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Measuring GHG Emissions Across the Agri-Food Sector Value Chain: The Development of BIO - a Bio-economy Input-Output Model[1]

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ABSTRACT

Sustainable intensification is one of the greatest challenges facing the agri-food sector which needs to produce more food to meet increasing global demand, while minimising negative environmental impacts such as agricultural greenhouse gas (GHG) emissions. Sustainable intensification relates not just to primary production, but also has wider value chain implications. An input-output model is a modelling framework which contains the flows across a value chain within a country. Input-output (IO) models have been disaggregated to have finer granular detail in relation to agricultural sub-sectoral value chains. National IO models with limited agricultural disaggregation have been developed to look at carbon footprints and within agriculture to look at the carbon footprint of specific value chains. In this paper we adapt an agriculturally disaggregated IO model to analyse the source of emissions in different components of agri-food value chains. We focus on Ireland, where emissions from agriculture comprise nearly 30% of national emissions and where there has been a major expansion and transformation in agriculture since the abolition of milk quota restrictions. In a substantial Annex to this paper, we describe the modelling assumptions made in developing this model. Breaking up the value chain into components, we find that most value is generated at the processing stage of the value chain, with greater processing value in more sophisticated value chains such as dairy processing. On the other hand, emissions are in general highest in primary production, albeit emissions from purchased animal feed being higher for poultry than for other value chains, given the lower direct emissions from poultry than from ruminants or sheep. The analysis highlights that emissions per unit of output are much higher for beef and sheep meat value chains than for pig and poultry meat value chains.

Keywords: Bio-economic Input-Output; LCA, Agri-Food Value Chain; Disaggregation methodology

JEL codes: Q53, C67, Q10

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1. INTRODUCTION

Sustainable intensification is one of the greatest challenges facing the agri-food sector which needs to produce more food to meet increasing global demand, while minimising negative environmental impacts such as agricultural greenhouse gas (GHG) emissions. Most goods produced in an economy have an impact on the environment. For many products, the greatest environmental impacts occur within the complexity of the value chain that leads from producer through processors and marketing intermediaries to the final consumer of the good. Thus, in many cases, much of the environmental footprint of specific goods lie in the purchases, materials and services required for production (Berners-Lee, 2011).

There is a considerable literature that addresses the carbon emissions generated by different production sectors (see for example Hendrickson et al. (2006); Weber et al. (2008)). Assessment of the emissions along the entire value chain has become a standard technique for developing policies associated with environmental management in order to address possible inefficiencies (Clift, 2000). In relation to the agri-food sector, environmental emissions generated in agri-food production processes have received considerable attention in the literature, in relation to individual products (Del Borghi et al., 2014; Sonesson et al., 2016; Palmieri et al., 2017) as well as collectively (Mylan et al., 2015), at sectoral or sub-sector level or as a regional/global supply chain (MacLeod et al., 2017; Porter et al., 2016; Mottet et al., 2017; Camanzi et al. 2017).

However, the production of agri-food products involves multiple, often inter-linking sub-sectors which may have differential efficiencies and inputs with consequently different emission footprints. Any processed food products may have food components from meat, dairy and grain value chains, which in turn will have input from animal feed, fertiliser and pesticide value chains which may span many countries in the creation of the final product.

In a world where agriculture needs to become more efficient in relation to emissions as well as cost, it is reasonable to expect that sub-sectors with greater emission efficiencies may have a comparative advantage in future policy and emission reduction debates. The achievement of increasing food production while complying with environmental regulation and consumer demands requires an assessment of emissions both across and within the agri-food value chain. This would allow for the identification of the sub-sectors where emissions per unit of value are the highest/lowest, with a view to assessing where environmental damage is compensated the least/most. However, the complexity of the within and between sector interactions in agri-food value chains presents data and methodological challenges.

There is a large literature on accounting and modelling methodologies that describe many facets of agri-food production processes. Single sector models such as the FAPRI model (Meyers et al. 2010), while containing great detail of global markets, do not capture the interplay, flows and connections between different sectors. Input-Output (IO) models on the other hand, incorporate all sectors within an economy and international connections via trade, but do not generally disaggregate beyond sectoral level. The extended I) model developed by Philippidis et al. (2014) provides a better understanding of the structure of the largely land-based agri-food focused bio-economy, while environmental impacts can be further incorporated using (IO) Life-Cycle Analysis (LCA) . According to Munksgaard (2001), IO LCA is a powerful accounting tool for examining the structure of economic activity and associated issues such as the pollution and/or resource use embodied, directly or indirectly, in the production, consumption and trade flows under different accounting principles.

While there is a substantial literature on IO-LCA research undertaken across the economy, there is little literature in relation to the addition of LCA analyses to agri-food disaggregated IO models (such as Philippidis et al., 2014), which are necessary for the measurement of sub-sectoral emissions within the agri-food value chain. There have been some individual value chain specific LCA analyses using IO models, such as Yan et al. (2013) or West & Marland (2002), who developed an IO-based LCA model to evaluate the greenhouse gas emissions in pasture-based milk production in Ireland and tillage systems in the USA respectively, or Virtanen et al (2011) who used an IO approach to consider the emissions associated with different lunch portions.

However, these analyses have not incorporated foreign production into the IO table to account for imported goods and services, nor have they been disaggregated to include the wider agri-food sector. This is possibly due to the complexity of the disaggregation involved in individually examining the allocation of inputs and outputs for agri-food sub-sectors such as dairy and beef production. However, this level of disaggregation is

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necessary to gain a greater understanding of the environmental sustainability of agricultural commodities across agri-food value chains.

In quantifying emissions along an agri-food value chain, Ireland presents an interesting case study. A European Commission report shows that the Irish grass-based production model has the lowest carbon footprint in the EU for milk, and the fifth lowest carbon footprint in the EU for beef (Leip et al., 2010). Largely on foot of the marketing of these sustainability credentials, Ireland has gained a reputation as a producer of high quality food and drink for global markets (FutureInFood, 2017) with exports in excess of 75% of its total agricultural output. Ireland also has targets to significantly expand agricultural production for the dairy and beef sectors. However, the achievement of further expansion while complying with environmental regulation will require an assessment of emissions along the value chain in order to address possible inefficiencies and to optimise expansion in sectors with the greatest environmental and economic comparative advantage.

This paper fills a gap in the literature by describing the development of a disaggregated agri-food bio-economy IO (BIO) model in order to identify indirect suppliers and thus indirect emissions associated with final agri-food products. The model is extended to include a relatively detailed LCA approach to examine between and within-sector differential emissions across the Irish agri-food value chain. The paper is structured as follows. The next section describes the theory of value chains and the context of the Irish agri-food value chain. The methodology and data sections describe the sectoral disaggregation of the agri-food sector and the assignment of emissions in the development of the LCA 'BIO' model. The results section presents the structure and associated emissions of the different components of the agr-food value chain. The paper concludes with policy recommendations, analytical caveats and suggestions for future research in this area. An Annex containing the detail of the agri-food inter- and within-sector BIO disaggregation is also provided to allow for replication of the model using Farm Accountancy Data Network (FADN) data.

2. VALUE CHAIN ANALYSIS

Theory of Global Value Chains

The term value chain was popularised by Michael Porter in the business literature, based on the idea that an organisation as a system was made up of sub-systems, each with inputs, transformation processes and outputs. Gereffi & Lee (2012) traced the emergence of global value chains (GVC) to the 1960s when globalisation elevated competition between firms from the local to the international stage, leading to a change in production methods as firms looked for ways to reduce production costs by outsourcing different segments of the production process overseas. The definition of value chains therefore is broadly defined as the full range of activities and processes that are needed to bring a product from conception through the intermediary stage of production to delivery to final consumers, "the sequence of all functional activities required in the process of value creation involving more than one country".

By using global value chains to gain competitive advantage, a country can improve income, employment, and productivity (OECD, 2013). For example, the Irish dairy value chain has previously been mapped and analysed by Heery et al., (2016). The authors found that the sector is relatively fragmented and optimisation at farm and processing levels is necessary to retain competitive advantage. According to their findings, the over-reliance of the Irish dairy system on basic commodity sales is a threat to the sector in the absence of scale and cost advantages.

For the Irish agri-food sector to be in a position to capitalise on the projected increase in global demand for food, the challenges presented by both the production process and the value chain need to be addressed. In this analysis, the GVC approach can help us to first qualitatively understand and map the structure of the agri-food sector, providing insights as to the information necessary to populate an input-output model. There are four basic elements that the GVC methodology investigates: input-output structure, geographical scope, governance structure and institutional context. In the agri-food value chain context, the GVC methodology allows us to understand questions such as:

- How can policy makers support the creation of employment, wealth and innovation amid increasing global competition?
- In which areas within the agri-food value chain are emissions concentrated?

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- Which sub-sectors can generate the greatest economic and emissions efficiencies?
- How can policy makers ensure that the benefits of investment in the agri-food sector, such as jobs, added value and innovation accrue to the domestic economy?
- What are the regulatory barriers to the development of the sector?

The Irish Agri-food Value Chain

The agri-food sectoral strategy Food Wise 2025 (DAFM, 2015) sets ambitious targets for the agri-food sector to increase exports by 85%, relevant primary production by 65% and value added by 70% (DAFM, 2015), with a target of 50% expansion in production envisaged for the dairy sector. However this presents environmental challenges as over the same period, Ireland has committed to reduce GHGs by over 20% (EPA, 2015). In addition, since the removal of milk quotas in 2015, there has been an increase in dairy cow numbers with a consequent increase (41%) in dairy beef meat (and a reduction (4%) in meat from beef animals) as illustrated in Table 1. As Irish dairy systems are in general more efficient than beef systems in relation to GHG emissions per unit of product (Hennessy et al., 2013) and because Irish dairy is comparatively more efficient relative to competitors than competitors, this shift to dairy beef needs to be investigated in relation to a potential shift in the relativity of emissions within the agri-food sector value chain. In a world where agriculture needs to be more environmentally efficient, there may be an argument for prioritising the most efficient systems under the Common Agricultural Policy.

