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The local economic impact of climate change mitigation in agriculture

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Abstract. Greenhouse gas (GHG) mitigation measures are currently being implemented in the agricultural sector across the globe. Questions have been raised about the distributional and spatial impacts of agricultural emissions mitigation policies, especially at the local level. This study examines the local impact of a low-income farming sector, beef farming, in a typical Irish beef farming county, County Clare. Input-output analysis reveals that Clare beef farmers purchase the vast majority of farm inputs within the county, with intra-county suppliers providing 90% of their inputs and overheads. We examine the impact of reducing the size of the beef herd in Co. Clare as a direct consequence of meeting national GHG emissions targets by 2030. Taking direct, indirect, and induced effects together, there is an €18.4 million reduction in economic activity in 2030 following the decrease in the beef herd with €14.72 million of that reduction taking place within the Mid-West region.

Keywords: GHG Mitigation, Agricultural economics, Input-output modelling, Micro-simulation.
JEL Codes: Q12, Q18, Q58, R15.

HIGHLIGHTS

- Irish beef farmers are highly dependent on local markets for inputs.
- GHG mitigation measures reducing herd size will heavily impact the local economy.
- Including multipliers, the overall economic loss is almost double the direct loss.

1. INTRODUCTION

Many countries are currently instituting policies to reduce their emission of greenhouse gases (GHG) in order to mitigate against climate change[1].

[1] Climate change mitigation is defined as a human intervention to reduce emissions or enhance the sinks of greenhouse gases (IPCC, 2018).

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In the European Union (EU), the European Green Deal aims to reduce net GHG emissions by at least 55% from 1990 levels by the year 2030, and to achieve net zero emissions by 2050 (European Commission, 2019). In Ireland, the 2021 Climate Action Plan provides a detailed plan for to achieve a 51% reduction in overall GHG emissions by 2030, with the aim of reaching net zero emissions by no later than 2050 (Government of Ireland, 2021).

Due to the historic importance of agriculture relative to other industries in Ireland, the agricultural sector is the single largest contributor to overall GHG emissions, accounting for 37.1% of emissions in 2020 (EPA, 2021). This compares with a figure of just over 10% for agricultural emissions in the EU as a whole (Mielcarek-Bocheńska & Rzeźnik, 2021). To meet abatement targets, the levels of GHGs intrinsic to agricultural production such as methane (CH4) and nitrous oxide (N2O) will need to be addressed.

However, questions have been raised about the distributional impacts of agricultural emissions mitigation policies, especially those that rely on the "polluter pays" principle, the effectiveness of which stems from the contraction of output that they induce, by reducing profits and causing farms to exit the sector (OECD, 2019). Polluter pays measures, such as pure carbon taxes, have generally been shown to be regressive, harming lower income households more than higher income ones (Wang *et al.*, 2016; Verde & Tol, 2009). Within agriculture, mitigation measures[2] that affect farms directly, or indirectly through increased input costs, are more likely to affect poorer farm households and lead to farm exit (Mosnier *et al.*, 2017) and may be ineffective in abating agricultural nonpoint pollution (Kahil & Albiac, 2013).

Agriculture is not just varied in terms of levels of farm income but also with regard to space. Soils, weather, and other agronomic conditions differ across space, influencing yields, agricultural outcomes, and choice of farming activity (O'Donoghue *et al.*, 2015). As farming in Ireland has become more specialised, local conditions have done much to determine which farming activity dominates in each area (Gillmor, 1987). Therefore, emissions mitigation measures that particular impact specific types of farming are likely to have an outsized impact in areas where that type of farming is dominant.

This paper examines the economic and environmental effect of agricultural emissions mitigation measures at a local level. We focus on Ireland as a country with a significant agri-food sector and ambitious targets in terms of reducing GHG emissions in the near future. Ireland has a significant agricultural footprint with about two-thirds of its land devoted to agricultural use. Agri-food is the largest indigenous business and accounted for 6.7% of GNI* in 2019 (DAFM, 2020). Spatially, the better quality agricultural land can generally be found in the south and east with the poorer land in the north and west (Frawley & Commins, 1996). The most profitable sub-sectors within agriculture, dairy, and to some extent, tillage farming, are predominantly concentrated in the south and east. The lower margin beef and sheep sectors are to a large extent located in the midlands, north and west of the country.

In this paper we focus on beef cattle farming which is the most widely practiced form of farming in Ireland. To examine the local impact of mitigation measures, we concentrate on beef farming in one county, Co. Clare in the west of the country. In general, farming in the county is not considered suitable for intensive production with 94% of the agricultural area classified as severely disadvantaged (DAFM, 2022).

The Irish government's agri-food strategy, Food Vision 2030, published in 2021, commits to a minimum 10% reduction in biogenic methane by the year 2030 (DAFM, 20201). Given the heterogenous nature of farming in Ireland, the implementation of a national level target such as this may have differential impacts across the country. This paper examines the impact of a 10% methane reduction on cattle beef farming in Co. Clare, taking account of the interlinkages between cattle beef farming and the local economy. This is accomplished by using spatial microsimulation to create a detailed dataset for local farmers and simulating the economic effect using input-output modelling of a reduction in the beef cattle herd in Co. Clare resulting from meeting the methane reduction target.

