



Sustainability and Potato Consumption

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Abstract

This paper analyses the frequency of the consumption of table potatoes in Norway. The analysis shows that the frequency of potato consumption is higher in older cohorts than in younger, and it declines over the life cycle. This indicates that the total consumption will continue to decrease as older potato eating cohorts are replaced with younger cohorts who eat potatoes less frequently. This is bad for food security, it is bad for nutritional health and it is bad for the environment. It is argued that nutritional and environmental organizations should work together to increase the status of the potato.

Keywords Age-period-cohort model · Double-bounded beta regression · Potato consumption · Sustainability

JEL Classification D12 · J10 · Q10

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Introduction

The world population is predicted to reach 9.7 billion people by 2050. According to the Food and Agriculture Organization of the United Nations (FAO 2018), the agricultural output will increase by 40–50 percent dependent upon the degree of sustainable development. This increase in agricultural production will have tremendous consequences in terms of land degradation, natural resource use and greenhouse gas emission. There will be a need to reorient the food system¹ in a more sustainable direction. This means that the food consumption and production should have a greater focus on sustainability, towards production and consumption of foods that have a lower carbon footprint, and a minimal use of land to produce food. The potato is exceptional in this sense in that it has a low CO₂ footprint and requires less land than many other fruits, vegetables and cereals. In addition, it contains most of the nutrients people need. Potatoes also contain essential sulphur-containing amino acids that are relatively scarce in other food stuffs². Nunn and Qian (2011) found that the introduction of potato in Europe accounted for approximately one quarter of the growth in population and urbanization between 1700 and 1900. The nutritional and caloric superiority of the potato also contributed to an increase in adults' height. There are more than 4500 different varieties of potato and they may be produced in a wider range of climate than any other plant (International Potato Center 2019). In 2008, FAO declared the potato as a future food crop and a major contributor towards food security, and that year was declared as the year of potato (FAO 2008).

In Norway, the Second World War resulted in food shortages, but the Norwegian population did not suffer from malnutrition and hunger mainly due to the traditional Norwegian protective foods: herring and potatoes (Njølstad 2016). The war resulted in changes in food consumption habits in Norway; potatoes became a staple food among ordinary people, and remained an important part of the diet also after the war. However, the consumption has been declining. The consumption of unprocessed table potatoes in Norway was 103 kg per capita in 1949, 89 kg in 1969 and 23 kg in 2015. Simultaneously, the consumption of less healthy processed potato products has increased from 5 kg per capita in 1969 to 28 kg in 2015. Figure 1 shows the development in potato consumption from 1989 to 2015, which corresponds to our data period. The main information we can see from the figure is that the per capita consumption of potatoes declined in the period 1989–2015, the period we are investigating. The consumption of table potatoes declined by almost 60 percent in that period. Processed potatoes, which consist mainly of French fries, chips and potato salad, increased by about 35 percent in the same period.

In the next section, a literature review about sustainability and food consumption with emphasis on potato consumption is presented. In the following section, the methods are described. First, data from the Norwegian Monitor database is introduced. After that, the double-bounded beta regression model is presented. Next, the estimation

¹ FAO (2018) defines food systems in the following way: food systems encompass the entire range of actors and their interlinked value-added activities involved in the production, aggregation, processing, distribution, consumption and disposal of food products that originate from agriculture, forestry and fisheries, and parts of the broader economic, societal and natural environment in which they are embedded.

² Thanks to a referee for informing me about that.

