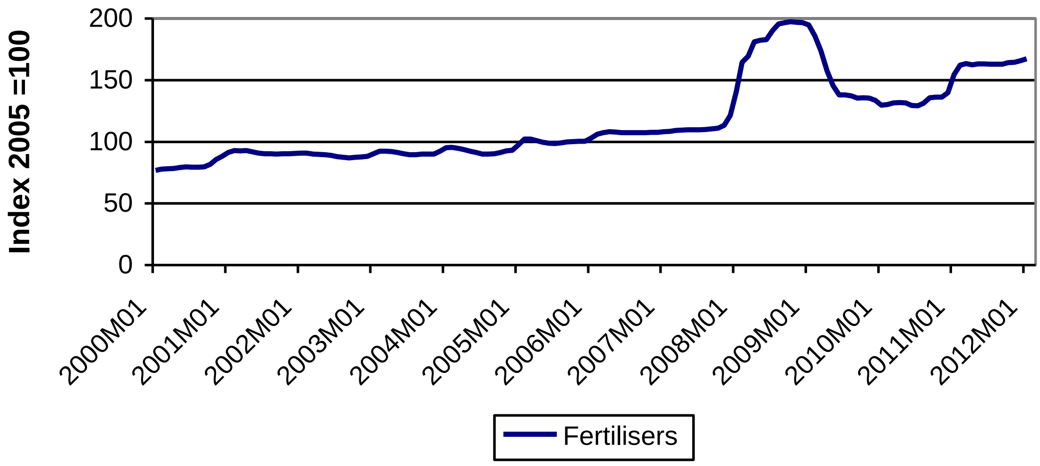


Source: Teagasc National Farm Survey (various years)[1]

The low level of artificial nitrogen use in 2008 was largely due to the extremely high fertiliser prices in that year. Fertiliser prices, which had been increasing steadily in the period 2000-2006 (see Figure 2 below), started to increase dramatically in late 2007/early 2008 due to a number of factors. These include higher energy prices, in particular natural gas prices, which are a key determinant of the price of nitrogen, strong fertiliser demand in countries such as Brazil, China and India and relatively fixed fertiliser production capacity over the short term. Increases in the level of fertiliser export taxes in China in 2008 also contributed to reduced global fertiliser trade. Fertiliser prices began to decline in 2009; this decline was in part due to lower energy prices and increased global supply of fertiliser. As a result, in 2009 and 2010 there has been some recovery in nitrogen application rates in Ireland. However, towards the end of 2010 fertiliser prices increased once again, and in early 2011 they increased sharply. Fertiliser prices remained at elevated levels throughout 2011; however as of April 2012 they had not hit the levels that were seen in 2008. (see Figure 2).

[1] In 2010 a new system (Mixed Livestock) was included in the Teagasc National Farm Survey, this system replaced the Dairy and Other System.

Figure 2: Monthly Price Index of Fertiliser in Ireland 2000 to 2011.



Source: Central Statistics Office (2012) *Agricultural Price Indices*

Better farm management practices and changes in environmental policy both domestically and internationally are also likely to have contributed to a decrease in fertiliser use on some Irish farms. Both the EU Nitrates Directive (91/676/EEC) (EEC 1991) and the environmental criteria set out under the Irish agri-environmental measure (AEM), known as the Rural Environmental Protection Scheme (REPS), have restricted fertiliser use on individual farms.

The main motivation for applying artificial fertiliser to agricultural land is to increase its production capacity and in turn farm profitability. As shown in Figure 1, specialist dairy and mixed livestock farms on average apply more artificial fertiliser to grassland than the other four farm types. These farms also have the highest stocking rates, with 1.91 and 1.85 livestock units per forage hectare respectively in 2010 (see Table 1). In contrast, the stocking rate on the drystock farms is substantially lower, for example the stocking rate on specialist sheep farms is only 1 livestock unit per hectare. Stocking rate may be conditional on a number of factors including *inter alia* the farmer’s managerial ability, the soil type on the farm and a farm’s regional location. However, the evidence would also suggest that higher fertiliser application rates facilitate higher stocking rates on farms. Therefore, changes in the level of chemical fertiliser application are likely to impact on stocking rate.