Moretti (2010) highlights the impact of changes in tradeable sectors on jobs in non-tradeable sectors. The agri-food sector is an example of a sector with potentially large local impacts in terms of local feed, animal, and service inputs, but is also part of a major globally traded system. Linkages can be relatively complex. Harriss (1987) finds that in addition to production impacts, consumption impacts can be even higher if a stronger agricultural sector reduces outward migration from a rural area. The effects of local spillovers from agriculture in the literature are relatively mixed. Santangelo (2016) finds evidence of positive spillovers from agriculture on the wider local economy in both the agriculture and non-agricultural areas, while Hornbeck and Keskin (2015) find local gains within the agricultural sector but

[2] Mitigation measures are technologies, processes or practices that contribute to mitigation, for example, renewable energy technologies, waste minimization processes and public transport commuting practices (IPCC, 2018).

limited gains elsewhere from an exogenous change on the sector via improved irrigation.

This is a novel piece of research in an Irish or European context. While previous studies such as Miller *et al.* (2014a) have examined the multiplier effects of agricultural output changes at a national level, few studies have examined the multiplier effects of output changes at a local level. There is also a gap in the literature with regards to the interaction between farm households and the local economy (Roberts *et al.*, 2013). The local economic impacts of nationally implemented GHG mitigation measures are also understudied in the literature. This is particularly relevant for livestock farming due to its emissions intensity and localised nature. In 2019, agriculture accounted for 1.9% of economic output in the EU-27, yet generated 15.6% of EU-27 GHG emissions, the second largest industrial share (Giannakis & Zittis, 2021). This is mainly due to beef and dairy production, which have significantly higher GHG emissions per euro of economic output than other agricultural sectors or aquaculture (Tsakiridis *et al.*, 2020).

Like Ireland, many European countries have regionalised livestock production, with specific regions specialising in beef and dairy farming. Examples include Wallonia in Belgium (Duluins *et al.*, 2022), Massif Central and Pays de la Loire in France (Balouzat *et al.*, 2020), and Galicia in northern Spain (Lomba *et al.*, 2022). Agricultural systems in these areas are frequently embedded in local value chains, with many inputs being sourced locally and outputs being processed within the region (Vázquez-González *et al.*, 2021; Pays de la Loire Regional Council, 2019). As a result, mitigation measures to reduce agricultural GHG emissions are likely to have an outsized economic impact in these regions due to value chain linkages. This study looks to provide evidence of the extent of that economic impact at a local level.

Additionally, this research applies a microsimulation approach to modelling the local economic impact. Microsimulation models have previously been applied in a spatial context to examine the multiplier effects of major job losses or gains at a local level (Ballas *et al.*, 2006a), the implications of CAP reform for the national spatial strategy (Ballas *et al.*, 2006b) and the local impact of the marine sector in Ireland (Morrissey *et al.*, 2014).

In the next section, we describe the background regarding the local economic impact of agriculture and the related literature. The methodology is described in section 3 followed by a description of the data sources. This is followed by three separate results sections, the first dealing with the spatial distribution of farms and farm income in the county, the second set of results dealing with the spatial distribution of livestock sales and the source location of inputs and the final results section dealing with the environmental impact of a reduction in the beef cattle herd and local multipliers. This is followed finally by the discussion and conclusions.

2. BACKGROUND

Cattle farming is the most prevalent form of farming in Ireland, accounting for 47% of agricultural land use in 2011 (Geoghegan & O'Donoghue, 2018). Cattle farmers in Ireland are highly dependent on publicly funded subsidies and have become increasingly vulnerable to a cost-price squeeze with declining margins per volume of beef (O'Donoghue, 2013; Hennessy *et al.*, 2008). Evidence suggests that many cattle farmers use subsidies to support loss-making production (Howley *et al.*, 2012). In combination with off-farm income, publicly funded subsidies allow many cattle farms to maintain a reasonable standard of living and be economically sustainable (Hynes & Hennessy, 2012). The retention of these farm households in rural areas supports the relevant local economies via the farm and non-farm expenditures attributed to these households.

Although the economic position of Irish cattle farmers is well covered in the economic literature, there is something of a void in relation to the treatment of the local economic effects of cattle farming production. Cattle farmers may not enjoy the profitability of their dairy farming counterparts, but they do contribute indirectly towards other economic activity in rural Ireland. The concept of 'good farmers' should account for the local social and economic outputs that farmers provide (Sutherland & Burton, 2011). Miller *et al.* (2014b) have developed a social accounting matrix to examine the wider economy effects of a decline in the beef sector and show that significant employment losses in the wider economy would result. The analysis is focused however, at a national rather than local or regional level.

The inadequate treatment of the wider local economic effects of agriculture in Ireland contrasts with the United States where numerous studies have examined this issue. Foltz and Zeuli (2005) find that small farms are more likely to purchase inputs locally in communities where an array of marketing outlets exist. In a study of Wisconsin dairy farmers, Lambert *et al.* (2009) find that farmers located in areas with relatively large farm populations appear to be better served by local input suppliers indicating that farm-community linkages are strongest where farms are numerous and where the sector is large enough to anchor a regional farm supply centre.

Aside from specific farming activities, farmers also contribute directly to local economies through off-farm employment. In Ireland, a relatively high proportion of Irish cattle farmers engage in off-farm employment, with 40 per cent of cattle farms operators being employed off-farm (Donnellan *et al.*, 2020). Pluriactivity is therefore likely to play an important role in determining the economic welfare of cattle farming households. Shucksmith and Ronningen (2011) argue that small farm holdings provide a base from which rural households are able to sustain their livelihoods through pluriactivity, keeping 'lights in the windows' and retaining populations in areas from which they would surely have been lost in the case of farm amalgamation.

