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Potential demand for synthetic meat

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ABSTRACT

The demand for meat products is rising globally. A potential substitute for meat is synthetic meat, meat produced in the laboratory. Synthetic meat is not in the market yet due to high production costs and regulatory issues, but it will probably be available during the next decade. If cheap and popular it may crowd out the demand and production of farmed meat and herby affect farmers income. In this study we have used data from a choice experiment in Norway to construct price and income elasticities for synthetic meat with three different assumptions. The data shows that half of the population does not accept synthetic meat. They will not buy it whatever the price. The own-price elasticities were estimated to be in the interval [-0.47,-0.08] and the cross-price elasticities were in the interval [0.09,0.40]. The income elasticities were all close to 0. If these elasticities were valid in a situation in which synthetic meat is available on the market, we could infer that the market for synthetic meat is limited.

Keywords: Meat substitutes, elasticities, choice experiment

1 Introduction

Globally the population is rising and hereby the demand for meat and meat products. A potential substitute for meat is synthetic meat (also known as cell-based meat, clean meat, cultured meat, or in-vitro meat). Synthetic meat consists of meat produced with different technologies in the laboratory. Due to high production cost (Vergeer et al, 2021) and lack of regulations (Stephens et al, 2018), synthetic meat products are not in the market yet, but they will probably be commercially available within the next decade. Substituting ordinary meat for synthetic meat may have significant advantages. It may help feeding more people, it may help reducing climate gas emission from food production, it will use less land and less water in the production process, and it may make animal welfare concerns obsolete. But there are also potential drawbacks: Synthetic meat, if cheap and popular, may also crowd out the demand, and production of beef, pork, chicken and lamb, and herby affect farmers income, maintenance of the cultural landscape, reduce agro-biodiversity, threaten the country's settlement pattern.

In this paper we analyze the consumers potential demand for synthetic meat in Norway. Since we don't know anything about the consumers reaction to changes in price and income, we base our study on a choice experiment to simulate price and income elasticities (Klöckner et al. 2022). The experiment consisted of 400 Norwegian consumers, choosing twelve times between a piece of synthetic meat, a piece of ordinary meat, or none of the two, conditional on relative prices, greenhouse gas emissions, health labels, and business model.

In the first section, the choice experiment and the data set are described. Next, we elaborate on our assumptions, and we explain how the new data set is constructed. We present our model and how we calculate the own-price, cross-price, and income elasticities. Next, the estimation results are presented, and the elasticities are calculated for different groups of consumers under different assumptions. Based on the results for the elasticities, we discuss the potential effects of the introduction of synthetic meat for Norwegian agriculture in the last section.

2 Data: About the choice experiment

The sample is representative for the adult population in Norway. There were 304 individuals participating in a choice experiment where the participants were asked to choose between synthetic meat, farmed meat or none of the two conditioned by the level of some key factors that were systematically between the trials. The following four factors were used as attributes in the choice experiment:

Price (4 categories):

The synthetic meat is

- 50% cheaper than the farmed meat
- 20% cheaper than the farmed meat
- same price as the farmed meat
- 20% more expensive than the farmed meat

Climate change impact (3 categories)

The synthetic meat

- saves 10% greenhouse gas emissions
- saves 50% greenhouse gas emissions
- saves 90% greenhouse gas emissions

Health (2 categories):

The synthetic meat

- carries the keyhole label  indicating that it is healthier than comparable meat products (e.g., less salt, less fat)
- does not carry the keyhole label

Business model (2 categories):

- produced by a Norwegian company with Norwegian ingredients,
- produced by an international company with ingredients from the international market

With these categories and factors a full factorial design would require 4x3x2x2 combinations = 48 repetitions of the choice sets. This is too much for getting reliable answers from people. Hence, the individuals were (randomly) divided into 4 blocks so that each of the combinations of price, climate impact, health and business model could be covered. Every person answered 12 trials with different combinations of factor levels.

A typical choice set would look like:

You are in the supermarket and would like to buy meat for your family dinner. You have the choice between a traditional piece of farmed meat and a piece of synthetic meat of the same size. Both pieces of meat look similar with similar taste.