Table 10 Growth in Agri-Food Volume 2012-2017 (Ratio 2017-2012)

	2012-2017 Growth Ratio
Beef and veal	1.23
Pig meat	1.13
Sheep meat	1.13
Poultry meat	1.11
Other meat	1.00
Seafood Processing	1.06
Dairy Products	1.39
Dairy Cows	1.26
Suckler Cows	0.94
Dairy Beef Meat*	1.41
Beef Meat*	0.96
Share of Beef from Dairy*	1.23

Source: Central Statistics Office (www.cso.ie)
*2012-2020

Value Chain Emissions Accounting

Under the United Nations Framework Convention on Climate Change (UNFCCC), countries are legally obliged to report national greenhouse gas inventories annually. The Environmental Protection Agency (EPA) Ireland estimates emissions using methodologies provided by IPCC using Common Reporting Format (CRF) software and prepares annual National Inventory Reports (NIR) (Duffy et al., 2017). The CRF is a set of spreadsheets containing numerous tables reporting emissions and background data for various sectors, the NIR describes the methodologies, data sources, background information and the entire process of inventory compilation (Duffy et al., 2017).

The Intergovernmental Panel on Climate Change (IPCC) territorial (or production-based) approach in emissions accounting is widely used for national emissions accounting but is also criticised (Schulte & Donnellan, 2012, (Peters & Hertwich, 2008) as it does not account for emissions embodied in international trade and transportation and exacerbates the process of carbon leakage (Schulte & Donnellan, 2012). The territorial approach to emissions accounting is incomplete as it does not capture all emissions along the value chain. The alternative method is consumption-based LCA approach to emissions accounting, which incorporates emissions associated with final domestic consumption as well as associated imports (Boitier, 2012).

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LCA research related to Irish agri-food production has generally focused on a particular product, process or portion of a value chain (Casey and Holden, 2005, 2006; O'Brien et al., 2011; Crosson et al., 2011; Foley et al, 2011; O'Brien et al., 2014), while Geraghty (2011) and Finnegan et al., (2015) focused specifically on the processing of Irish dairy products. Although informative, such process-based LCAs are of limited value to policy-making when decisions are made on a regional or countrywide scale. With its tight system boundary specification, process-based LCA can potentially suffer `truncation' error whereby the full range of resource requirements and pollutant releases associated with upstream production processes are not fully accounted for (Lenzen, 2000; Suh et al., 2004).

Given the complexity of inter-sectoral and within-sector linkages, IO LCA analysis is a powerful accounting tool for examining the structure of economic activity and associated issues such as the pollution and/or resource-use embodied directly or indirectly, in the production, consumption and trade flows under different accounting principles (Munksgaard, 2001). IO analysis allows the magnitude of backward and forward linkages between a sector and the supplies of its inputs and users of its outputs to be evaluated (Acquaye et al., 2011a; Acquaye et al., 2011b; Puttanpong et al., 2015), as well as allowing for the decomposition of the Leontief multiplier into direct and indirect paths using Structural Path Analysis (SPA) (Puttanpong et al., 2015; Yang et al., 2015). IO LCA has thus become an increasingly commonly used technique to measure and allocate responsibility for emissions (Puttanpong et al., 2015; Turner et al., 2009; Yang et al., 2015). In addition, the use of Environmentally Extended (EE) IO further allows for the capture of inter-relationships between sectors in the economy and the tracking of emissions which are embodied in raw materials, intermediate and final products, from sector to sector (Kitzes, 2013).

This paper chronicles the development of a Bio-Economy Input-Output (BIO) model to create an Environmentally Extended Input-Output (EE IO) model and calculate direct and indirect emissions along the value chain. The IPCC country-specific emissions from energy and production processes are augmented by emissions associated with imports and exports. In addition, IO LCA is used to assess the magnitude of emissions to identify if there are emissions 'hot spots' along the dairy products value chain.

3. Methodology : Bio-Economy Input Output Model

The main aim of this study is to assess the greenhouse gas (GHG) emissions along the agri-food value chain in Ireland. In order to undertake a value chain analysis of the agri-food sector, it is necessary to have a disaggregated Input-Output Model (IO). The analysis is based on Input-Output tables generated every five years by the Central Statistics Office (CSO), which describe the flows between sectors. However national IO tables contain only two agri-food sectors, Agriculture and Forestry & Fisheries (AFF).

In this section we describe the development of a (42 sector Agri-Food) and (33 sector Energy) Bio-Economy IO (BIO) Model. This work builds on earlier work by O'Toole and Matthews (2002) and Miller et al. (2009) that developed Agri-Food Input-Output Models based on 1993 and 2005 data respectively. In this work we undertake a number of additions including

- the adaptation of the most recent 2010 CSO Input-Output Model for Ireland 2010
- the expansion of the agricultural sectors, making more consistent with the accounting flows and characteristics of the Teagasc National Farm Survey
- the systematisation of the development of the model to make it easier to replicate in future.

The IO approach is comprehensively described in the research literature. It is a linear modelling framework that was first developed by Leontief in the 1930s (Hendrickson et al., 1998 1998; Lave et al., 1995). The production in an economy is described as a cyclical system in which inputs are used to produce outputs, which in turn can be used as inputs to other processing systems. These help to analyse interdependencies that exist in an economy and trace input requirements through a product life cycle (Grealis & O'Donoghue, 2015).

Inputs to the production cycle come from imports, labour and capital. However, firms also use outputs of other firms – intermediate consumption – as inputs to their production. Outputs are designated to exports and final demand represented by households, governments and non-profit organisation. Such a framework is useful in analysing knock-on effects of changes in demand, output, employment, gross value added (GVA) and

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household income (Grealis & O'Donoghue, 2015). In the context of policy decision-making in relation to the allocation of limited economic resources, such analysis enables one to target investments where combined benefits are the greatest.

The mathematical structure of IO consists of a set of linear equations. The IO system can be written as in Equation 1, where *a* represents a technical coefficients matrix, x is a vector of total outputs of the sectors, f is a vector that represents the exogenous final demand and *ax* denotes intermediate demand (Joshi, 2000). Equation 1 can be re-written as a vector of the sectoral outputs needed to accommodate changes in exogenous demand as in Equation 2 and known as Leontief's inverse (Hendrickson et al., 1998; Joshi, 2000; Lave et al., 1995).

$$\boldsymbol{x} - \boldsymbol{ax} = \boldsymbol{f} \quad (1)$$

$$\boldsymbol{x} = [\boldsymbol{I} - \boldsymbol{a}]^{-1}\boldsymbol{f} \quad (1)$$

The first part of model creation involves the disaggregation of sectors into sub-sectors. We do this for Agriculture, Forestry, Fisheries, the food processing sector and the fuel sectors. In order to do this, we use the most disaggregated data available. Where data are limited, we apply shares based upon output, assuming the same cost function per sector. Given that the existing IO table is balanced, we balance the new table, keeping the totals constant. While there are a variety of ways of doing this such as general entropy or the RAS approach, we take a relatively conservative approach, manually balancing based upon expert judgement.

Environmentally Extended Input-Output Model

The BIO model has been adapted to develop a hybrid IO LCA model to analyse emissions embedded in the agri-food value chain in Ireland. A similar approach was previously described by Munksgaard (2001) who analysed consumption of foods produced in Denmark using EE IO, while foods and inputs imported to Denmark were analysed using process LCA by including trade, transport, travel distances and energy data in the analysis (Munksgaard, 2001). The model process adapted for analysis of emissions associated with the Irish agri-food sector is depicted in Figure 1. This input-output framework can be extended for environmental analysis by multiplying ***x*** by the matrix of environmental burden coefficients *r* (the ratio of environmental burdens to output for each sector) to find a vector of total environmental burdens associated with final demand, denoted *e* (Kitzes, 2013).

$$\boldsymbol{e} = \boldsymbol{rx} = \boldsymbol{r}[\boldsymbol{I} - \boldsymbol{a}]^{-1}\boldsymbol{f} \quad (3)$$

The *r* matrix can include environmental coefficients of any environmental impacts of interest such as energy use and GHG emissions (Joshi, 2000). In this analysis, the environmental burden coefficients per million euros of output, expressed as Carbon dioxide equivalents (CO_2eq.), include emissions from energy consumption as well as process emissions (e.g. animal and soil emissions from agriculture).