While the ability of mitigation measures to reduce GHG emissions in agriculture has been much discussed in the literature, the potential trade-offs between economic and environmental concerns in agriculture, especially at a local level, have not been as well studied. Some national-level studies have been performed, making use of economic analysis models such as input-output (IO) and computable general equilibrium (CGE) modelling. Like Ireland, Brazil's biggest source of GHG emissions is from the agricultural sector. Using a national-level IO model, De Souza *et al.* (2016) find that an overall 1% reduction in Brazilian GHG emissions would fall heaviest on the livestock sector, which in turn, would greatly impact poor households who rely on livestock as their main source of income. Wu *et al.* (2015) use a CGE model to simulate the effect of a GHG emissions intensity levy imposed on the agri-food sector in Northern Ireland. They find that without the adoption of feasible technology, there is a risk of serious damage to agri-food competitiveness with relatively limited economy-wide environmental gain, leading to trade diversion and GHG emission leakages. Bourne *et al.* (2012) use a CGE model to examine the potential impact of Kyoto and EU environmental policy targets on specific agricultural activities in Spain and find a reduction in agricultural output, increased prices for agricultural products and a cumulative fall in agricultural incomes of €1.5 billon compared with a business-as-usual scenario. Research from Chile by Mardones and Lipski (2020) shows that a CGE-modelled environmental tax applied only to the agricultural sector results in a sectoral contraction and a generalised increase in the production of all other sectors, without a substantial fall in overall GHG emissions.

In addressing the local economic effects of agriculture, researchers have focused analysis on a relatively small geographical area e.g., a particular district within New York state in Jablonski and Schmit (2014) and Wisconsin dairy communities in Foltz *et al.* (2002). This approach can be justified on the basis of data collection costs and the desire for a relatively homogenous sample of farms. Our analysis is focused on the cattle sector in a particular area of Ireland, Co. Clare. This county is chosen as cattle farming is overwhelmingly the most important agricultural enterprise in the county. According to the 2010 Census of Agriculture, approximately 78 per cent of farms in County Clare are classified as specialist beef production which far exceeds the national average of 56 per cent.

3. METHODOLOGY

The objective of this study is to model the impact of cattle farming on the local economy. This objective has a number of methodological challenges. While good micro farm level data exist containing incomes, costs, and technical attributes at national level and while there exists spatial census information in relation to small area statistics of farm structures, no dataset contains both detailed income sources and fine spatial attributes. It is therefore necessary to utilise a methodology to synthetically generate spatially differentiated, micro data.

One methodology that allows us to simulate the necessary data is spatial microsimulation (O'Donoghue *et al.*, 2014). Hynes *et al.* (2009a) outline three main benefits of using synthetic data: the ability to create micro data from aggregated macro data at different spatial resolutions; the ability to retain a number of characteristics of micro units within the data and facilitate a multivariate analysis; and the ability to assess the impact of policies on particular groups within the population.

The SMILE-FARM model simulates spatially representative households and farms at an electoral district (ED) level using several data sets: the Teagasc National Farm Survey, the Census of Population, and the Census of Agriculture (COA) amongst others (O'Donoghue, 2017). The data simulation process involves the sampling of farms from the micro dataset containing detailed farm level data from the Teagasc NFS to make it consistent with the COA. The constraint variables used include farm size, farm system, soil type, and stocking rate.

The SMILE-FARM model is used in this paper to create an enhanced spatial microsimulation model by combining SMILE-FARM with the farm-level survey information collected for Co. Clare using a quota sampling technique (O'Donoghue *et al.*, 2017). The most recent SMILE-FARM model which is from the year 2014 is combined with the survey data which were collected in the year 2010. Although the two datasets are not contemporaneous, NFS data show that there was relatively little change in the characteristics of cattle farming in Co. Clare over this time period so combining the two datasets is appropriate.

Input-Output

In order to estimate the multiplier effect associated with changes in the size of the beef cattle herd, a sub-regional input-output model is employed. A multiregional input output (MRIO) model for sub-regions takes the same form as that of a regional MRIO with a multiregional matrix (of technical coefficients. The objective is to capture the various economic transactions between and among the several regions in a multiregional economy.

A p-region MRIO would be expressed as follows:

$$(I-A)x=d$$

and the solution for x is shown as follows (similar to the standard I-O solution for x):

$$x=(I-A)^{-1}d$$

where:

$$A=\begin{bmatrix} A^{11} & 0 & \cdots & A^{1p} \\ A^{21} & A^{22} & \cdots & A^{2p} \\ \vdots & \vdots & \ddots & \vdots \\ A^{p1} & 0 & \cdots & A^{pp} \end{bmatrix}, I=\begin{bmatrix} I & 0 & 0 \\ 0 & I & 0 \\ \vdots & .. & \vdots \\ 0 & 0 & I \end{bmatrix},$$

$$x=\begin{bmatrix} x^1 \\ x^2 \\ \vdots \\ x^p \end{bmatrix}, \text{and } d=\begin{bmatrix} f^r \\ f^2 \\ \vdots \\ f^p \end{bmatrix}$$

