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Consumer Demand for Organic Food Groups and Implications for Farmers' Revenues under the Organic Land Subsidy Scheme: The Case of Denmark

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Abstract

We fit a family of differential demand systems to Danish organic food data and use the selected model's parameters to calculate conditional expenditure and price elasticities for five organic food groups (cereals, meats, dairy products, fruits and vegetables, and other organic foods) to evaluate the implications of the Danish Organic Land Subsidy Scheme for organic farmers. Simulations indicate that, without conversion subsidies, producers of the five organic food groups would have experienced disproportionate changes in revenues due to higher nonsubsidized organic food prices. Producers of meats and other organic foods would lose most in revenues, followed by fruit and vegetable producers.

Keywords: Organic Land Subsidy Scheme, conditional differential demand systems, organic food

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Introduction

The global organic market grew from US$17.9 billion in 2000 to US$81.6 billion in 2015 (Willer and Lernoud, 2017, p. 23). In Europe, the organic food market expanded from 2000 (€7 billion) to 2015 (€29.8 billion) according to data compiled by the Research Institute of Organic Agriculture and the Agricultural Market Information Company. The highest per capita consumption of organic food in 2015 was in Switzerland (€262), followed by Denmark (€191) (Willer, Schaack, and Lernoud, 2017, p. 229). In 2017, Denmark had the largest share of organic foods to total foods in the world (Kaad-Hansen, 2019).

A major force behind the rapid growth of the organic food industry since 2000 has been consumer demand for organic food (Wier et al., 2003, p. 261; Dimitri and Dettmann, 2012). The response to consumer demand has led to a rapid increase in farmland allocated to organic farming and in government incentives designed to encourage farmers to switch from conventional farming to organic farming. As a result, organic food has turned from a niche product sold in a limited number of retail outlets to one available in a wide variety of venues, including supermarkets, convenience stores, farmers' markets, and pharmacies (Willer and Lernoud, 2017).

Most of the research on demand for organic food has focused on analyzing the demand for single organic food groups, such as dairy products (e.g., Wier et al., 2003, for Denmark; Schröck, 2012, for Germany; Alviola and Capps, 2010; Chen, Saghaian, and Yuqing, 2018; Li, Peterson, and Xia, 2012, for the United States), baby food (e.g., LeBeaux, Epperson, and Huang, 2009, for the United States), disaggregated organic fruits (e.g., Lin et al., 2009, for the United States), or disaggregated vegetable products (e.g., Zhang et al., 2011; Kasterisdis and Yen, 2012, for the United States; Fourmouzi, Genius, and Midmore, 2012, for the United Kingdom). None of these studies, to the best of our knowledge, examines the within-group demand relationships of different organic food aggregates. In this study, we use the systemwide approach to consumer demand to fit a demand system to the data of a variety of organic food groups (Theil, 1980). We use the estimated elasticities for simulations to evaluate the impact of government subsidy programs on different organic food industries.

The organic food industry—in Europe in general and in Denmark in particular—continues to enjoy significant governmental support to help farmers convert from conventional to organic farming. Proper evaluation of governmental or regional support programs requires reliable estimates of organic consumers' responsiveness to changes in prices and expenditures. Elasticity estimates allow us to draw conclusions on the extent to which Danish government efforts to increase the organic food supply leave farmers better off. Accurate estimates of organic food demand elasticities also help farmers, wholesalers, distributors, food processors, and retailers plan for production and sales.

Our objective is to provide a detailed demand system analysis of organic food consumption in Denmark and to use the estimated elasticities to evaluate the impact of the Organic Land Subsidy Scheme on Danish organic producers' revenues.[1] Four competing differential demand systems—the Rotterdam model (Theil, 1965), the Central Bureau Service (CBS) model (Keller and van Driel, 1985), the Almost Ideal Demand System (AIDS) (Deaton and Muellbauer, 1980), and the National Bureau of Research (NBER) model (Neves, 1994)—are fit to the data. Additionally, we use a nesting model, first developed by Barten (1993) and extended by Lee, Brown, and Seale (1994), to choose the model that best fits this dataset. Expenditure elasticities and price elasticities are estimated from the parameters of the chosen model. Based on these elasticity estimates, we simulate the effects of the Organic Land Subsidy Scheme on organic food producers.

Overall, our results suggest that, conditional on total organic food expenditures, organic cereals and organic dairy products are expenditure-inelastic, while organic meats, fruits and vegetables, and other organic foods are expenditure-elastic. Conditional on total organic food expenditures, organic cereals and meats are price-inelastic, and organic dairy, organic fruits and vegetables, and other organic food products are price-elastic, holding both real income and nominal income constant. Simulation results indicate that, in the absence of the Organic Land Subsidy Scheme, different organic producers would have experienced disproportionate changes in revenues as a result of the same percentage increase in prices of all organic food groups.

Background

The first organic crop sold in Danish retail stores was carrots in 1982 (Organic Denmark, 2016). The first legislation governing organic food production was passed in 1987, followed by the introduction of the Danish state-controlled organic inspection label (the red Ø-label) in 1989. Denmark was the first country in the world to pass a law on organic farming and to introduce government inspection of the organic production chain. Today, Denmark continues to enjoy strong government support for organic agriculture (Organic Denmark, 2017a,b).

The Danish government implemented both supply-side subsidy programs and demand-side marketing policies to boost organic production and consumption. In 1987, the government introduced direct farm subsidies to ease conversion from conventional to organic farming for the first 3 years of the conversion period. Additional conversion payments for organic livestock production were introduced in 1989. The passage of European Economic Community (EEC) Regulation 2078/92 in 1992 prompted the Danish government to introduce permanent subsidies for organic farming in 1994 (Daugbjerg and Svendsen, 2011).[2] This new scheme provided land-based conversion subsidies for 2 years and permanent organic subsidies. Eligibility required

[1] The Organic Land Subsidy Scheme is part of the Organic Action Plan for Denmark (Ministry of Food, Agriculture and Fisheries of Denmark, 2015).

[2] The full title of this regulation is "Council Regulation (EEC) No. 2078/92 of 30 June 1992 on Agricultural Production Methods Compatible with the Requirements of the Protection of the Environment and the Maintenance of the Countryside."

organic farming for at least 5 years. In 1993, organic food consumption spiked when the retail chain SuperBrugsen joined efforts to boost organic consumption by offering massive reductions in organic prices and increasing the marketing of organic food. Other retail chains followed SuperBrugsen, leading to an overall price reduction of 15%–20% for organic foods (van der Grijp and den Hond, 1999, p. 31).

The relative success of Danish organic farming was interrupted by a period of stagnation and decline between 1992 and 1994. The organic subsidy scheme was changed in 1996 to provide additional support to organic produce farms and to pay a specific subsidy to organic pork producers. The government's efforts, coupled with increased demand-side policies and consumer confidence in the Ø-mark standards, led to a resurgence in organic food sales after the stagnation period (Organic Denmark, 2016).

