An Extended Input-Output Table for Organic Farming

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Introduction

The agricultural sector plays a key role in the context of Sustainable Development. On the one hand, it has a significant impact on the natural environment, for instance through greenhouse gas (GHG) emissions or the use of pesticides. On the other hand, agriculture will have to adapt to global warming, changes in precipitation and further challenges. Moreover, when consumers try to adopt more sustainable lifestyles, many of their decisions involve the use of agricultural products. They would like to know, for instance, the ecological footprint associated with a vegetarian or vegan diet, different types of farming (conventional or organic), and preferring regional products to imported products that may have travelled thousands of kilometers ("food miles").

In principle, input-output analysis (IOA) can be a useful tool for studying the environmental impacts associated with food consumption and agricultural production. However, there are severe restrictions in terms of data availability. In the case of Germany, the official input-output tables represent agriculture in a rather crude form as only one industry (i.e. one column) and agricultural products are represented as one aggregated commodity (i.e. one row). The same is true for many other countries. These data limitations make it virtually impossible to distinguish between different types of food and different farming practices.

The goal of the present project is to explore how an extended input-output table could enhance our understanding of the links between nutritional choices, agricultural production, and the associated environmental impacts. We focus on the difference between organic farming on the one hand and conventional farming on the other hand. The project involves a literature survey, conceptual work on the input-output table, fieldwork in the form of interviews, and the construction of an extended model for the German economy with a disaggregated agricultural sector.

Related Literature

Previous research on different types of farming has identified significant differences between organic and conventional farming. One stream of literature focusses on the relative efficiency or profitability of the two different approaches (Breustedt et al., 2011, Brümmer, 2001, Brümmer et al., 2002, Kumbhakar et al., 2009, Oude Lansink et al., 2007, Tzouvelekas et al., 2001). Another stream is concerned with the environmental impacts resulting from food production and agriculture. These studies are often based on life-cycle assessment (LCA), focusing on individual products (Andersson et al., 1998, Berlin, 2002, Cederberg & Mattsson, 2000). Although LCA is conceptually similar to IOA; it has different advantages and disadvantages. Therefore, some authors have applied a combined IOA-LCA approach to the analysis of agriculture (Engström et al., 2007).

In both conventional and organic farming systems different types and quantities of inputs are needed for production. **Morgan, K. and Murdoch, J., 2000** have analyzed the evolution of knowledge distribution, power and innovation in both the conventional and the organic food chain in the UK. They have described the conventional food production process as part of the industrial production network. This mass production has resulted not only in increased outputs (yields) but also into a strong reliance on external inputs (agro-chemicals), a loss of knowledge and sustainable practices as well as a disregard of local ecosystems **(Morgan, K. and Murdoch, J., 2000**). In comparison to such high-input systems organic farming systems are integrated sustainable food production systems that rely mostly on natural and renewable inputs (i.e. on-farm fertilizers). **Gundogmus, E. and Bayramoglu , Z., 2006** show for the organic raisin production in the Aegean Region of Turkey a 25% lower energy input use. From an output (yield) perspective **Van Stappen, F. et al., 2015** found for Wallonia (Belgium) organically cropped wheat to be inferior to conventionally cropped wheat with regard to the mass (kg) whereas organically cropped wheat seems to be more environmentally sound in terms of land area (ha). The economic input-output analysis can help to identify inputs of regional food production chains in terms of advances among the economic sectors. This can contribute to a reduction of negative environmental and socio-economic impacts.

Organic farming

A central concern of studies on ecological farming is to analyze its local, regional or global environmental and socio-econoimic impacts in comparison to conventional farming systems (**Ki, S.L. et al., 2015; Reganold, J.P., (2016); Tuomisto, H.L. et al., 2011**). Different research focuses in literature that have focused on single dimensions only can be grouped, e.g.: emissions of greenhouse gases (**Kristensen, T. et al., 2011); Meisterling, K. et al.; Bos, J. et al., 2014**). Other aspects include biodiversity **(Meier et al., 2015; Tuck, S.L. et al., 2014**) and yields **(Seufert et al., 2012; De Ponti et al., 2012; Seufert, V. et al., 2015**). With regard to agrochemicals (growth regulators, pesticides and mineral fertilisers) comprehensive research investigations have been made (**Barański, M. et al., 2014**). Life Cycle Assesment (LCA) is an increasingly used research method to compare outputs from conventional and ecological farming systems (**Meier et al., 2015; Mohamad, R.S. et al. 2014; Meisterling, K. et al., 2009, Küstermann, B. et al. 2008**).