The MRIO can then be expressed as:

x – a vector of gross output for each of the p regions

A^{rr} a regional technical coefficient matrix intra-spatial unit $A^{rr}=\begin{bmatrix} a_{11}^{rr} & \cdots & a_{1n}^{rr} \\ \vdots & \ddots & \vdots \\ a_{n1}^{rr} & \cdots & a_{nn}^{rr} \end{bmatrix}$

A^{rs} a technical coefficient matrix inter-spatial unit between unit r and s $A^{rs}=\begin{bmatrix} a_{11}^{rs} & \cdots & a_{1n}^{rs} \\ \vdots & \ddots & \vdots \\ a_{n1}^{rs} & \cdots & a_{nn}^{rs} \end{bmatrix}$

I the Identity matrix ("1" in the diagonal, "0" in all other fields)

$(I-A)^{-1}$ an inverse of a square matrix (also known as the Leontief inverse). A sector's output can be broken down in output required to meet final demand and output used by other sectors (intermediate demand). The Leontief inverse matrix allows the estimation of individual sectoral output multipliers capturing the direct and indirect economic effects of exogenous shifts in final demand.

An induced or Type II multiplier incorporates the impact of household spending in addition to the direct and indirect impact. Augmenting the Leontief Inverse Matrix with wage income per unit output[3] w and FC_r is the total final consumption of households[4], we produce the Augmented Leontief Inverse Matrix:

$$(I_a-A_a)^{-1}$$

The input-output model can be extended to account for environmental emissions associated with production activities by multiplying the economic output of a sector at each stage (vector x as shown earlier) by the diagonal matrix of sectorial environmental burden coefficients (e.g. GHG emissions per monetary or physical unit of output) B

$$e_k = B_k(I - A)^{-1}d$$

where e is the total (direct and indirect) environmental impacts vector per unit of final demand (Tsakiridis *et al.*, 2020). The subscript k denotes the type of environmental impact, while matrix B_k has diagonal elements representing the environmental impacts of interest per unit of output for each process (Hendrickson *et al.*, 1998). This process relates GHG emissions, in this case methane, to economic output so demonstrates how big a fall in beef output is required to achieve a 10% reduction in methane. The extent to which the exogenous shock of the herd reduction spreads through the rest of the economy is indicated through the use of multiplier effects.

The sub-regional model, based on work by O'Donoghue (2021), provides multipliers for three regions: Limerick city, the Mid-West NUTS 3 region, and the rest of the country. The Mid-West region in the is model is comprised of the rest of Co. Limerick, Co. Clare, and Co. Tipperary. Therefore, the sub-regional IO model can provide economic multipliers related to changes in economic activity at a level quite close to the county level examined in this paper. The data used for the sub-regional IO model is further described in the Annex.

4. DATA

The survey used for this study was undertaken in Co. Clare, in the west of Ireland. Clare was chosen as the

[3] Including Operating Surplus for sectors with high numbers of sole traders, such as agriculture, construction, transport etc.

[4] The consumption rate per € of wage is defined as $c_{r,i}=FC_{r,i}/W_r$.

Table 1. Comparison of farming in Clare and Ireland.

	Clare	National
Population	118,817	4,761,865
Daytime working population	34,761	2,304,037
People in agriculture, forestry, and fishing	3,423	89,116
Number of Farms	6,297	135,037
Specialist Beef Farms	5,109	74,159

Source: Census of Agriculture 2020 and Census of Population 2016.

study area for this paper for two specific reasons. Firstly, nearly 10% of the working population in the county are employed in agriculture, forestry, and fishing (see Table 1). This is substantially higher than the number employed in agriculture for the entire country, which is just under 4%.

Secondly, Table 1 shows that, of the 6,297 farms located in Co. Clare, over 81% of them are beef specialists. Again, this value is much higher than the national average, which is 55%. Hence, cattle farming is a relatively important source of employment in Clare. In this paper, we hypothesise that cattle farmers' earnings feed into the wider Clare community, thus meeting one of the primary goals of the CAP's Rural Development Plan: rural viability. We then estimate how changes to the local beef sector in Clare would hypothetically influence rural viability in the county.

While the SMILE-FARM model provides the spatial distribution of farms with their incomes, costs, and technical attributes, we also need to collect data in relation to the location of purchases and sales by type of good. This data provided us with the necessary information about the source location for inputs and the output destination for cattle outputs among cattle farmers in the county. The resulting sample of Clare farms was matched with the SMILE-FARM model so that spatial analysis could be carried out with reference to the activities of all cattle farms in the county. A more detailed description of the data sources used for this paper and the methodology used to collect the data from Clare farmers is available in the Annex.

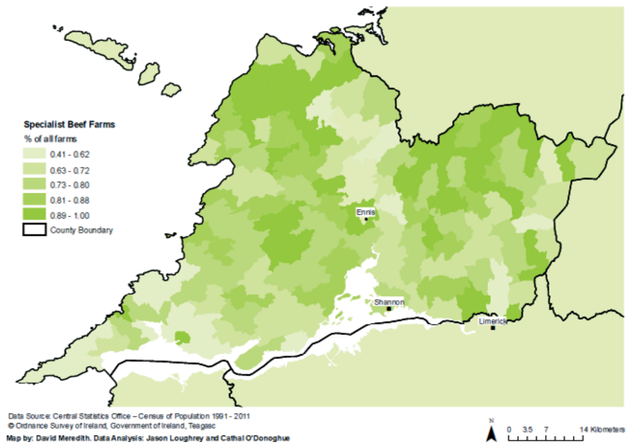

Figure 1. The share of farmers classified as specialist beef producers in Clare.