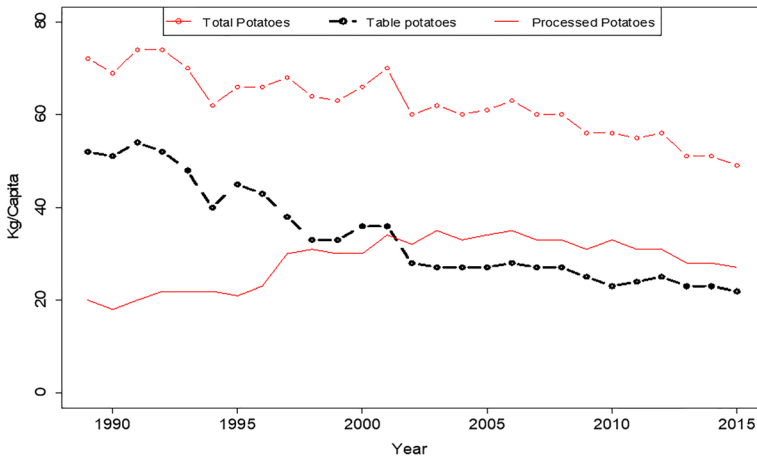


Fig. 1 Per capita consumption of table potatoes, processed potatoes and total potatoes in Norway from 1989 to 2015 (source: Budsjettnemnda for jordbruket)

results with the simulation and the elasticities are presented. Then, a discussion section follows and finally the paper concludes.

Sustainable Diets and Potato Consumption

The food and agriculture organization of the United Nations defines a sustainable diet as (FAO 2016): “Those diets with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy; while optimizing natural and human resources.”

Boiled potatoes should be included in a sustainable diet: potatoes are a good source of several B vitamins, vitamin C, dietary fiber, potassium, folate and iron. They are rich in carbohydrates and energy and have little fat. In addition, they contain a lot of antioxidants (Camire et al. 2009). In recent years, potatoes have gained a poor reputation due to some observational studies linking potatoes to obesity (French et al. 1994; Halkjær et al. 2009; Mozaffarian et al. 2011) and risk of diabetes 2 (Halton et al. 2006; Muraki et al. 2016). Yet, at the same time, there are studies showing that potato eating has no effect on obesity (Halkjær et al. 2004; Linde et al. 2006) or negative effects on diabetes 2 (Villegas et al. 2007; Farhadnejad et al. 2018). According to Robertson et al. (2018), these studies may be biased since they do not separate boiled potatoes and baked potatoes from French fries. In addition, these studies do not control for red meat or other dietary factors that could account for the association. Borch et al. (2016) conducted a systematic review of observational studies examining the link between obesity and potato eating and diabetes 2 and potato eating. They concluded that there is no evidence of an association between potato consumption and obesity or potato eating and diabetes 2. One advantage with potatoes is that they have a very high rating of satiety. It means that people get more satisfied (or filled up) compared to the equal number of calories from other food. Holt et al. (1995) found that among 38 of the

most common foods in Australia, boiled potatoes has the highest satiety score. The satiety of potatoes was confirmed by Erdmann et al. (2007) who compared potatoes with rice and pasta. They found that the satiety of potatoes ingested together with meat was greater for potatoes than for rice and pasta. The Norwegian Directorate of Health (Helsedirektoratet 2017) has no quantitative recommendation regarding potato consumption. The Directorate states that potatoes are part of a varied diet and boiled and baked potatoes should be eaten instead of fried potatoes.

2008 was declared the international year of the potato by the United Nations (FAO 2008). It is stated that the potato yields more nutritious food more quickly on less land and in harsher climates than any other major crop: up to 85 percent of the plant is edible human food, while for cereals the figure is around 50 percent. It has low carbon footprint compared to most other foods (Rose et al. 2019; Bruno et al. 2019; Mertens et al. 2019), it has low water footprint compared to most other foods (Mekonen and Hoekstra 2012) and it uses less land per kg production compared to most other food (Mertens et al. 2019). Unfortunately, the potato also has some disadvantages: it requires a relatively large amount of seed tubers to be used for starting material, and it is very perishable³. The potato is not a globally traded commodity, so potato prices are normally determined by local production costs. It is therefore a highly recommended food security crop that can help low-income farmers and vulnerable consumers ride out turmoil in world food supply and demand (FAO 2008). Masset et al. (2014) combined environmental, nutritional and affordability indicators to identify sustainable foods in France. Potatoes were among the foods with lowest GHG emissions, lowest air acidification and lowest freshwater eutrophication and with high nutritional quality. Potatoes were one of the cheapest food items and it was the commodity with the lowest price per energy content. Masset et al. (2014) concluded that a sustainable diet should contain high amounts of legumes, potatoes and dairy products.

