Using Green Biorefinery Technology to Enhance Domestic Self-Sufficiency in Protein Feed Supply – Economic Impacts on Conventional and Organic Farming

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Contribution presented at the XV EAAE Congress, "Towards Sustainable Agri-food Systems: Balancing Between Markets and Society"

August 29th – September 1st, 2017

Parma, Italy

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Abstract

This paper examines the sector economic consequences of protein extraction for non-ruminant feeding from grass, using green biorefinery conversion technology to increase domestic self-supply of protein. Impacts for conventional and organic farming are analysed in a partial equilibrium model of the Danish farm sector, which enables assessment of distributional effects between different farm types. The analysis suggests that crop production value and feed costs will increase, leading to a net economic loss in the conventional sector and a small gain for organic farming. Some variation across farm types in terms of adoption of biomass production and economic outcomes were found.

Keywords: Bio-refining, high-value protein, organic, conventional, agricultural sector model,

1 Introduction

Worldwide, it is increasingly acknowledged that there is need for changes in the approach to production, consumption, processing, storage, recycling and disposal of biological resources. In 2012, the European Commission launched its strategy for the bio-based economy: "Innovating for Sustainable Growth: A Bioeconomy for Europe" (European Commission, 2012), with the vision to create economic growth and jobs in rural areas, reduce fossil fuel dependence and improve the economic and environmental sustainability of primary production and processing industries via better utilization of bio-resources, including bio-resources produced in agriculture and forestry.

At the same time, the agricultural sector is also looking for opportunities for further value creation, and strategies towards production of feedstock for non-food bio-products, such as biomaterials, "green" chemical products or biofuels might be promising (OECD, 2008). Utilizing new biotechnology may however also boost value creation in the food supply chain, for example by enhancing the nutrient accessibility in crops for feeding, thus enabling the utilization of high-yielding crops for feeding to non-ruminants.

In many European countries, intensive livestock production is increasingly relying on imported protein feeds from other parts of the world, such as soy beans from South America (de Visser et al. 2014). Whereas conventional livestock farming may utilize imported protein feeds from countries with no clear distinction between crops from genetically modified organisms (GMO) and non-GMO's, this is not an option for organic livestock production, and the supply of protein feeds may hence constitute a limiting factor for the growth of organic farming, especially in livestock-dense countries like e.g. Denmark. Furthermore, transport of feeds over long distances may constitute a challenge for long-term environmental sustainability.

Green biorefinery technology may contribute to a solution to these feed supply challenges, both for conventional and for organic livestock sectors. Normally, high-yielding grass crops are not digestible for non-ruminant animals (pigs, poultry) due to a high content of cellulose, but separation and fermentation processes may be utilized to extract and convert the protein in grass into digestible components, while still retaining a feed value for ruminant animals (cattle, sheep, horses) in the residue.

Large-scale implementation of such technology for feed supply may be expected to influence the structure of agricultural production, because land suitable for grass production (which traditionally supplies cattle production) may now be more profitably used in relation to bio-refining for pig or poultry production, and because the technology may imply better overall utilization of feed resources in livestock production on both organic and conventional farms.

The purpose of this paper is to examine the agricultural economic consequences of large-scale implementation of green biorefining, where the domestic self-sufficiency in protein feeds is increased by processing protein from grass into protein that is digestible to non-ruminants, using Denmark as an illustrative case. Denmark is characterised by a relatively high livestock density in general, and also with a relatively large share of organic livestock (especially dairy) production. In particular, we analyse this issue with a distinction between protein feeds for organic versus conventional farming.

2 Methodology

A green bio-refinery system to produce protein feed from a grass feedstock comprises three major stages: primary production of grass, bio-refining and utilization of residues (Andersen & Kiel, 2000, Fog & Thierry, 2016). The bio-refining stage can be decomposed into three steps: separation of grass biomass into juice and solid fraction, extraction of protein pasta from the juice fraction through fermentation technology, and drying of the protein pasta. The solid fraction from the first stage can be used directly as cattle feed, with relatively little loss of nutritional value. Residues from the protein extraction can be entered into biogas production and recycled for spreading on farm land as a substitute for fertilizer.

