Dependency of domestic food sectors on imports: Finland as a case study

by Ellen Huan-Niemi, Marja Knuuttila, Jyrki Niemi, and Eero Vatanen

Dependency of domestic food sectors on imports: Finland as a case study

Ellen Huan-Niemi[1]

ellen.huan-niemi@luke.fi

Marja Knuuttila[2]

marja.knuuttila@luke.fi

Jyrki Niemi[1]

jyrki.niemi@luke.fi

Eero Vatanen[3]

eero.vatanen@uef.fi

[1]Natural Resources Institute Finland (Luke), Latokartanonkaari 9, 00790 Helsinki, Finland

[2]Natural Resources Institute Finland (Luke), Lönnrotinkatu 7, 50100 Mikkeli, Finland

[3]University of Eastern Finland, KTL, Yliopistokatu 2, 80100 Joensuu, Finland

Abstract

This study examined how dependent is agricultural production and domestic food sectors on imported goods and services. The objective is to produce indicators for measuring the import content of the domestic food and service sectors as well as the import dependency of the inputs supplied into these sectors. Primary agriculture, food processing, distribution and food service providers in Finland are heavily dependent on imported fossil fuels concerning energy and chemical inputs, including high reliance on imported protein feed for livestock production. However, most of the inputs supplied to the Finnish food sectors are domestic because only 20% of the total output is dependent on imported goods and services as well as capital goods. The rate of self-sufficiency in food supply is high in Finland, but international trade is essential to provide the necessary energy and chemical inputs needed for food production along with livestock's supplementary protein feed. Replacing fossil energy with sustainable renewable energy will reduce the dependence on Russia for energy supply and promoting human consumption of plant-based foods will reduce the demand for livestock feed.

Key words:

self-sufficiency, food supply, primary agriculture, food processing, distribution, food service providers

Introduction

The Malthusian theory (Malthus 1798) proposed that food production will not be able to keep up with growth in the human population, resulting in disease, famine, war, and calamity. Concerns that world population will grow faster than food production has been a fundamental topic since the publication of Malthus's Theory of Population until current times. Subsequently, David Lam (2011) examined how the world survived the population bomb with lessons from 50 years of extraordinary demographic

history. From 1961 to 2011, world population grew at rates that have never been seen before. There were worries about the potential impact of rapid population growth in the 1960s, including mass starvation in countries such as India, depletion of non-renewable resources, and increased poverty in low-income countries (Ehrlich 1968). Contrary to the worries, world food production increased faster than world population in every decade since the 1960s, resource prices fell during most of the period, and poverty declined significantly in much of the developing world (Lam 2011, Evenson and Gollin 2003, Simon 1996, Dyson 1994). Porkka et al. (2013) indicated that global food availability has improved substantially both in absolute and relative terms during the study period of 1965–2005. The percentage of population living in countries with sufficient food supply (>2500 kcal/capita/day) has almost doubled from 33% in 1965 to 61% in 2005.

Food is produced predominantly to secure domestic food supply and only secondarily for export. Countries strive to develop national policies and paths toward self-reliance in food production for food security reasons (Baer-Nawrocka and Sadowski 2019). Food security is a measure of food supply (the availability of food), individuals' ability to access it, and other dimensions as well (FAO 2006). Porkka et al. (2013) highlighted the importance of food trade for food supply: in the beginning of the study period (1965–2005), insufficient domestic production meant insufficient food supply, but at the end of the study period the food deficit has been increasingly compensated by rising food imports. Therefore, moving from food insufficiency towards a rising dependency on food trade is a concern because the links between food security and agricultural trade are inherently complex (D'Odorico et al. 2014).

Security of food supply requires resilient food production and supply chains, effective international trade relations, functioning logistics and infrastructure as well as the availability of agricultural inputs are secured. However, the world is becoming increasingly unstable and uncertain due to climate

change, global pandemics, destruction of ecosystems, geopolitical tensions and commodity price fluctuations (Godfray et al. 2010, Foley et al. 2005, Tilman et al. 2001). Large scale shocks, such as the COVID-19 pandemic outbreak, are causing exceptional global economic impact (Addison et al. 2020) and national challenges to the health and functioning of human society (Sen 2020). Continuing the flow of agricultural inputs between countries, even in quarantine restrictions or closing borders, is vital for the proper functioning of food production. Therefore, measures to facilitate the trade of farming inputs such as machinery, fertilizers, pesticides, and animal feed should be taken seriously because these requirements are crucial for food production activities to continue smoothly (FAO 2020).

With Finland as a case study, the objective of this paper is to assess the dependency of domestic food sectors on imported agricultural inputs, intermediate inputs, and raw materials as well as services. How dependent is agricultural production and the Finnish food sectors on imported goods and services? This involves tracing the inputs imported and utilised in the agricultural and food sectors in Finland. More specifically, this paper produces indicators for measuring the import content of the domestic food and service sectors plus the import dependency of the inputs supplied into these sectors.

The calculation of import dependency in food production requires that both direct and indirect raw materials along with intermediate inputs are considered. Direct imports refer to goods and services that are imported to the sectors where the inputs are directly used. By tracing the indirect imports of inputs engaged in the process of production and service provision, the sum of all imports that indirectly end up in a sector's production process from other sectors are therefore included in the supply chain. This provides a deeper picture of a sector's total dependency on imports. The only way to add together various dissimilar inputs is in value terms. Thus, the import content by sector is calculated by dividing

the imported inputs (€) with the sector's total output (€). An output-driven input-output analysis is used to calculate the direct imported inputs together with the indirect imported inputs.

Material and methods

The input-output model

The imported inputs supplied into the food industries are calculated by using the input-output model (See Knuuttila et al. 2007, Ahtikoski et al. 2011), which is the application of the Leontief's basic model (equation 1).

$$\mathbf{X} = (\boldsymbol{I} - \boldsymbol{A})^{-1}\mathbf{F}, \quad (1)$$

where **X** is the vector of outputs, **F** is the vector of final demands, **A** is the matrix of fixed input coefficients ($A = Z\hat{X}^{-1}$, and **Z** is the matrix of intermediate uses) and **I** is the identity matrix. The so-called Leontief's inverse matrix $\mathbf{(I-A)^{-1}}$ represents a multiplier used to calculate the overall relationships in industrial outputs caused by final demands. For a more complete account of the input-output analysis, see Miller and Blair (2009).