After many years of overproduction of organic dairy and cereals, selective support schemes for specific commodity groups were abandoned and replaced by the 2004 scheme, which instead paid organic farmers an environmental subsidy for environmentally friendly farming.[3] The only remaining organic-only subsidy in 2004 was the conversion payments, for which dairy farmers were ineligible at the time. In 2007, dairy farmers became eligible for conversion subsidies again due to the low forecast for future organic dairy production (Daugbjerg and Svendsen, 2011).

Currently, Denmark has a simplified subsidy scheme for organic farmers. In 2011, the government paid a permanent subsidy of 750 Danish kroner (DKK) per hectare per year for environmentally friendly farming and a conversion subsidy of 1050 DKK per hectare per year for the first 2 years, followed by 100 DKK per hectare per year for subsequent years in the commitment period (Norfelt, 2011). The Danish government is committed to doubling total organically farmed area by 2020, which would account for approximately 12% of Danish farmland (MFAFD, 2015).[4] According to Statistics Denmark (2014), the official Danish statistical agency, sales of selected major organic foods between 2003 and 2007 showed a persistent increase, peaking at a 33% increase in 2007. Between 2003 and 2013, total sales of the major organic food groups increased from approximately 2 billion DKK to around 5.8 billion DKK. Over the same period, the total quantity sold of the selected products increased from approximately 154,000 tons to around 248,000 tons (Statistics Denmark, 2014). The Danish organic market further expanded by 12% between 2014 and 2015, and retail sales reached €1,079 million (or 8.1 billion DKK) in 2015 (Willer, Schaack, and Lernoud, 2017, pp. 227–229).

Methods

We consider a family of differential demand systems to estimate demand for organic food groups in Denmark. Theil (1965) derived the differential demand equation,

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[3] Nonorganic but environmentally friendly farmers were also eligible for these new subsidies; however, organic farmers were prioritized (Daugbjerg and Svendsen, 2011).
[4] The support is partly financed through the European Union's Rural Development Program.

(1) $$w_{it} d\left(\ln q_{it}\right) = \theta_i \, d\left(\ln Q_t\right) + \sum_j \pi_{ij} d\left(\ln p_{jt}\right),$$

where w_{it} is the budget share of good $i = 1, \ldots, n$ at time t; n is the number of goods; θ_i is the marginal share of good i at time t; $d\left(\ln Q_t\right) = \sum_j w_{it} d\left(\ln q_{it}\right)$ is the Divisia volume index, representing the log change of real expenditure; and the π_{ij} are Slutsky (compensated) price parameters. The matrix $\pi = \left[\pi_{ij}\right]$ is negative semidefinite of rank $n - 1$. Note that θ_i and π_{ij} need not be constants.

To make the problem of estimating the demand for five groups of organic foods (i.e., cereals, meats, dairy products, fruits and vegetables, and other organic food products) manageable, we apply a commonly used method of two-stage budgeting (Theil, 1975; Barten, 1977; Rickertsen, 1998; Carpentier and Guyomard, 2001). In this approach, consumers first allocate their total income (expenditure) among broad categories of goods, including organically grown food consumed at home and conventionally grown food consumed at home. In the next stage, consumers allocate total expenditure for organically grown food at home among, in this case, the five groups of organically grown foods.

In its conditional form, the differential demand system may be written as

(2) $$w_{it}^* d\left(\ln q_{it}\right) = \theta_i^* d\left(\ln Q_{gt}\right) + \sum_{j \in S_g} \pi_{ij}^* d\left(\ln p_{jt}\right), \; i, j \in S_g,$$

where $w_{it}^* = \dfrac{w_{it}}{W_{gt}}$ is the conditional budget share of good $i \in S_g$ at time t; W_{gt} is the budget share of group S_g; $\theta_i^* = \dfrac{\theta_i}{\Theta_g}$ is the conditional marginal share of $i \in S_g$ at time t; Θ_g is the marginal share of group S_g; and the π_{ij}^* are conditional Slutsky (compensated) price parameters. The matrix $\pi^* = \left[\pi_{ij}^*\right]$ is negative semidefinite of rank $n - 1$. As in the unconditional differential demand system of equation (1), θ_i^* and π_{ij}^* need not be constants.

By treating θ_i^* and π_{ij}^* in equation (2) as constants to be estimated, Theil (1965) developed the Rotterdam model. The conditional Rotterdam in finite-change form instead of the infinitesimal-change form is

(3) $$\bar{w}_{it}^* Dq_{it} = \theta_i^* DQ_{gt} + \sum_{j \in S_g} \pi_{ij}^* Dp_{jt} + \varepsilon_{it}^*, \; i, j \in S_g,$$

where $\bar{w}_{it}^* = \frac{1}{2}\left(w_{i,t}^* + w_{i,t-1}^*\right)$; $Dq_{it} = \ln q_{i,t} - \ln q_{i,t-1}$; $Dp_{jt} = \ln p_{j,t} - \ln p_{j,t-1}$; $DQ_{gt} = \sum_{j \in S_g} \bar{w}_{jt}^* Dq_{jt}$ is the Divisia volume index for group S_g, representing total real expenditure for all goods in group S_g; and ε_{it}^* is a random error term. The conditional Rotterdam model satisfies the adding-up $\left(\sum_{i \in S_g} \theta_i^* = 1;\ \sum_{i \in S_g} \pi_{ij}^* = 0\right)$, homogeneity $\left(\sum_{j \in S_g} \pi_{ij}^* = 0\right)$, and Slutsky symmetry $\left(\pi_{ij}^* = \pi_{ji}^*,\ i, j \in S_g\right)$ theoretical constraints.

There is no theoretical reason for the parameters of equation (2) to be constant, and Keller and van Driel (1985) developed the CBS model by replacing the constant marginal shares of the Rotterdam model with the marginal shares of Working's (1943) model, $w_{it} = \alpha_i + \beta_i \ln Q_t + \varepsilon_{it}$, where $\theta_i = \beta_i + w_i$, β_i is the income parameter of Working's model and Q represents real income. In the conditional context, $\theta_i^* = \beta_i^* + w_{it}^*$, substituting $\beta_i^* + w_{it}^*$ for θ_i^* in equation (3) and rearranging terms yields the conditional CBS model:

(4) $$\bar{w}_{it}^* D\frac{q_{it}}{Q_{gt}} = \beta_i^* DQ_{gt} + \sum_{j \in S_g} \pi_{ij}^* Dp_{jt} + \varepsilon_{it}^*,\ i, j \in S_g.$$

The following constraints of demand theory apply to the CBS model: adding-up $\left(\sum_{i \in S_g} \beta_i^* = 0;\ \sum_{i \in S_g} \pi_{ij}^* = 0\right)$; homogeneity $\left(\sum_{j \in S_g} \pi_{ij}^* = 0\right)$; and Slutsky symmetry $\left(\pi_{ij}^* = \pi_{ji}^*,\ i, j \in S_g\right)$.