The economic impacts of large-scale green biorefining are analysed in a partial equilibrium model of the Danish farm sector, which determines output, use of variable inputs, livestock, labour, capital and land in 36 lines of agricultural production, including 25 crops and 11 livestock sectors at the farm type level, which can be aggregated to desired levels (e.g. national, regional, farm-type, farm-size level, etc.), taking into account possible interactions between different farm types, such as utilization of biorefinery residues for feed in cattle production. An outline of the model structure is given in Figure 1.

[Figure 1. The agricultural sector economic model]

Danish farmers are generally assumed to be profit maximizers. In the model, this profit maximization comprises cost minimization in individual lines of production for given output, and determination of profit maximizing output on the respective production lines given the minimized costs and the availability of fixed inputs, such as land. The farmers are also assumed to be price takers. Exceptions are however roughage (grass, silage, green maize) for cattle, sheep and horses, where there is assumed to be equilibrium between within-farm supply and demand, and biomass for biorefining, where the price is determined to fulfil a stated output goal. The production technology (forming the basis for cost minimization) in each line of production is described by nested constant-elasticity-of-substitution (CES) technologies, where elasticities of substitution σ between different inputs (or input composites) have been estimated from econometric analyses of farm accountancy

(FADN) data or derived from agronomic data, such as field experiment data. Based on the initial cost structure and the elasticities of substitution, the demanded composition of input quantities x in the respective lines of production can be determined from the response to changes in relative "effective" prices (where a change in "effective" input price $\hat{w}$ incorporates changes in market price w, taxes τ, subsidies s and shadow prices λ, the latter representing bindingness of quantitative restrictions etc.)

$$(1) \qquad \dot{x}_i - \dot{x}_j = \sigma_{ij} \cdot \left(\dot{\hat{w}}_j - \dot{\hat{w}}_i \right) \quad , \qquad \dot{\hat{w}}_j = \frac{\Delta w_j + \Delta \tau_j - \Delta s_j + \Delta \lambda_j}{w_j^0}$$

The farm's supply of the g'th individual agricultural product y_g is determined by the two-component supply function

$$(2) \qquad y_g = \begin{cases} y_g^0 \cdot \left(1 + \varepsilon_g \cdot \left(\dot{p}_g - \sum_i s_i^g \cdot \dot{\hat{w}}_i \right) \right) & \text{,if } y_g^0 > 0 \\ \dfrac{e^{\alpha_g + \beta_g \cdot \left(\dot{p}_g - \sum_i s_i^g \cdot \dot{\hat{w}}_i \right)}}{1 + e^{\alpha_g + \beta_g \cdot \left(\dot{p}_g - \sum_i s_i^g \cdot \dot{\hat{w}}_i \right)}} \cdot y_g^{\max} & \text{,if } y_g^0 = 0 \end{cases}$$

depending on whether this production is already active in the baseline or not (i.e. whether the baseline output y_g^0 is positive or zero). If the production is already active, the supply response to a change in effective price conditions (difference between change in output price p and input price composite $\sum_i s_i^g \cdot \dot{\hat{w}}_i$) is given by the farm-level supply elasticity ε_g. If the production is not active initially, the potential introduction of it on the farm is described by a logistic function of the change in price conditions. This "S-shaped" functional form implies a "soft threshold" for the introduction of the production on the farm, where the production will mainly become active if an improvement in the effective price conditions exceeds a certain range, as determined by the α- and β-parameters, up to a maximum extent given by $y_g^{\max}$. The logistic functional form reflects a "bell-shaped" distribution for the threshold return to land for which the currently inactive (biomass) crop becomes profitable, compared to other crops, across farms within the farm type aggregate. For a crop production, the maximum extent $y_g^{\max}$ may be given by the maximum area available for the crop (taking into account e.g. restrictions due to crop rotation concerns, etc.), multiplied by an average yield per hectare. This latter component of the supply function is important when analysing the introduction of novel crops, such as biomass crops for biorefining, but can also be relevant for other crops that are not currently active on all farm types in the model. The α- and β-parameters reflect differences in the baseline profitability from the inactive production, relative to active reference productions, but reflect also the marginal cost pattern when expanding this production. In the case of biomass, this may be shaped by e.g. of availability of suitable land or transport distance to a biorefinery. The parameters are calibrated on the basis of cost data from other studies (Bojesen et al. 2016) and an estimated distribution of transport distances.