Table 1: Average Stocking Rate by Farm Type in 2010

	Dairy	Dairy-Other	Cattle Rearing	Cattle Other	Sheep	Tillage
Stocking Rate	1.91	1.85	1.13	1.31	1.00	1.54

Source: Hennessy et al. (2011)

The increased interest in mitigating GHG emissions from agriculture has heightened the need to better understand the relationship between fertiliser use and fertiliser price, as well as the relationship between fertiliser use and stocking rate. Chemical fertilisers can contribute to the production of GHG emissions by two means. Firstly, the compounds of nitrogen contained in the fertiliser break down and produce nitrous oxide (N_2O), a particularly potent greenhouse gas; with one ton of N_2O having the same global warming potential as 310 tons of CO_2. Second, the application of chemical fertilisers also impacts on GHG emissions indirectly, since their use enables farmers to stock more animals per hectare which in turn leads to increased GHG emissions per hectare via the emissions associated with ruminant livestock production (CH_4 from enteric fermentation and manure management and N_2O from slurry and solid wastes associated with livestock production).

These two emission sources were also identified by Burrell (1989) in considering alternative means to reduce artificial fertiliser use and the resulting pollution. She argued that although a tax on fertiliser would be the easiest approach to reduce fertiliser usage, the success of such a tax would be largely dependent on the responsiveness of the demand for fertiliser to changes in the price of fertiliser. Burrell (1989) also noted that, given the interdependence of agricultural inputs when implementing a fertiliser tax, policymakers should be conscious of the knock-on implications for agricultural output levels and the demand for other agricultural inputs due to changes in relative prices.

Despite the importance of chemical fertiliser to Irish agriculture, the estimation of the elasticity of demand for chemical fertiliser has received only limited attention. O'Rourke and McStay (1978), Boylan et al. (1980) and Boyle (1982) have all used aggregate data to estimate the elasticity of demand for chemical fertiliser. The FAPRI-Ireland model that has been used to evaluate the impact of agricultural policy change on Irish agriculture and the impact of Irish agriculture on GHG emissions (Binfield et al., 2003, 2008; Donnellan and

Hanrahan, 2006) also includes a model of fertiliser demand. The FAPRI-Ireland model, like that of O'Rourke and McStay (1978), Boylan et al. (1980) and Boyle (1982), is based on aggregate data (Binfield, Donnellan and McQuinn, 2000). Within the FAPRI-Ireland model nitrogen use on grassland is modelled as a function of their price, the price of feed (a substitute), the output intensity of production (output per hectare) and weather.

Only Higgins (1986) has thus far used farm-level data to estimate an elasticity of demand for chemical fertiliser in Ireland. Higgins used cross sectional data from the 1982 NFS to estimate the elasticity of supply for three outputs and elasticity of derived demands for nine inputs, one of which was fertiliser. However, Higgins (1986) noted that the use of panel data would allow for the inclusion of price expectations and risk in the analysis. Furthermore, the longitudinal dimension within a panel of data would allow for the examination of the extent to which changes in fertiliser price over time have impacted on fertiliser use. Panel data models have been used previously to estimate the responsiveness of farmers to changes in input and output prices. Thijssen (1992) used 12 years of panel data to estimate supply response and input demand (one of which was demand for chemical fertiliser) for Dutch dairy farms. Another advantage of using farm-level panel data, such as that from the NFS, is that detailed information on the volume of different types of fertiliser that have been applied and the crops on which these different fertiliser products have been applied on are available. Thus, we can potentially estimate and compare the elasticity of demand for alternative chemical fertiliser products and alternative end uses.

Methods and Procedures

Burrell (1989) divides studies in which fertiliser demand equations are estimated into three broad categories. The first of Burrell's categories of demand studies are those in which input demand functions are derived from dual cost functions using Shephard's lemma. In such studies the derived demand functions are conditional on a given level of output. The second category of studies derives input demand and output supply functions from the primal profit function using Hotelling's lemma (Varian, 1992). In these studies input demands are functions of input and output prices and output supplied and inputs used are free to adjust. Burrell's (1989) third category of input demand studies are those based on production theory in which demand for an input such as fertiliser is regressed on own and cross prices and other shift variables, with the results interpreted as Marshallian elasticities of demand – implying at least an implicit assumption of profit maximisation.