Deaton and Muellbauer's (1980) time-series AIDS model can also be written in the conditional differential form (Barten, 1993):

(5) $$d\bar{w}_{it}^* = \beta_i^* DQ_{gt} + \sum_{j \in S_g} \gamma_{ij}^* Dp_{jt} + \varepsilon_{it}^*,\ i, j \in S_g.$$

This time-series AIDS model satisfies the adding-up $\left(\sum_{i \in S_g} \beta_i^* = 0;\ \sum_{i \in S_g} \gamma_{ij}^* = 0\right)$, homogeneity $\left(\sum_{j \in S_g} \gamma_{ij}^* = 0\right)$, and Slutsky symmetry $\left(\gamma_{ij}^* = \gamma_{ji}^*,\ i, j \in S_g\right)$ theoretical conditions.

Another variant of the differential demand system, the NBER model proposed by Neves (1994), can be obtained by replacing β_i^* in equation (5) with $\theta_i^* - w_{it}^*$ and rearranging the terms:

(6) $$d\bar{w}_{it}^* + \bar{w}_{it}^* DQ_{gt} = \theta_i^* DQ_{gt} + \sum_{j \in S_g} \gamma_{ij}^* Dp_{jt} + \varepsilon_{it}^*.$$

The NBER model satisfies adding-up $\left(\sum_{i\in S_g}\theta_i^* = 1;\ \sum_{i\in S_g}\gamma_{ij}^* = 0\right)$, homogeneity $\left(\sum_{j\in S_g}\gamma_{ij}^* = 0\right)$, and Slutsky symmetry $\left(\gamma_{ij}^* = \gamma_{ji}^*,\ i,j\in S_g\right)$ theoretical conditions.

All four models discussed have the same righthand-side (RHS) parameterization and variables but different left-hand-side (LHS) variables. Also, none of the models is nested with the others. Barten (1993) developed a more general model that nests the above four models with the addition of only two more parameters. Lee, Brown, and Seale (1994) extended Barten's method by rearranging the four models to have the same Rotterdam dependent variables with different RHS parameterizations. Specifically, the four models with Rotterdam dependent variables are, in conditional form,

(7) Rotterdam: $$\bar{w}_{it}^* Dq_{it} = \theta_i^* DQ_{gt} + \sum_{j\in S_g}\pi_{ij}^* Dp_{jt} + \varepsilon_{it}^*,\ i,j\in S_g;$$

(8) CBS: $$\bar{w}_{it}^* Dq_{it} = \left(\beta_i^* + \bar{w}_{it}^*\right) DQ_{gt} + \sum_{j\in S_g}\pi_{ij}^* Dp_{jt} + \varepsilon_{it}^*,\ i,j\in S_g;$$

(9) AIDS: $$\bar{w}_{it}^* Dq_{it} = \left(\beta_i^* + \bar{w}_{it}^*\right) DQ_{gt} + \sum_{j\in S_g}\left(\gamma_{ij}^* - \bar{w}_{it}^*\left(\delta_{ij} - \bar{w}_{jt}^*\right)\right) Dp_{jt},\ i,j\in S_g;$$

where δ_{ij} is the Kronecker delta, which equals 1 for $i = j$ and 0 otherwise, and

(10) NBER: $$\bar{w}_{it}^* Dq_{it} = \theta_i^* DQ_{gt} + \sum_{j\in S_g}\left(\gamma_{ij}^* - \bar{w}_{it}^*\left(\delta_{ij} - \bar{w}_{jt}^*\right)\right) Dp_{jt},\ i,j\in S_g.$$

Next, Lee, Brown, and Seale (1994) developed the nesting model:

(11) $$\bar{w}_{it}^* Dq_{it} = \left(d_i^* + \delta_1\bar{w}_{it}^*\right) DQ_{gt} + \sum_{j\in S_g}\left(e_{ij}^* - \delta_2\bar{w}_{it}^*\left(\delta_{ij} - \bar{w}_{jt}^*\right)\right) Dp_{jt},\ i,j\in S_g,$$

where $d_i^* = \delta_1\beta_i^* + \left(1-\delta_1\right)\theta_i^*,\ i\in S_g$, and $e_{ij}^* = \delta_2\gamma_{ij}^* + \left(1-\delta_2\right)\pi_{ij}^*,\ i,j\in S_g$, with δ_1 and δ_2 the two additional parameters to be estimated. When $\delta_1 = 0$ and $\delta_2 = 0$, the nesting model is the Rotterdam model; when $\delta_1 = 1$ and $\delta_2 = 0$, the nesting model is the CBS model; when $\delta_1 = 1$ and $\delta_2 = 1$, it is the AIDS model; and when $\delta_1 = 0$ and $\delta_2 = 1$, it is the NBER model. The nesting model obeys the adding-up $\left(\sum_{i\in S_g} d_i^* = 1-\delta_1;\ \sum_{i\in S_g} e_{ij}^* = 0\right)$, homogeneity $\left(\sum_{j\in S_g}\gamma_{ij}^* = 0\right)$, and Slutsky symmetry $\left(e_{ij}^* = e_{ji}^*,\ i,j\in S_g\right)$ conditions.

The four differential demand systems and the nesting system can be estimated using the maximum likelihood (ML) method. Due to the adding-up condition, the contemporaneous covariance matrix Ω is singular. Barten (1969) showed that ML estimates of the parameters of the complete n-equation system can be obtained using estimates from $n-1$ equations. Further, the procedure yields ML estimates that are invariant to the equation deleted. Therefore, we estimate the conditional differential demand systems considered in the previous section with ML using iterative seemingly unrelated regressions (SUR). The cross-equation restrictions of symmetry necessitate the use of iterative SUR to obtain efficient point estimates (Barten, 1969). This SUR procedure iterates over Ω and converges to the ML estimator if the normality of the error terms holds (Berndt and Savin, 1975; Rickertsen, 1998).

Results and Discussion

Data on organic food expenditures and quantities are constructed using surveys conducted by Statistics Denmark (2015) of Danish supermarket chains, department stores, and wholesale chains between 2003 and 2015. The detailed commodities surveyed by Statistics Denmark are aggregated into five major Danish organic food groups for estimation purposes: cereals, meats, dairy products, fruits and vegetables, and other organic food products. The cereals group consists of rice, bread, pasta, flour, groats, cornflakes, muesli, crispbread, rice cakes, and other flour and groats products. The meats group is made up of beef, pork, chicken, cold cuts of meat and poultry, meat spreads, and offal. The dairy group consists of milk; cream; sour cream; other mild, fermented products; and cheeses. The fruits and vegetables group consists of fruits (fresh citrus, fresh bananas, fresh apples, fresh stone fruits and berries, pineapple, kiwi, melon, other fruits, dried fruit, nuts, and almonds) and vegetables (fresh lettuce, fresh Chinese cabbage, fresh spinach, fresh cabbage, fresh tomatoes, fresh cucumbers, fresh sweet peppers, fresh capsicum, fresh carrots, fresh potatoes, fresh onions, frozen vegetables, potato products, and canned vegetables). The other organic food products group consists of eggs, fats and oils including butter and cooking oils, fish, sugar, jams, syrup, honey, chocolate, candy, ice cream, spices and stocks, ketchup, dressing, mayonnaise, processed baby food, coffee, tea, cocoa, juices and fruit juices, wine, cider, and beer. [5]