A number of constraints determine the interactions between different lines of agricultural production, and these constraints define the model closure. One (technical) constraint is an area constraint, stating that the areas for individual land uses should add up to the total area on each farm type. Combined with an equilibrium condition stating that the shadow price of land (reflecting the marginal returns to land) should be equal in all uses, this constraint determines the allocation of land to agricultural uses within the farm type (and the shadow prices feed back into the effective prices determining input composition and output in equations (1-2)). Another technical constraint is a within-farm supply-demand balance for roughage. Constraints can also be determined by policy, e.g. quota on output or input use or requirements on livestock density, but such constraints are not applied in this study. Each such constraint is associated with a "shadow price", which represents the extent to which this constraint is binding on the individual farm type, which also results in farm-specific shadow prices. More details on the model can be obtained from Jensen & Ørum (2012). In the case of green biorefining, the solid fraction of the biomass – representing 70 per cent of the ruminant-digestible feed value from the green biomass - is assumed to be channelled back to (and paid for by) farms with ruminant production as a substitute for roughage, enabling these farms to reduce their use of other purchased or on-farm produced roughage (such as grass or green maize). Hence, the green biorefining systems may affect the production structure, both on the farms producing the biomass crops but also on cattle farms receiving the roughage by-product.

The model analysis addresses the distributional effects within the Danish agricultural sector, as represented by 15 different farm types (Table 1).

[Table 1. Farm typology]

In particular, we analyse the economic impacts on the Danish farm sector of increasing the self-sufficiency rate for protein feeds for conventional farms and for organic farms, respectively, compared with a baseline scenario (the observed situation in 2011).

We assume that the cost of primary grass production for biorefining corresponds to the costs of producing grass for roughage in the baseline situation. It is further assumed that the bio-refining of green biomass (grass, clower, etc.) to extract proteins can be done at costs as displayed in Table 2. Furthermore, it is assumed that the extracted protein feed product is a perfect substitute for soya meal. The value of the roughage substitute is deducted from the cost of biorefining and hence from the price of the protein concentrate, and similarly, the net value of biogas produced from the residues is subtracted.

[Table 2. Assumptions regarding costs of biorefinery processing of grass]

In the scenarios, we analyse the impacts of 5 percentage points increase in the domestic self-sufficiency rate for conventional and organic protein feeds, respectively, by means of green biorefining of grass specifically grown for that purpose. The scenarios are implemented in the economic model in terms of the biomass price p_{bio}, which is set at a level ensuring the achievement of this +5% self-sufficiency goal, either for the group of conventional farm types or for the group of organic farm types.

With an increased domestic protein feed production, the average price of concentrate feeds will change:

$$\dot{w}_{conc\_feed} = 0.05 \cdot \left(\frac{p_{bio} / \eta + c_{biorefining} - w_{soya}}{w^0_{feed}} \right)$$

The variable $c_{biorefining}$ represents the net cost of the complete biorefining process (adjusted for value of by-products – roughage and biogas, cf. Table 2), and η is protein content rate in the biomass. The price per kg dried protein feed is €1.24 for conventional protein feed and €1.34 for organic protein feed (of which the net refinery costs constitute around €0.25 in both cases) at the baseline cost level for grass production, which may be compared with prices of conventional and organic soya meal of around €0.30 and €0.50-0.60, respectively. If the biomass production is changed significantly, the costs of primary grass production also changes.

3 Results

Using the partial equilibrium model outlined above, economic effects for the Danish agricultural sector, including impacts of the scenarios on agricultural production and its composition, agricultural income and employment have been assessed, both at an aggregate sector level and for different farm types within the agricultural sector.

Sector level results

Table 3 displays the calculated economic impacts of the two scenarios at the agricultural sector level.