This study utilises the output-driven, instead of the traditional demand-driven, input-output model. In the output-driven input-output model, the outputs of industries are dependent on the outputs of other industries. Szyrmer (1992) generated the multiplier matrix of the output-driven model (equation 2) from the inverse of the Leontief matrix in the following way:

$$\boldsymbol{TF} = (\boldsymbol{I} - \boldsymbol{A})^{-1}\widehat{\boldsymbol{D}}^{-.1}, \quad (2)$$

where $\hat{\mathbf{D}}$ refers to a diagonal matrix based on the Leontief inverse matrix. Thus, the **TF** matrix captures the multiplier effects of a unit of the output (Szyrmer 1992, Knuuttila et al. 2007).

The output-driven model is best suited to explain the existing structures and interactions between different industries (Szyrmer 1992). It describes the effects related to the output of the industry in question at a given point in time. The overall effects of a change in the output of a particular industry on the other industries is obtained in the model by multiplying the diagonal matrix composed of the outputs of all industries ($\hat{\boldsymbol{X}}$) by the **TF** matrix (Vatanen 2001).

$$\boldsymbol{R} = (\boldsymbol{TF})\hat{\boldsymbol{X}}, \tag{3}$$

The diagonal cells of the matrix **R** in equation 3 indicate the outputs of different industries, and the off-diagonal column cells indicate the direct and indirect output requirements of the industry represented by the row concerned with respect to the output of the industry denoted by the column. The sum of the column is the total impact of the industry on the economy.

The import effects of the output

The value of imported goods and services in the production of industry in respect to the output value of the industry is the direct rate of import in the industry. The direct rate of import $\boldsymbol{m_j}$ is defined in equation 4 for one industry and the direct rates of import for all industries $\boldsymbol{m'}$ in equation 5.

$$\boldsymbol{m_j} = \frac{\boldsymbol{M_j}}{\boldsymbol{X_j}}, \tag{4}$$

where $\boldsymbol{X_j}$ and $\boldsymbol{M_j}$ are the output and the direct import of industry j.

$$\boldsymbol{m'} = \boldsymbol{M'\widehat{X}^{-1}}, \quad (5)$$

where $\widehat{\mathbf{X}}^{-1}$ is the inverse of diagonal matrix of all industries' outputs

and $\mathbf{M}'$ a row vector of all industries' direct imports.

The industry's output contains also indirect imports, which are included in the domestic intermediates bought by the industry from other industries to be utilised as inputs in its own production. Thus, the total rate of imported inputs ($\mathbf{mt_j}$) in industry *j* is the direct import plus the indirect import divided by the output of industry *j*. Thus, $\mathbf{mt'}$ is a row vector which includes the rates of the total imported inputs in all industries. The methods for the calculations are presented in equation 6 and 7.

$$\boldsymbol{mt_j} = \frac{\boldsymbol{M_j + IM_j}}{\boldsymbol{X_j}}, \quad (6)$$

where X_j , M_j ja IM_j are the output, the direct and indirect import of the industry j.

$$\boldsymbol{mt'} = \boldsymbol{m'R\widehat{X}^{-1}} \quad (7)$$

The imported products of the output

The total imported amounts (in euros) of different goods and services required for the output of industries can be calculated by the imports of different industries. For this purpose, the rate of direct imports by product or service in each industry $\boldsymbol{mc}$ is determined in equation 8.

$$\boldsymbol{mc} = \boldsymbol{MC\widehat{X}^{-1}}, \quad (8)$$

where the matrix $\mathbf{MC}$ includes direct import of different products by industries.

The total amount of different imports required by each industry *j* can be calculated using the matrix **RMC**^{j}, which is obtained by multiplying the **mc** matrix by the diagonal matrix formed from column *j* of the output matrix $\widehat{\boldsymbol{R}}_{\boldsymbol{j}}$ (equation 9). The column of matrix indicates how much of the output from industry *j* would demand outputs from different industries and how much of these outputs would require the imports of different products or services = the cells of the columns in matrix **RMC**^{j}. The sums of rows in this matrix $\boldsymbol{MC}_i^j$ reveal how much of each input must be imported for the output of industry *j* (equation 10). The total imports of different inputs required by the output of industry *j* is the sum of all cells in the matrix **MC**^{j} (equation 11).

$$\boldsymbol{RMC}^j = \boldsymbol{mc}\widehat{\boldsymbol{R}}_{\boldsymbol{j}} \quad (9)$$

$$\boldsymbol{MC}_i^j = \boldsymbol{RMC}^j\ \boldsymbol{i};\ \boldsymbol{i} = \text{unit vector (column)} \quad (10)$$

$$\boldsymbol{MC}^{\boldsymbol{j}} = \boldsymbol{i}'\boldsymbol{MC}_i^j;\ \boldsymbol{i}' = \text{unit vector (row)} \quad (11)$$

where $MC^j = M_j + IM_j$

The rate of imported inputs in all food industries (import dependency)

The rate of imported inputs in all food industries is calculated by removing the duplicative parts of the import effects on the food industries. Part of the indirect import of each food industry, which is the direct import of some other food industry, is duplicative. Vatanen (2001, 2011) presents how the duplicative parts of the direct and indirect import effects can be eliminated from the total effects of industry output.

$$\boldsymbol{MR} = \widehat{\boldsymbol{m}}\boldsymbol{R} \quad (12)$$

MR is the analytical matrix of industries' total imports (equation 12). Its diagonal cells indicate the direct imports of industry in columns and the off-diagonal cells indicate the indirect imports of industry in rows, which are required for producing the output of the particular industry. The sum of columns indicates the total imports.

The net imports of industries (**NM**) in equation 13 is obtained by adding the direct imports of a particular industry (**M**) with its effects on the total imports of other industries (the sum of **MR** in columns) and reducing the import of other industries from that particular industry (the sum of **MR** in rows).

$$\boldsymbol{NM} = \boldsymbol{M} + \boldsymbol{i}'\boldsymbol{MR} - \boldsymbol{MRi} \quad (13)$$

In the case of industry *j*, the net imports of *j* are presented in equation 14

$$\boldsymbol{NM_j} = \boldsymbol{M_j} + \sum_i^n \boldsymbol{MR_{ij}} - \sum_j^n \boldsymbol{MR_{ij}} \quad (14)$$

By using the net imports effect calculation method presented above, the total imported inputs required by food industries can be derived. Hence, the total imported inputs required by the food industries $\boldsymbol{CEM_e}$ is presented in equation 15

$$CEM_e = \sum_e \sum_i MR_{ie} \; - \sum_e \sum_{e^*} MR_{ee^*}$$

$i, j = 1, \ldots, n$

$e^*, e \in i, j = a-d, h-m, p, q, s:$ food industries

IF e*=e, so $MR_{ee^*} = 0$. (15)