The synthetic meat is

- 20% more expensive than the farmed meat
- saves 90% climate gases as compared to the farmed meat

- Carries the keyhole label  indicating that it is healthier than comparable meat products (i.e less salt, less fat)
- is produced in Norway by a Norwegian company

Which piece of meat do you buy:

1) the farmed meat
2) the synthetic / cultured meat
3) none of the two

Based on their choices the individuals may be divided in four groups: 1) those who chose farmed meat at least once and synthetic meat at least once 2) Those who chose ordinary meat at least once, but never chose synthetic meat 3) those who never chose ordinary meat but chose synthetic meat at least once, and 4) Those who never chose farmed meat and never chose synthetic meat. Table 1 present the frequencies in each group.

Table 1.

Number of individuals who chose farmed meat and synthetic meat at least once

		Synthetic meat (chosen at least once)		
		Yes	No	
Farmed meat (chosen at least once)	Yes	139 (45.7)	127 (41.8)	266 (87.5)
	No	25 (8.2)	13 (4.3)	38 (12.5)
		164 (53.9)	140 (46.1)	304 (100)

Note: Percentage in parentheses

Table 1 shows that 164 individuals, 53.9% of the sample, accept synthetic meat, and chose it at least once in the experiment. 140 individuals, 46.1% of the sample did not choose synthetic meat one single time in the 12 choices. 103 of the individuals in the survey, 45.7%, chose both farmed meat and synthetic meat. These individuals are assumed to be price and income responsive. The individuals that chose synthetic meat at least once but never farmed meat are assumed to be responsive to the price of synthetic meat, but not to the price of farmed meat. The individuals that never chose synthetic meat, are assumed to be not price or income responsive.

Table 2.

Socioeconomic variables

Variable	Explanation	Mean	Sd
Male	=1 if sex is male, 0 otherwise	0.54	0.50
Univ	=1 if college education, 0 otherwise	0.51	0.50
Inc	= monthly household income before taxes in NOK	52939.28	29473.95
Age	= individual's age	45.17	17.24

Table 2 shows a summary of the socioeconomic variables. 54% of the sample is male, 51% have college education or more, average monthly income is about 53 000 NOK, and average age is 45 years.

3 Method

Our aim is to construct own-price elasticity for synthetic meat, cross-price elasticity between synthetic and farmed meat, and income elasticity for synthetic meat. Our data is 304 individuals with age between 17 and 80 years, where we know the monthly income, sex and education level. Further we know the choices they made to buy synthetic meat, farmed meat or none of the two, with different levels of relative prices, the saving of climate gases, health label, and if the synthetic meat was produced in Norway or imported.

According to the choices in table 1 we may assume something about the elasticities: Individuals who never choose synthetic meat do not like synthetic meat and will never choose synthetic meat regardless of price, climate gas saving, health label or origin. For these individuals, the own-price elasticity, the cross-price elasticity, and the income elasticity for synthetic meat is 0. According to table 1 this group consists of 46.1 % of the sample. For those who chose both synthetic meat and farmed meat the own-price elasticity is negative, the cross-price elasticity is positive, and the income elasticity is positive (or zero). This group consists of 45.7% of the sample. For those who eat synthetic meat, but not farmed meat the own-price elasticity is negative, the income elasticity is positive, but the cross-price elasticity between synthetic meat and farmed meat is 0. This group consist of 8.2% of the sample. To get the total aggregate elasticities we need to find the elasticities in each group and aggregate them according to the probability of belonging to the group.

But we also need some assumption about the quantity of meat consumed. How much will be chosen for different price levels? We opted for three different assumptions:

a) Constant value of synthetic meat
b) The quantity increase is half the price reduction
c) No change in quantity, the quantity increase with reduced prices is 0

Our basic piece of farmed meat is 0.150 kg with a price of 300 NOK/kg. This piece of meat has a value of 45 NOK. We have four price options for synthetic meat. The synthetic meat may be 50% cheaper, 20% cheaper, similar price, or 20% more expensive. The choices in the experiment are all between a similar quantity of farmed meat and synthetic meat. Table 3 List the quantities and prices for farmed meat (Q1, P1) and synthetic meat (Q2, P2). Below assumption 1) is described in more detail.