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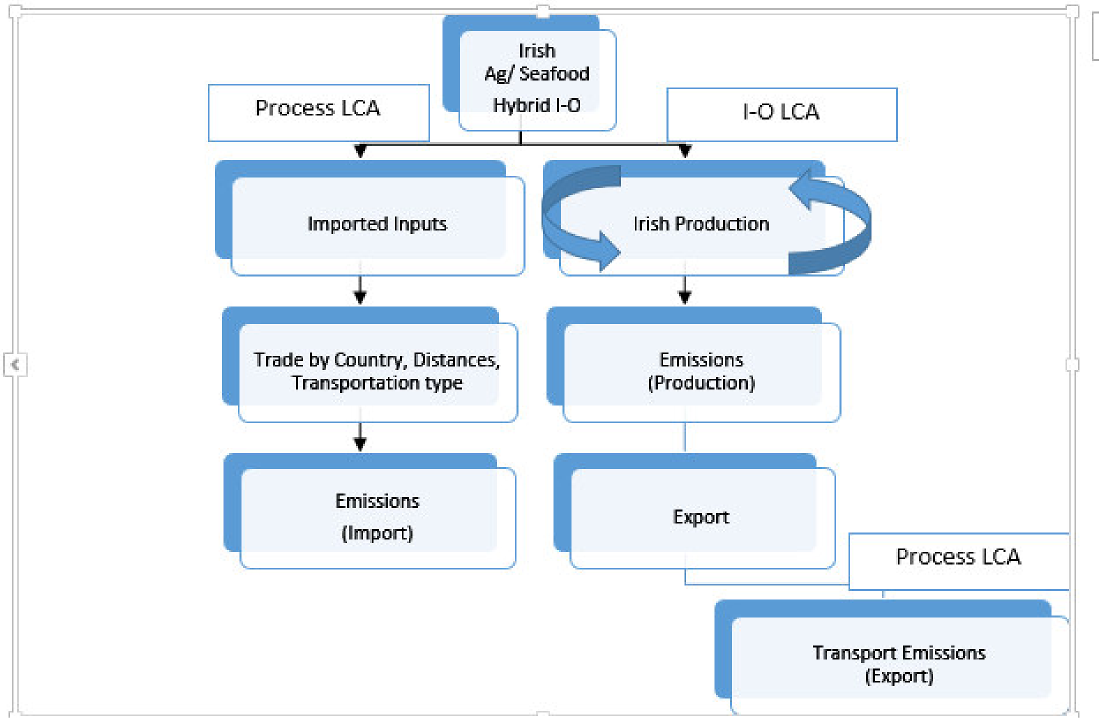
Figure 1. Model Process



Source: Adapted from (Munksgaard, 2001).

The *e* matrix captures both direct and indirect (or total) emissions that originate from sales to final consumers (Kitzes, 2013). Direct emissions are released as a result of activities directly related to production (rI). Indirect emissions are associated with direct and indirect suppliers and are the difference between direct and total emissions (Acquaye & Duffy, 2010).

Estimating Emissions from Agriculture: Livestock

Emissions from agricultural livestock sheep, cattle, horses, pigs, poultry, deer and goats) are calculated using the methodology as outlined in the Irish National Inventory Report (Duffy, 2017) and described in IPCC (2006). Emissions factors and animal stock inventories, as reported in the common reporting format (CRF) tables (UNFCCC, 2003:13) of the NIR (Duffy et al., 2017) and in line with the CSO livestock survey (CSO, 2017), are used to calculate aggregate livestock (sectoral) emission factors per million euro of output. Emissions factors are applied to the outputs from IO sectoral tables to describe associated emissions flows. In this case, all emissions associated with animal activities are calculated for 2010, such that the sum of emissions for the livestock sectors match the figures reported in the CRF tables accompanying the NIR.

There are a number of environmental impacts that can be accounted for in the LCA that include air pollution, water pollution, waste, consumption of resources, etc. In this analysis only air pollution impacts with Global Warming Potential (GWP) e.g. Carbon dioxide (CO_2), Nitrous oxide (N_2O) and Methane (CH_4) emissions were included. The details of the calculation methodology and data requirements are presented in Appendix 1 of the BIO Annex.

In the case of methane emissions, simplified emissions factors per unit livestock or total CH_4 emissions are derived by combining the implied emissions factors for enteric fermentation and manure management.

As with CH_4 emissions, a total N_2O emissions factor for each livestock (sector) is calculated by summing derived direct emissions factors (from manure management and fertiliser application to managed soils) and indirect emissions factors (from manure management and dung and urine deposition). The emissions factors are then converted to express emissions in kilo tonnes, per million euro of output (kt N_2O/ €m). The emissions output from the livestock sectors in terms of nitrous oxide N_2O and methane CH_4 emissions are subsequently

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calculated by multiplying the economic output for each product stage/ livestock sector in the IO tables by the environmental impacts per million euro of output as measured by derived emissions factors for N_2O, CH_4, as presented in Table 2. This is in line with the approach presented in Hendrickson et al. (2006).

Table 11 Methane and Nitrous Oxide emission factors for livestock per unit of output value

	Kt CH_4 /€m	Kt N_2O /€m
Dairy	0.081	0.0011
Cattle	0.168	0.0059
Sheep	0.162	0.0031
Horses	0.014	0.0015
Pigs	0.028	0.0017
Poultry	0.017	0.0014
Deer and Goats	0.004	0.0005

Estimating Emissions from Agriculture: Feed Crops

An LCA approach is applied to Teagasc National Farm Survey (NFS)[2] data to calculate the emission factors associated with growing the range of key crops on Irish farms which include concentrates (wheat, barley & oats), pasture, winter forage, silage, hay and root crops. The NFS collects associated sales price and input cost data, which, along with production data on input use and output yield, enables the calculation of emissions per unit value of crop. Once the economic output for each product stage (disaggregated agriculture sector) is calculated, a vector of environmental outputs can be obtained by multiplying the economic output at each stage by the environmental impact per euro of output (Hendrickson et al., 2006).

On-farm and off-farm input use emission factors and their sources are detailed in Appendix 2 of the BIO Annex, in Tables 10 & 11 respectively. Pesticide application by feed crop (Table 12) and fuel use by machine operation per crop output (Table 13) are also presented in Appendix 2. A crops sub-model is developed to calculate the input and resources use and emissions associated with the full range of crops grown, processed and fed to livestock. This enables the calculation of emissions from downstream input production (e.g. Carbon dioxide emissions from the production of diesel, fertiliser, pesticides, etc.) and the emissions associated with their subsequent transformation through on-farm processes (e.g. Nitrous oxide emissions from the interaction of fertiliser applications with the soils and Carbon dioxide emissions from on-farm combustion of fuel used for machinery operation). The emissions associated with each individual crop (fuel, fertiliser, lime etc.) were summed and an average total emissions factor per unit value of crop was calculated and presented in Table 3.

Table 12 Carbon Dioxide emission factors for feed crops per unit of output value

Feed type	Crops kt CO2 /€m
Concentrate Own Produced	1.69
Concentrate Opening Balance	1.69
Pasture	8.11
Winter Forage	4.11
Winter Forage Opening Balance	4.11
Winter Forage Purchases	1.49
Silage Own Produced	3.04
Hay Own Produced	3.94
Silage Opening Balance	3.04
Hay Opening Balance	3.94
Roots	2.15

Estimating Emissions from Energy

GHG emissions are usually presented in line with UNFCCC accounting rules and IPCC reporting guidelines, which do not readily capture changes in fuel and the sectoral mix of energy use both upstream (e.g., emissions associated with the combustion of fossil fuels in electricity production that is subsequently used by consumers)

[2] see Data section for further detail

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and downstream (e.g., combustion of fossil fuels such as natural gas and coal). Using energy balance and cost data from the sustainable energy authority (SEAI, 2016; SEAI, 2010), we address this issue by detailing the energy sources being consumed across economy sectors and the upstream sources of that same energy and consequent emissions.

A detailed analysis of energy flows requires a much greater disaggregation of the energy sector than is commonly undertaken. Therefore, production sectors which produce primary energy (coal, lignite, crude oil) or transform it into secondary energy (coke, petroleum products, electricity, produced gas, steam and warm water) are listed individually. The resultant energy balances are detailed material inputs (e.g., coal and crude oil extracted) and intermediate energy inputs, which are transformed into secondary energy sources or consumed (combusted). From the energy balances, the transformation or combustion of energy can be calculated in terms of 'residual outputs' (unwanted polluting by-products), in this case GHG emissions.

In the case of energy balances, the calorific energy content of energy flows from the industrial sectors is calculated on a terra joule basis, having converted monetary values from the I-O tables to kilowatt hours (KWhs) based on commercial and domestic fuel price data (c/kWh) for 2010 (SEAI, 2010). KWhs are subsequently converted to tera joules[3], where one KWh is the equivalent of 3.6E-6 tera joules. The use of tera joules ensures that all quantities of the different energy sources can be aggregated by column and row. The Sustainable Energy Authority Ireland (SEAI) published data was sourced to provide energy emissions factors for the range of fuel/energy sources on a tera joule basis, enabling the subsequent calculation of GHG emissions (CO_2 equivalents) throughout the entire supply chain. The methodology for calculating energy flows is in line with Beutel (1983) where the IO table is extended to enable the estimation of emissions associated with the direct and indirect energy content of products.

Estimating Emissions from Transporting, Imports and Exports

Depending on data availability, there are three methods of calculating emissions from transportation:

- fuel-based method, based on the amount of fuel consumed;
- distance-based method, based on the mass, distance, and mode of each shipment and appropriate mass-distance emission factors for the vehicle used;
- spend-based method, based on the amount of money spent on each mode of transport and secondary, IO, emission factors (Protocol, 2013).

The fuel-based method is used when data for fuel use from transport providers from vehicle fleets (e.g., trucks, trains, planes, vessels) can be obtained. In calculating CO_2 emissions, the fuel-based method is more accurate than other methods, because fuel consumption is directly related to emissions. However, the data requirements for this method are high. If the fuel-based method and distance method cannot be applied (e.g., due to data limitations), the spend-based method to calculate the emissions from transportation can be adopted. In this method, the amount spent on transportation by type is multiplied by the relevant factor from the IO table expressed as CO_2/€. This is the least accurate method of inferring transport emissions.