The import dependency ($\mathbf{m_{ea}}$) of food industries is calculated by dividing the required total imported inputs of food industries with the total outputs of all food industries (equation 16)

$$\boldsymbol{m_{ea}} = \frac{\boldsymbol{CEM_e}}{\boldsymbol{FX}} = \text{ the rate of import inputs in all food industries} \quad (16)$$

$where\ FX = \sum_e X_e =$ the total outputs of all food industries

Data

The input-output tables (IOTs) are provided by Statistic Finland (2020a) for year 2016. The IOTs are based on the supply and use tables (SUTs) of national accounting (Statistic Finland 2020b). The SUTs provide the details of product flows in the national economy. The IOTs are suited for analysing production activity structures and interdependencies between industries, including the imported inputs. The total inputs of the industries provided by Statistics Finland are divided into 75 product groups according to statistical classification.

In this study, the Finnish food sectors are divided into 15 sub sectors: primary agriculture sector, fishing & aquaculture sector, 10 processing sectors, wholesale sector, retail sector, and the restaurants & food services sector. The total inputs of the industries are aggregated into 20 product groups according to the statistical classification provided by Statistics Finland.

In addition to the input-output tables provided by Statistic Finland, foreign trade statistics provided by the Uljas statistical database (Finnish Customs 2020) is utilised to interpret the import dependency results from the input-output model. The foreign trade statistics also provide information on the quantities as well as the values of the imported goods and services.

Results

The total value of Finnish food markets is €33 billion in 2016 (Figure 1). In addition to the production output from the domestic food sectors, the total value of food markets includes ready-to-eat foods that have been imported for domestic consumption but excludes the value of exported food products. The total value of imported goods and services is €8,5 billion, whereby € 5,6 billion is the value of imported inputs for domestic production, and €2,9 billion is the imports of prepared food products (ready-to-eat foods). The value of imported inputs is nearly twice the value of prepared food products. The import dependency of the Finnish food markets is 25 % by considering both the inputs utilised in the domestic food chain and the imported ready-to-eat foods for domestic consumption.

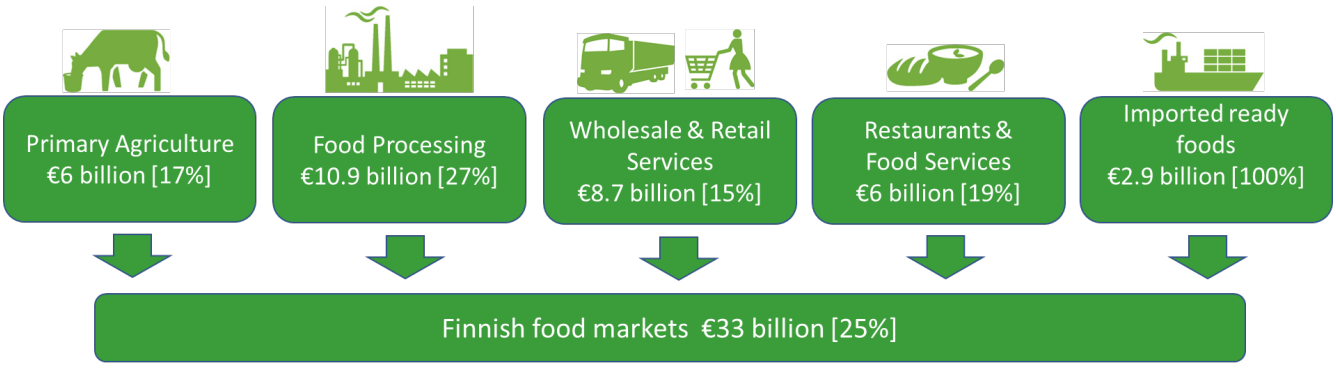
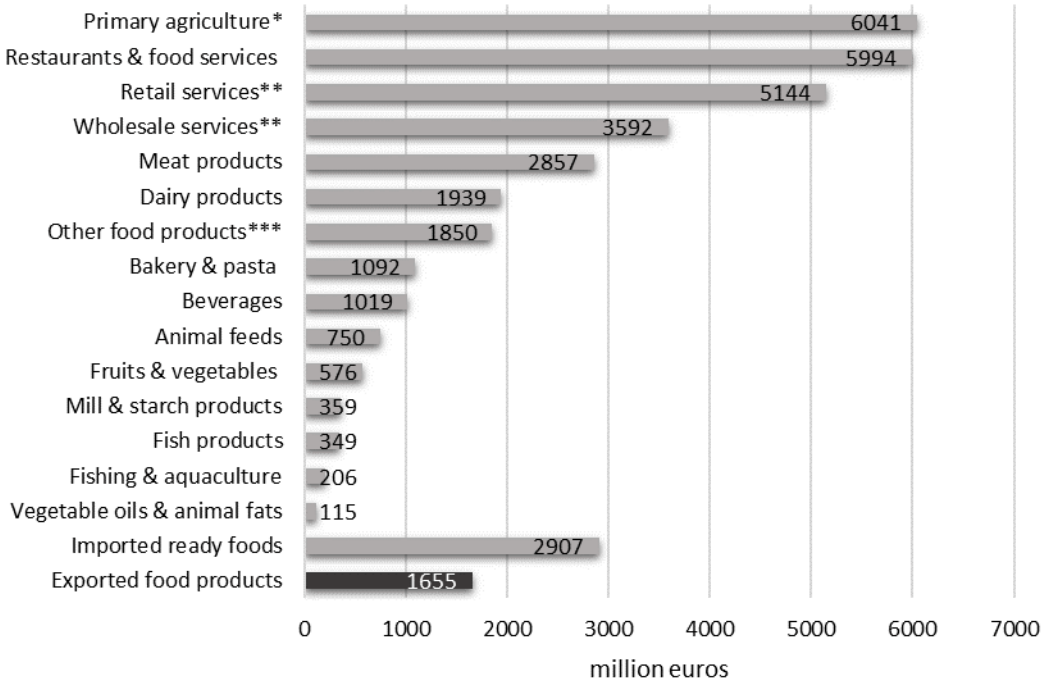


Fig. 1. The total output of Finnish food sectors and dependency on imports [in percentage] in 2016 (Knuuttila and Vatanen 2021)

The total output of the Finnish food sectors is €31.9 billion in 2016, including the exported food products. In this study, the Finnish food sectors are divided into 15 sub sectors (Figure 2). The import dependency of domestic food production without the imported ready-to-eat foods and capital goods imports is 18%. The import dependency of domestic food production is 20% if the imports of capital goods is considered. Therefore, the Finnish food sectors are mainly reliant on the domestic supply of inputs, whereby only 20% of the total output is dependent on imported goods and services as well as capital goods.