Assumption 1. Constant value of the synthetic meat:

When the synthetic meat is 50% cheaper the individuals chose between 0.3 kg of farmed meat and 0.3 kg of synthetic meat with a price of 300 NOK/kg for farmed meat and 150 NOK for the synthetic meat. The piece of synthetic meat will then cost 150·0.3= 45 NOK.

When the synthetic meat is 20% cheaper the individual chose between 0.1875 kg of farmed meat and 0.1875 kg of synthetic meat with a price of 300 NOK/kg for farmed meat and 240 NOK for synthetic meat. The piece of synthetic meat will then cost 240·0.1875=45 NOK

When prices are similar, both pieces are 0.150 kg, with a price of 300 NOK/kg, and the cost of the pieces of meat are each 300·0.150=45

When synthetic meat 20% more expensive, the individual chose between 0.125 kg of farmed meat and 0.125 kg of synthetic meat with a price of 300 NOK/kg for farmed meat and 360 NOK/kg for synthetic meat. The piece of synthetic meat will then cost 360·0.125=45 NOK. The options with the different alternatives are stated in table 3

Table 3.

Assumptions for prices and quantity for farmed meat (Q1, P1) and synthetic meat (Q2, P2)

		Q1 (kg)	P1 (NOK/kg)	Q2 (kg)	P2 (NOK/kg)	Value q2 (NOK)
Assumption 1	-50	0.300	300	0.300	150	45
	-20	0.1875	300	0.1875	240	45
	0	0.150	300	0.150	300	45
	+20	0.125	300	0.125	360	45
Assumption 2	-50	0.1875	300	0.1875	150	28.125
	-20	0.165	300	0.165	240	39.6
	0	0.150	300	0.150	300	45
	+20	0.135	300	0.135	360	48.6
Assumption 3	-50	0.150	300	0.150	150	22.5
	-20	0.150	300	0.150	240	36
	0	0.150	300	0.150	300	45
	+20	0.150	300	0.150	360	54

When constructing the price and quantity variables for farmed meat and synthetic meat we drew all the Q1, Q2, P1, P2 from normal distributions with the numbers in table 3 as means and small standard deviations. This was done to avoid singularity problems.

To estimate the demand for synthetic meat with the three different price-quantity assumptions we used a simple two step model. In the first step we estimated a probit model for the probability of choosing synthetic meat. In the second stage, conditional on a positive purchase we estimated an ordinary least squares regression on log form.

$$1) \qquad P(Q2 > 0|x) = \Phi(x'\alpha)$$

$$2) \qquad E(\log(Q2|Q2 > 0, z) = z'\beta$$

where

x'=(log(P2/P1), log (Inc), Univ, Male, Label, Local, K2, K3)

z'=(log(P2/P1), log (Inc), Univ, Male, Label, Local)

where P1 is the price of farmed meat, P2 is the price of synthetic meat, Inc is an income variable, Univ is a dummy for university education, Male is a dummy for male, Label is a dummy for key-whole label, Local is a dummy indicating that synthetic meat is produced in Norway, K2 is a dummy indicating that the synthetic meat emits 50% less greenhouse gases than farmed meat, K3 is a dummy indicating that synthetic meat emits 90% less greenhouse gases than farmed meat. Φ is the cdf for the standard normal distribution and α and β are parameter vectors to be estimated. Combining 1) and 2) the law of iterated expectation gives

$$3) \qquad E(\log(Q2|, x, z) = (z'\beta)\Phi(x'\alpha)$$

According to table 1 we may construct three groups with different elasticities. The group that doesn't chose synthetic meat independent of the price, the group that chose both farmed and synthetic meat, and the group that chose synthetic meat but not farmed meat. Differentiating log(Q2) with respect to the log of the prices and the log of the income we get the formulas in table 4, where ϕ is the pdf of the standard normal distribution.