[Table 3. Estimated agricultural sector economic impacts of increased self-sufficiency in protein feed]

Increasing the Danish self-sufficiency of conventional protein feeds by 5 percentage points by means of green biomass for bio-refining requires a biomass area of 470,000 ha. The increase in green biomass area occurs primarily at the cost of traditional cash crops, especially ordinary grain production (spring barley and wheat), and to some extent by including currently idled area. The value of agricultural outputs increases by around €250 million, mainly via an increase in the value of crop output (but a decrease in the value of livestock outputs, although pig and poultry production increase slightly). However, the scenario also implies an increase in the costs, mainly to concentrate feeds (which stems from the higher net cost of green biorefinery protein feed than for the current protein sources). Hence, the net economic sector outcome is a decrease in agricultural sector gross income of around €0.2 billion and in sector net profit of €0.18 billion. At the same time, the scenario gives rise to an increase in direct agricultural employment at around 400 full-time jobs. On top of this comes employment effects in biorefining and transport of biomass between farms and biorefinery/biogas plant, roughly around 800 full-time equivalent jobs, estimated on the basis of the cost structure in biorefining and biomass transportation.

As the organic farming sector (and in particular the parts of the sector with high demand for protein feed) is much smaller than its conventional counterpart, the sector level impacts of a +5% increased protein self-sufficiency in organic livestock production is also much smaller than those for an increased protein self-sufficiency in conventional farming. In particular, the model analysis suggests that the +5% increased self-sufficiency for organic protein can be reached with a biomass area of 14.000 ha, which occurs mainly at the cost of grain area, but also with enrolment of fallow areas. As in the conventional protein scenario, the increased self-sufficiency leads to an increased value of crop production, a minor reduction in the value of livestock production, and hence an increase in total output value of around € 5million, whereas the sector-level variable cost remains fairly unchanged. Hence the economic net outcome of this scenario is a slight increase in the sector's gross and net income, respectively, and no employment change in the primary agricultural sector. The reason for this positive outcome for organic protein – as compared to the results for conventional protein above – is the fact that the cost add-on for organic feed processing is similar to that for conventional feed in absolute terms, and hence that the relative price differential for the organic protein is not so dramatic, compared to the price differential of other organic protein sources. As in the above conventional scenario, there will be additional employment effects in the biorefinery and transport sectors, corresponding to around 15 full-time jobs.

It should be noted that the positive effects on crop output value to some extent are derived from the assumption that the price of biomass crop increases in order to stimulate the supply of biomass for the green biorefineries. With regard to conventional protein feed, this means a biomass price increase of 36 per cent and for the scenario with organic protein feed a biomass price increase of 37 per cent, compared with the baseline costs of biomass production. If the biomass producers are not able to obtain such price increases, the value of crop production would increase less than suggested by the model calculations. On the other hand, the biomass component of the protein feed price would also be lower, leading to a reduction in the feed costs, as compared with the presented results.

Farm level results

As mentioned previously, the present study considers 15 farm types, distinguished according to main production, farm size, soil type, organic status and full-time/part-time status. Figure 2 illustrates how the biomass production is distributed on the 15 farm types in the two self-sufficiency increase scenarios.

The analysis suggests some variation across these farm types in terms of their adoption of biomass production for industrial purposes. In particular, conventional part-time farms represent around one quarter of the biomass production in the conventional protein feed scenario, whereas organic part-time farms constitute slightly less than a quarter of biomass production in the organic self-sufficiency scenario. This may be explained by a relatively low economic return to traditional crop production for these part-time farms, and hence that "new" biomass crops may be more competitive on these farms compared to the existing production. On the other hand, it should also be kept in mind that part-time farms exhibit lower productivity than larger full-time farms, due to e.g. lower capital endowment and less professional management, which may tend to reduce the gap in economic returns between biomass grass and existing crops on these farms. Other major contributors to the biomass production include cattle farms, which in the organic self-sufficiency scenario represent more than half of the biomass production, and in the conventional scenario around 20 per cent. Cattle farms may have a competitive advantage in grass production, which may contribute to explain, why these farms account for a relatively large share of the biomass production, and furthermore, the replacement of traditional roughage with the solid fraction from the biomass refining process releases some land for biomass production on these farms. Furthermore, part-time and cattle farms' relatively large shares of the biomass production can also be related to the fact that these farm types occupy significant shares of the total agricultural area in conventional and organic farming, respectively.