*Primary agriculture includes traditional crop and livestock production, horticulture and other livestock production (reindeer, bees, fur animals). The output includes about €1.547 billion of agricultural subsidies.

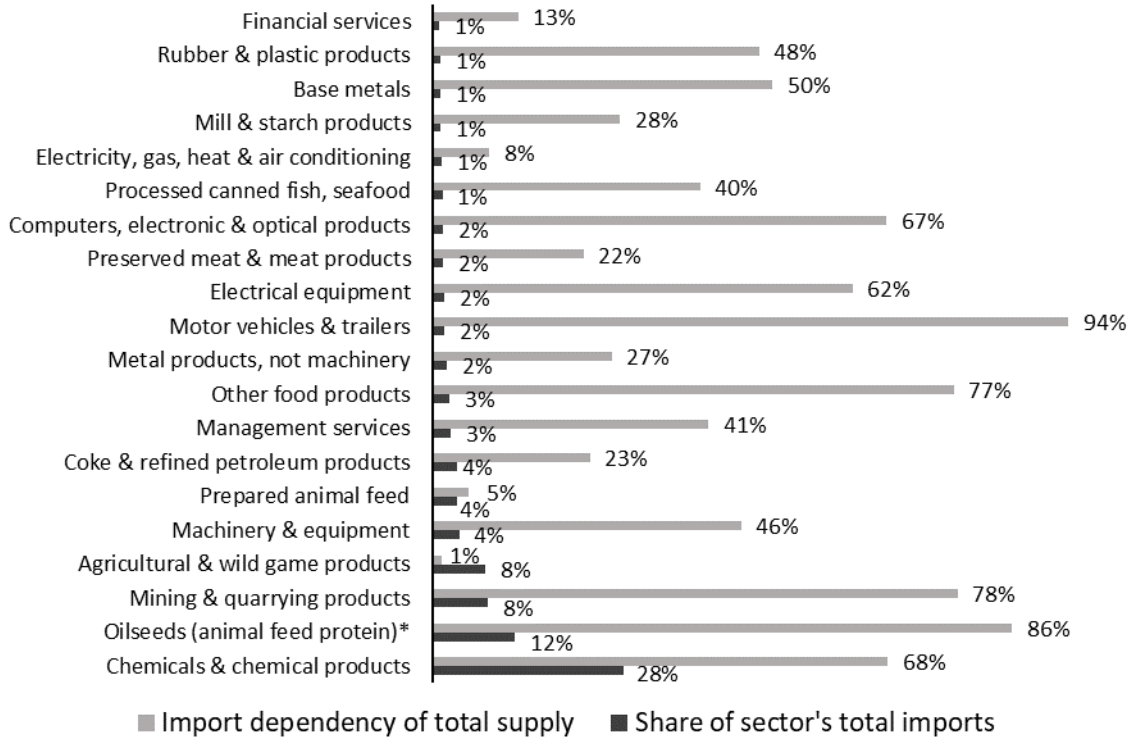
**The output of retail and wholesale does not include the value of the goods sold, but only the value-added function.

*** Other food products include sugar, confectionery, coffee, tea, spices, condiments, specialty foods and the preparation of prepared meals, i.e. sectors which are not presented as their own food sectors.

Fig. 2. Total output from Finnish food sectors with the imported and exported food products in 2016

Primary Agriculture

Primary agriculture in Finland is mainly dependent on domestic supplies, whereby only 17% (Figure 1) of the total output is dependent on imported goods and services. Regarding the total imports of farming inputs (Figure 3), “chemicals & chemical products” represent the largest share with 28% of primary agriculture’s total imports of inputs needed for production. However, this percentage does not show how dependent is primary agriculture on imported “chemicals & chemical products”. When the total supply of “chemicals & chemical products” to primary agriculture is examined, 68% of the supplied products are imported. This indicate that only 32% of the total supply of “chemicals & chemical products” to primary agriculture is domestic and the majority is imported inputs. Similarly, 78% of the total supply of “mining & quarrying products” to primary agriculture is imported, thus indicating that the bulk of total supply is not domestic. “Oilseeds” represent the second largest share with 12% of primary agriculture’s total imports of inputs needed for production. In the same way, 86% of the total supply of “oilseeds” to primary agriculture is imported, hence showing that supplementary protein feed for livestock production is mostly imported to Finland. The results demonstrate that primary agriculture in Finland is heavily dependent on imported fossil fuels concerning chemical and energy inputs required for primary agricultural production as well as high dependence on the imports of supplementary protein feed for livestock production. The high import dependency of “oilseeds” is also validated by the protein balance sheet calculated by Niemi and Niskanen (2019) to examine the self-sufficiency of protein availability in Finland.



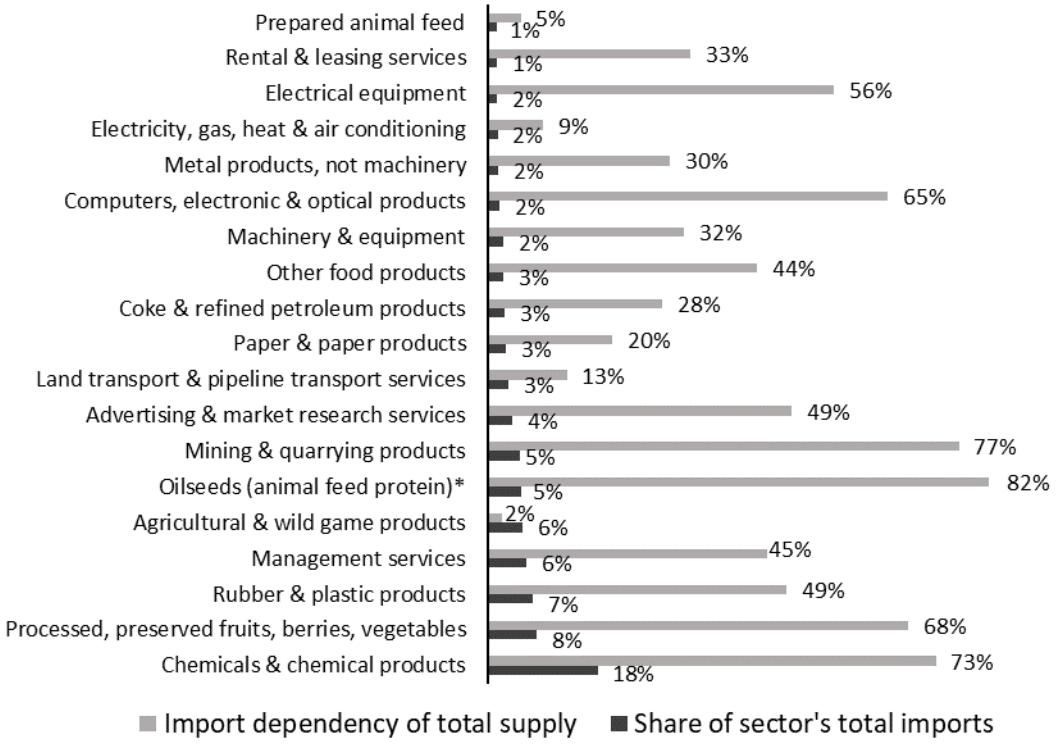
* In the category of "Vegetable oils & animal fats"