Data and Methods

The purpose of this paper is to analyse the downturn in potato consumption from a generational perspective. If we assume that equal amount of potatoes is eaten on each occasion, then the frequency of potato consumption is proportional to total potato consumption. We use bi-yearly frequency data from 1989 to 2015 to model individual potato consumption. For this data, the beta regression model is well suited because the relative frequency varies between 0 and 1, as the beta distribution.

The beta distribution is a continuous statistical probability distribution in the interval (0, 1). The probability density of the beta distribution has two parameters that define the shape of the distribution. Depending on the combination of the parameter values, the distribution can assume a number of different shapes, and this makes it very flexible and well suited for statistical modelling. The distribution can also be reparametrized to include a mean and a dispersion parameter instead of the original parameters. This way,

³ Thanks to a referee for informing me about that.

it is possible to link covariates to the mean of the outcome, and this way to define a likelihood function based on regression variables and parameters. Maximizing this likelihood function will then give the estimated parameters in a beta regression model. But the beta distribution does not include the limits 0 and 1. And in the model, we must include individuals who never eat potatoes, and individuals who eat potatoes every day. Hence, probability measures are included in the endpoints. The transformation of the outcome variable, from intervals to a continuous variable, is done by simulation, as explained below.

Data

We analysed the frequency of consumption of unprocessed food potatoes using the Norwegian Monitor (NM) survey. This survey is a nationally representative cross-sectional survey of adults that has been repeated every second year since 1985. In each survey, 3000–4000 respondents answer questions about food consumption, health, time use and preferences. The respondents are drawn from the Norwegian population who are 15 years and above, from telephone directories. In the first round, respondents are interviewed by telephone. The respondents then answer the bulk of the questions in a self-completion questionnaire. The frequency of potato consumption was introduced in NM for the first time in 1989. The NM database is explained in Hellevik (2016). NM has been used in a lot of other research, including Øvrum et al. (2014) and Gustavsen and Rickertsen (2018).

Our analysis focused on the answers to two questions: (i) how often do you eat boiled potatoes, and (ii) how often do you eat baked potatoes? The respondents checked one of the following responses: every day, 3–5 times a week, 1–2 times a week, 2–3 times a month, about once every month, 3–11 times a year, less than 3 times a year or never. Table 1 shows the frequency of potato eating in the NM database from 1989 to 2015. Table 1 shows that 16 percent eat boiled potatoes every day, while most people, 45 percent, eat boiled potatoes 3–5 times a week. Seven percent eat boiled potatoes once a month or less. Baked potatoes are less frequently used. Just 2 percent eat baked potatoes weekly. This means that the probability distribution will have a spike in 1, since there are approximately 16 percent that eat table potatoes every day. In

Table 1 Frequencies and percentages of table potato consumption

	Every day	3–5 times per week	1–2 times per week	2–3 times per month	1 time per month	3–11 times per year	Less	Never	Total number of obs
Frequencies									
Boiled	7154	19914	9649	3845	1407	1155	520	197	43,841
Baked	24	99	806	3711	6293	14147	14238	4107	43,425
Percentages									
Boiled	16.3	45.4	22.0	8.8	3.2	2.6	1.2	0.4	100.0
Baked	0.1	0.2	1.9	8.5	14.5	32.6	32.8	9.5	100.0

the other limit, the spike will be low since few individuals eat neither baked nor boiled potatoes.

Table 2 shows the covariates used in the beta regression model. The average age in the data sample is 44.7 years and the average individual was born in 1958. Twenty-eight percent of the data is in the period 1989–1997; 40 percent of the data is in the period 1997–2007. Hence, 32 percent of the data is in the period 2009–2015. Real household income⁴ per consumer unit is 372,000 NOK⁵, measured in 1998 prices. The real price of potatoes is an index measuring the nominal prices deflated by the consumer prices with base year 1998. Furthermore, we see that 48 percent of the individuals in the sample have a university education, 54 percent are women, 71 percent are married, or cohabit and 37 percent of the women are married. Before the estimation process, the continuous variables are divided by their maximum value to have the variables on the same scale, and to avoid numerical problems in the estimation process. The sample consists of individuals from 20 to 85 years old who were born after 1930.