[Table 4. Distribution of effects on farm types]

The distributional economic effects within the farming sector are also shown in Table 4, represented by calculated changes in land rent in each of the 15 farm types in the two scenarios.

Two overall observations can be made on this issue. First, the scenarios lead to economic redistribution within the agricultural sector. In particular, crop farms tend to gain – relative to other farm types – due to the higher crop price that is assumed to drive the expansion of biomass production. On the other hand, the smaller conventional pig farms tend to loose in relative terms, mainly due to higher feed costs, compared with a higher reliance on imported protein feeds as in the baseline, whereas large pig farms tend to be among the relative winners, because they have relatively large crop production as well, and hence reap the gains from the opportunity of biomass production. In the organic feed scenario, the organic pig farms tend to lose, relative to the other organic farm types. It is remarkable that the economic impacts on cattle farms is close to the sector average, as their economic costs of higher protein feed price is outweighed by the potentials in biomass production – and in replacement of current roughage production with cash crops.

4 Discussion

The work with analysing economic impacts of biomass production for green bio-refining is a field in progress, given that the development of biomass processing technologies for high-value purposes is still at its infancy. As a natural consequence, results of quantitative economic analyses of such technologies will also be a somewhat uncertain predictor of actual economic outcomes, once the scenarios have become reality. Nevertheless, economic model tools and analyses are deemed useful to identify some of the critical assumptions for the economic viability of alternative technologies within the field of biomass refining and hence for the economic sustainability of the bio-based economy.

Using advanced biotechnology to refine agricultural products is definitely a way to improve value-added in the agri-business sector and in associated industries, including industries that develop, operate and market these technologies. Furthermore, such technological solutions may involve improved utilization of natural resources and contribute positively to long-run environmental sustainability goals. The results in this study however also suggest that there may be winners and losers from such strategies within the agricultural sector. Within the organic farming sector, protein feeds – and particularly protein feed of domestic origin – is a scarce resource, and green biorefining technologies may alleviate one of the most important barriers for the expansion of organic livestock production – even without increasing feed costs dramatically as compared with current prices of organically produced protein feed. On the other hand, the use of such advanced bio-technology in organic supply chains may invoke some resistance among consumers of organic products, and may be perceived as compromising on the “naturalness” of organic products, an attribute that is often seen as relatively important vis-à-vis organic foods (Lockie et al., 2002; Lusk & Briggeman, 2009).

One key component in the economic analysis is the transportation – of biomass from the fields to the biorefinery, of the solid fraction from the biorefinery to cattle farms, and of biomass residues back to the fields. In the above calculations, such transportation costs have a magnitude close to the total processing cost net of the value of side-streams. This suggests that the location of the refinery and its adjacency to relevant biomass areas will be crucial for the economic performance.

Having considered economic sustainability with regard to biorefining technologies, it is also of importance to consider aspects related to the environmental sustainability of these technologies. Conversion of green biomass to high-value protein feed has implications for the import of soya from e.g. South America (with associated environmental consequences), but could also have other environmental impacts. Parajuli et al (2015) review some of the pathways for sustainable biorefinery value chains and their assessment.

The results in this study suggest that increasing the self-sufficiency with protein feeds for a livestock dense agricultural sector like the Danish one will imply an economic cost for the sector, as compared with the present situation relying on imported protein feeds from other parts of the world. This finding naturally relies on the assumed price relations, including the world market price for protein feeds, as well as the direct and indirect costs associated with green biorefining. Hence, making green biorefining economically competitive will likely require some reduction in these costs, including the costs of establishing and running the plants, but also the utilisation of side-streams from the processes, such as the solid fraction of the biomass or the residues from the fermentation process, which is currently used for biogas production.