Total sales and quantities of the organic commodities in the data are converted to per capita measures using annual population data obtained from Statistics Denmark (2019) for the same period. Computed unit prices (per capita expenditures divided by per capita consumption) are used for the analysis due to lack of explicit retail price information. Table 1 reports summary statistics of data. From 2003 to 2015, the budget share of organic cereals increased by about 7%, while the share of meats increased by 44%, the share of dairy products decreased by 37%, the share of fruits and vegetables increased by 79%, and the share of other organic food products increased by approximately 22%. In the same period, the unit prices per ton of cereals, meats, dairy products, fruits and vegetables, and other organic food products increased by 46%, 42%,

[5] Organic fish quantities and expenditures are reported as 0 for most cases. As such, leaving "fish" in the "meats" category would have caused meat expenditures to be independent of meat prices. We included "fish" in "other organic foods" category to circumvent this issue.

50%, 65%, and 33%, respectively. The highest mean budget share in the sample period was for dairy products (40%), followed by fruits and vegetables (21%), other organic food products (20%), cereals (13%), and meats (7%). There was substantially more variation in the budget share of organic dairy products than in the budget share for the other four organic food products (Table 1).

Table 1. Summary Statistics of Danish Organic Food Data, 2003–2015 ($N = 280$)

Organic Food Groups	Cereals	Meats	Dairy	Fruits–Veg.	Other
Per capita consumption (kilograms per capita)					
Minimum	2.70	0.33	19.38	3.68	1.53
Mean	4.56	0.63	23.98	7.62	2.81
Maximum	6.18	1.03	27.21	12.47	4.36
Std. dev.	1.30	0.19	2.62	2.66	0.90
Unit prices (Danish kroner per kilogram)					
Minimum	15.20	65.54	9.87	15.19	45.76
Mean	21.90	89.87	12.32	21.52	54.75
Maximum	26.16	103.53	15.54	27.31	65.82
Std. dev.	4.38	11.79	2.06	4.32	7.18
Expenditures (Danish kroner per kilogram)					
Minimum	41.14	21.52	191.30	58.15	70.21
Mean	104.61	58.33	298.59	172.73	159.08
Maximum	144.99	96.00	386.95	324.39	265.42
Std. dev.	43.99	21.45	71.53	83.18	66.42
Budget shares (percentage of total organic food expenditures)					
Minimum	0.10	0.06	0.32	0.15	0.18
Mean	0.13	0.07	0.40	0.21	0.20
Maximum	0.15	0.09	0.51	0.27	0.22
Std. dev.	0.02	0.01	0.06	0.04	0.02

Note: Cereals includes rice, bread, pasta, flour, groats, cornflakes, muesli, crispbread, rice and cakes, and other flour and groats products. Meats includes beef, pork, chicken, cold cuts of meat and poultry, meat spreads, and offal. Dairy includes milk, cream, sour cream, other mild, fermented products, and cheeses. Fruits and vegetables includes fruits (fresh citrus, fresh bananas, fresh apples, fresh stone fruits and berries, pineapple, kiwi, melon, other fruits, dried fruit, nuts, and almonds) and vegetables (fresh lettuce, Chinese cabbage, spinach, cabbage, tomatoes, cucumbers, sweet peppers, capsicum, carrots, potatoes, and onions; frozen vegetables; potato products; and canned vegetables). Other organic food products includes eggs, fats and oils (including butter and cooking oils), fish, sugar, jams, syrup, honey, chocolate, candy, ice cream, spices and stocks, ketchup, dressing, mayonnaise, processed baby food, coffee, tea, cocoa, juices and fruit juices, wine, cider, and beer. Unit prices are computed as per capita expenditures divided by per capita consumption.

Estimated Differential Demand Systems and Elasticities

We first estimate unconstrained forms of the models given in equations (7)–(10) along with the nesting model in equation (11). The theoretical restrictions of homogeneity are tested using a small sample Hotelling's T^2 test developed by Laitinen (1978). The test statistics for homogeneity restrictions for all five models are all smaller than the 5% critical value of 46.39 (Table 2). Therefore, the null of homogeneity cannot be rejected for any of the five functional forms and should be imposed on all five demand systems. We test symmetry relative to the homogeneity-restricted models for all five demand systems using log-likelihood-ratio (LR) tests. All models have LR test statistics lower than the 5% critical value of 12.59; therefore, symmetry is not rejected for any of the five models at the 5% significance level (Table 2).

Table 2. Homogeneity, Symmetry, and Autocorrelation Tests for the Five Demand Systems

	Test Statistic					**Critical Value**
Restriction/Test	**Rotterdam**	**CBS**	**AIDS**	**NBER**	**Nesting**	**(α = 0.05)**
Homogeneity	22.93	16.30	23.08	23.89	16.88	46.39
Symmetry	8.65	4.28	3.02	3.43	4.81	12.59
Autocorrelation	2.35	1.32	3.61	0.18	1.81	3.84

Notes: Homogeneity is tested using Hotelling's T^2 test, as recommended by Laitinen (1978). Symmetry restrictions and AR(1) autocorrelation are tested using log-likelihood-ratio tests.

We also test for first-order autocorrelation, AR(1), in the error terms of each demand system by testing the AR(1)-imposed demand systems with ML using the Hildreth–Lu (1960) method with the LR test. We reject AR(1) autocorrelation in all of the demand systems considered (Table 2). For all five systems, the test statistics are smaller than the critical value at the 5% level. This is not surprising, because the log-difference transformations of the data in the conditional differential demand systems tend to wipe out the autocorrelation in the data (Barten, 1969, 1977).[6]

Next, based on the homogeneity and symmetry-imposed demand systems, we use LR tests to select the model that best fits the dataset compared to the nesting model. Table 3 reports the LR test statistics and critical value of 5.99 at the 5% level for model selection tests. When tested against the nesting model, none of the four competing models (i.e., Rotterdam, CBS, AIDS, and NBER) are rejected. In other words, the LR tests indicate that, from a statistical point of view, all models fit the data as well as the nesting model does. However, from an economics viewpoint, the four models do not perform well. In the case of the four competing models, the required negativity condition of the Slutsky price matrix is violated; the own-price parameter of organic cereals is statistically 0 but positive. Because the nesting model is more flexible than the other

[6] Unit-root tests have also been implemented to confirm the stationarity of the variables used in the model. The null of unit roots has been rejected in all cases. Results are available upon request.

four models, its added flexibility is able to handle the negativity condition of the Slutsky price matrix, that is, the negativity condition is not violated, and all own-price Slutsky parameters are negative, as dictated by economic theory. Based on its added flexibility, its adherence to the negativity condition, and that it is considered a complete demand system in its own right, we use its parameters to calculate and report conditional expenditure elasticities, conditional Slutsky price elasticities, and conditional Cournot price elasticities (Barten, 1993; Lee, Brown, and Seale, 1994; Asci et al., 2016).