In this paper we use data from the Teagasc National Farm Survey (NFS) to construct an 11 year unbalanced panel of dairy farms. This panel is then used to estimate two fixed effects models. In the first fixed effects model we econometrically estimate a demand function for a key nitrogen fertilizer (CAN) used on Irish dairy farms. The estimated model falls into the "single equation input demand model" of Burrell's (1989) typology. The dependent variable is total application on grassland of CAN per farm and the choice of explanatory variables largely follows the approach taken by Burrell's (1989) and includes the price of CAN, prices of alternative nitrogen fertiliser, the price of milk, as well as a number of other variables. The second fixed effects model estimated explores the relationship between production intensity on Irish dairy farms (as measured by stocking rate) and the use of Nitrogen fertiliser on grassland. By examining the relationship between stocking rate and Nitrogen fertiliser use, we hope to gain a better understanding of the potential impact that an increase in fertiliser price might have both on livestock numbers and emissions from livestock production.

Fixed Effects Models

In order to estimate the elasticity of demand for CAN fertiliser (Model 1) and the production response (Model 2) to nitrogen fertiliser on Irish farms, the following fixed effects model was employed:

$$A_{it} = \alpha + u_i + \beta_1 x_{it1} + \beta_2 x_{it2} \ldots\ldots \beta_k x_{itk} + e_{it} \qquad \text{(eq 1)}$$

where A_{it} is the quantity of CAN applied per farm i in year t (t = 1,…, 11), α is the regression cross-sample constant term, u_i is the farm specific constant term (fixed effect) and x_{it1-k} are the explanatory variables.

Model 1 Total nitrogen use per farm can be expressed as a function of

$$N = g(w, v, p, Z) \qquad \text{(eq 2)}$$

where the farm level demand for nitrogen (***N***) is a derived demand and is a function of the price of fertiliser (***w*),** the price of other inputs (***v***), the output price (***p***) and other farm specific variables (***Z***). A description of the variables used in constructing the fixed effects model is presented in Table 2. In order to estimate the price elasticity of demand for nitrogen fertiliser, the price per tonne of nitrogen fertiliser is included as an explanatory variable. Much of the fertiliser use in Ireland is for the production of grass, which is the main feed input in Irish dairy and beef systems. However, concentrate feed is a substitute for grass and grass silage and so the total expenditure on concentrate feed per dairy livestock unit is also included as an explanatory variable in the model. The impact of output price effects is captured through the inclusion in the model of the total value of milk sales as an explanatory variable; with the *a priori* expectation that higher milk sales should, everything else being equal, result in increased expenditure on fertiliser. Farm stocking rate is included as a measure of production intensity, as other things being equal, higher stocking rates should result in increased fertiliser application per hectare. Farm size is also included as an explanatory variable and would be expected to be positively correlated with total nitrogen demand. A dummy variable indicating whether or not a farmer cuts silage more than once a year was also included. Those farmers who make grass silage more than once in the year (two cut silage) would be expected to apply more nitrogen fertiliser than farmers using a single cut grass silage system. A dummy variable identifying farmers in the REPS agri-environmental measure was also included in the model, as qualification for REPS payments requires an adherence to a ceiling on fertiliser usage and is, therefore, typically associated with a lower intensity of fertiliser use than farms which are not participating in REPS.