OECD (2007) discusses a range of potential measures to support the development of the bioenergy sector, and several of these measures – as well as the potentials and challenges associated with them - also apply to the biomass uses in the present analysis. In relation to biomass production, such measures might include traditional agricultural policy instruments, such as subsidies or quotas. Biomass conversion may be supported by improved market infrastructures, reduced R&D costs, reduced production costs or guaranteed price or market access for the refined products. As with "traditional" agricultural support, it should however be considered, whether such support measures do not cause unintended economic distortions – in the biomass sector, in the agricultural sector as well as in other sectors.

5 Conclusion

The present study has assessed some agricultural economic impacts of extensive implementation of biorefining technology to increase value-added and protein self-sufficiency in agricultural production, including the distributional effects within the farming sector, using Denmark as an example. Two alternative strategies were assessed: pursuit of increased self-sufficiency for protein feeds in conventional farming - and a corresponding goal for organic farming.

Both scenarios suggest that such scenarios will lead to an increased value of crop production, but also an increase in the feeding costs in livestock production, and hence large-scale green biorefining will imply some economic redistribution within the agricultural sector. An increased self-sufficiency of conventional protein feed is estimated to imply an overall economic loss for the agricultural sector, whereas increased self-sufficiency of organic protein tends be economically neutral or even yield a slightly positive economic impact. The specific extent of redistribution however depends on the pricing of biomass for the green biorefineries.

Based on the study, two recommendations can be derived in order to ensure the economic sustainability in the use of green biorefinery technology. First, there is still need to refine the technologies to lower the costs, and to refine the utilization of side-streams from the refining processes. Second, there is need for a strong focus on transportation costs, which play a highly important role for the economic performance of the value chain.

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Table 1. Farm typology

Type	Approximate number, 2011	Area per farm (ha)	Total area (1000 ha)
Small conventional crop full time farm, clay soil	901	134	121
Large conventional crop full time farm, clay soil	582	377	219
Small organic crop full time farm, clay soil	24	141	3
Large organic crop full time farm, clay soil	14	433	6
Small conventional crop full time farm, sandy soil	608	111	67
Large conventional crop full time farm, sandy soil	464	334	155
Small organic crop full time farm, sandy soil	23	134	3
Large organic crop full time farm, sandy soil	18	425	8
Conventional cattle full time farm	3930	117	460
Organic cattle full time farm	448	181	81
Small conventional pig (+other) full time farm	3607	85	307
Large conventional pig (+other) full time farm	1174	317	372
Small organic pig (+other) full time farm	82	114	9
Conventional part time farm	16135	36	581
Organic part time farm	801	38	30

Large farm: > 200 ha, Part time: < 1665 standard working hours annually

Source: Danish Farm Accountancy Data (Statistics Denmark)

Table 2. Assumptions regarding costs of biorefinery processing of grass

	Conventional	Organic
Grass yield (ton/ha)	63	54
Dry matter yield (ton/ha)	12.6	10.8
Dried protein feed (kg/ha)	1445	1239
Baseline field cost (€/ton grass)	22.74	25.21
Pressing cost (€/ton grass)	7.24	7.24
Extraction cost (€/ton grass)	4.35	4.36
Drying cost (€/ton grass)	4.30	4.30
Biorefining total (€/ton grass)	15.89	15.91
Net value of by-products		
- cattle feed (€/ton grass)	13.71	13.71
- biogas (€/ton grass)	-3.43	-3.43
Total cost (€/ton grass)	38.63	41.12
Total cost net (€/ton grass)	28.36	30.85
Total net cost (€/kg dried protein feed)	1.24	1.34
- primary production	0.99	1.10
- processing net cost	0.24	0.25

Source: Fog & Thierry (2016)