When the data are limited, the spend-based method can also be used to calculate the emissions from transportation. In this method, the amount spent on transportation by type (*V*) is multiplied by the relevant factor from the IO table expressed as CO_2/€ (EF_{IO}) (Equation 4). The spend-based method is effective for screening purposes, however, it has high levels of uncertainty and the fuel-based and distance-based methods are recommended for accounting for transportation emissions.

$$\boldsymbol{CO_2 = V \times EF_{IO}} \tag{4}$$

In the distance-based method, distance is multiplied by mass or volume of goods transported and relevant emission factors that incorporate average fuel consumption, average utilization, average size and mass or volume of the goods and the vehicles, and their associated GHG emissions, as in Equation 5, where *d* is distance travelled by *m*'s mode of transport, *T* is weight of goods and *EF* is a mode-specific emissions factor.

$$\boldsymbol{CO_2 = \sum_m^M d \times T \times EF_m} \tag{5}$$

[3] Tera joule: physical heat unit which measures the energy content of each energy flow

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Accuracy is generally lower than the fuel-based method as assumptions are made about the average fuel consumption, mass or volume of goods, and loading of vehicles (Protocol, 2013).

In this analysis the distance-based method (Equation 5) was applied to estimate a weighted-average emission factor per euro of import (Equation 6), where CO_2 is total emissions from distance-based method (weighted by distance, mode of transport and weight) and IV is total import value (millions of euros). This factor is then applied to the value of imports (reported as part of BIO) to calculate transport emissions from imported inputs.

$$\boldsymbol{EF_{transp} = CO_2/IV} \quad (6)$$

Estimating Emissions from Imports

It was assumed that imports are made with domestic technologies. This approach is popular as it assumes that the same emissions intensities are imbedded in import sectors as in domestic industries, allowing a domestic emissions vector to be applied to imports data (Andrew et al., 2009; Tukker et al., 2013).

Caveats

This analysis has a number of limitations that need to be highlighted to caution the reader before interpreting the results. The first caution is associated with the limitation of the IO analysis. 1) As a linear model, it assumes that inputs are proportional to outputs, so potential future economies of scale are not taken into the account in such models. This limits the efficacy of this model in performing overly large scale demand shocks or long-term analysis hypothesis testing. 2) The homogeneity assumption implies that each product and process is homogeneous within a sector. In reality there is likely to be a non-significant variety in performance and processes across the sector. 3) The boundaries of the IO analysis are limited by the geographic region of a country. As such, important processes which may have large indirect impacts on global markets lie outside of such boundaries (Duffy et al., 2017). The final caution is related to the assumption of 'Irish technology' associated with imports, which may distort emissions associated with imports (Lenzen, 2004; Wiedmann, 2007).

4. DATA

This analysis uses a range of datasets from different sources which include primary and secondary food sources such as the CSO National Accounts, the Teagasc National Farm Survey, the CSO Census of Industrial Production, the Sustainable Energy Authority of Ireland and the Environmental Protection Agency.

Primary Food Sectors

In the CSO Input-Output Table for 2010, primary production is grouped into Agriculture, Forestry and Fisheries. Specifically we divide sectors into the following sub-sectors[4]

- Agriculture into the main animals and crop sub-sectors
- Sea fishing and Aquaculture
- Forestry

Farm-Level Data

The main source of data for the agricultural sector is the Teagasc National Farm Survey (NFS). This dataset is the Irish component of the EU Farm Accountancy Data Network (FADN), for which data have been collected over a 40 year period for the main land based agricultural systems, (with partial information for the pig and poultry sectors)on about 1000 farms annually.

[4] The disaggregation of the Sea fishing and Aquaculture is explained in (Grealis & O'Donoghue, 2015).

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Of particular relevance to our work is the fact the NFS decomposes inputs and outputs at the enterprise level. Irish agriculture contains mainly pastoral animal systems, where farms may have at least one animal enterprise, together with enterprises that produce animal feed. Systems that are 'mainly dairy' may contain both a dairy enterprise and a cattle enterprise for non-milking animals. The beef industry is a very important sector in Ireland, with about 90% of farms in the NFS having rearing beef cattle. Many tillage-only farms have multiple crop enterprises. In this model, we utilise this information to track inputs and outputs.

Appendix 3 of the BIO Annex contains the detail of the structure of the NFS data and how emissions are allocated to different sub-sectors within the agri-food value chain (using NFS data) is presented in Appendix 3, along with a description of the preparation of the agricultural inputs and outputs and the consistency of outputs with the National Accounts (Table 18). Appendix 3 also presents the disaggregation of feed into sub-components, the allocation of output by final use and the sources of input into the AFF sector, along with animal inputs and crop outputs.

Forestry

In developing the forestry component of the model, we draw upon work of colleagues in UCD and UCC who developed an Input-Output Model for Forestry (see Ní Dhubháin, 2009). In our model, we utilise the same coefficients for the forestry sector described in Table 9, using expert judgement to disaggregate. A forest industry economic survey is planned to improve the structure of the Input-Output model for the forestry primary and processing sectors.

Table 13 Distribution of Output by Source of Input in Forestry

	Share of Output
Intermediate Consumption	0.21
Wages and Salaries	0.21
Profits	0.28
Other Domestic Inputs	0.03
Imports	0.26
Total	1.00

Secondary Food Sectors

In disentangling the 'Food & beverages and tobacco products' sector, we utilise the Census of Industrial Production (CIP), which provides turnover, output, labour and cost information for the following sectors:

- Processing and preserving of meat and production of meat products (disaggregated further with industry data into individual meat sectors)
- Processing and preserving of fish, crustaceans and molluscs
- Processing and preserving of fruit and vegetables
- Manufacture of vegetable and animal oils and fats
- Manufacture of dairy products
- Manufacture of grain mill products, starches and starch products
- Manufacture of bakery and farinaceous products
- Manufacture of other food products
- Manufacture of prepared animal feeds
- Manufacture of beverages
- Manufacture of tobacco products

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Inputs

The CSO Input-Output table contains more disaggregated information in relation to costs than the CIP. The latter contains information on:

- Materials and fuels
- Industrial Services
- Non-industrial Services

In general, except for Agriculture, Forestry & Fisheries, we assume the same pattern of inputs within these categories. We allocate all Input-Output headings to the three categories, using the Wholesale Trade variable as a balancing device.

In the BIO Annex we report the detailed disaggregation of (a) the food and beverages sector into sub sector components, (b) the agriculture and fisheries inputs into the processing sector and (c) the food to food primary flows and the destinations of flows from the food processing sectors. In Appendix 4 (Tables 21 and 22), we disaggregate total food and beverages into sub-sector components at the domestic level. We subtract imports for intermediate use (Imports less Goods for Resale) to get domestic output. In the input-output model, we further disaggregate the three input components using the same ratios as at the total sector level. Utilising data, consistent with the primary food sectors in Table 23, we report the agriculture and fisheries inputs into the processing sector, while in Table 24, we report the food sector to food sector primary flows. Without further information, we make the assumption that this is diagonal with inputs from the same sector and without any inter-sub-sector flows. While this is a relatively strong assumption, it will have relatively minor qualitative impact upon the overall multipliers. Table 25 describes the destinations of flows from the food processing sectors.

Energy Data

In order to disaggregate the energy sectors (Mining, quarrying and extraction, Petroleum; furniture; other manufacturing, Electricity and gas supply), we utilise totals and energy flows in the SEAI Energy Balance Statistics 2016. Other than the differential fuel inputs, there is no further data available on inputs, so existing shares are assumed. Emissions from the Energy sector are taken from the EPA's common reporting format data files.

Validation

While the SEAI Energy Balance statistics contain only volumes, we derive monetary flows utilising industry and consumer prices for individual goods utilising SEAI fuel prices. Utilising data from different sources, there is no guarantee that estimates will be comparable. Table 5 compares total expenditures by sector on energy, utilising the SEAI and the Input-Output table databases. Overall use is about 11% higher in the IO, with domestic demand being almost identical. Inter-industry differences are 16%, but this masks some variability across sectors. Differences of this order are not unusual when comparing different data sources.

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Table 14 SEAI Energy Balance versus IO Expenditures

	SEAI Energy Balance	IO	IO (Inter)	IO	IO (Inter)
	€m			Ratio relative to SEAI	
Industry & Transformation	4663	6544	5809	1.40	1.25
Transport, Commercial and Public	4332	3947	2528	0.91	0.58
Agri & Fisheries	374	385	385	1.03	1.03
Inter-Industry	9369	10876	8721	1.16	0.93
Domestic Final Demand	4824	4841	4841	1.00	1.00
Total Output	14193	15716	13562	1.11	0.96

In this analysis the IPCC country-specific emission factors compiled by the EPA Ireland and reported by the CSO are augmented by emissions associated with transportation of imported inputs as an extension of the IPCC's production-based method. Table 6 provides a similar validation comparing greenhouse gas emissions from the BIO-LCA analysis with similar emissions from the EPA. We ignore in the latter a number of emission sources that are not modelled in BIO such as Waste and Land Use Change. Future variants of the model will be developed to incorporate these emissions. In general the overall emissions ae relatively similar, with EPA 1% lower than the IO and with relatively small variations by sector, except for the Industry sector at 15%.