Table 3. Functional Form Tests of Four Alternative Models against the Nesting Model

Model	H_0	Likelihood Ratio Test	Critical Value (α = 0.05)
Rotterdam	$\delta_1 = 0,\ \delta_2 = 0$	5.90	5.99
CBS	$\delta_1 = 1,\ \delta_2 = 0$	4.68	5.99
AIDS	$\delta_1 = 1,\ \delta_2 = 1$	3.21	5.99
NBER	$\delta_1 = 0,\ \delta_2 = 1$	4.03	5.99

Table 4 reports the conditional demand elasticity estimates.[7] The top panel reports the conditional expenditure and Slutsky (compensated) price elasticities. The bottom panel reports the conditional Cournot (uncompensated) price elasticities. The conditional expenditure elasticities, η_i^*, are positive and significantly different from 0 at the 5% significance level. Those of the organic groups of meats, fruits and vegetables, and other organic food products are conditionally elastic with point estimates greater than unitary. Conditional expenditure elasticities of meats and fruits and vegetables are 1.5, while that of other products is 1.1.

As total expenditures for organic foods in Denmark increase, quantities demanded of meats and fruits and vegetables are expected to grow the fastest for a given percentage change in total organic food expenditure. Demand for organic cereals and dairy products are conditionally expenditure-inelastic, with point estimates less than unitary. The smallest is that of dairy (0.6). For a 1% increase in total organic food expenditure, the quantity demanded by Danish consumers of the organic groups of meats, fruits and vegetables, and other organic food products would increase by more than 1% and those of organic cereals and dairy products by less than 1%; the quantities demanded by Danish consumers of organic groups meats, fruits and vegetables, and other organic food products are more sensitive to a change in total organic food expenditure than those of organic cereals and dairy products.

[7] The complete set of formulae to calculate conditional demand elasticities for the nesting model is given in Lee, Brown, and Seale (1994).

Table 4. Conditional Demand Elasticities of Five Organic Food Groups, Denmark, 2004–2015

Commodity	Conditional Expenditure Elasticity	Cereals	Meats	Dairy	Fruit–Veg.	Other
Conditional Slutsky (compensated) price elasticities (S_{ij}^*)						
Cereals	0.90**	−0.06	−0.20	0.76	−0.16	−0.34**
	(0.36)	(0.42)	(0.21)	(0.50)	(0.41)	(0.13)
Meats	1.51**	−0.35	−0.73**	0.14	0.49	0.45**
	(0.35)	(0.36)	(0.33)	(0.55)	(0.47)	(0.20)
Dairy	0.59**	0.25	0.03	−1.15**	0.38	0.48**
	(0.20)	(0.17)	(0.11)	(0.36)	(0.29)	(0.09)
Fruit–veg.	1.53**	−0.10	0.17	0.70	−1.05**	0.28**
	(0.31)	(0.25)	(0.17)	(0.53)	(0.48)	(0.14)
Other	1.10**	−0.22**	0.17**	0.94**	0.30**	−1.19**
	(0.10)	(0.09)	(0.07)	(0.18)	(0.15)	(0.10)
Conditional Cournot (uncompensated) price elasticities (C_{ij}^*)						
Cereals		−0.18	−0.27	0.41	−0.35	−0.52**
		(0.44)	(0.20)	(0.48)	(0.42)	(0.16)
Meats		−0.54	−0.85**	−0.44	0.17	0.15
		(0.38)	(0.32)	(0.53)	(0.48)	(0.22)
Dairy		0.18	−0.02	−1.38**	0.26	0.36**
		(0.18)	(0.10)	(0.35)	(0.30)	(0.11)
Fruit–veg.		−0.29	0.06	0.11	−1.38**	−0.02
		(0.26)	(0.16)	(0.52)	(0.49)	(0.16)
Other		−0.37**	0.09	0.52**	0.07	−1.41**
		(0.09)	(0.07)	(0.18)	(0.15)	(0.10)

Notes: Elasticities are calculated from the nesting model, homogeneity and symmetry imposed. Numbers in parentheses are asymptotic standard errors. Double and single asterisks (**, *) indicate significance at the 5% and 10% levels, respectively.

The conditional Slutsky own-price elasticities (S_{ii}^{*}) are compensated and measure the percentage change in quantity demanded when own-price changes by 1%, keeping the real total organic food expenditure constant. The conditional own-price elasticities (both S_{ii}^{*} and C_{ii}^{*}) are all negative as expected, with four of the five significantly different from 0 at the 5% significance level. Demand for two organic groups (cereals and meats) is conditionally inelastic, with S_{ii}^{*} less than 1 in absolute value, fruits and vegetables is essentially unitary-elastic, and dairy and other organic foods are own-price elastic with elasticities greater than 1 in absolute values. This indicates that the quantities demanded of other organic food products and dairy products are the most sensitive to changes in their own prices, followed by organic fruits and vegetables and then meats. The quantity demanded of organic cereals is least sensitive to an own-price change among the five organic food groups. This is likely because Danes consider cereals (including bread and pastries) to be staples in their habitual diet (Engeset et al., 2015).

The conditional Cournot own-price elasticities (C_{ii}^{*}) are uncompensated and measure the percentage change in quantity demanded when own-price changes by 1%, keeping the nominal total organic food expenditure constant. The conditional Cournot (C_{ii}^{*}) own-price elasticities are larger in absolute values than the corresponding Slutsky (S_{ii}^{*}) ones. The conditional own-price elasticities of cereals (−0.18) and meats (−0.85) continue to be inelastic, with that of cereals still the smallest. The other three conditional Cournot own-price elasticities (dairy, fruits and vegetables, and other organic foods) are still larger than 1 in absolute values, with other organic foods having the largest elasticity (−1.41) and dairy and fruits and vegetables both having a Cournot own-price elasticity of −1.38. Note that Cournot price elasticities include both the substitution effect and the income effect of a price change on quantity demanded, while Slutsky price elasticities only measure the substitution effect of a price change.

A conditional cross-price elasticity measures the percentage change in quantity demanded of good i when the price of good j changes by 1%. A positive conditional Slutsky cross-price elasticity indicates that goods i and j are substitutes. As such, the quantity demanded of good i increases when the price of good j increases. A negative sign indicates that goods i and j are complements. Of the 20 conditional Slutsky cross-price elasticities (S_{ij}^{*}, for $i \neq j$), 14 are positive. The pairs for meats–other, dairy–other, and fruits and vegetables–other are positive and significantly different from 0, indicating that these goods are substitutes. Only the cereals–other pair has negative and significant Slutsky cross-price elasticities, indicating that cereals and other products are complements. The remaining conditional Slutsky cross-price elasticities are not significantly different from 0. For example, the quantity demand of organic meats is not sensitive to a change in the price of organic cereals and vice versa. Other pairs like these are meats–dairy, meats–fruits and vegetables, dairy–fruits and vegetables, and cereals–fruits and vegetables.