Table 2: Variable Definitions and Descriptive Statistics for Model 1

Variable	*Variable Definition*	*N*	*Sample Mean*	*Std. Dev.*	*Minimum*	*Maximum*
CANUse	CAN application per hectare of forage area	1978	14.91	12.66	0.10	85.90
CANPrice	Price of CAN per tonne	1978	211.20	52.72	87.41	446.76
UreaPrice	Price of Urea per tonne	1978	598.31	145.00	218.07	1260.87
ConcExpDairyLU	Value of Expenditure on Concentrate Feed per Dairy LU	1978	179.03	97.70	15.58	712.70
MilkSales	Value of total Milk Sales	1978	91790.05	62773.24	1380.21	569065.
StockingRate	Stocking rate, livestock units per forage hectare	1978	2.04	0.47	0.46	7.53
TwoCutSilage	Dummy variable denoting whether or not a farm cut grass silage more than once in the year	1978	0.76	0.42	0	1
FarmSize	Total Utilisable Agricultural Area measured in hectares	1978	62.19	31.83	5.67	280.00
REPS	Dummy variable identifying whether or not farms were participating in REPS	1978	0.18	0.38	0	1
OffFarmJob	Dummy variable denoting whether or not the farmer was employed off the farm	1978	0.09	0.29	0	1
Age	Age of the main farm holder	1978	47.84	10.77	21.00	85.00

Model 2 Stocking rate per hectare can be expressed as

$$S = g(n, c, Z) \qquad \text{(eq 3)}$$

where the stocking rate (***S***) is modelled as a function of the level of application of nitrogen fertiliser per hectare of grassland (***n*),** the volume of concentrate feed per LU (***c***), and other farm specific variables (***Z***). The variables used in the construction of model 2 are presented in Table 3. As Irish dairy and beef production is largely pasture based, the stocking rate at farm level is highly dependent on the ability to produce grass, which in turn is dependent on a number of factors including the volume of chemical fertiliser applied. The volume of concentrates feed per livestock unit is also included as an explanatory variable, as one would expect those farms with a higher level of concentrate feed per livestock unit to also have a higher stocking rate per hectare. A dummy variable for soil type was also included. Farms were classified according to soil type into one of three categories: those with soil type 1 denoting farms with the best soil conditions, followed by soil type 2, and soil type 3 denoting farms with average and poor soil types respectively.

Table 3: Variable Definitions and Descriptive Statistics for Model 2

Variable	*Variable Definition*	*N*	*Sample Mean*	*Std. Deviation*	*Minimum*	*Maximum*
StockingrRate	Stocking rate livestock units per forage hectare	4637	1.936641	0.504082	0.462195	7.525972
NitrogenUse	Nitrogen application per hectare of forage area	4637	173.2394	83.68247	0	1271.741
FeedUse	Concentrate Feed use per LU	4637	890.5962	507.8534	0	13390.5
Soil1	Soil Type 1	4637	0.56804	0.495402	0	1
Soil2	Soil Type 2	4637	0.363382	0.481025	0	1
FarmSize	Total Utilisable Agricultural Area measured in hectares	4637	58.11385	32.89951	5.67	281.4
MilkSales	Total volume of milk sold	4637	255530.8	177542.2	1955	1492383
REPS	Dummy variable identifying whether or not farms were participating in REPS	4637	0.221264	0.415143	0	1
OffFarmJob	Dummy variable denoting whether or not the farmer was employed off the farm	4637	0.108691	0.311285	0	1
Age	Age of the main farm holder	4637	49.34246	11.00737	21	86

Results

The maximum likelihood parameter estimates for Model 1 and Model 2 are presented in Tables 4 and 5 below. Both models were estimated within STATA.

Model 1

As expected *a priori*, the estimated price elasticity of demand for CAN is found to be inelastic with a value of -0.396. The coefficient for stocking rate is estimated as 0.667, indicating that a 1 percent increase in stocking rate results in a 0.667 percent increase in CAN demand. This relationship is to be expected *a priori* since a stocking rate increase raises the demand for grass and as a result the demand for nitrogen fertiliser increases also. The coefficient for the log of the urea price was found to be positive and significant indicating that as the urea price increases CAN use increases. Both urea and CAN are highly concentrated nitrogen based fertilisers; however they are not perfect substitutes. Urea is the recommended fertiliser for first cut silage, whereas CAN is the recommended fertiliser for second cut silage. The inclusion of the two cut silage variable may thus capture some of the explanatory power that would otherwise be associated with the substitute good urea). Furthermore, historically the prices of CAN and urea in the Irish market, while subject to temporary short term deviations, have generally tracked each other closely when examined over a longer period, and this may in turn have limited the incentive for substitution between the two fertilisers in the past.