IO Analysis in both conventional and organic farming systems

IO Analyses are often performed to analyze advances in regional energy supply chains. **Zhu, Q. et al. 2012** have focused on indirect carbon emissions from residential consumption in China based on comparable price input–output tables. With regard to the Turkish economy several studies have concentrated on energy input-output relations (**Karkacier, O. and Goktolga, Z.G., 2005; Yildiz, T., (2016)**). **Hussain, A. B. and Azlina, A., 2010** have focused particularly on the direct backward linkages between agriculture and the energy sectors in Malaysia.

Other researchers have evaluated farms as agroecosystems applying indicators via IO methodologies (**Tellarini,V. and Caporali,F., 2000** for central Italy). **Goodlass, G. et al., 2003** have found that IO accounting systems in the member states of the EU are not homogeneously applied, but IO accounting systems are considered to become more often applied tools in assessing the environmental performance of farms. **Johnson, T.G. and Kulshreshtha, S.N., 1982** have compared the

impacts of various types of farms with regard to the aggregate output levels of Saskatchewan economy by an IO model, finding relatively little differences in the effects on a per dollar of output basis.

An Input-Output Analysis was performed for the agricultural and livestock sector of Brazil in order to analyze the behaviour's evolution in this sector. The results indicate that the agricultural and livestock sector has not only been generating an increasing number of inputs for other sectors in Brazil, but generally becomes a more important sector in terms of production, employment and incomes (**Silveira, T.S. et al. 2015**).

For the German agricultural sector **Schmidt, T. et al. (2005)** have focused on environmental impacts of agricultural production by disaggregating it into single production steps. At the same time this model helps to understand the economic part of agriculture much better.

Piaggio, M. et al., 2014 have identified directly (cattle farming sector) and indirectly polluting sectors (induced activities in other sectors) of the Uruguayan economy. As a result technical improvements are more effective for directly polluting sectors whereas demand policies in the indirect sectors might be more effective.

Summary

Most of the research studies have found organic farming systems to be more sustainable from different points of view. A majority of the approaches have been realized by LCA. Little studies have been performed by IO Analysis. We have not found a study that explicitly has analyzed production input data only for organic farming systems according to the official IOTs and have compared them to the data of conventional farms.

In total we argue that IO analyses can be a comprehensive and important tool that not only helps to understand inter-sectoral linkages in terms of environmental impacts, but also supports a more comprehensive perspective on the development of regional economies. One of the major contributions of IO analyses on farming systems is to support the increasing conversions from conventional to organic farming systems. IO Analysis in this context can make the conversion process much more predictable.

Methodology

The present project contributes to the literature with a case study of German agriculture. Its goal is to develop an extended input-output table, where the agricultural sector from the official table is split into “organic farm” on the one hand and “conventional farming” on the other hand. The layout of the extended table is shown in Figure 1. We hope that the extended table will be useful for a variety of applications. For example, it can be used to study the difference between households consuming products of organic farming (row 1) and products of conventional farming (row 2), including the environmental impact (e.g. greenhouse gas emissions) as well as the direct and indirect employment effects.

Figure 1: Extended input-output table

	Homogenous branches				Final use				
	Organic farming	Conventional farming	Other branches	*Total*	Consumption by households	Other domestic final use	Exports	*Total*	*Total*
Products of organic farming									
Products of conventional farming									
Other products									
Total									
Compensation of employees									
Other components of value added									
Value added									
Output									
Imports of similar products									
Total supply of products									

Source: authors’ illustration

In order to complete the extended IOT with actual data, we conduct a number of semi-structured interviews with farmers both from the organic farming sector and the conventional farming sector. This approach allows us to identify differences between organic farming and conventional farming and to compare the different input structures

Preliminary Results

Before showing the results of the interviews, we analyze the input structure of the agricultural sector as a whole, drawing on the official input-output table for the homogeneous branch (Table 1) and the official use table for the industry (Table 2).