Fig. 3. Primary agriculture dependency on imports for the total supply of inputs into the sector

Food Processing

Food processing in Finland is mainly dependent on domestic supplies, whereby only 27% (Figure 1) of the total output is dependent on imported goods and services. The dairy products sector (Figure 4) is chosen as an example to demonstrate how dependent is food processing on imported inputs because milk production is the largest agricultural sector in Finland. “Chemicals & chemical products” signify the largest share with 18% of dairy products sector’s total imports of inputs needed for dairy production. When the total supply of “chemicals & chemical products” to the dairy products sector is examined, 73% of the supplied chemical products are imported. This is an indication that the dairy products sector is highly dependent on imported “chemicals & chemical products”. However, the

highest import dependency of total supply is from “oilseeds” with 82%, but “oilseeds” represent only 5% of dairy products sector’s total imports of inputs needed for production. Similarly, 77% of the total supply of “mining & quarrying products” to the dairy products sector is imported, but “mining & quarrying products” represent only 5% of dairy product sector’s total imports of inputs needed for production. The results demonstrate that the dairy products sector, comparable to primary agriculture, is heavily dependent on imported fossil fuels concerning chemical and energy inputs required for dairy production as well as high dependence on imports of supplementary protein for livestock feed in milk production.



* In the category of "Vegetable oils & animal fats"

Fig. 4. Dairy products dependency on imports for the total supply of inputs into the sector

Wholesale and Retail Services

Wholesale and retail services in Finland are mainly dependent on domestic supplies, whereby only 15% (Figure 1) of the total output is dependent on imported goods and services. The retail sector (Figure 5) is chosen as an example to demonstrate how dependent is the food distribution sector on imported inputs. “Management services” represent the largest share with 25% of the retail sector’s total imports of inputs needed for providing the retail services, whereby 59% of the utilised “management services” are imported. “Rental & leasing services” signify the second largest share with 12% of the retail sector’s total imports of inputs needed for providing the retail services, whereby 69% of the utilised “rental & leasing services” are imported. In comparison to “management services”, “chemicals & chemical products” stand for only 3% of the retail sector’s total imports of inputs needed for providing the retail services, but the import dependency of total supply is equally as high with 59%. Likewise, “mining & quarrying products” represent only 4% of the retail sector’s total imports of inputs needed for providing the retail services, however the import dependency of total supply is among the highest with 69%. The results reveal that the retail services in Finland are not only dependent on the imports of “management services” and “rental & leasing services”, but also very dependent on imported fossil fuels concerning energy and chemical inputs required for distribution services.

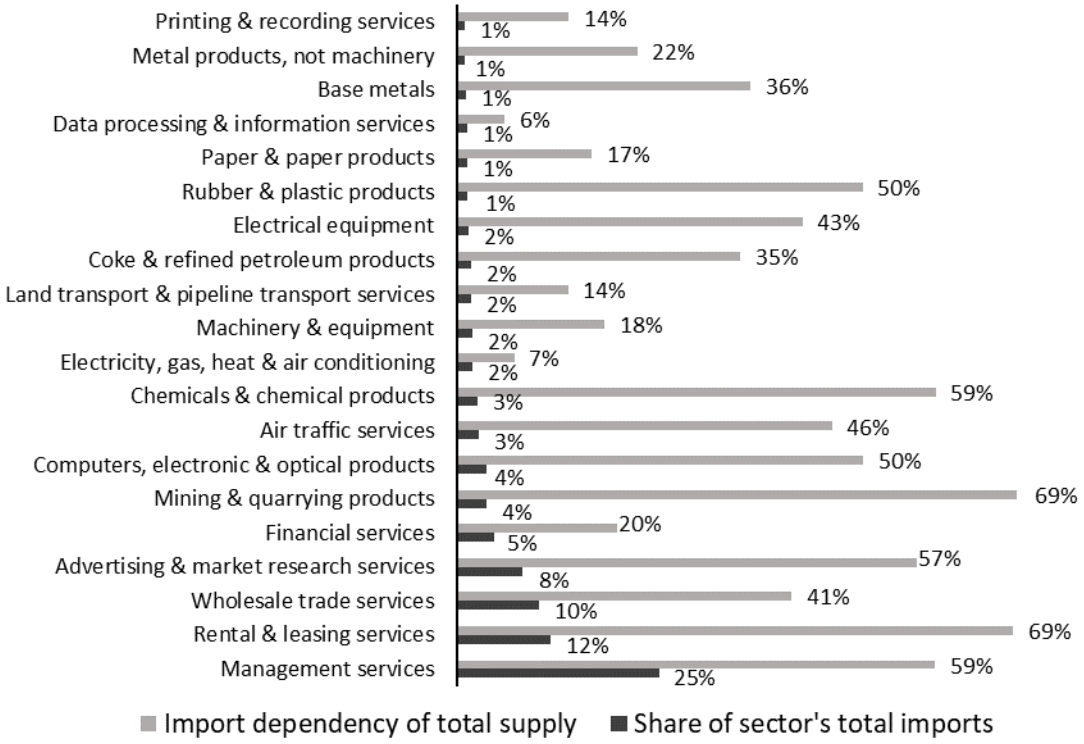


Fig. 5. Retail services dependency on imports for the total supply of inputs into the sector

Restaurants and Food Services

Restaurants and food services in Finland are mainly dependent on domestic supplies, whereby only 19% (Figure 1) of the total output is dependent on imported goods and services. Both "management services" and "agricultural & wild game products" have the largest shares with 9% of the restaurants and food services sector's total imports of inputs needed for providing the food services. In contrast with the earlier examined results, "agricultural & wild game products" have low import dependency of total supply with only 24% and the majority of supply in "management services" is domestic with import dependency rate of 45%. However, the import dependency of total supply for "mining & quarrying products" as well as "chemicals & chemical products" are high with 73% and 67% respectively. Therefore, like the earlier examined results, restaurants and food services are dependent

on imported fossil fuels concerning energy and chemical inputs required for providing food services in Finland.