The coefficient for Two Cut Silage indicates that farmers who make more than one cut of silage per season will demand 15 percent more CAN than farmers who only take one cut of silage. This finding would appear to be in line with common practice on Irish farms and recommended best practice (Teagasc, 2007), whereby CAN is widely used on grassland when a second cut of silage is being made, while urea is the preferred grassland fertiliser for first silage cut. Model 1 indicates that farmers apply more CAN fertilise if they have an off-farm job. There are two possible explanations for this result. Firstly, having an off-farm job results in a positive wealth effect, this enables farmers to purchase more fertiliser. A second possible explanation is that more efficient management of fertiliser use is reliant on good grassland management. Good grassland management can be a time consuming practice entailing grass measuring, grass budgeting, strip grazing of paddocks and so on. Farmers with an off-farm job may have less time to dedicate to grassland management and therefore the grass requirement on their farm may be increased due to poor grassland management, thereby resulting in less efficient utilisation of grass. As a result, they would need to spread more fertiliser than full-time farmers in order to produce more grass.

The coefficient for the log of farm size is 0.772 indicating that as farm size increases fertiliser demand per hectare increases also again this is in line with the a priori assumption that as a farm increases in size fertiliser use will increase also. Similarly the coefficient for the log of the total value of milk sales is also positive again this result is in line with expectations that as the value of milk sales on a farm increases their expenditure on fertiliser will increase also. Farmers who spent more on concentrate feed per dairy cow were found to have used more CAN fertiliser, this result would appear to be somewhat counter intuitive as concentrate feed and grass based feeds are in effect substitutes and so one would have expected a negative sign on this coefficient. This result may reflect difficulties on individual farms to produce a sufficient volume of grass due to weather or grass growing conditions and as a result higher volumes of fertiliser and feed were used. Alternatively, this result may reflect poorer management on individual farms which resulted in higher volumes of fertiliser and feed being purchased. The coefficients on both the dummy variable for participation in REPS and farmer age were negative as one would expect, however in both cases the result was found to be statistically insignificant.

Table 4: Model 1 Regression Results for CAN Fertiliser Demand

	Coefficients	Std. Err.	t-value	P-value
Constant	-3.830	1.413	-2.710	0.007
Log of CAN Price	-0.396	0.140	-2.820	0.005
Log of Urea Price	0.251	0.137	1.840	0.066
Log of Concentrate Expenditure per Dairy Cow	0.129	0.067	1.920	0.055
Log of Milk Sales	0.270	0.117	2.310	0.021
Log of Stocking Rate	0.667	0.160	4.160	0.000
TwoCutSilage	0.149	0.061	2.460	0.014
Log of Farm Size	0.772	0.205	3.770	0.000
REPS	-0.080	0.076	-1.050	0.292
Off Farm Job	0.272	0.079	3.430	0.001
Log of Age	-0.139	0.144	-0.970	0.335

Model 2

The second model aims to estimate the relationship between the dependent variable stocking rate per hectare of forage area and nitrogen use on grassland. As can be seen from Table 5 below, the estimated coefficient for the log of nitrogen use is 0.115 indicating that for each 1 percent increase in the application of nitrogen per forage hectare, an increase in the stocking rate per forage hectare of 0.115 percent can be expected. This supports the hypothesis that nitrogen application and stocking rate are positively correlated and, thus, a decrease in nitrogen application is likely to result in a decrease in stocking rate on dairy farms.

The coefficient for farm size variable was -0.393, indicating that smaller farms are more intensively stocked. There are a number of likely contributing factors to this result. Firstly, on average, specialist dairy farms are smaller in size, but more intensively stocked than non-specialist dairy farms. The average farm sizes were 48 and 57.3 hectares respectively in 2010, while the average stocking rate was 1.91 LU per hectare on specialist dairy farms compared with 1.88 LU per hectare on non-specialist dairy farms (Hennessy et al. 2011). Secondly, while larger farms may benefit from scale economies, there is likely to be a greater pressure to increase stocking rate on smaller farms in order to increase profitability. Thirdly, in practical terms the milk quota regime places an upper constraint on the number of dairy cows, since the addition of further dairy cows necessitate a reduction in milk yields if the milk quota is already binding and acquisition of additional milk quota is problematic. In contrast, milk quotas do not constrain the number of drystock animals that may be kept. However, typically in Irish agriculture drystock animals are less profitable than dairy cows and as a result the economic incentive to keep these drystock animals may not be substantial. Therefore, on larger farms which produce milk there may be less incentive to increase the number of non-dairy livestock due to the low returns associated with these animals.