As we were interested in overall unprocessed potato consumption, we aggregated the two frequencies by first calculating the yearly intervals of consumption of boiled and baked potatoes, respectively, for each respondent. Then, within each interval and for each respondent, we drew the frequency from a uniform distribution with the limits of the intervals used as the limits of each distribution. The alternative “every day” is set to 365 days and the alternative “never” is set to 0 days. Finally, we added the consumption frequencies of the two types of potatoes and restricted the frequency to between 0 and 365 days. Dividing these frequencies by 365, we obtained a double-bounded beta distribution.

Table 2 Summary statistics

		Mean	SD
APC variables			
<i>A</i>	Age	44.73	14.47
<i>C</i>	Cohort (birth year)	1958.50	13.82
<i>P</i> ₁	= 1 if survey period is 1989–1997	0.28	0.45
<i>P</i> ₂	= 1 if survey period is 1999–2007	0.40	0.49
Socioeconomic variables			
<i>I</i>	Real household income	372.66	188.04
<i>Price</i>	Real price of potato	0.71	0.18
<i>E</i>	= 1 if university education	0.48	0.50
<i>W</i>	= 1 if woman	0.54	0.50
<i>M</i>	= 1 if married	0.71	0.18
<i>WM</i>	= 1 if woman and married	0.37	0.48

⁴ The nominal income per consumer unit deflated by the consumer price index with 1998 as base year.

⁵ In January 1999, 1€ = 8.66 NOK.

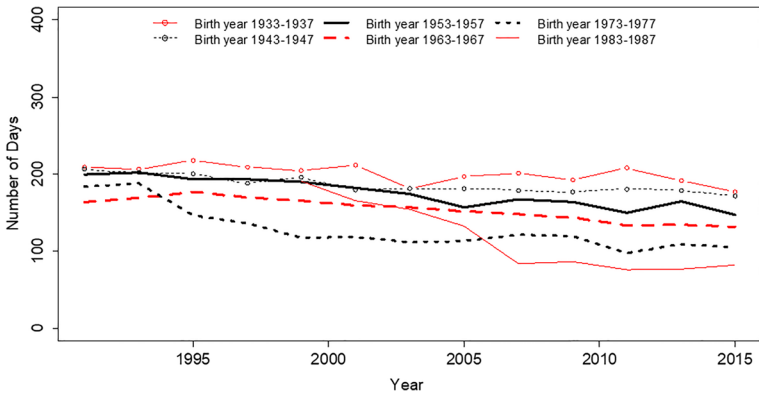


Fig. 2 Yearly number of potato eating days in cohorts

Figure 2 shows the development in yearly frequency of consumption of table potatoes in 6 different cohort groups, aggregated in 5-year intervals. We see that the frequency of potato consumption declines in each cohort group in the period from 1989 to 2015. In addition, older cohorts eat table potatoes more frequently than younger cohorts. The figure indicates a positive cohort effect and a negative period effect.

But if we rearrange the graphs in Fig. 2, and put age on the x-axis instead of year, we get a different picture. The graphs in Fig. 3 progress from the youngest cohort to the oldest starting with the youngest on the left, the solid red line, to the oldest on the right with broken red line with circles. We see that for every cohort, when measured at the same age, the older cohort eats potatoes more frequently than the younger cohort. And in every cohort, the potato frequency declines over the life cycle. This indicates a negative age effect, the consumption frequency declining with age. In addition, the figure indicates a positive cohort effect. To get the whole picture, we also have to take into account other variables as well.