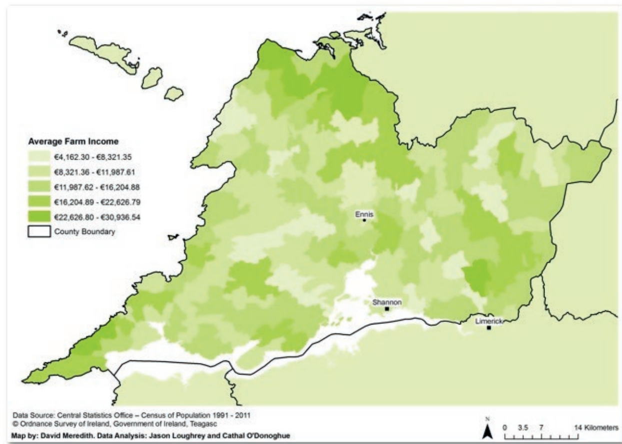

Figure 2. Spatial distribution of family farm income in 2006.

5. RESULTS

Outputs from the SMILE Model – Spatial distribution of agriculture in County Clare

The census data indicate the importance of specialist beef production to farming in Clare with some variability within the county in terms of the reliance upon specialist beef production. In Figure 1, we show the share of farmers engaged in specialist beef production. The results indicate some variability between the north and south of the county. Farming in many parts of the north is almost exclusively dependent on specialist beef production. Many parts of the south have a relatively high share of farmers devoted to other activities such as dairying or mixed livestock grazing. This explains why the share engaged in specialist beef production is below 63 per cent in parts of the south.

In Figure 2, we present the spatial distribution of family farm income using five income brackets. The definition of family farm income includes agricultural subsidies but excludes off-farm income. Figure 2 indicates that farm income is highest in the very north of the county. The relatively high farm income in this area may be attributed to the higher than average farm size. The

Table 2. Share of cattle farm output sold in Co. Clare regions according to geographical point of sale.

Region	Outside	North-west	South-west	North-east	South-east	Ennis
North-west	71.5	12.7	3.4	0.6	1.5	10.4
South-west	57.5	12.0	13.5	0.1	2.9	14.1
North-east	73.7	0.1	0.0	15.6	4.0	6.6
South-east	79.7	0.3	0.1	4.4	9.2	6.3
Ennis	83.5	1.6	0.0	0.0	7.2	7.6
Total	72.0	6.9	4.0	3.7	4.3	9.2

relatively lower income in the south emerges despite the fact that dairy farms have higher incomes than specialist beef producers and dairy farms are more common in the south. The patterns suggest that there are many low-income specialist beef producers in the south and north-east of the county. These farm households are economically vulnerable unless decent off-farm employment is available.

Cattle farmer income and expenditure in County Clare

In this section, we present results regarding the flows of cattle farming inputs and outputs in the county as facilitated by the matching of the Clare survey data to the SMILE model. For analytical purposes, we provide these results according to six regions i.e. North-West Clare, South-West Clare, North-East Clare, South-East Clare, Ennis and outside Clare. The four within-Clare regions are defined roughly according to their position relative to the town of Ennis. As Figures 1 and 2 show, the majority of the geographical area in the county is west of Ennis town. It is therefore unsurprising to find that the majority of farmers and agricultural output comes from that part of the county.

In Table 2, we provide the share of output[5] for each of the six regions based on the geographical point of sale. This includes the share of output sold to outside the county. Table 2 shows that 72% of beef cattle farm output goes outside of the county. This high figure is primarily driven by how beef cattle farming in structured in Clare and the rest of the country. Cattle farming in Clare is dominated by suckler farming, where calves from suckler cows are reared for six to nine months until weaning takes place and the calf is sold to another farm for further finishing (Teagasc, 2015). These finishing farms are located mainly outside Clare, principally in the east of Ireland. The remaining output goes to the west of the county (10.9%), the east (9%) and Ennis town (9.2%), with the majority of output not going outside the county staying within each region.

Inputs and overheads

We have now established some important findings about the point of sale for livestock sales. In Table 3, we present the share of direct inputs and overheads purchased from each of the six regions. Direct inputs include feed, machinery hire, casual labour and fertiliser. Overheads include electricity, telephone costs, interest payments and depreciation of assets. We find that almost 9% of expenditures are sourced from Ennis town and 10.5% from outside the county. Among specialist beef farms, we find that just over half of all overheads and inputs are sourced from the west of the county. Approximately 29.5% are sourced from the east of the county.

Table 3 also shows that for all regions except Ennis, the majority of inputs are purchased within the same regional area. This is particularly the case in the western part of the county, where over 60 per cent of inputs are purchased locally. The findings have much in common with those of Pritchard *et al.* (2012) where there is clear evidence that farm households and businesses make extensive use of their local towns for maintenance purchases and a range of other supplies. Pritchard *et al.* (2012) label this tendency to buy local as the ‘local if possible principle’.

Overall, the findings suggest that a change in the volume and value of the cattle herd in Clare will lead to output changes for those companies supplying the specialist beef farmers with inputs. The information supplied in Table 3 suggests that nearly 90% of these output changes would come from within the county. The multiplier effects at the county level are therefore likely to be more important than in the case of most other industries.

[5] In this context, by output we mean the monetary value of production.