Table 1: Intermediate input structure of the homogenous branch agriculture (CPA 01)

CPA	Description	Share
01	Products of agriculture, hunting and related services	0.30202724
10-12	Food products, beverages, tobacco products	0.09069792
78	Employment services	0.07562559
46	Wholesale trade services, except of motor vehicles and motorcycles	0.07243163
20	Chemicals and chemical products	0.07105902
77	Rental and leasing services	0.05242319
47	Retail trade services, except of motor vehicles and motorcycles	0.03898744
19	Coke and refined petroleum products	0.03431528
37-39	Sewerage services, waste services, remediation services	0.02560448
35.1, 35.3	Electricity, steam and air conditioning services	0.02343997

Source: own calculation based on the German IOT (2013)

Table 1 shows the ten most important intermediate inputs of the homogenous branch agriculture (based on their respective shares in the intermediate consumption of that branch). The most important input is “products of agriculture, hunting and related services” (CPA 01), which accounts for roughly 30% of the intermediate consumption, followed by “food products, beverages, tobacco products” (CPA 10-12) with a share of 9%. The next three inputs are “employment services” (CPA 78), “wholesale trade services” (CPA 46), and “chemicals and chemical products” (CPA 20) with share of approximately 7% each.

Table 2: Intermediate input structure of the industry agriculture (NACE 01)

CPA	Description	Share
10	Food products	0.18013934
01	Products of agriculture, hunting and related services	0.11513717
20	Chemicals and chemical products	0.10547018
78	Employment services	0.09556985
19.2	Refined petroleum products	0.09370312
77	Rental and leasing services	0.06740225
28	Machinery	0.04586820
35.1, 35.3	Electricity, steam and air conditioning services	0.03253442
64	Financial services	0.02766759
38	Waste collection, treatment and disposal services; materials recovery services	0.02760092

Source: own calculation based on the German use table (2013)

If we perform the same calculations with the use table, we can examine the intermediate input structure of the industry agriculture. Table 2 reports the results. They are slightly, but not dramatically, different from the results in Table 1. Inputs such as “food products” (18%) and “products of agriculture, hunting and related services” (11.5%) are still among the most important inputs. The share of chemicals and chemical products (10.5%) is slightly higher than in Table 1. Moreover, the share of refined petroleum products (9.3%) is substantially higher than in Table 1, where they accounted for approximately 3%.

Based on these findings, we may conclude that the key inputs to agriculture include agricultural products (CPA 01), food products (CPA 10), employment services (CPA 78), rental and leasing services (CPA 77), chemical products (CPA 20), refined petroleum products (CPA 19.2), electricity (CPA 35.1) and waste collection, treatment and disposal services (CPA 38).

Table 3: Intermediate input structure of the interviewed farms

CPA	Products	All farms	Conventional farms	Organic farms
01	Products of agriculture, hunting and related services	0.19283696	0.15702966	0.24058004
10	Food products	0.19224179	0.20939053	0.16937680
20	Chemicals and chemical products	0.10797087	0.16155121	0.03653041
21	Pharmaceutical products	0.02399115	0.04118263	0.00106919
19.2	Refined petroleum products	0.16598690	0.21917662	0.09506727
35.1, 35.3	Electricity, steam and air conditioning services	0.03081663	0.03612143	0.02374357
28	Machinery	0.08701280	0.10296188	0.06574737
38	Waste collection, treatment and disposal services; materials recovery services	0.00664838	0.00980396	0.00244093
64	Financial services	0.01560796	0.00891834	0.02452745
77	Rental and leasing services	0.00446628	0.00713012	0.00091449
78	Employment services	0.00039193	0	0.00091449

Source: own calculations

Table 3 shows the results of our interviews. We compute the average shares of the individual inputs in overall intermediate consumption for all farms in our sample and for the conventional and organic farms separately. In general, our results are not too far from the "official" ones. The two most important inputs continue to be "products of agriculture, hunting and related services" (CPA 01) and "food products" (CPA 10). Inputs such as "refined petroleum products" (CPA 19.2) and "chemicals and chemical products" (CPA 20) also play important roles.