Because conditional Cournot cross-price elasticities are equal to the corresponding Slutsky ones minus a positive income effect of price changes, they do not indicate whether a good is a complement or a substitute. They are, however, better indicators of the market response of a price change than the Slutsky cross-price elasticities. For instance, a Cournot cross-price elasticity may be negative while the corresponding Slutsky one is positive if the income effect of a price change is larger in absolute value than the substitution effect of the same price change. The conditional Cournot cross-price elasticities of dairy and other organic foods continue to be positive and significantly different from 0 while those of cereals and other organic foods continue to be negative and significantly different from 0. Note that magnitudes of Cournot cross-price elasticities may be asymmetric between goods A–B and goods B–A.

Simulated Effects of the Danish Organic Land Subsidy Scheme

In this section, the estimated Cournot price elasticities are used to simulate the impact of the Organic Land Subsidy Scheme on Danish organic food demand.[8] In general, demand for organic products is high in Denmark and is expected to continue to grow (Organic Denmark, 2017b). The Organic Land Subsidy Scheme essentially removes barriers associated with large sunk costs of entering into the organic agricultural industry. Without the Organic Land Subsidy Scheme, prices would have to be higher to attract new farmers to enter the market and to compensate conventional farmers for the cost of changing over to organic food production.

The subsidies provided to organic farmers by the Danish government to convert conventional agricultural land to organic agriculture decrease the current or observed prices relative to what prices would be without those subsidies. In this section, we simulate the effects of higher nonsubsidized prices on production and revenues for the five categories of organically produced products (i.e., cereals, meats, dairy products, fruits and vegetables, and other organic food products). Specifically, the simulations are based on 2015 quantities, expenditures, and prices under four price scenarios, which are that prices without the Organic Land Subsidy Scheme would be 10%, 20%, 30%, or 40% higher than the observed (conversion subsidized) prices.

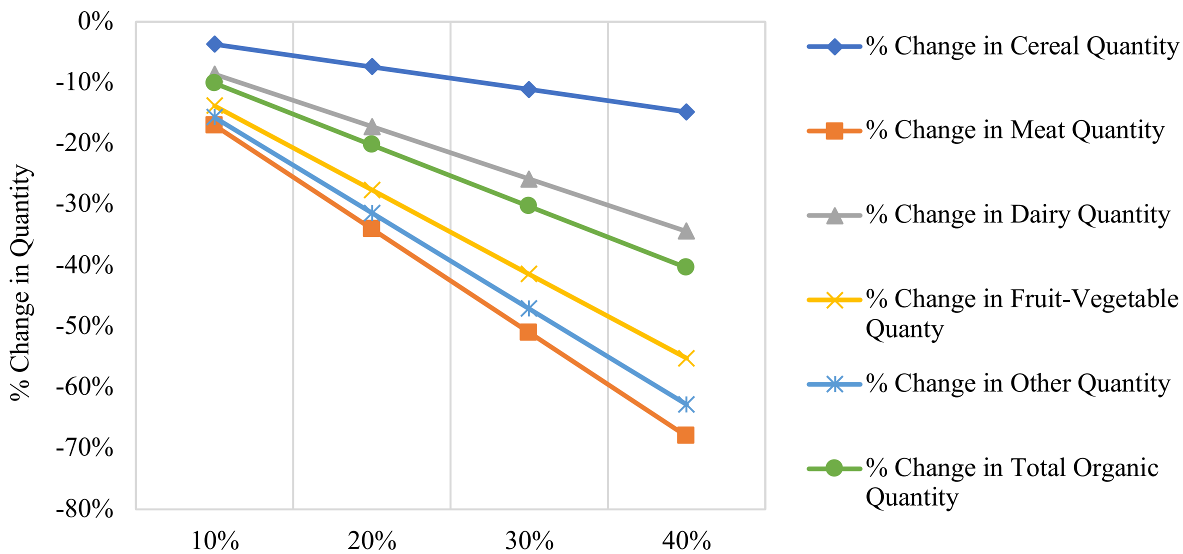
In the four simulation scenarios of higher prices without conversion subsidies, the quantities demanded of all five organic food groups decrease relative to the corresponding 2015 base quantities (Table 5 and Figure 1). The quantity responses to the price changes vary, with the quantity demanded of cereals the least sensitive to its own-price change or to price changes in the other four organic food groups. Quantities demanded of dairy are moderately sensitive to price changes, with its quantities demanded decreasing less percentage-wise than the percentage increases in all prices. For example, when all prices increase by 40%, the quantity of dairy demanded decreases by 34%. The quantities demanded of the other three groups—meats, fruits and vegetables, and other organic foods—decrease more in percentages than the percentage increases in all prices. Of these three groups, the quantities demanded of meats fall the most, followed by quantities demanded of other organic foods and then quantities demanded of fruits and vegetables. The percentage change in demand for total organic food range from −10% for a 10% higher (hypothesized) nonsubsidized price to −40% for a 40% higher nonsubsidized price. The same pattern exists for the 20% and 30% price-increase scenarios, indicating that the effect of a percentage change in all prices of the five organic food groups due to hypothesized absence of the Organic Land Subsidy Scheme on the total organic food quantity is unitary.

[8] Statistically insignificant Cournot elasticities are treated as no changes in quantities due to the price changes.

Table 5. Cumulative Simulated Effects of Four Price Scenarios on Five Organic Food Groups Based on Cournot Price Elasticities