Table 3. Share of cattle farm inputs coming from Co. Clare regions.

Region	Outside	North-west	South-west	North-east	South-east	Ennis
North-west	13.4	60.7	11.1	3.1	3.5	8.2
South-west	4.6	13.7	68.9	0.9	4.0	7.8
North-east	9.6	7.0	2.6	53.1	18.7	9.0
South-east	10.8	5.8	2.8	18.6	53.2	8.8
Ennis	10.5	25.2	7.7	4.7	15.1	36.8
Total	10.5	25.8	25.4	12.3	17.2	8.8

Effects of changes in the beef industry to the environment and local economy

In this section, we present results regarding the overall effect for the wider Clare economy of a hypothetical decline in the size of the cattle herd in the county. The Food Vision 2030 policy document was published by the Irish government in 2021, providing a roadmap for the Irish agri-food sector up to the year 2030 (DAFM, 2021). The document commits to a reduction of at least 10% in biogenic methane by 2030 (based on 2018 levels) in the agri-food sector in Ireland. We assess what the overall impact of a such a reduction would be in an area heavily dependent on cattle farming such as Co. Clare. It is assumed that the 10% reduction in methane is achieved entirely through a reduction in the beef cattle herd, with dairy cattle numbers continuing to increase at the current rate and sheep numbers staying constant. This is compared with a scenario where beef cattle number increases seen post-quota removal (2016-2018) are extrapolated at a decreasing rate to the year 2030 until a steady state is achieved. There are two main reasons for concentrating of a reduction in the beef cattle herd. First, beef has the highest GHG footprint per euro of output of all the major sources of protein produced in Ireland (Tsakiridis *et al*. 2021). Second, the other main source of agricultural methane emissions (dairy) is currently far more profitable at the farm level than beef farming (Dillon *et al*., 2021).

The environmental impact of a 10% reduction by 2030 in methane in Co. Clare is shown in Table 4. An overall 10% reduction in the beef cattle herd is unequally distributed across the county. In order to achieve a 10% county wide reduction, reductions of 16.3% in the north-west, 13.5% in the south-west and 11.7% in the south-east are necessary. This compares with lower levels of methane reduction in the north-east and Ennis regions. Table 4 also shows that reducing methane emissions through reduction in the beef cattle herd also reduce the production of organic nitrogen with the highest percentage nitrogen reductions being achieved in the west of the county.

Table 4. Percentage change in emissions in the Clare Regions with a 10% cut in methane emissions in cattle production.

Region	Methane	Greenhouse Gases	Organic N
Clare	-9.8	-9.7	-11.9
North-west	-16.3	-16.2	-18.6
South-west	-13.5	-13.4	-15.7
North-east	-5.4	-5.3	-7.2
South-east	-11.7	-11.6	-13.9
Ennis	-9.5	-9.4	-11.4
National	-4.6	-4.4	-6.4

In Figure 3, the relative economic impact of reducing methane by 10% is observed. The reduction in the beef cattle herd causes an 18.6% fall in output from that sector by 2030, relative to 2018. As the dairy herd continues to increase in size, a 27.8% increase in dairy output is observed. The sheep herd remains constant so only a 0.008% drop in economic output is seen from 2018 to 2030. Although there is a larger percentage increase in dairy output than there is a drop in beef cattle output, the much larger size of the beef herd means that overall economic output over the time period remains almost flat, with a 0.01% fall in output being observed.

The wider economic effects of the 10% reduction in methane can be seen in Table 5. The reduction in the beef cattle herd results in a €9.34 million decrease in total output in 2030 relative to a scenario where cattle numbers continue to increase at the current rate. The reduction in output is concentrated in the Mid-West region of which Clare is part with €8.59 million of the reduction taking place there. The indirect multiplier is 0.68, indicating that there is an additional €680,000 loss to the Irish economy for every €1 million reduction in spending by beef cattle farmers in Clare. The majority of indirect spending takes place in the Mid-West region but more of the multiplier effect is felt out-

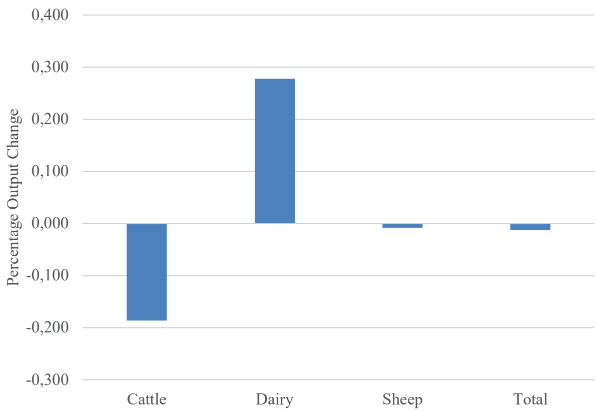

Figure 3. Percentage change in output in County Clare for a 10% reduction in methane.

side the region than for the direct multiplier with 37% of spending taking place outside the Mid-West region. The induced multiplier which takes employee spending effects into account is 0.29. The small size of the multiplier reflects the limited amount of employment provided by agriculture compared to other industries. Again, a large proportion of the multiplier (78%) is located within the Mid-West region. When direct, indirect and induced effects are taken together, there is an €18.4 million reduction in economic activity in 2030 following the decrease in the beef cattle herd with €14.72 million of that reduction taking place within the Mid-West region.