Table 4.

Elasticities for the different groups of consumers

	Own-price elasticity	Cross-price elasticity	Income elasticity
1: Never chooses synthetic meat	0	0	0
2: chooses both synthetic and farmed meat	$\beta_2\Phi(x'\alpha) + \alpha_2\phi(x'\alpha)z'\beta$	$-\beta_2\Phi(x'\alpha) - \alpha_2\phi(x'\alpha)z'\beta$	$\beta_3\Phi(x'\alpha) + \alpha_3\phi(x'\alpha)z'\beta$
3: chooses synthetic but not farmed meat	$\beta_2\Phi(x'\alpha) + \alpha_2\phi(x'\alpha)z'\beta$	0	$\beta_3\Phi(x'\alpha) + \alpha_3\phi(x'\alpha)z'\beta$

Note: In group 3, P1 was replaced by 1 in the equations and the elasticity formulas

4 Results

We estimated the model 1) and 2) for group 2 and 3 in table 4. The results are in table 5. The first step, the probit regressions, have equal results under the three different assumptions. That is because the assumptions are dealing with the size of the quantity, but not of the choice itself. Table 5 shows that for group 2 the significant estimates are relative prices, the health label, and if the synthetic meat is produced in the most climate friendly way (save 90% of the climate gases compared to farmed meat). For group 3 relative prices did not have effect. What actually had significant effect was the education level of the individuals and the age. In step 2, for all the assumptions, relative prices was the only significant variable.

Table 5.

Results from the estimations

	Assumption 1		Assumption 2		Assumption 3	
	Group 2	Group 3	Group 2	Group 3	Group 2	Group 3
Step 1. Probit						
Intercept	0.65	-4.07	0.65	-4.07	0.65	-4.07
Log (p1/p2)	-1.28	-0.29	-1.28	-0.29	-1.28	-0.29
Log (Inc)	-0.09	0.22	-0.09	0.22	-0.09	0.22
Univ	0.04	0.65	0.04	0.65	0.04	0.65
Male	0.12	-0.17	0.12	-0.17	0.12	-0.17
Log (Age)	-0.08	1.07	-0.08	1.07	-0.08	1.07
Label	0.16	0.05	0.16	0.05	0.16	0.05
Local	0.12	0.04	0.12	0.04	0.12	0.04
K2	0.08	0.12	0.08	0.12	0.08	0.12
K3	0.18	0.31	0.18	0.31	0.18	0.31
Step 2 OLS						
Intercept	0.52	6.15	0.49	2.20	0.47	-0.15
Log (p1/p2)	-0.95	-0.99	-0.25	-0.31	0.13	0.09
Log (Inc)	0.01	0.00	0.01	0.01	0.01	0.01
Univ	0.01	0.00	0.02	0.01	0.02	0.00
Male	-0.01	-0.02	-0.01	-0.03	-0.01	-0.03
Log (Age)	-0.01	0.01	0.00	0.02	-0.01	0.02
Label	0.01	-0.01	0.01	-0.01	0.01	-0.01
Local	0.00	0.01	0.01	0.00	0.01	-0.01
R2	0.79	0.80	0.13	0.21	0.03	0.02

Note: Significant results marked with bold

We used the elasticity formulas in table 4 and the parameter estimates in table 5 to construct the elasticities. All the elasticities are evaluated at the mean values of the variables. The combined elasticities are then a weighted mean of the elasticities in the groups, where the frequencies in table 1 are used as weight.

Table 6.