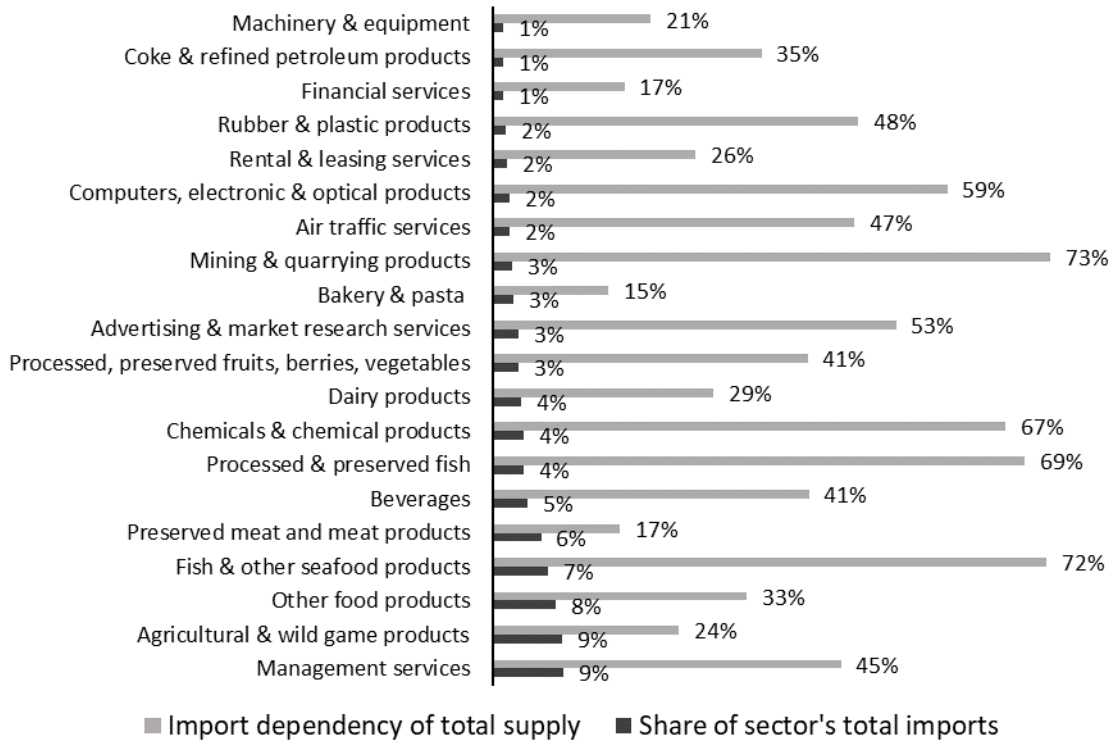


Fig. 6. Restaurants and food services dependency on imports for the total supply of inputs into the sector

Discussion

How many people can the Earth sustain? Humans with ingenuity, science and technology have the ability to adapt the environment to produce ever-increasing amounts of food to feed the growing population through various agricultural and food systems. However, more land than ever is dedicated to agriculture (Foley et al. 2005), with higher resource intensity and overwhelming environmental impacts (Rockström et al. 2009), while diverting a large portion of crops to feed animals (Berners-Lee et al.

2018), biofuels (Fargione et al. 2008) and other non-food uses. In order to solve these challenges, tremendous progress should be made to halt agricultural land expansion, close yield gaps on underperforming lands, increase cropping efficiency, reduce food waste, and transition toward sustainable diets (Huan-Niemi et al. 2020, Foley et al. 2011, Godfray et al. 2010). Furthermore, agricultural and food systems must continue the efforts to reduce dependence on fossil fuels and optimize energy inputs in order to reduce greenhouse gas emissions in the attempt to fight climate change.

Modern agriculture is heavily reliant on fossil energy (Pelletier et al. 2011, Woods et al. 2010, Pimentel and Pimentel 2003). Large amount of fossil fuels is required to power heavy farming machinery, to process foods, to refrigerate foods during transportation, to produce packaging materials, and to manufacture and transport chemical inputs such as fertilizers and pesticides. This paper reveals that Finland is deeply dependent on imported fossil fuels concerning energy and chemical inputs needed not only for primary agricultural production and food processing, but also for distribution services and delivering food services in Finland. Fossil energy from imported inputs of "mining & quarrying products" is mainly consist of raw materials such as crude oil, coal and natural gas. The study made by Knuuttila and Vatanen (2021) has disclosed that most of the crude oil (87%), coal (53%) and natural gas (99%) are imported from Russia. Furthermore, the study has showed that the majority of fertilisers (63%) are also imported from Russia, hence Finland is very dependent on Russia not only on the imports of fossil fuels, but also on the imports of fertilisers. According to EU statistics (Eurostat 2020), Russia is the main supplier of crude oil, natural gas and coal to EU countries. Therefore, Finland along with many other EU countries are highly dependent on Russia concerning the imports of fossil fuels for their energy supply. However, EU aims to be climate-neutral by 2050; consequently, there are plans to decarbonise all sectors, including the food sectors, and diminish the use of fossil fuels from EU's

energy consumption. Replacing fossil energy with sustainable renewable energy will reduce the reliance on Russia for energy supply in the domestic food sectors as well as mitigate climate change.