Moreover, our preliminary results seem to suggest that there are in fact substantial differences between organic farms and conventional farms. For example, the share of "chemical and chemical products" (the product category that includes fertilizer) is 16.1% for the conventional farms and 3.7% for the organic farms. Furthermore, the share of pharmaceutical products is 4.1% for the conventional farms and 0.1% for the organic farms. These numbers would indicate that organic farms consume much lower amounts of chemical products and pharmaceutical products per unit of output than their conventional counterparts, as should be expected.

Conclusion and Outlook

Our preliminary findings show that there are apparently substantial difference between organic farms and conventional farms which can be captured in the input-output framework at the level of product groups. In future research, we plan to conduct more interviews and broaden the empirical basis of our analysis. We hope that this approach will allow us to construct a reliable input-output table with a disaggregated agricultural sector.

References

Andersson, K., T. Ohlsson, P. Olsson, P. (1998): “Screening life cycle assessment (LCA) of tomato ketchup: a case study”, *Journal of Cleaner Production*, 6, 277-288.

Barański, M. et al., (2014). Higher antioxidant and lower cadmium concentrations and lower incidence of pesticide residues in organically grown crops: a systematic literature review and meta-analyses*. British Journal of Nutrition,* 112 (2014) 794–811.

Berlin, J. (2002): “Environmental life cycle assessment (LCA) of Swedish semi-hard cheese”, *International Dairy Journal*, 12, 939-953.

Bilalis, D. et al. (2013). Energy Inputs, Output and Productivity in Organic and Conventional Maize and Tomato Production, under Mediterranean Conditions *Not Bot Horti Agrobo,* 41 (2013) 190-194.

Bos, J. et al., (2014). Energy use and greenhouse gas emissions in organic and conventional farming systems in the Netherlands. *NJAS – Wageningen Journal of Life Sciences*, 68 (2014) 61-70.

Breustedt, G., U. Latacz-Lohmann, T. Tiedemann (2011): “Organic or conventional? Optimal dairy farming technology under the EU milk quota system and organic subsidies”, *Food Policy*, 36, 223-229.

Brümmer, B. (2001): “Estimating confidence intervals for technical efficiency: the case of private farms in Slovenia”, *European Review of Agricultural Economics*, 28 (3), 285–306.

Brümmer, B., T. Glauben, G. Thijssen (2002): „Decomposition of productivity growth using distance functions: the case of dairy farms in three European countries”, *American Journal of Agricultural Economics*, 84 (3), 628–644.

Cederberg, C., & B. Mattsson (2000): “Life cycle assessment of milk production – a comparison of conventional and organic farming”, *Journal of Cleaner Production*, 8, 49-60.

Chen, X.K. et al., (2008). Yearly Grain Output Predictions in China 1980–2004. *Economic Systems Research*, 20 (2008) 139-150.

De Ponti, T. et al., (2012). The crop yield gap between organic and conventional agriculture. *Agricultural Systems,* 108 (2012) 1-9.

Engström, R., A. Wadeskog, G. Finnveden (2007): „Environmental assessment of Swedish agriculture”, *Ecological Economics*, 60, 550-563.

Goodlass, G. et al., (2003). Input output accounting systems in the European community - an appraisal of their usefulness in raising awareness of environmental problems. *European Journal of Agronomy*, 20 (2003) 17-24.

Gundogmus, E. and Bayramoglu , Z. , (2006). Energy Input Use on Organic Farming: A Comparative Analysis on Organic versus Conventional Farms in Turkey. Journal of Agronomy, 5 (2006) 16-21.

Hussain, A. B. and Azlina, A., (2010), Energy Use in Agriculture Sector: Input-Output Analysis. Journal of International Business Research, 3 (2ß10) 111-121.

Johnson, T.G. and Kulshreshtha, S.N., (1982). Exogenizing Agriculture in an Input-Output

Model to Estimate Relative Impacts of Different Farm Types. Western Journal of Agricultural Economics, 7 (1982) 187-198.

Karkacier, O. and Goktolga, Z.G., (2005). Input–output analysis of energy use in agriculture. Energy Conversion and Management, 46 (2005) 1513-1521.

Ki, S.L. et al., (2015). Measuring the environmental effects of organic farming: A meta-analysis of structural variables in empirical research. Journal of Environmental Sciences, 162 (2015) 263-274.