Table 3. Estimated agricultural sector economic impacts of biomass scenarios

		Baseline	Conventional +5%	Organic +5%
Average price of protein feed	€/kg	1.00	1.30	1.20
Biomass area	1000 ha	4	470	14
Trad. cash crop area	1000 ha	1,701	1,368	1,701
- organic		54	54	48
Roughage area	1000 ha	491	467	491
- organic		79	80	78
Total area grown	1000 ha	2,330	2,439	2,332
Dairy cows	1000 hds	501	485	501
- organic		52	52	51
Produced finisher pigs	1000 hds	29,782	30,065	29,782
- organic		152	152	152
Crop output	Mill. €	3,166	3,508	3,183
Livestock output	Mill. €	7,517	7,431	7,506
Total output	Mill. €	10,684	10,939	10,689
Costs	Mill. €	7,692	8,141	7,691
Gross factor income	Mill. €	2,992	2,798	2,998
Sector profit	Mill. €	380	196	387
Sector employment	1000*	39,776	40,186	39,776

*Full-time equiv.

Table 4. Distribution of results on farm types

Type	Conventional +5%			Organic +5%		
	Biomass area pr. farm (ha)	Share of biomass area	Δ profit, €/ha	Biomass area pr. farm (ha)	Share of biomass area	Δ profit, €/ha
Small conv. crop full time farm, clay	19	5%	-29	0	0%	0
Large conv. crop full time farm, clay	54	8%	1	0	0%	0
Small organic crop full time farm, clay	0	0%	2	21	2%	-9
Large organic crop full time farm, clay	0	0%	2	61	3%	-6
Small conv. crop full time farm, sand	21	3%	-39	0	0%	0
Large conv. crop full time farm, sand	62	8%	-9	0	0%	0
Small organic crop full time farm, sand	0	0%	0	25	2%	11
Large organic crop full time farm, sand	0	0%	0	76	6%	0
Conventional cattle full time farm	19	20%	-41	0	0%	0
Organic cattle full time farm	0	0%	4	32	58%	-18
Small conv. pig (+other) full time farm	14	13%	-57	0	0%	0
Large conv. pig (+other) full time farm	53	16%	-28	0	0%	0
Small organic pig (+other) full time farm	0	0%	3	20	7%	-46
Conventional part time farm	6	26%	-61	0	1%	0
Organic part time farm	0	0%	1	7	21%	-20

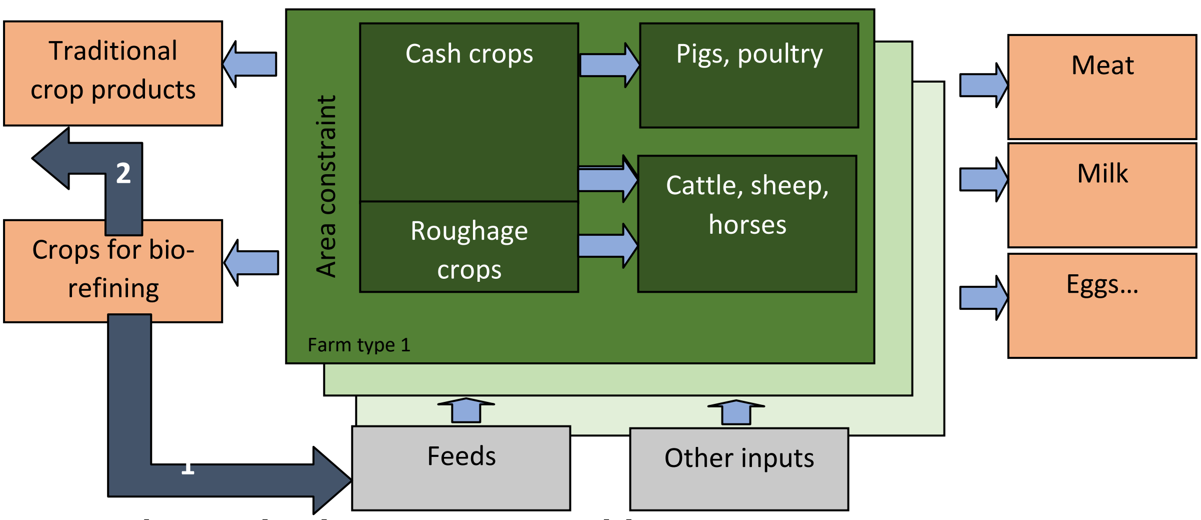

Figure 1. The agricultural sector economic model