Following on from the effects of a reduction in methane emissions on the wider economy, the effects of the methane reduction at the farm level can be seen in Table 6. Teagasc, the Irish agricultural advisory service, defines a farm business as being economically viable if family farm income (FFI) is sufficient to remunerate family labour at the minimum wage and provide a five per cent return on the capital invested in non-land assets, i.e. machinery and livestock. Table 6 shows the percentage of beef cattle farms that are considered viable with and without the 10% reduction in methane emissions. There are 9% fewer viable beef cattle farms in Co. Clare following the methane reduction, with the largest falls in the number of viable farms taking place in the north-west, the north-east and Ennis. The viability gap measures how far the average farm is from the viability threshold. The imposition of a reduction in methane emissions would put the average beef cattle farm 60% below the viability threshold, compared with 52% with the emissions reduction taking place. Farms in the north-west of the county would suffer the biggest viability gap increase, moving a further 16% away from the viability threshold.

Table 5. Economic effects of beef industry changes after a 10% reduction in methane.

Region	Direct	Indirect	Induced	Total
Rest of country	-0.37	-1.66	-0.39	-2.42
Mid-West	-8.59	-4.02	-2.11	-14.72
Limerick	-0.38	-0.67	-0.20	-1.25
Total	-9.34	-6.35	-2.71	-18.40
Multipliers				
Rest of country	0.039	0.178	0.042	0.259
Mid-West	0.920	0.431	0.226	1.577
Limerick	0.041	0.071	0.022	0.134
Total	1.00	0.68	0.29	1.970

Table 6. Changes in beef cattle farm viability with 10% methane reduction.

	Viability Rate			Viability Gap		
Region	Baseline	Methane Cut	Change	Baseline	Methane Cut	Change
North-west	0.27	0.24	-11%	0.45	0.52	16%
South-west	0.29	0.27	-5%	0.49	0.56	14%
North-east	0.28	0.25	-11%	0.47	0.52	9%
South-east	0.31	0.29	-9%	0.50	0.56	13%
Ennis	0.26	0.23	-12%	0.46	0.51	12%
Total	0.29	0.26	-9%	0.52	0.60	13%

6. DISCUSSION AND CONCLUSIONS

In this paper, we have examined the importance of the beef cattle sector to the local economy of Co. Clare in Ireland and the potential impact of GHG mitigation measures in this sector upon wider economic activity. Our findings suggest that Irish beef cattle farmers are inclined to purchase most of their inputs from within their own immediate area, thus indicating that the 'local if possible principle' is followed by many farmers in the county. The findings suggest that a substantial share of livestock sales tend to take place in the main county town of Ennis and thus away from the immediate hinterland of many cattle farmers. This shows that farmers will travel longer distances for specific transactions, but the overall results indicate that small towns and villages are deeply connected with the agricultural hinterlands. As in the case of Pritchard *et al.* (2012), the analysis suggests that a viable local farming sector supports local towns and the basic commercial functions demanded by farm households.

The empirical analysis has further examined the impact of a reduction in the size of the herd in Co. Clare to meet GHG emission targets. The overall impact of such a decline is capable of reducing total primary cattle output by €9.3 million, with €8.6 million of the reduction located within the Mid-West region. When multiplier effects are included, the overall decline in economic output is €14.7 million in the Mid-West region and €18.4 million overall. The number of beef cattle farms in Co. Clare considered viable is also reduced by 9% as a result of the mitigation measures. Overall direct economic output within the agricultural sector in Co. Clare remains almost unchanged due to increases in dairy output that offsets the beef output reduction.

The results are in line with other analyses such as Wu *et al.* (2015) and Bourne *et al.* (2012) that show that the implementation of GHG mitigation measures in agriculture can lead to a reduction in output from the agricultural sector, in this case beef. When multiplier effects are included, the overall economic loss is almost double the direct loss, showing how strongly linked the beef sector is to the local economy.

This analysis shows that the distributional and spatial impact of mitigation measures must be taken into account when designing policy instruments. Given the high global warming potential (GWP) associated with methane, ruminant animal agricultural systems are highly likely to be subject to increasing emissions mitigation measures in the coming years. With the wide disparity between Irish beef cattle and dairy farm incomes, as well as value added opportunities, it is likely that methane reductions will be concentrated on the beef sector. As a result, policymakers must prepare mechanisms to offset the costs incurred by those most affected by these measures.

The results of the multiplier analysis show that the beef sector is highly embedded within the regional economy with indirect and induced effects almost doubling the direct impact of the cattle herd reduction. Localised value chains are also observed in other regions of Europe where beef cattle farming is prominent (Vázquez-González *et al.*, 2021; Pays de la Loire Regional Council, 2019). GHG mitigation measures that impact upon cattle farming will affect not just the farmers themselves, but a chain of businesses and households connected to the beef value chain. In an environment where such policy measures are becoming more likely to be implemented, as well as shifting consumer demand away from meat products, governments will need to quantify the size of the impact on affected industries, as well as what steps should be taken to assist those affected.

Some attention has been paid to the idea of a 'just transition' for those most affected by climate change mitigation measures, in order to support communities transitioning to a low carbon economy (Blattner, 2020; Heyen *et al.*, 2020). As part of the European Green Deal, a Just Transition Mechanism (JSM) worth €55 billion over six years exists to alleviate the socioeconomic impact of the transition to a low carbon economy. Investments such as these will be required to offset losses arising from GHG mitigation measures, especially in areas where alternative sources of employment are scarce. Such a possibility is put forward by Hynes *et al.* (2009b) who use spatial microsimulation to model an agricultural methane tax in Ireland with revenue raised being redistributed in the form of an environmental subsidy to farmers. The study found that such a measure would encourage farmers to participate in the scheme and could also have the effect of moving low income farms up the earnings distribution ladder.