Organic Food Category	2015 Quantity (tons)	2015 Expenditure (million DKK)	2015 Prices (DKK/ton)	Hypothesized Nonsubsidized Prices (DKK/ton)	Change from 2015 Quantity (tons)	Change in Quantity (%)	Expenditure Based on Nonsubsidized Prices (million DKK)	Change in Expenditure (million DKK)	Change in Expenditure (%)
10% increase in without-conversion-subsidy prices									
Cereals	35,004	812.2	23,203.1	25,523.4	−1,295.1	−3.7	860.4	48.2	5.9
Meat	5,851	543.4	92,870.8	102,157.9	−994.7	−17.0	496.1	−47.3	−8.7
Dairy	146,091	2,190.1	14,991.7	16,490.8	−12,563.8	−8.6	2,202.0	11.8	0.5
Fruits–veg.	70,569	1,836.0	26,017.5	28,619.2	−9,738.5	−13.8	1,740.9	−95.1	−5.2
Others	24,690	1,502.3	60,846.5	66,931.2	−3,876.3	−15.7	1,393.1	−109.2	−7.3
Total	282,205	6,884.1			−28,468.5	−10.1	6,692.5	−191.6	−2.8
20% increase in without-conversion-subsidy prices									
Cereals	35,004	812.2	23,203.1	27,843.7	−2,590.3	−7.4	902.5	90.3	11.1
Meat	5,851	543.4	92,870.8	111,444.9	−1,989.3	−34.0	430.4	−113.0	−20.8
Dairy	146,091	2,190.1	14,991.7	17,990.0	−25,127.7	−17.2	2,176.1	−14.0	−0.6
Fruits–veg.	70,569	1,836.0	26,017.5	31,221.0	−19,477.0	−27.6	1,595.1	−240.9	−13.1
Others	24,690	1,502.3	60,846.5	73,015.8	−7,752.7	−31.4	1,236.7	−265.6	−17.7
Total	282,205	6,884.1			−56,937.0	−20.2	6,340.8	−543.2	−7.9
30% increase in without-conversion-subsidy prices									
Cereals	35,004	812.2	23,203.1	30,164.0	−3,885.4	−11.1	938.7	126.5	15.6
Meat	5,851	543.4	92,870.8	120,732.0	−2,984.0	−51.0	346.1	−197.2	−36.3
Dairy	146,091	2,190.1	14,991.7	19,489.2	−37,691.5	−25.8	2,112.6	−77.5	−3.5
Fruits–veg.	70,569	1,836.0	26,017.5	33,822.7	−29,215.6	−41.4	1,398.7	−437.3	−23.8
Others	24,690	1,502.3	60,846.5	79,100.5	−11,629.0	−47.1	1,033.1	−469.2	−31.2
Total	282,205	6,884.1			−85,405.5	−30.3	5,829.2	−1,054.8	−15.3
40% increase in without-conversion-subsidy prices									
Cereals	35,004	812.2	23,203.1	32,484.3	−5,180.6	−14.8	968.8	156.6	19.3
Meat	5,851	543.4	92,870.8	130,019.1	−3,978.7	−68.0	243.4	−299.9	−55.2
Dairy	146,091	2,190.1	14,991.7	20,988.3	−50,255.3	−34.4	2,011.4	−178.7	−8.2
Fruits–veg.	70,569	1,836.0	26,017.5	36,424.5	−38,954.1	−55.2	1,151.6	−684.5	−37.3
Others	24,690	1,502.3	60,846.5	85,185.2	−15,505.3	−62.8	782.4	−719.9	−47.9
Total	282,205	6,884.1			−113,874.0	−40.4	5,157.6	−1,726.4	−25.1

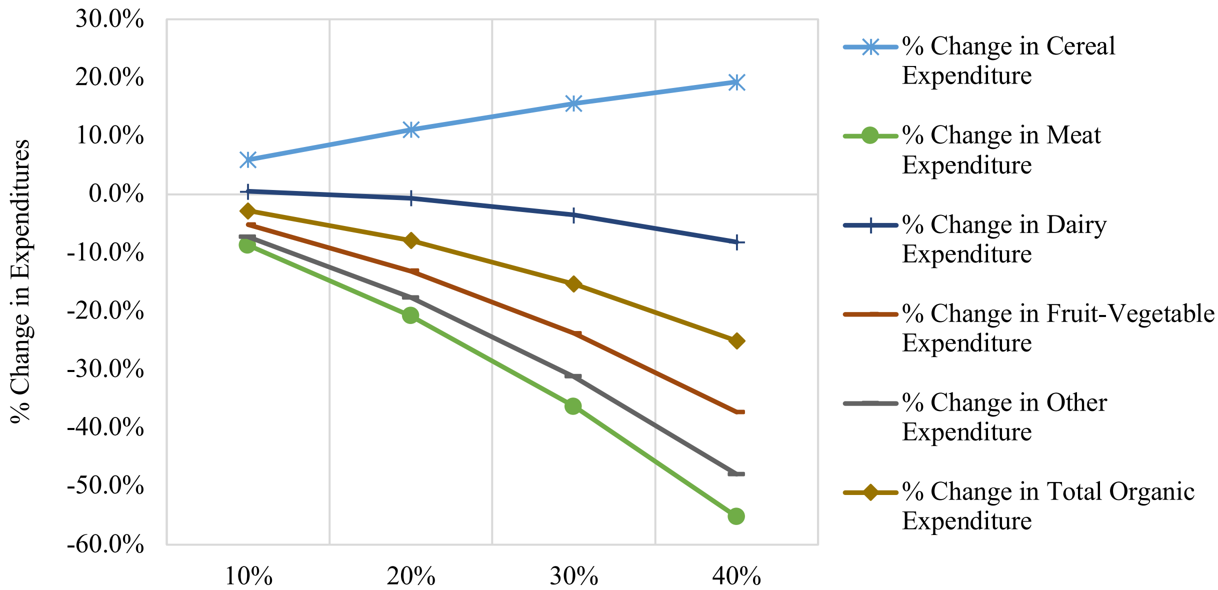
Figure 1. Simulation Results: Percentage Changes in Five Organic Food Group Quantities as a Result of Hypothesized 10%, 20%, 30%, and 40% Increases in Without-Conversion-Subsidy Prices



Source: Authors' computations.