Table 15 Comparing Carbon dioxide Emissions in Input-Output Table and Adjusted EPA Carbon Emissions

	Input-Output	EPA*	Ratio
Available final energy consumption	29782.7	29266.0	0.98
Energy & Industry	41268.0	42442.0	1.03
Net Transformation	13965.4	13176.0	0.94
Industry	3893.3	4472.9	1.15
Transport	13555.2	14137.9	1.04
Other	9854.1	10655.2	1.08
Total	42790.7	42442.0	0.99

Note: EPA totals adjusted for emissions not modelled in the Input-Output Table

5. RESULTS

Structure of the Agri-Food Value Chain

Grouping the agri-food value chain into meat and dairy pathways, we present the structure of the agri-food value chain as described in the BIO Model in Table 7. As the BIO model contains 138 sectors, in summarising the value chains we categorise components as follows:

- Primary 1: The Primary Inputs from the same Value Chain (i.e. Milk for the Dairy Products Value Chain)
- Primary 2: Other Primary Inputs from the Value Chain (Milk for the Beef and Veal Meat Products Value Chain)
- Secondary 1: The Secondary Inputs from the same Value Chain (Dairy Processing for the Dairy Products Value Chain)
- Secondary 2: Other Primary Inputs from the Value Chain (Dairy Products for the Beef and Veal Meat Products Value Chain)
- Industry: All other Industrial Inputs into the Value Chain
- Services: All other Service Inputs into the Value Chain
- Energy: Energy Inputs into the Value Chain

We utilise the Leontief Inverse Matrix to produce the Direct and Indirect Inputs per unit of Output. Table 7 describes the share of the output multiplier from each of the meat and dairy value chains. The value chains can be grouped into three categories. The pastoral meat value chains (beef, sheep and other) have the highest share of primary inputs at about 25%, reflecting both the relatively extensive nature, combined with lower value added processing. The next group at about 18% contains the higher value added dairy, seafood and pig meat sectors, while the heavily industrialised poultry sector has the lowest share of value added in the Primary sector. Processing has the highest share of the multiplier with 40-65% for Secondary 1, highest for poultry and lowest for beef. Secondary 2, which is predominantly processed animal feed, is highest for the pig sector,

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reflecting its reliance on processed feed. Other services and industrial inputs (including fertilisers and pesticides) account for a similar proportion of the multiplier as the Primary sector. Overall energy inputs are relatively low at about 2-3%.

Table 16 The Distribution of Value Across the Agri-Food Value Chain

Share of Multiplier	Primary1	Primary2	Secondary1	Secondary2	Industry	Services	Energy	Total
Beef and veal	18.9	8.4	43.6	6.8	6.6	12.6	3.1	100.0
Pig meat	13.7	3.9	49.0	12.4	6.2	11.6	3.2	100.0
Sheep meat	19.5	4.0	50.2	6.0	5.7	11.8	2.9	100.0
Poultry meat	6.1	1.1	64.8	4.9	6.6	13.2	3.4	100.0
Other meat	22.2	4.3	49.9	5.8	5.9	9.6	2.2	100.0
Dairy Products	15.0	3.4	55.2	3.4	3.9	17.3	1.8	100.0

Emissions Associated with Final Demand

Table 8 describes the distribution of emissions across the agri-food value chain. The proportion of emissions from the Primary 1 sector is significantly higher in the large animal pastoral sectors (beef, sheep and dairy), where these emissions account for 81%-84% of total emissions. Over 80% of dairy emissions are at farm level which is consistent with the 80% finding of Finnegan et al. (2015). Poultry has relatively low primary emissions reflecting lower enteric fermentation in poultry versus ruminant animals. Seafood has negligible primary emissions.

Other primary farm level inputs are relatively small, with the next biggest share coming from Industry, which incorporates the contribution of fertiliser inputs and processed concentrate feed. The share of energy emissions varies from six percent in the relatively low intensity, high enteric fermentation beef and sheep meat value chains to 46.5% for the fuel and energy intensive seafood processing sector and 25-38% in the industrialised pig and poultry sectors.

Table 17 The Distribution of Life-Cycle Emissions across the Agri-Food Value Chain

Share of Multiplier	Primary1	Primary2	Secondary1	Secondary2	Industry	Services	Energy	Total
Beef and veal	81.7	1.3	0.3	0.0	10.2	0.0	6.4	100.0
Pig meat	46.4	0.9	1.4	0.0	25.8	0.0	25.4	100.0
Sheep meat	83.6	0.4	0.4	0.0	8.7	0.0	7.0	100.0
Poultry meat	23.2	0.9	2.9	0.0	35.0	0.0	38.0	100.0
Other meat	22.5	1.6	1.9	0.0	47.6	0.0	26.3	100.0
Dairy Products	81.0	0.7	0.2	0.0	7.7	0.0	10.4	100.0

Table 9 reports the share of greenhouse gas emissions in terms of kT of CO_2 equivalent per €m of output. This indicates the degree of value added, which is higher in dairy, pigs and poultry and lower in beef and sheep and in the relative emissions. This results in the highest emissions per unit output in beef and sheep meat, medium for dairy and low for pig, poultry and seafood. The substitution from beef to dairy that has been visible since the elimination of milk quota in 2015 will see an overall reduction in the emissions per euro of output.

Table 18 Greenhouse Gas Emissions (CO_2 equivalent) per €m of Output

	kTCO_2Eq /€m of Output	Protein tonne/ €m output	Energy (M) kcal/ € m output
Beef and veal	3.59	54.9	932.6
Pig meat	0.90	73.7	1831.4
Sheep meat	2.53	37.1	630.8
Poultry meat	0.44	71.6	809.8
Dairy Products	1.02	36.5	854

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6. Conclusion

Sustainable intensification is one of the greatest challenges facing the agri-food sector which needs to produce more food to meet increasing global demand, while minimising negative environmental impacts such as agricultural greenhouse gas (GHG) emissions. There is a growing need to exploit international food market opportunities in a sustainable way that minimises the impact on land use and GHG emissions, as consumers across the globe demand enjoyable, safe, healthy, high quality, food products (Trienekens et al. 2012).

Sustainable intensification relates not only to primary production, but also has wider value chain implications. An input-output model is a modelling framework which contains the flows across a value chain within a country. Input-output models have been disaggregated to have finer granular detail in relation to agricultural sub-sectoral value chains. National IO models with limited agricultural disaggregation have been developed to look at carbon footprints and also to look at the carbon footprint of specific agricultural value chains. In this paper we develop an agriculturally disaggregated input-output model (BIO) to analyse the source of emissions in different parts of agri-food value chains.

We focus on Ireland, where emissions from agriculture comprise nearly 30% of national emissions and where there is a major expansion and transformation in agriculture after the abolition of milk quota restrictions. In Ireland, the ambitious agri-food sector expansion targets (DAFM 2015) highlight the importance of the measurement of the relative sustainability of agriculture and food exports. This provides the sustainability credentials for the 'Origin Green' export marketing campaign developed by Ireland's food marketing board (Bord Bia) which highlights the extensive, low-input, grass-based production systems employed in Irish food production, giving Irish food exports a competitive advantage in global markets. In a substantial appendix, we describe the modelling assumptions made in developing this model for Ireland. Maintaining this competitive advantage will require data on emissions efficiencies along the wider agri-food value chains. In this analysis emissions associated with the agri-food value chain were assessed using an adapted EEIO analysis.

Notwithstanding cautionary remarks in relation to assumptions about the nature of the technology, the analysis presented in this paper allows us to map emissions along the agri-food value chain. Such analysis is valuable in identifying the hot spots along the value chain and addressing the problems if possible.

Breaking up the value chain into components, we find that most value is generated at the processing stage of the value chain, with greater processing value in more sophisticated value chains such as dairy processing. On the other hand, emissions are in general highest in primary production, albeit emissions from purchased animal feed is higher for poultry than for other value chains, given the lower animal based emissions from poultry than from cows or sheep. The analysis highlights that emissions per unit of output are much higher for beef and sheep meat value chains than for pig and poultry meat value chains.

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BIO ANNEX:

Appendix 1: Methodology and data requirements for calculation of emissions from livestock

Methane – CH_4

Ireland's emissions inventory applies a Tier 2[5] approach to calculating the main source of national CH_4 emissions, i.e., emissions associated with enteric fermentation and manure management from cattle production systems. For the other livestock sectors, a Tier 1 approach is utilised. From the NIR CRF tables, we derive simplified emissions factors per unit livestock or total CH_4 emissions by combining the implied emissions factors for enteric fermentation and manure management. Given sectoral output from the IO table and livestock population statistics from the CRF tables, we then convert livestock emissions factors to express the emissions in kilo tonnes per million euro of output (kt CH_4/ €m)

Nitrous oxide - N_2O

The other agriculture emissions which are a function of livestock numbers are Nitrous oxide (N_2O) emissions. This includes four categories: direct and indirect N_2O emissions from manure management, direct N_2O emissions from soils associated with manure application from housed animals, direct N_2O emissions from soils associated with urine and dung deposition by grazing animals. As with CH_4 emissions, simplified total N_2O emissions factors for each livestock (sector) are calculated by summing the four derived emissions factors categories. This calculation requires the following information and data sources:

- Direct N_2O emissions from manure management: These emissions factors are sourced directly from the CRF 'Table 3.B(b)'.
- Calculation of the indirect N_2O emissions from manure management by livestock category: This requires additional data on ammonia balances sourced from the EPA. Ammonia (NH_3) losses by livestock were converted to N_2O -N and subsequently N_2O to calculate the N_2O factor by livestock.
- Calculation of the direct N_2O emissions from manure applied to managed soils: This required supplementary data from the EPA in the form of representative N excretion rates and straw bedding factors per livestock type, as well as the N content of straw. The relevant N_2O soil emissions coefficients were taken from the NIR. Applying this data, the total kg of N excreted by livestock was adjusted to take account of direct and indirect ammonia losses from storage and housing (described above), as well as N additions from straw bedding.
- Calculation of the N_2O emissions from urine and dung deposited on soils by grazing animals: This required supplementary information from the EPA on the 'Allocation of Animal Wastes to Manure Management Systems' while the relevant N_2O soil emissions coefficients were taken from the NIR. Applying these data, N_2O emissions were calculated for the portion of manure deposited by grazing animals on pasture and expressed on a per unit livestock basis.

Appendix 2: Methodology and data requirements for calculation of emissions from feed crops

The development of a crops sub-model enables the calculation of emissions from downstream input production (e.g. Carbon dioxide emissions from the production of diesel, fertiliser, pesticides, etc.) and the emissions associated with their subsequent transformation through on-farm processes (e.g. Nitrous oxide emissions from the interaction of fertiliser applications with the soils and Carbon dioxide emissions from on-farm combustion of fuel used for machinery operation). On-farm and off-farm input use emission factors and their sources are detailed in Tables 10 and 11 respectively.