The results show that the livestock sector in Finland is highly reliant on the imports of supplementary protein feed. Protein crops self-sufficiency in Finland is low because cereals dominate the field cropping systems in areas that are also favourable for legumes and rapeseed (Peltonen-Sainio et al. 2013). Moreover, risky and demanding crops such as legumes and rapeseed would not become the mainstream crops to be cultivated by farmers in Finland (Suvanto et al. 2020). Knuuttila and Vatanen (2021) has discovered that most of the rapeseed (95%) is imported within the EU common market from Baltic countries and Germany. However, almost all soybeans are imported from Brazil and North America. According to the European Parliament (2011), the deficit in the supply of protein feed and crops is also a concern at the EU level because domestic production covers only 30% of the protein crops consumed as animal feed in the EU. Consequently, 70% (42 million tonnes in 2009) of the protein crops consumed, especially soymeal for animal feed, are imported mainly from Brazil, Argentina and the United States. In fact, the growing demand for livestock feed has resulted significant greenhouse gas emissions from land use change due to the expansion of soybean cultivation in Latin America (Castanheira and Freire 2013). Therefore, various promotion measures should be used to promote human consumption of plant-based foods and reduce the demand for livestock production in the efforts to lower the overwhelming environmental impacts of land use change in Latin America, especially Brazil, due to the expansion of soybean cultivation for animal feed. Diverting crops to feed humans instead of animals will be beneficial not only for the nature, but also to prevent climate change.

Conclusions

Security of food supply requires resilient food production and supply chains, effective international trade relations, functioning logistics and infrastructure as well as secured availability of agricultural inputs. This study examined how dependent is agricultural production and the food sectors on imported goods and services with Finland as a case study. The objective is to produce indicators for measuring the import content of the domestic food and service sectors plus the import dependency of the inputs supplied into these sectors. Primary agriculture in Finland is heavily dependent on imported fossil fuels concerning chemical and energy inputs required for production as well as high dependence on the imports of supplementary protein feed for livestock production. The dairy products sector, as an example for the food processing sector, is also dependent on imported fossil fuels concerning chemical and energy inputs required for dairy production as well as profound dependence on imports of supplementary protein for livestock feed in milk production. In the service provider sectors, the retail services are not only reliant on the imports of management services and rental & leasing services, but also very reliant on imported fossil fuels concerning energy and chemical inputs required for distribution services in Finland. Moreover, the restaurants and food services are also reliant on imported fossil fuels concerning energy and chemical inputs required for providing food services in Finland. Despite of this, most of the inputs supplied to the Finnish food sectors are domestic because only 20% of the total output is dependent on imported goods and services as well as capital goods. The rate of self-sufficiency in food supply is high in Finland, but international trade is essential to provide the necessary energy and chemical inputs needed for food production along with protein feed for livestock production.

The high rate of self-sufficiency in food supply is due to the high level of agricultural subsidies (approximately €1.6 billion per year) provided to primary agricultural production in Finland. These subsidies should be targeted to sustainable farming practices in conjunction with supporting the livelihood of farmers in Finland. In fact, Finland is striving to be climate-neutral by 2035 compared to the EU target of 2050. Therefore, reducing reliance on fossil fuels in the domestic food sectors will help to achieve the climate-neutral target set in Finland. However, Finland should avoid relying on agricultural biofuels or forest bioenergy in substituting for fossil fuels due to the inherently low efficiency of exploiting photosynthesis for energy, since the amount of electricity that can be produced from a hectare of land using photovoltaics is at least 50–100 times more than biomass (Norton et al. 2019, Geyer et al. 2013, Fthenakis and Kim 2009). Furthermore, increasing the domestic production of protein feed for livestock production in Finland is not a good solution. A better solution is to redirect crops to feed humans instead of animals to decrease the demand for imported protein feed, thus the long term solution is to promote the consumption of plant based foods in order to lower the demand for animal based products in Finland.

References

Addison, T., Sen, K. & Tarp, F. 2020. COVID-19: macroeconomic dimensions in the developing world. WIDER Working Paper 2020/74. Helsinki: UNU-WIDER. https://doi.org/10.35188/UNU-WIDER/2020/831–3.

Ahtikoski, A., Tuulentie, S., Hallikainen, V., Nivala, V., Vatanen, E., Tyrväinen, L. & Salminen, H. 2011. Potential trade-offs between nature-based tourism and forestry, a case study in Northern Finland. Forests 2(4): 894–912.

Baer-Nawrocka, A. & Sadowski, A. 2019. Food security and food self-sufficiency around the world: A typology of countries. PLoS ONE 14(3): e0213448. https://doi.org/10.1371/journal.pone.0213448.

Berners-Lee, M., Kennelly, C., Watson, R. & Hewitt, C. N. 2018. Current global food production is sufficient to meet human nutritional needs in 2050 provided there is radical societal adaptation. Elementa: Science of the Anthropocene 6(1): 52. https://doi.org/10.1525/elementa.310.

Castanheira, E.G. & Freire, F. 2013. Greenhouse gas assessment of soybean production: implications of land use change and different cultivation systems. Journal of Cleaner Production 54: 49–60. https://doi.org/10.1016/j.jclepro.2013.05.026.

D'Odorico, P., Carr, J. A., Laio, F., Ridolfi, L. & Vandoni, S. 2014. Feeding humanity through global food trade. Earth's Future 2(9): 458–469. https://doi.org/10.1002/2014EF000250.

Dyson, T. 1994. Population Growth and Food Production: Recent Global and Regional Trends. Population and Development Review 20(2): 397–411. https://doi.org/10.2307/2137524.

European Parliament 2011. The EU protein deficit: what solution for a long-standing problem? Rapporteur: Martin Häusling, Report 4.2.2011. Committee on Agriculture and Rural Development. Brussels, Belgium. https://www.europarl.europa.eu/doceo/document/A-7-2011-0026_EN.html.

Eurostat 2020. Energy production and imports. Statistical office of the European Union. https://ec.europa.eu/eurostat/statistics-explained/index.php/Energy_production_and_imports.

Evenson, R. E. & Gollin, D. 2003. Assessing the Impact of the Green Revolution, 1960 to 2000. Science 300(5620): 758–762. https://doi.org/10.1126/science.1078710.

Ehrlich, P.R. 1968.The population bomb. New York: Ballantine Books.

FAO 2020. Policy responses to keep input markets flowing in times of COVID-19. Food and Agriculture Organization of the United Nations (FAO).http://www.fao.org/3/ca8979en/CA8979EN.pdf.

FAO 2006. Food Security. Policy Brief, June 2006, Issue 2. Food and Agriculture Organization of the United Nations (FAO). http://www.fao.org/fileadmin/templates/faoitaly/documents/pdf/pdf_Food_Security_Cocept_Note.pdf.

Fargione, J., Hill, J., Tilman, D., Polasky, S. & P. Hawthorne, P. 2008. Land Clearing and the Biofuel Carbon Debt. Science 319(5867): 1235–1238. https://doi.org/10.1126/science.1152747.