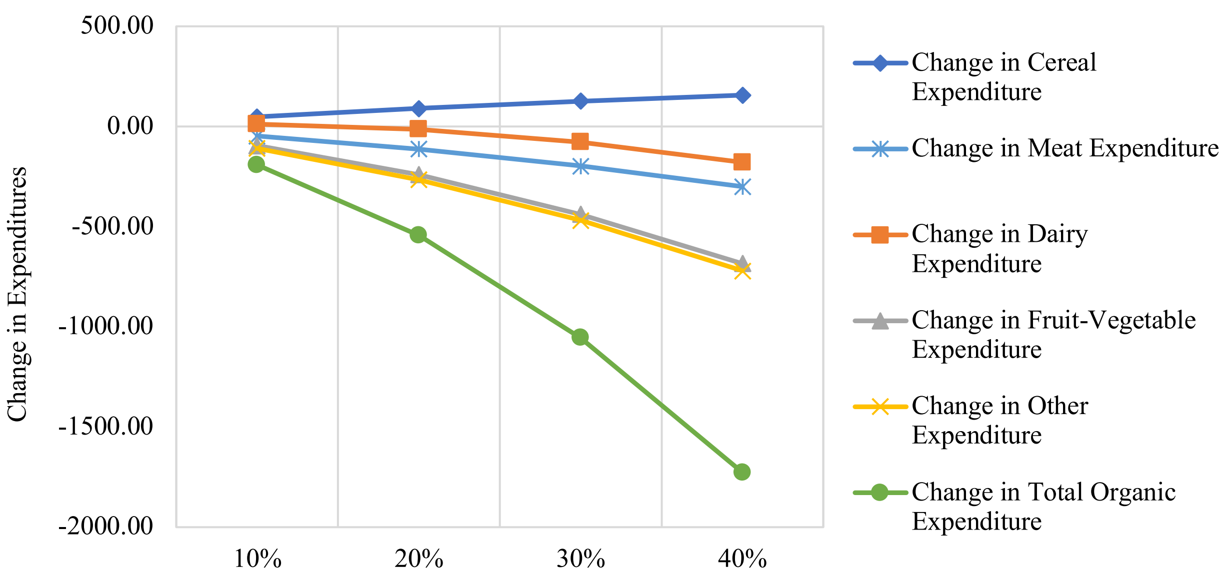
Differences in the effects on expenditures of the five organic food groups of having higher without-conversion-subsidy prices are striking. For the first scenario of 10% increases in without-conversion-subsidy prices, two groups—organic cereals and organic dairy—would have realized 5.9% and 0.5% higher total expenditures, respectively, without the Organic Land Subsidy Scheme and with the higher resulting (hypothesized) nonsubsidized prices. The other three groups—meats, fruits and vegetables, and other organic foods—would have realized lower total expenditures without the Organic Land Subsidy Scheme (Table 5, Figures 2 and 3). For the other three price scenarios of 20%, 30%, and 40% increases in without-conversion-subsidy prices, only organic cereals would have received higher expenditures without the Organic Land Subsidy Scheme, with gains of 11%, 16%, and 19%, respectively. Expenditures for dairy products increase with a 10% higher hypothesized price but decrease at all other, higher hypothesized prices (20%, 30%, and 40%). The losses in terms of lower expenditures (i.e., revenues) due to (hypothesized) nonsubsidized prices are lowest for dairy products (ranging from −0.6% to −8.2%), next for fruits and vegetables (ranging from −5.2% to −37.3%), next for other organic foods (ranging from −7.3% to −47.9%), and highest for organic meats (ranging from −8.7% to −55.2%). For the whole organic food sector, the percentage changes in total revenue (expenditure) for the four price-change scenarios range from −2.8% to −25.1%. The absolute-value changes in expenditures for the five organic food categories under the four price-change scenarios follow similar patterns as those with respect to the percentage changes in expenditures (Figure 3). Overall, removing the Organic Land Subsidy Scheme and the resulting (hypothesized) increases in prices of organic foods would most affect producers of meats and other organic foods in terms of a reduction in revenues. In other words, the Organic Land Subsidy Scheme helps the organic food industry disproportionately, with producers of organic meats and other organic foods likely realizing the highest revenue gains due to subsidies.

Figure 2. Simulation Results: Percentage Changes in Five Organic Food Group Expenditures as a Result of Hypothesized 10%, 20%, 30%, and 40% Increases to Without-Conversion-Subsidy Prices



Source: Authors' computations.

Figure 3. Simulation Results: Changes in Five Organic Food Group Expenditures (millions DKK) as a Result of Hypothesized 10%, 20%, 30%, and 40% Increases to Without-Conversion-Subsidy Prices



Source: Authors' computations.

Conclusions

In this study, we estimate Danish consumers' demand for five organic food groups. We accomplish this by first fitting four differential demand systems and a nesting model to Danish data on five organic food groups. While the four models statistically fit the data as well as does the nesting model, all four violate the negativity condition, while the more flexible nesting model does not. Accordingly, we use the parameters of the more flexible nesting model, a valid demand system in its own right, to estimate conditional demand elasticities for the five organic food groups.

Our results indicate that the organic food groups of meats, fruits and vegetables, and other respond more than proportionately to a proportionate change in Danish total expenditure allocated to organic food consumption; these groups are conditionally expenditure-elastic. Dairy consumption will grow slowest among the five groups, while consumption of meats and fruits and vegetables will grow fastest for a given percentage increase in total organic food expenditure. Evidence from the nesting model indicates that the own-price elasticities are negative and consistent with economic theory. Quantities demanded of organic cereals are found to respond the least to own-price changes. The organic meats group is also own-price inelastic, while organic dairy, fruits and vegetables, and other organic foods are own-price elastic. Conditional Slutsky cross-price elasticities reveal that, in general, most organic food groups are economically "unrelated" to each other for Danish consumers; in other words, quantity demanded of one organic group is typically not responsive to changes in the prices of remaining organic food groups. The exception to this is the other organic foods group; the pairs other–meats, other–dairy, and other–fruits and vegetables are substitutes, while other–cereals are complements. The complementarity of cereals (including breads) and other organic foods is likely driven by the inclusion of butter, fats, oils, jams, and other sweets in the other organic foods group.

In all simulated cases, the percentage changes in quantities demanded of the five organic food groups due to the hypothesized absence of the Organic Land Subsidy Scheme with accompanying increases in prices (relative to observed lower subsidized prices) are all negative, as expected, but of different magnitudes. The percentage decrease in quantity demanded due to price increases is smallest for organic cereals, moderate for dairy and fruits and vegetables, and higher for meats and other organic foods. The changes in expenditures among the five organic food groups (thus, revenues for organic producers) resulting from higher without-conversion-subsidy prices are also asymmetric across the five organic food groups. Organic cereals would have observed higher total expenditures in the absence of the Organic Land Subsidy Scheme that would have resulted in price increases of 10%, 20%, 30%, or 40%. Organic dairy would have realized a slight increase in expenditures with a 10% hypothesized price increase; however, the gains in expenditures would disappear at higher hypothesized price increases. Under four scenarios, the remaining three organic food groups—meats, fruits and vegetables, and other organic foods—would have had decreases in total expenditures due to the absence of the Organic Land Subsidy Scheme and resulting increases in their prices relative to lower observed subsidized prices. For the organic food industry as a whole, removing the Organic Land Subsidy

Scheme, which increases prices by 10%, 20%, 30%, or 40%, would lead to negative percentage changes in total expenditures (i.e., total revenues) in the organic industry.

Our findings have interesting implications for the Danish organic food sector. We find that the Danish Organic Land Subsidy Scheme induces higher revenues for the organic food sector as a whole under all four simulation scenarios. In other words, removing the current Organic Land Subsidy Scheme would result in revenue losses for the organic food industry as a whole. Moreover, our simulation exercises show that the same percentage increase in prices due to the hypothesized absence of the Organic Land Subsidy Scheme would result in disproportionate changes in revenues for different organic sectors. In all the hypothesized price-increase scenarios (i.e., the absence of the Organic Land Subsidy Scheme), producers of organic cereals gain in terms of increased expenditures, while those of organic meats, fruits and vegetables, and other organic foods lose revenues relative to the case in which conversion subsidies are present. Organic dairy would have experienced a slight benefit in the case of no land conversion subsidies and accompanying differences of 10% between subsidized and nonsubsidized prices; however, this gain would disappear if differences between subsidized and nonsubsidized were higher. The organic food industry as a whole always benefits from higher revenues due to the Organic Land Subsidy Scheme. Overall, the Organic Land Subsidy Scheme results in higher quantities demanded of organic food for consumers and higher revenues for producers, except for organic cereals producers. Revenue gains (losses) in the presence (absence) of the Organic Land Subsidy Scheme are highest for producers of meats and other organic foods, followed by producers of fruits and vegetables.

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