Table 19 Key on-farm emission and energy factors

		Emission or energy factor	Unit	Reference(s)
Nitrous oxide (N_2O-N)				

[5] The 2006 IPCC Guidelines provide advice on estimation methods at three levels of detail, from Tier 1 (the default method) to Tier 3 (the most detailed method) (IPCC, 2006). Tier 1 employs IPCC Guidelines and default emission factors and other parameters whereas Tier 2 generally uses the same methodological approach as Tier 1 but applies emission factors and other parameters which are specific to the country. Tier 3 uses higher-order methods including emissions models tailored to address national circumstances.

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Synthetic N fertilizer application	On-farm	0.01 × N fertilizer applied (KG N)	kg N_2O-N/kg N	(IPCC, 2006; Carbon Trust, 2013; Vellinga et al., 2013)
Nitrogen leaching from synthetic N application	On-farm	0.0075 × fraction N applied (10% of N input to managed soils that is lost through leaching)	kg N_2O/kg N	
Atmospheric Deposition of nitrogen (N) volatilised from synthetic N	On-farm	0.01 × fraction N volatilised (3% of synthetic fertilizer N applied to soils volatilises as NH3 and NOX, 8% for livestock N))	kg N_2O/kg N	
Carbon Dioxide (CO_2)				
Diesel	On-farm	2.63 × diesel use (litres)	kg CO_2/l	IPCC (2006)
Gasoline	On-farm	2.30 × gasoline use (litres)	kg CO_2/l	IPCC (2006)
Kerosene	On-farm	2.52 × kerosene use (litres)	kg CO_2/l	IPCC (2006)
Urea application	On-farm	0.733× urea application (KG Urea)	kgCO_2/kg urea	IPCC (2006)
Lime application	On-farm	0.44 × lime application (Kg Lime)	kgCO_2/kg lime	IPCC (2006)

Table 20 Key off-farm emission and energy factors

		Emission or energy factor	Unit	Reference(s)
Diesel	Off-farm	.38 × diesel use (litres)	kg CO_2/l	
Lime application	Off-farm	0.15 × lime application (Kg)	kgCO_2/kg lime	Carbon Trust (2013)
Urea	Off-farm	2.89 × urea application (KG N)	kg CO_2/kg N	Carbon Trust (2013)
P fertilizer	Off-farm	1.87 × P application (KG P)	kgCO_2/kg P	Carbon Trust (2013)
K fertilizer	Off-farm	1.80 × K application (KG K)	kg CO_2/kg K	Carbon Trust (2013)
Ammonium Nitrate	Off-farm	3.63× K application (KG N)	kg CO_2/kg N	Carbon Trust (2013)
Pesticides	Off-farm	8.40 × Active Ingredient (KG)	kgCO_2/kg active ingredient	Carbon Trust (2013)

While the NFS provides detailed farm level data on the quantity of inputs used in crop and pasture production as well as the quantities and cost of purchased feed, additional data were required to estimate inputs for which there was insufficient information. The NFS records information on the quantities of crops (home-grown and purchased) and fed to the different livestock enterprises. Inputs of seed, fertiliser, etc., and associated direct costs of crop production and pasture are broken down by crop type. IPCC (2006) emissions factors and NFS input use records were used to estimate on-farm emissions from lime and urea application, and diesel fuel use (Table 10). N_2O emissions resulting from the application of synthetic fertilisers were estimated by multiplying the direct and indirect N_2O emissions factors for synthetic fertilisers by the quantities applied as recorded in the NFS. Lime was treated as a capital land improvement expenditure item in the NFS and application rates are assumed on the basis of the total utilisable agricultural area (UAA) and assigned to crops accordingly.

NFS data on fuel and pesticide use is recorded at farm level in monetary terms and not allocated to individual crops. Fuel use by contract machine hire is also not recorded in the NFS (O'Brien et al., 2015). To calculate the emissions associated with these crop inputs a representative crops sub-model was developed. Field work processes were ascribed to each crop. Representative pesticide use factors (kg active ingredient/ha) were calculated for the main feed crops recorded in the NFS based on a national pesticide survey of arable crops (DAFF, 2004; DAFM, 2012) (Table 12). These fuel and pesticide use factors were applied to NFS records of the area of feed crops and pasture grown.

Table 21 Pesticide application by Feed crop

	Economic Allocation Factor	kg Active Ingredient/ha	Average Number of

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			pesticide applications
weighted barley total	0.92	2.318	8.585
weighted wheat total	0.95	4.823	13.471
weighted oats total	0.95	2.789	7.920
straw total (average of all cereal)	0.068	0.230	10.055
protein beans	1	3.25	5.48
triticale	1	2.8	8.1
potatoes	1	18.9	15.9
sugar beet	1	2.355	6.73
fodder beet	1	2.355	6.73
maize	1	2.295	3.05
arable silage	1	1.195	1.89
turnips	1	1.915	0.69
kale	1	0.9	1.96
rape	1	0.9	1.96
Grass (permanent pasture)	1	0.11	0.09
Silage	1	0.11	0.10
Hay	1	0.11	0.01

Source: (DAFM, 2012; DAFF, 2004)

Fuel use factors per litre/ha and per litre/hour (depending on the machine operation) were used to calculate representative fuel use data per unit area (Table 13). Fuel use factors for the range of field operations were adapted from Nemecek & Kägi, (2007). The creation of a representative set of field processes was informed by the national production research literature (DAFM, 2012; Phelan, 2017; Teagasc, 2011).

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Table 22 Fuel Use by machine operation per crop output (tonnes/ha)

	Wheat	Barley	Oats	Beans	Turnip	Fodder beet	Kale	Rape	Straw	Triticale	Arable Silage	Hay	Silage	Maize silage	Pasture	
Machine operation	Litres of Diesel Fuel by machine operation															Unit/output
Spray application	28.29	18.03	16.63	11.51	1.44		4.11	4.11	21.11	17.01	3.96	0.21	0.22	6.40	0.19	Litres /ha
Fertiliser spreading	18.90	18.90	18.90	6.30	6.30	12.60	6.30	6.30	18.90	6.30	6.30	6.30	6.30	6.30	6.30	Litres /ha
Topping (pasture)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.18	Litres /ha
Ploughing	31.08	31.08	31.08	31.08	31.08	31.08	31.08	31.08	31.08	31.08	31.08	0.00	0.00	0.00	0.00	Litres /ha
Spring Tine harrow	5.28	5.28	5.28	5.28	5.28	5.28	5.28	5.28	5.28	5.28	5.28	0.00	0.00	0.00	0.00	Litres /ha
Rotary cultivator	16.80	16.80	16.80	16.80	16.80	16.80	16.80	16.80	16.80	16.80	16.80	0.00	0.00	0.00	0.00	Litres /ha
Chisel cultivator	0.00	0.00	0.00	18.48	18.48	18.48	18.48	18.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	Litres /ha
Rolling	3.78	3.78	3.78	3.78	3.78	3.78	3.78	3.78	3.78	3.78	3.78	0.00	0.00	0.00	0.00	Litres /ha
Sowing	4.55	4.55	4.55	0.00	0.00	0.00	4.55	4.55	4.55	4.55	4.55	0.00	0.00	0.00	0.00	Litres /ha
Planting	0.00	0.00	0.00	0.00	20.00	20.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	Litres /ha
Beet harvesting	0.00	0.00	0.00	0.00	0.00	123.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	Litres /ha
Harvesting Maize	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	44.31	44.31	0.00	0.00	44.31	0.00	Litres /ha
Combine harvesting	39.65	39.65	39.65	0.00	0.00	0.00	0.00	0.00	39.65	0.00	0.00	0.00	0.00	0.00	0.00	Litres /ha
Mowing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.13	5.13	0.00	0.00	Litres /ha
Tedding	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.28	0.00	0.00	0.00	Litres /ha
Rowing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.50	0.00	0.00	0.00	Litres /ha
Baling Hay/straw	1.36	1.36	1.36	0.00	0.00	0.00	0.00	0.00	1.36	0.00	0.00	0.00	0.00	0.00	0.00	Litres /ha
Loading bales	0.64	0.64	0.64	0.00	0.00	0.00	0.00	0.00	0.64	0.00	0.00	0.00	0.00	0.00	0.00	L/tonne
Transporting crop(straw)	0.05	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	L/tonne

Transport crop (Wheat)	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	L/tonne
Transport crop (Barley)	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	L/tonne
Transporting crop (Oats)	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Transport crop (Straw)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	L/tonne
Transport crop(Silage)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.30	0.00	0.00	L/tonne
Transport crop(Other)	0.00	0.00	0.00	0.05	0.05	0.05	0.05	0.05	0.00	0.00	0.00	0.05	0.05	0.00	0.00	L/tonne
Fuel Use per unit output of feed crop																
	Wheat	Barley	Oats	Beans	Turnips	Fodder beet	Kale	Rape	Straw	Triticale	Arable Silage	Hay	Silage	Maize silage	Pasture	
Total Harvest operations	150.43	140.17	138.77	93.23	103.16	245.35	90.38	90.38	143.26	129.11	116.06	17.42	11.65	57.01	10.67	Litres /ha
Total Harvest operations	0.00	0.00	0.00	0.05	0.05	0.05	0.05	0.05	0.00	0.00	0.00	0.05	1.36	0.00	0.00	Litres /tonne

Source: Adapted from Nemecek & Kägi (2007)

* Average weighted cereal - straw

Appendix 3: Farm level data

Structure of NFS Data

The objective of the data structure in the NFS is to collect data so that a measure known as family farm income can be calculated. Family Farm Income is defined as Market Gross Output plus Farm Subsidies minus Direct Costs minus Overhead Costs. Market Gross Output, some Enterprise Specific Subsidies and Direct Costs can be allocated to the enterprise level.