Finnish Customs 2020. Uljas statistical database. https://uljas.tulli.fi. (in Finnish).

Foley, J., Ramankutty, N., Brauman, K. et al. 2011. Solutions for a cultivated planet. Nature 478: 337–342. https://doi.org/10.1038/nature10452.

Foley, J., DeFries, R., Asner, G. et al. 2005. Global Consequences of Land Use. Science 309(5734): 570–574. https://doi.org/10.1126/science.1111772.

Fthenakis, V. & Kim, H. C. 2009. Land use and electricity generation: A life-cycle analysis. Renewable and Sustainable Energy Reviews 13: 1465– 474. https://doi.org/10.1016/j.rser.2008.09.017.

Geyer, R., Stoms, D. & Kallaos, J. 2013. Spatially-explicit life cycle assessment of sun-to-wheels transportation pathways in the U.S. Environmental Science and Technology 47: 1170– 1176. https://doi.org/10.1021/es302959h.

Godfray, C., Beddington, J., Crute, I. et al. 2010. Food Security: The Challenge of Feeding 9 Billion People. Science 327(5967): 812–818. https://doi.org/10.1126/science.1185383.

Huan-Niemi, E., Kaljonen, M., Knuuttila, M., Niemi, J. & Saarinen, M. 2020. The impacts of dietary change in Finland: food system approach. Agricultural and Food Science 29(4): 372–382. https://doi.org/10.23986/afsci.95282.

Knuuttila, M. & Vatanen, E. 2021. Food market import dependence in 2003-2016. Natural resources and bioeconomy study 44/2021. Natural Resources Institute Finland (Luke). http://urn.fi/URN:ISBN:978-952-380-231-5. (in Finnish).

Knuuttila, M., Vatanen, E. & Jansik, C. 2007. Finnish food industry in 1989-2002: an output-oriented input-output analysis. Acta Agriculturae Scandinavica, Section C: Food Economics 4(4): 217–228.

Lam, D. 2011. How the World Survived the Population Bomb: Lessons From 50 Years of Extraordinary Demographic History. Demography 48(4): 1231–1262. https://doi.org/10.1007/s13524-011-0070-z.

Miller, R. & Blair, P. 2009. Input–Output Analysis: Foundations and Extensions. New York, USA: Cambridge University Press.

Malthus, T.R. 1798. An Essay on the Principle of Population, as it affects the future improvement of society. With remarks on the speculations of Mr Godwin, M. Condorcet, and other writers. Harmondsworth: Penguin, 1970; 7th edition, New York: Kelley 1970.

Niemi, J & Niskanen, M. 2019. Use and sources of vegetable protein in 2018. Plant and animal protein balances from 2010 to 2018. Natural Resources Institute Finland (Luke). http://urn.fi/URN:NBN:fi-fe202001011012. (in Finnish).

Norton, M, Baldi, A, Buda, V, et al. 2019. Serious mismatches continue between science and policy in forest bioenergy. Global Change Biology Bioenergy 11: 1256–1263. https://doi.org/10.1111/gcbb.12643.

Peltonen-Sainio, P., Hannukkala, A., Huusela-Veistola, E. et al. 2013. Potential and realities of enhancing rapeseed- and grain legume-based protein production in a northern climate. The Journal of Agricultural Science 151(3): 303–321. https://doi.org/10.1017/S002185961200038X.

Porkka, M., Kummu, M., Siebert, S. & Varis, O. 2013. From Food Insufficiency towards Trade Dependency: A Historical Analysis of Global Food Availability. PLoS ONE 8(12): e82714. https://doi.org/10.1371/journal.pone.0082714.

Pelletier, N., Audsley, E., Brodt, S., Garnett, T., Henrikkson, P., Kendall, A., Kramer, K., Murphy, D., Nemecek, T. & Troell, M. 2011. Energy intensity of agriculture and food systems. Annual Review of Environment and Resources 36: 223–246. https://doi.org/10.1146/annurev-environ-081710-161014.

Pimentel, D. & Pimentel, M. 2003. Sustainability of meat-based and plant-based diets and the environment. The American Journal of Clinical Nutrition 78(3): 660S–663S. https://doi.org/10.1093/ajcn/78.3.660S.

Rockström, J., Steffen, W., Noone, K. et al. 2009. A safe operating space for humanity. Nature 461: 472–475. https://doi.org/10.1038/461472a.

Statistics Finland 2020a. Detailed input-output data 2008–2016. Separate data was ordered for the year 2016 and obtained from Statistics Finland on August 13th, 2020.

Statistics Finland 2020b. National Accounts. https://www.stat.fi/til/vtp/tau_en.html.

Sen, K. 2020. COVID-19 and socioeconomic impact in Asia: The case of India. WIDER Background Note 2020/1. Helsinki: UNU-WIDER. https://doi.org/10.35188/UNU-WIDER/WBN/2020-1.

Suvanto, H., Niemi, J.K. & Lähdesmäki, M. 2020. Entrepreneurial identity and farmers' protein crop cultivation choices. Journal of Rural Studies 75:174-184.https://doi.org/10.1016/j.jrurstud.2020.01.022.

Simon, J. L. 1996. The ultimate resource - 2 (revised edition). Princeton, N.J: Princeton University Press.

Szyrmer, J. M. 1992. Input—Output Coefficients and Multipliers from a Total-Flow Perspective. Environment and Planning A: Economy and Space 24(7):921-937. https://doi.org/10.1068/a240921.

Tilman, D., Fargione, J., Wolff, B. et al. 2001. Forecasting Agriculturally Driven Global Environmental Change. Science 292(5515): 281–284. https://doi.org/10.1126/science.1057544.

Vatanen, E. 2011. The Output Model in Input-Output Analysis – the Method, Theoretical Underpinnings and Empirical Applications at a Local and Regional level. Publications of the University of Eastern Finland. Dissertations in Social Sciences and Business Studies. N:o 19. (in Finnish).

Vatanen, E. 2001. Local economic effects of timber harvesting and timber transport in Juva, Keuruu and Pielinen Karelia regions. Communications from the Finnish Forest Research Institute 825, 2001. Joensuu Research Center. (in Finnish).

Woods, J., Williams, A., Hughes, J.K., Black, M. & Murphy, R. 2010. Energy and the food system. Phil. Trans. R. Soc. B 365: 2991–3006. https://doi.org/10.1098/rstb.2010.0172.