To find out more about the decline in the frequency of potato consumption, we have to find the effects of economic factors such as prices and income; the effects of age, cohort and period; and the effect of socioeconomic factors such as education, marital status and gender. We use the data with a double-bounded beta regression model to

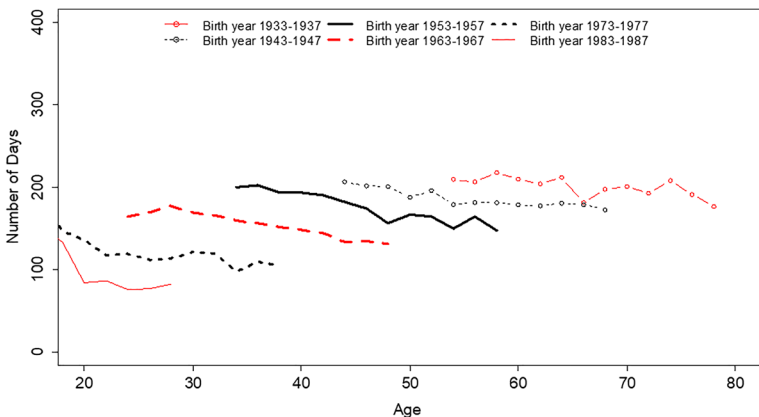


Fig. 3 Yearly number of potato eating days in cohorts

estimate the consumption frequency of table potatoes. And we use the estimated model to simulate the frequency of potato consumption over the life cycle.

The Double-Bounded Beta Regression Model

The beta distribution for a continuous variable q is a two-parameter distribution within the range of $(0, 1)$. If we think of this as a relative frequency of yearly potato eating, we also have to take account of individuals who never eat potatoes ($q = 0$) and individuals who eat potatoes every day ($q = 1$). Assuming that the frequency of potato consumption, q , is beta distributed, i.e.

$$f(q|a, b) = \frac{\Gamma(a+b)}{\Gamma(a)\Gamma(b)} q^{a-1} (1-q)^{b-1}, \quad 0 < q < 1 \quad (1)$$

where $\Gamma()$ is the gamma function, and a and b are parameters.

To be able to include covariates the beta distribution is reparametrized as in Ferrari and Cribari-Neto (2004). But we must also include individuals who never eat potatoes, and individuals who eat potatoes every day. This is done by including the probabilities of never eating potatoes (P_0) and the probabilities of eating potatoes every day (P_1). Assuming the same covariates in the three parts, the whole conditional distribution then becomes:

$$f(q|x) = \begin{cases} P_0(x) & \text{if } q = 0 \\ P_1(x) & \text{if } q = 1 \\ f(x) & \text{if } (0 < q < 1) \end{cases} \quad (2)$$

where $f(x)$ in our case is the beta distribution. The likelihood function will then be based on

$$(1-P_0(q=0|x)-P_1(q=1|x))f(q|x) \quad (3)$$

The model may then be estimated with the R package GAMLSS, where the probabilities are included as odds ratios with log link functions to include covariates in the likelihood function (Stasinopoulos et al. 2017). We bootstrap the model to find the beta regression parameters, their elasticities and covariance matrices, and we simulate the model over the life time for five different cohorts.

Estimation Results

To estimate the model, we first have to transform the intervals in Table 1 to a continuous beta distribution. Within each interval and for each respondent, we drew the frequency from a uniform distribution with the limits of the intervals used as the limits of each distribution⁶. The alternative “every day” was set to 365 days and the

⁶ In the cases where the upper limit of the lower interval does not meet the lower limit of the interval next to it, the limits are set in the midpoint between them.

alternative “never” was set to 0 days. First, for each individual, we drew the frequency of boiled potato consumption; then, we drew the frequency of baked potato consumption. We then added the two frequencies, setting frequencies larger than 365 as 365. Dividing each observation by 365, we have the continuous beta distribution in the interval (0, 1) and bounds in 0 and 1. Doing the bootstrap, $N \times K$ draws, where $N = 43841$ and $K = 500$, were performed. N = the number of individuals and K is the number of bootstrap repetitions.

The GAMLSS package in R is used to estimate the beta regression model. In this model, the likelihood function (3) is used with the beta distribution and logit link functions. In addition, the odds ratios $O_0=P_0/P_2$ as the odds of not eating table potatoes and $O_1=P_1/P_2$ as the odds of eating table potatoes every day where $P_2=(1-P_0-P_1)$ and the odds ratios have log link functions. The result from the estimation of the frequency of potato consumption is shown in Table 3.

The first two columns show the estimated parameters with their corresponding standard deviations from the O_0 part of the likelihood function, i.e. the odds of not eating potatoes. The next two columns show the beta regression part of the model, and the last two columns show the estimated parameters and standard deviations for the odds of eating potatoes every day.