Estimated elasticities for synthetic meat

	Assumption 1			Assumption 2			Assumption 3		
	Own-price	Cross-price	Income	Own-price	Cross-price	Income	Own-price	Cross-price	Income
Group 1	0	0	0	0	0	0	0	0	0
Group2	-0.87	0.87	-0.02	-0.43	0.43	-0.02	-0.19	0.19	-0.01
Group3	-0.89	0	0.03	-0.30	0	0.03	0.05	0	0.03
Total	-0.47	0.40	-0.01	-0.22	0.20	0.00	-0.08	0.09	0.00

Table 6 shows that the own-price elasticities in group 2 are -0.87, -0.43 and -0.19 for the three different assumptions. The cross-price elasticities are similar but with different size. This is because of how the model looks like, a simple linear model on log form with relative prices as covariate. For group 3 the own-price elasticities are -0.89, -0.22, and 0.05. The last number is probably not significant and can be set to 0. The cross-price elasticities are forced to be 0. All the income elasticities are close to 0 in both groups for all the assumptions. The total elasticities are weighted averages of the elasticities in the three groups. The own-price elasticities are -0.47, -0.22, and -0.08 for the three assumptions. The cross-price elasticities are 0.40, 0.20 and 0.09 for the same assumptions. And the income elasticities are close to 0.

5 Discussion and conclusion

Do we believe in these numbers? A weighted average of the three own-price elasticities is -0.26. We think that an own-price elasticity for synthetic meat between -0.25 and -0.50 is plausible. In the forecast model of Gustavsen and Rickertsen (2018) the Norwegian own-price elasticities for farmed beef/lamb, pork, and chicken were estimated to -0.92, -0.92 and -0.82 respectively. Gustavsen (2015) estimated cohort specific elasticities for farmed meat, vegetables, and fish in Norway. For meat the own-price elasticities varied between -1.22 and -1.55. Abadie et al (2016), also in the Norwegian setting, estimated own-price elasticities for farmed ruminants, pork, and chicken to be -1.20, -0.79, and -0.50.

In assumption 3, the own-price elasticity was estimated close to 0. The reason for that was that quantity of meat was constant, independent of the price level. But this is contrary to demand theory (Deaton and Muellbauer, 1980) in which individuals choose a higher quantity when prices of the same good is lower. The own-price elasticities for farmed meat are higher in absolute value, but this can be explained by the share of Norwegians who eat ordinary meat. Table 1 shows that 88% of the sample chose farmed meat at least once compared to 54% who chose synthetic meat at least once.

The estimated cross-price elasticities are in the same size as the estimated own-price elasticities. But this are attributed to model and the information we have. In this data set we only have relative prices. In other studies, the cross-price elasticities are often a lot smaller than the own-price elasticities.

The cross-price elasticities for most food products are most often closer to 0 than the own-price elasticity because the consumer choose among a lot of different alternatives. Then the price effect will be spread out. In Abadie et al (2016) the level of the cross-price elasticity of pork on ruminants was 30% of the level of the own-price elasticity of ruminants. The level of the poultry effect on ruminants was 20% the level of the own-price elasticity of ruminants.

The estimated income effect was close to 0. This seems very low. In the papers cited above, the income elasticities for different cuts of farmed meat expenditure elasticities were estimated to be in the interval 0.3 to 0.7.

Given the appropriateness of the results, the own-price elasticity of synthetic meat seems to be lower in absolute value than that of farmed meat. This would mean that consumers of synthetic meat are less price sensitive than consumers of farmed meat. This result seems reasonable since synthetic meat is not yet on the market. Consumers may not yet have full knowledge about the benefits and disadvantages of synthetic meat and may therefore be more cautious.

If the survey results were valid in a situation in which synthetic meat is available on the market, we could infer that the market for synthetic meat is limited. About one half of the respondents would still choose farmed meat and reject synthetic meat. Hence, the market potential of synthetic meat would be restricted to half of the size of the current meat market. Although it would mean a very substantial reduction of farmed meat consumption (and production), the introduction of synthetic meat in Norway would not mean the abolition of farmed meat production. There would still be a sizeable amount of meat production, probably in connection with dairy production. An interesting question for further research in this regard would be whether synthetic meat is more likely to replace fresh meat cuts or processed meat, and also whether synthetic meat is more likely to replace which type of meat (beef, lamb, pork, poultry). Finally, these questions could be studied in more detail using agricultural sector models for which the estimation of demand elasticities for synthetic meat is a prerequisite.

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