Kristensen, T. et al., (2011).Effect of production system and farming strategy on greenhouse gas emissions from commercial dairy farms in a life cycle approach. Livestock Sciences, 140 (2011) 136-148.

Kumbhakar, S.C., E.G: Tsionas, T. Sipiläinen (2009): “Joint estimation of technology choice and technical efficiency: an application to organic and conventional dairy farming”, *Journal of Productivity Analysis*, 31 (3), 151–161.

Küstermann, B. et al. (2008). Modeling carbon cycles and estimation of greenhouse gas emissions from organic and conventional farming systems. Renewable Agriculture and Food Systems, 23(2008) 38–52.

Madau, F.A. (2007): “Technical efficiency in organic and conventional farming: evidence from Italian cereal farms”, *Agricultural Economics Review*, 8 (1), 5–21.

Morgan, K. and Murdoch, J., (2000). Organic vs. conventional agriculture: knowledge, power and innovation in the food chain. Geoforum, 31 (2000) 159-173.

Meier, M.S. et al., (2015). Environmental impacts of organic and conventional agricultural products-are the differences captured by life cycle assessment? Journal of Environmental Sciences, 149 (2015) 193-208.

Meisterling, K. et al., (2009). Decisions to reduce greenhouse gases from agriculture and product transport: LCA case study of organic and conventional wheat. Journal of Cleaner Production, 17 (2009) 222-230.

Mohamad, R.S. et al. (2014).Optimization of organic and conventional olive agricultural practices from a Life Cycle Assessment and Life Cycle Costing perspectives. Journal of Cleaner Production, 70 (2014) 78 – 89.

Oude Lansink, A., K. Pietola, S. Baeckman (2002): “Efficiency and productivity of conventional and organic farms in Finland 1994–1997”, *European Review of Agricultural Economics*, 29 (1), 51–65.

Piaggio, M. et al. (2014). GREENHOUSE GAS EMISSIONS AND ECONOMIC STRUCTURE IN URUGUAY. Economic System Research, 26 (2014) 155-176.

Reganold, J.P., (2016). Organic agriculture in the twenty-first century. Nature Plants, 2 (2016) 1-8.

Schmidt, T. et al. (2005). Aufbau des Berichtsmoduls 'Landwirtschaft und Umwelt' in den Umweltökonomischen Gesamtrechnungen.

Seufert, V. et al., (2015). Comparing the yields of organic and conventional agriculture. Nature, 485 (2012) 229-232.

Silveira, T.S. et al. (2015). Input-Output Analysis for agricultural and livestock sector in the Brazilian economy. Rivista di Economia Agraria 52 (2015) 33-54.

Tellarini,V. and Caporali,F., (2000). An input/output methodology to evaluate farms as sustainable agroecosystems: an application of indicators to farms in central Italy. Agriculture, Ecosystems and Environment 17, (2000) 111-123.

Tuck, S.L. et al., (2014). Land-use intensity and the effects of organic farming on biodiversity: a hierarchical meta-analysis. Journal of Applied Ecology 51 (2014) 746–755.

Tuomisto, H.L. et al., (2011). Does organic farming reduce environmental impacts? - A meta-analysis of European research. Journal of Environmental Management, 112 (2012) 309.

Tzouvelekas, V., C.J. Pantzios, C. Fotopoulos (2001): "Technical efficiency of alternative farming systems: the case of Greek organic and conventional olive-growing farms", *Food Policy*, 26 (6), 549–569.

Van Ittersum, M.K., (2013). Yield gap analysis with local to global relevance—A review. Field Crops Research, 143 (2013) 4-17.

Van Stappen, F. et al., (2015). Organic versus conventional farming: the case of wheat

production in Wallonia (Belgium). Agriculture and Agricultural Science Procedia,

7 (2015)272 – 279.

Yildiz, T., (2016). An Input-Output Energy Analysis of Wheat Production in Çarşamba District

of Samsun Province. Journal of Agricultural Faculty of Gaziosmanpasa University, 33

(2016) 10-20.

Zhu, Q. et al. (2012). Calculation and decomposition of indirect carbon emissions from residential consumption in China based on the input–output model. Energy Policy, 48 (2012) 618-626.