Efforts to meet GHG emission targets are not the only potential reason for a decline in the cattle herd. Beef cattle farming continues to be loss-making on average, with an increasing age profile, and greater competition for farmland. Regardless of the cause for the decline in the cattle herd, the multiplier effects remain important. The potential losses to farm income further underline the importance of off-farm employment as an alternative income source.

The effect of a reduction in beef cattle farming is also complicated by the nature of agricultural land in Co. Clare, 94% of which is classed as severely disadvantaged, and thus unsuitable for the intensive production seen in dairy farming. Alternative approaches to agriculture have proven successful in the region with agri-environment schemes such as the Burren Farming for Conservation Programme (BFCP) and Burren Programme (BP) proving successful in the Burren region, which covers an estimated 72,000 ha of land in Counties Clare and Galway (Dunford & Parr, 2020). These programmes utilise a 'hybrid' approach whereby farmers are rewarded annually for their environmental performance while also having access to a fund to carry out self-nominated 'conservation support actions' to help improve conservation performance over time.

In addition, the Basic Payment Scheme, environmental and the rural development payments play an important role in sustaining these farming communities. Given the increasing environmental orientation of EU policy, future agricultural payments to farmers should take account of the role of farmers in environmental stewardship and as economic pillars of local communities (McGurk *et al.*, 2020; Rizov *et al.*, 2018). Conversion to organic beef farming may also be an option for some farmers as required inputs are very similar to non-organic beef farming and incentive schemes already exist to support the sector (O'Donoghue *et al.*, 2018). Additionally, organic farms tend to localise in places like Co. Clare, far from more competitive agriculture, characterised by a high specialization in arable crops and a more intensive use of mechanisation and chemicals (Bonfiglio & Arzeni, 2019). While this paper has emphasised the local economic impact of beef cattle farming, it should be acknowledged that beef production has a strong export orientation and that a wider treatment of the contribution of beef cattle farming to the overall economy should reach beyond a local/global dualism.

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THE LOCAL ECONOMIC IMPACT OF CLIMATE CHANGE MITIGATION IN AGRICULTURE - ANNEX

Sub-regional IO model data

The sub-regional IO model uses census-derived, commuting flow employment data at a sub-county or district scale to downscale regional and national input-output data. The national IO table containing 58 industrial sectors is collapsed to an 8-sector[6] model for which localised employment data derived from the most recent 2016 census exist. Spatial interaction models of the inputs and outputs in different sectors in different areas are estimated as a function of the distance to different markets and the characteristics of these markets using information from an industry survey.

Data collection

To facilitate data collection, an application was made to undertake a series of queries on the Teagasc Client Information Management System (CIMS). This request was granted subject to a number of conditions associated with ensuring the confidentiality of the data. A number of queries were run to (i) identify all Teagasc clients in Co. Clare; (ii) identify all Teagasc clients with a beef enterprise from this subset of data; and (iii) identify those enterprises where beef production was the primary type of farming undertaken on the farm.

Using spatial analytical techniques, Co. Clare was divided into four sub-regions by applying a horizontal and vertical transept that bisected Ennis. (i.e. Clare was divided into four sub-regions with Ennis at the centre). Each of the farms selected from the CIMS was allocat-

[6] These 8 sectors are food and agriculture; manufacturing and industry; building and construction; commerce; training, storage and communications; public administration and defence; education, health and social work; and other.

ed a sub-region identification number based on their address. These data were incorporated into a statistical analysis package and a random sample of 100 farms was identified from each sub-region.

The survey was carried out by contacting the selected farmers by telephone. If a farmer did not wish to participate in the survey, the next farmer on the list was contacted until 13 farms in each of the sub-regions had been surveyed. This resulted in a sample of 52 farms being surveyed.

Once complete, the survey data were entered into a spreadsheet and the data restructured to extract four individual survey sections. These included (i) the address of the farm; (ii) the structure of the farm enterprise; (iii) the source (address) of inputs to the farm; and (iv) the destination (address) of outputs. All sections that incorporated address data were geocoded to facilitate spatial analysis (location allocation) within the SMILE model.

The survey data were then matched to the SMILE model using a statistical matching process known as the distance method. This method of matching from the survey to the SMILE model involves a set of overlapping variables that are common to both the survey data and the SMILE model. These variables included the farm type (i.e. dairy, specialist beef, crops etc.), demographic variables such as age and marital status, and economic variables such as the amount of direct payments. This allows the matching of farms of similar type from the farm survey data to the SMILE model and therefore achieve the necessary scale for spatial analysis.

The most basic implementation of the distance method uses distance functions with finite weights for the overlapping variables (Decoster *et al.*, 2020). To be precise, for a given record in the survey, the distance in the (selected) overlapping variables to every record in SMILE model is calculated. This could for instance be the difference in age, the difference in farm type, the difference in direct payments, etc. Then the weighted sum of these differences is calculated and finally the record in SMILE which has the smallest weighted sum is picked out. If there are several records which result in the same minimum distance, one of these records is chosen at random.