Crop information in the NFS is stored at multiple levels

- Year
- Farm Code
- Crop Code

In other words, crop inputs are stored only for crops that exist on the farm. There are 66 different types of crop recorded in the NFS.

The collected information is stored in a number of different tables:

- Labour Input
- Crop Output, Uses (Feed x Animal Type, Sales, Seed, Waste, Closing Balance, Home Use)
- Fertilizer
- Expenses (Seed, Crop Protection, Transport Cost, Machinery Hire)
- Disposal of Feed stuff

In addition to the fertiliser table, there is another layer as different types of fertiliser are recorded. These files are combined together, so that direct costs and output can be identified in one file for one period for each crop type. Fertiliser usage is not identified separately in the direct costs, but combined together.

There is a time period issue with the data. Some crop volumes are utilised in the current year with the remainder used in the following year and so counts as a closing balance. Some of the crops used for the following year then come from the opening balance.

For cash crops, the value of output is the market price, while for non-cash fodder crops, the value of the output relates to the cost of production. Thus the price for opening balances and crops used in the current year may have different prices. As a result, an extension of earlier models is to separate crops into opening balance-based crop usage and current year harvested crops.

Crops are allocated by use, whether as feed, seed, sales, home use, waste or into the closing balance for the year. Crops that are fed to animals are further allocated to the animal enterprise (dairy, cattle, sheep, goats, deer, horses, poultry, pigs, etc.). We can thus identify the amount in terms of both volume and value (based upon calculated unit costs) of each crop type by animal enterprise. As we record the inputs of each crop that are used in the current year and because the dataset is a panel dataset, we record the inputs of crops that enter this year's account in the opening balance, we can track the input use such as fertiliser used in silage fed to sheep.

However this can cause time period problems as fertiliser can be bought in period one, stored as a closing balance and used in period two as an input into a crop that is harvested in period three, stored and part of an opening balance in year four and fed to an animal in that year. Thus in this case, a price change in fertiliser may have an impact on an animal based direct input three years later.[6]

Each animal system also contains other non-feed input costs which are allocated to each enterprise including:

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[6] This animal may potentially be sold two years later, meaning that in a life-cycle situation the price change may affect a life-cycle margin for 6 years. However in the NFS, we incorporate direct costs in specific years, with change in value of the animals being incorporated in the gross output for a particular year.

- Veterinary and Medical
- Artificial Insemination
- Purchased Feed (Concentrate and Bulk)
- Miscellaneous Expenses
- Transportation
- Labour

In the NFS, animal purchases are treated as a deduction from output rather than as an input cost. Changes in value as well as flows between cattle and dairy enterprises such as calves and heifers are also incorporated in the gross output. Farm direct costs are calculated as the sum of animal and crop direct costs less inter-enterprise transfers such as milk fed to calves.

Crop market gross output includes crops sold outside the farm, but excludes fodder crops used on farm as an input into the animal enterprises, which are treated as costs. Dairy market gross output includes milk sales plus the value of calves and the net transfer between the cattle system. Other animal systems include sales minus purchases, net transfers with dairy and value changes in stock. Land rented out, home-use, sales of other farm outputs like turf and contracting/rental of machinery are also included in market gross output at the farm level.

Market gross margin at either farm level or enterprise level can be defined as the market gross output minus direct costs, while gross margin (at both levels) is the market gross margin plus subsidies. Overhead costs (including depreciation) are calculated at the farm level and subtracted from farm level gross margin to get the family farm income, and when subtracted from market gross margin gives us a measure known as the net margin.

Preparation of Agricultural Inputs and Outputs

In our model, we take the CSO IO table as the primary source of our constraint data. While we take information from the national accounts and the NFS, we make any adjustments consistent with the macro totals in the CSO national accounts. In Table 14, we describe the allocation of output into domestic output and imports as well as exports. Due to balancing and definitional differences between the national accounts totals for these sectors and the IO totals, total output in the IO table is 1% lower than the national accounts, while imports are 6% higher and exports are 27% higher.

Table 23 Output Adjustment to Ensure Consistency between National Acc. and Input-Output Table €m

	National Accounts				Adjusted			
€m	Output	Domestic Output	Exports	Imports	Output	Domestic Output	Exports	Imports
Cattle	1676	1502	339	173	1671	1488	247	183
Pigs	334	334			330	330		
Sheep	166	166			164	164		
Horses	151	151	73		149	149	54	
Poultry	112	112			111	111		
Milk	1542	1542			1527	1527		
Other	41	41			40	40		
Cereals	377	377			373	373		
Fruit & Veg	1257	346	227	912	1308	342	166	966
Forage	701	701			694	694		
Other Crops	102	102			101	101		
Seafood	504	337	370	167	511	334	270	177
Aquaculture								
Forestry	417	417	302		413	413	220	
HG Seed	19	19			19	19		
Contract Work	278	278			275	275		
Total	7676	6424	1312	1252	7688	6362	957	1326
IO	7688	6362	957	1326	7688	6362	957	1326
Ratio NACC:IO	1.00	1.01	1.37	0.94				

Source: CSO Agricultural, National Accounts (2010)

We use national accounts to source inputs by sector, therefore we scale all national accounts sectors on a pro rata basis. We disaggregate cereals in Table 15 using NFS data with aggregated cereals, fruit and vegetable, forage and other crops sectors.

Table 24 Disaggregation of Feed into Sub-Components

Feed		
Cereals	Concentrate Own	0.93
	Concentrate Opening	0.07
Forage	Pasture	0.35
	Winter Forage Own	0.07
	Silage own	0.54
	Hay Own	0.04
	Winter Forage Opening balance	0.00
	Silage Op	0.00
	Hay Op	0.00
	Winter Forage Purchases	0.00

Source: Teagasc National Farm Survey (2010)

In Table 16 we describe the allocation of output by final use. We allocate a number of sectors as intra-agricultural flows including fodder and part of the cereals and the milk used as input into the cattle sector (taken from the NFS). Inputs into construction and the timber in the original CSO IO table are assigned to the forestry sector. Except for the food processing sector, there are relatively few inter-industry inputs into other sectors, which are allocated in proportion to the total share of inter-industry outputs from that sector. The rest of the outputs from primary agri-food are allocated to the secondary processing sector.

Table 25 Allocation of Primary Output by Final Use (2010) €m

	Output (Agri-Food)	Output (Processing)	Output (Wood Processing)	Output (Construction)	Output Other	Total inter-industry	Final consumption	Gross fixed capital formation	Change in inventories	Exports f.o.b. (free on board)	Total Final uses €m
Cattle	0.0	1336.1	0.0	0.0	0.0	1336.1	0.0	-11.1	99.0	247.0	1671.0
Pigs	0.0	294.2	0.0	0.0	14.3	308.5	0.0	-2.8	25.0	0.0	330.0
Sheep	0.0	146.0	0.0	0.0	7.1	153.1	0.0	-1.4	12.0	0.0	164.0
Horses	0.0	0.0	0.0	0.0	0.0	0.0	92.0	-2.0	6.0	54.0	149.0
Poultry	0.0	73.9	0.0	0.0	3.6	77.5	26.2	-0.9	8.0	0.0	111.0
Milk	42.8	1294.5	0.0	0.0	65.1	1402.4	0.0	-12.7	137.0	0.0	1527.0
Other Products	0.0	36.0	0.0	0.0	1.8	37.7	0.0	-0.3	3.0	0.0	40.0
Cereals	25.7	306.2	0.0	0.0	16.2	348.1	0.0	-3.1	28.0	0.0	373.0
Fruit & Veg	0.0	274.1	0.0	0.0	13.3	287.4	786.7	-8.5	76.0	166.0	1308.0
Forage	674.8	0.0	0.0	0.0	0.0	674.8	0.0	-5.8	25.0	0.0	694.0
Other Crops	0.0	90.1	0.0	0.0	4.4	94.5	0.0	0.0	7.0	0.0	101.0
Seafood	11.1	172.9	0.0	0.0	9.0	192.9	38.7	-1.1	10.0	270.0	511.0
Aquaculture	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Forestry	0.0	0.5	145.3	39.2	0.0	185.0	0.0	-1.0	9.0	220.0	413.0
Seed	19.2	0.0	0.0	0.0	0.0	19.2	0.0	0.0	0.0	0.0	19.0
Machinery Hire	254.4	0.0	0.0	0.0	0.0	254.4	0.0	0.0	21.0	0.0	275.0
Total	1028.0	4024.4	145.3	39.2	134.7	5371.5	943.6	-50.7	466.0	957.0	7688.0

Source: Teagasc National Farm Survey (2010)

The sources of inputs into the AFF Sector are presented in Table 17. Animal and crop inputs are presented in Tables 18 and 19.