The coefficient for the log of milk sales volume was positive indicating that as the volume of milk sales (which given that the milk quota is binding in Ireland can be taken as a proxy for milk quota) increases, the stocking rate increases also.

The coefficient for the log of feed use was -0.027. This result was surprising as anecdotally one would typically associate higher stocking rates with higher feed use. Irish dairying is predominantly a grass-based system and over the last 15 years a number of papers in the dairy science literature (for example Shalloo and Horan 2008) have highlighted the economic benefits of compact calving of dairy cows in Ireland in the early spring, with the aim of getting cows out to grass early and extending the grazing season in the autumn in order to minimise the expenditure on concentrate feed and overall production costs. This model of milk production in Ireland is widely viewed by both Irish dairy farmers and agricultural extension service as best practice. The adoption of these practices on Irish farms may explain the negative relationship between concentrate feed and stocking rate. It should also be noted that the size of this coefficient is relatively small, therefore while the result may be surprising the overall effect is likely to be minimal. Both soil type 1 and 2 were positive and significant at the 5 and 10 percent levels respectively. The coefficient for REPS was also found to be positive but in this case insignificant, while having an off-farm job and age were negative but insignificant.

Table 5: Model 2 Regression Results for Stocking Rate per Forage Hectare

	Coefficients	Std. Err.	t-value	P-value
Constant	0.201364	0.202682	0.99	0.321
Log of Nitrogen Use	0.11486	0.009693	11.85	0.000
Log of Feed Use	-0.02673	0.007065	-3.78	0.000
Soil1	0.033493	0.016848	1.99	0.047
Soil2	0.043564	0.026248	1.66	0.097
Log of Farm Size	-0.39268	0.03316	-11.84	0.000
Log of Milk Sales volume	0.125954	0.012797	9.84	0.000
REPS	0.000359	0.007656	0.05	0.963
Off Farm Job	-0.01398	0.012152	-1.15	0.25
Log of Age	-0.00233	0.021491	-0.11	0.914

Conclusion

The demand for CAN in Ireland was found to be inelastic. This finding is not at variance with findings in previous studies in which the demand for fertiliser in Ireland was also found to be inelastic (Boyle 1982; Higgins 1986). Burrell (1989) concluded that technological change, nitrogen price and agricultural output prices had all been influential factors in determining nitrogen demand in the UK, and that the demand for nitrogen was inelastic (in the region of -0.4 to -0.6) with respect to nitrogen price. The magnitude of the elasticity estimated in this study is -0.39 and is therefore towards the lower end of the range reported by Burrell (1989). This study differs from Burrell (1989) in that it estimates the elasticity of demand for a single fertiliser type (CAN) as opposed to the elasticity of demand for fertilisers in total. Secondly, this study focusses on Irish dairy farms which have been shown to be the most intensive users of nitrogen fertiliser. Finally, CAN is widely recommended in Ireland as a fertiliser to be used on grassland both for the production of grass for grazing and silage (Teagasc 2007) and this may have altered the perceived substitution opportunities.

The results from model 2 confirm that an increase in nitrogen use allows for an increase in stocking rate. It is important to note that this result does not indicate whether or not an increase in fertiliser use will lead to an increase in farm profitability, as this will be dependent on whether or not the increase in fertiliser costs and other costs can be offset by the increase in the value of gross output that will result from the additional livestock. This finding is also important in an environmental context as it highlights the link between fertiliser use and stocking rate, indicating that a reduction in nitrogen fertiliser use would also lead to a reduction in stocking rate and given that Irish agriculture is a price taker, a concomitant reduction in total national production. Therefore, if a tax on nitrogen fertiliser were to be introduced, this tax is likely to not only reduce fertiliser use levels and the resulting emissions from fertiliser use, but could also be expected to lead to some reduction in stocking rate and as a result the emissions of GHG from livestock.

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