We see from the O_0 part of the model that few parameters are significantly different from zero. But cohorts with higher numbers (younger cohorts) have higher odds of not eating potatoes than older cohorts. And married individuals have lower odds of not eating potatoes. Both of these results are highly plausible. From the beta regression part of the model, as expected from Fig. 3, we see that the frequency of potato consumption

Table 3 Estimation results for double censored beta (BE) regression for potato consumption

Variable	Description	O_0		BE (0, 1)		O_1	
		Parameter	SD	Parameter	SD	Parameter	SD
Intercept		-13.35	(5.05)	4.33	(0.30)	7.02	(2.10)
APC variables							
A	Age	6.26	(11.41)	-3.36	(0.64)	-20.09	(4.56)
A_2	Age squared	1.87	(6.52)	1.32	(0.37)	10.53	(2.39)
C	Cohort (birth year)	8.96	(4.36)	-4.89	(0.26)	-11.51	(2.14)
A_C	Interaction term	-5.38	(7.22)	0.77	(0.42)	11.50	(3.33)
P_1	First survey period	-0.11	(0.65)	0.07	(0.04)	0.43	(0.24)
P_2	Second survey period	-0.51	(0.52)	0.03	(0.03)	0.19	(0.20)
Socioeconomic variables							
I	Income	1.96	(2.65)	-1.20	(0.16)	-0.52	(1.06)
I_2	Income squared	-6.55	(5.06)	0.29	(0.25)	-1.12	(1.90)
$Price$	Real price of potato	0.76	(1.05)	-0.14	(0.06)	0.24	(0.37)
E	University education	0.11	(0.19)	-0.21	(0.01)	-0.38	(0.08)
W	Woman	-0.44	(0.25)	-0.16	(0.02)	-0.30	(0.13)
M	Married	-1.53	(0.28)	0.41	(0.02)	0.28	(0.11)

Note: The estimation results are based on 500 bootstraps

decreases with age, but it decreases non-linearly. Cohorts with higher birth year (younger cohorts) eat potatoes less frequently than older cohorts. The income effect is negative, and the price effect is negative. Individuals with a university education eat potatoes less frequently than individuals without university education and females eat potatoes less frequently than males. Marriage has a positive impact on the frequency of potato eating. From the O_1 part of the model, we see that the odds of eating potatoes every day decreases with age (for individuals inside the same cohort). In addition, older cohorts (cohorts with a lower birth year) have higher odds of eating potatoes every day than cohorts born in later periods. University-educated individuals have lower odds of eating potatoes every day while women have lower odds than men, but marriage increases the odds of eating potatoes every day. All of these results are highly plausible.

Simulation of Potato Consumption over the Life Cycle for five Different Cohorts

The model is used to simulate the frequency of potato consumption over the lifetime for the five cohort groups. We constructed the expected frequencies in the following way: first, we found the odds ratio from their respective link functions by inserting their inverses: $O_0 = \exp(x'\beta_0)$ and $O_1 = \exp(x'\beta_1)$. Then, the probabilities are found by

$$P_0 = O_0 / (1 + O_0 + O_1) \text{ and } P_1 = O_1 / (1 + O_0 + O_1) \quad (4)$$

Then, the expectation is found by:

$$E(q|x) = \left((1 - \hat{P}_0 - \hat{P}_1) \hat{\mu} + \hat{P}_1 \right) \cdot 365 \quad (5)$$

The estimated P_0 and P_1 in 5 are inserted from (4) and the estimated μ is calculated from the logit link function and the estimated parameters in Table 3.

The results in Table 3 are used to simulate consumption frequency over the life time. In Fig. 4, we show the simulated frequencies for five different cohorts: cohorts born in 1955, 1965, 1975, 1985 and 1995. The results show that the frequency of potato consumption decreases with age over most of the life time and older cohorts have larger consumption than younger cohorts. As older cohorts are replaced by younger cohorts, who have a similar consumption pattern as the youngest cohorts in the sample, the consumption frequency of unprocessed potatoes is expected to continue to decline.