Table 26 Sources of Input from the Primary Agriculture, Fisheries and Forestry Sector (2010) €m

	Total intermediate consumption	Product taxes less subsidies	Total consumption at purchasers' prices	Value added	Total inputs (=Total domestic supply row in Table 1)	Imports (=Imports in Table 1)	Total (=Total domestic supply + imports in Table 1)
Cattle	1027.0	10.1	1037.0	450.0	1487.0	183.0	1671.0
Pigs	228.0	2.2	230.0	100.0	330.0	0.0	330.0
Sheep	113.0	1.1	114.0	50.0	164.0	0.0	164.0
Horses	103.0	1.0	104.0	45.0	149.0	0.0	149.0
Poultry	77.0	0.8	77.0	34.0	111.0	0.0	111.0
Milk	1054.0	10.4	1065.0	462.0	1526.0	0.0	1526.0
Other Products	28.0	0.3	28.0	12.0	40.0	0.0	40.0
Cereals	257.0	2.5	260.0	113.0	373.0	0.0	373.0
Fruit & Veg	236.0	2.3	239.0	103.0	342.0	966.0	1308.0
Forage	479.0	4.7	484.0	210.0	694.0	0.0	694.0
Other Crops	70.0	0.7	71.0	31.0	101.0	0.0	101.0
Seafood	219.0	2.3	221.0	112.0	334.0	177.0	511.0
Aquaculture	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Forestry	306.0	2.8	308.0	104.0	412.0	0.0	412.0
Seed	0.0	0.0	0.0	19.0	19.0	0.0	19.0
Machinery Hire	0.0	0.0	0.0	278.0	278.0	0.0	278.0
Total	4198.0	41.2	4240.0	2122.0	6362.0	1326.0	7688.0
IO	4198.0	41.2	4240.0	2122.0	6362.0	1326.0	7688.0

Source: Teagasc National Farm Survey (2010)

Table 27 Animal Inputs (2010)

	Own Feed Current	Own Feed (OB)	Purchased Feed	Milk Substitution	Vet and Medical	AI	Transport	Misc	Labour	Other
Milk	0.10	0.11	0.31	0.13	0.12	0.11	0.05	0.03	0.05	0.00
Cattle	0.11	0.09	0.26	0.15	0.12	0.13	0.02	0.03	0.07	0.02
Sheep	0.14	0.13	0.32	0.16	0.11	0.07	0.03	0.02	0.03	0.01

Horses	0.10	0.14	0.16	0.14	0.23	0.08	0.06	0.03	0.01	0.03
Pigs	0.00	0.06	0.80	0.01	0.05	0.07	0.00	0.00	0.00	0.00
Poultry	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Deer and Goats	0.14	0.13	0.32	0.16	0.11	0.07	0.03	0.02	0.03	0.01

Source: Teagasc National Farm Survey (2010)

Table 28 Crop Inputs (2010)

	Fertiliser	Labour	Seed (HG)	Crop Protection	Seed (Purchased)	Transport	Machinery Hire	Misc
Concentrate Own	0.34	0.00	0.00	0.30	0.13	0.00	0.21	0.01
Concentrate (OB)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
Pasture	0.73	0.00	0.00	0.04	0.05	0.00	0.18	0.00
Winter Forage	0.25	0.00	0.00	0.11	0.15	0.00	0.41	0.07
Silage	0.32	0.00	0.00	0.00	0.00	0.00	0.60	0.08
Hay	0.50	0.00	0.00	0.01	0.00	0.00	0.47	0.03
Winter Forage (OB)	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00
Hay (OB)	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00
Forestry	0.00	0.00	0.00	0.00	0.00	0.00	0.41	0.59
Other Cash Crop	0.27	0.00	0.00	0.16	0.19	0.00	0.37	0.01
Potato, Fruit & Veg	0.20	0.06	0.16	0.19	0.15	0.00	0.13	0.12
Setaside	0.00	0.00	0.00	0.00	0.16	0.00	0.36	0.48
Sugar Beet	0.43	0.00	0.00	0.39	0.18	0.00	0.00	0.00
Total	0.41	0.01	0.02	0.09	0.06	0.00	0.36	0.05

Source: Teagasc National Farm Survey (2010)

Given that we use the Teagasc National Farm Survey to disaggregate the National Accounts inputs by enterprise, it is important to understand systematic differences between the two datasets. In Table 20, we compare the animal outputs for the NFS and CSO national accounts. Cattle and dairy totals are reasonably close, with a 5% higher CSO cattle total output figure than that derived from the NFS, reflecting the small farms that are not present in the NFS. The NFS dairy output is just 8% higher than the national accounts. There is however a large difference between the sheep output in the NFS and the CSO national accounts, reflecting the fact that the NFS sample does not cover the commercial pig and poultry farms (and horse producers that do not have other farm enterprises), output from these sectors are not comparable. On this basis, it may be worth engaging in a wider dialogue between CSO and the NFS in relation to differences between the different sources of data.

Table 29 Teagasc National Farm Survey vs CSO National Accounts Animal Output comparison (2010) €m

	CSO	NFS	Ratio
Dairy	1541.9	1673.00	0.92
Cattle	1502.3	1437.00	1.05
Sheep	165.6	275.00	0.60
Horses	150.8	11.80	12.8
Pigs	333.7	24.60	13.6
Poultry	112.2	0.06	1898.3
Deer and Goats	40.8	0.00	n/a
Total (Dairy, Cattle, Sheep)	3209.8	3385.00	0.95

Source: Teagasc National Farm Survey (2010), CSO Agricultural, National Accounts (2010)
Note: Value of calf and animals moved from Dairy to Cattle in NFS

Appendix 4: Inputs

Table 30 Structure of Inputs for Food and Beverages Sector (€m) (CIP 2010)

	Intermediate Consumption (Domestic)	Materials and fuels	Industrial Services	Non-industrial Services	Stock changes during year - Materials & fuels	Intermediate Consumption	Imports	Imports for IC	Goods for resale without further processing
Food	11410.0	8700.4	167.5	4597.6	33.1	13465.5	5077.7	2055.5	3022.2
Beverages	1206.3	882.2	32.8	586.6	56.6	0.0	547.3	295.3	252.0
Total	12616.2	9582.5	200.3	5184.1	89.7	13465.5	5624.9	2350.8	3274.1

Table 31 Allocation of Inputs across Disaggregated Food Sectors (Domestic) (€m)(CIP 2010)

	Meat and meat products	Fish, crustaceans and molluscs	Fruit and vegetables	Vegetable, animal oils and fats	Dairy products	Grain mill products, starches/starch products	Bakery and farinaceous products	Other food products	Prepared animal feeds	Beverages	Total
Materials & fuels	3181	241	85	13	2889	28	245	1198	739	847	9465
Industrial Services	38	8	4	1	52	3	15	34	11	34	198
Non-industrial Services	108	14	34	4	32	0	91	4255	29	562	5129
Imports	644	63	20	4	518	21	82	530	212	316	2409
Domestic Intermediate Consumption	3326	263	123	17	2973	30	351	5488	779	1443	14793

Table 32 Inputs from the Primary Agriculture and Fisheries sector (€m) (CIP 2010)

	Meat & meat products	Fish, crustaceans and molluscs	Fruit & vegetables	Vegetable, animal oils and fats	Dairy products	Grain mill products, starches and starch products	Bakery and farinaceous products	Other food products	Prepared animal feeds	Beverages	Total
Cattle	1336	0	0	0	0	0	0	0	0	0	1336
Pigs	294	0	0	0	0	0	0	0	0	0	294
Sheep	146	0	0	0	0	0	0	0	0	0	146
Horses	0	0	0	0	0	0	0	0	0	0	0
Poultry	74	0	0	0	0	0	0	0	0	0	74
Milk	0	0	0	0	1295	0	0	0	0	0	1295
Other	36	0	0	0	0	0	0	0	0	0	36
Cereals	0	0	0	0	0	12	0	0	280	14	306
Fruit & Veg	0	0	0	0	0	0	0	274	0	0	274
Forage	0	0	0	0	0	0	0	0	0	0	0
Other Crops	0	0	0	0	0	0	0	90	0	0	90
Seafood	0	90	0	0	0	0	0	83	0	0	173
Aquaculture	0	173	0	0	0	0	0	0	0	0	173
Forestry	0	0	0	0	0	0	0	0	0	0	0

Table 33 Food to Food Flows (€m) (CIP 2010)

	Meat and meat products	Fish, crustaceans and molluscs	Fruit and vegetabl es	Vegetable, animal oils and fats	Dairy produ cts	Grain mill products, starches and starch products	Bakery and farinaceous products	Other food products	Prepared animal feeds	Bev erag es
Meat and meat products	676	0	0	0	0	0	0	0	0	0
Fish, crustaceans and molluscs	0	0	0	0	0	0	0	0	0	0
Fruit and vegetables	0	0	70	0	0	0	0	0	0	0
Vegetable, animal oils and fats	0	0	0	10	0	0	0	0	0	0
Dairy products	0	0	0	0	1042	0	0	0	0	0
Grain mill products,	0	0	0	0	0	11	0	0	0	0

starches and starch products										
Bakery and farinaceous products	0	0	0	0	0	0	201	0	0	0
Other food products	0	0	0	0	0	0	0	524	0	0
Prepared animal feeds	0	0	0	0	0	0	0	0	319	0
Beverages	0	0	0	0	0	0	0	0	0	679

Table 34 Destinations of Food and Beverage Sectors (€m) (CIP 2010)

	Agriculture, forestry and fishing	Food & beverages and tobacco products	Non-Food Inter-Industry	Inter Industry	Final consumption of h'holds, excl govt transfers	NPISH	Govt consumption plus transfers	Gross fixed capital formation	Exports	Output
Original IO	1154	3533	2130	6816	1724	-577	80	1	17680	25724
Meat and meat products	0	676	470	1146	361	98	17	0	2760	5379
Fish, crustaceans and molluscs	0	0	41	41	31	-11	1	0	286	466
Fruit and vegetables	0	70	19	89	15	-5	1	0	30	217
Vegetable, animal oils and fats	0	10	2	13	2	-1	0	0	8	28
Dairy products	23	1042	417	1482	319	67	15	0	1890	4765
Grain mill products, starches	0	11	6	17	5	-2	0	0	2	72
Bakery and farinaceous products	0	201	54	255	42	-15	2	0	192	621
Other food products	0	524	901	1426	691	-648	32	0	10478	10313
Prepared animal feeds	1131	319	0	1450	91	0	4	0	278	1358
Beverages	0	679	219	898	168	-61	8	0	1756	2505
Total	1154	3533	2130	6816	1724	-577	80	1	17680	25724