Marginal Effects

Marginal effects of price, income, age, period, cohort, education, gender and marital status are estimated. These effects are estimated for five birth cohorts: born in 1955, 1965, 1975, 1985 and 1995. The marginal effects of age for each cohort are calculated in the following way: expected consumption frequencies for each age 20, 21, ..., 85 are found using Eqn (5) while all the other variables are

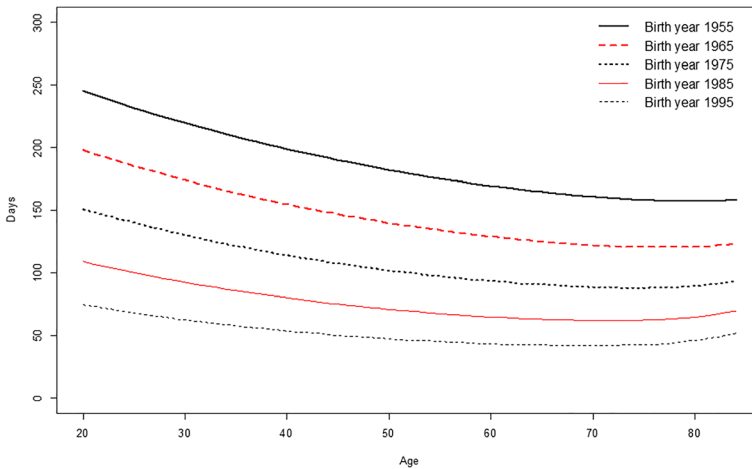


Fig. 4 Simulation of frequency of potato eating days in cohorts

kept at their mean values in 2015. The differences between frequencies for age a and age $(a-1)$ are then found for each age group. Then, averages over the life cycle are calculated. The same for cohort y , the difference between consumption frequency for the cohort born in year y and year $(y-1)$ is found. The differences in consumption frequency are then calculated for each age 20, 21, ..., 85. For income, the differences in consumption frequency between individuals with mean income in 2015 and individuals with 1 percent higher income are calculated for each age. For price, the difference in expected frequency when the real price of potato is as in 2015 and 1 percent increase is calculated. For the indicator variables, the difference in consumption frequency between individuals with and without university education, the differences between males and females and the differences between married and not married, holding the other variables at 2015 level, are calculated for each age 20, 21, ..., 85, and average values are calculated.

We see from Table 4 that the age effect is significantly negative for individuals born in 1955 and 1965, but not significant for the other cohorts. For individuals born in 1955, the expected reduction in yearly frequency of potato eating is 1.4 times per year. For the older age groups, the marginal effect of cohort represents an increase in the consumption frequency of four times per year, i.e. for two identical respondents with a 1-year difference in the birth year, the oldest respondent is expected to eat potatoes four times more per year. For the younger respondents, the corresponding difference is about two times per year. The income effects are negative but insignificant and the price effects are small but significantly different from zero at 5 percent level. Males eat potatoes more often than females, married respondents eat potatoes more often than unmarried and respondents without a university education eat potatoes more often than those with a university education.

Table 4 Marginal frequency effects in different cohorts

Year of birth of cohort	1955	1965	1975	1985	1995
Age	-1.41 (0.31)	-1.24 (0.43)	-0.96 (0.51)	-0.63 (0.57)	-0.31 (0.64)
Cohort	-4.29 (0.21)	-4.08 (0.22)	-3.51 (0.17)	-2.76 (0.13)	-2.02 (0.12)
Income	-0.82 (0.51)	-0.86 (0.54)	-0.82 (0.54)	-0.72 (0.51)	-0.60 (0.47)
Price	-0.05 (0.02)	-0.05 (0.02)	-0.05 (0.02)	-0.04 (0.02)	-0.03 (0.02)
University education	-20.33 (1.07)	-19.42 (1.15)	-16.85 (1.28)	-13.43 (1.45)	-10.00 (1.61)
Woman	-14.41 (2.11)	-13.39 (2.27)	-11.23 (2.34)	-8.59 (2.30)	-6.06 (2.18)
Married	38.43 (2.11)	36.88 (2.41)	32.20 (2.47)	25.95 (2.43)	19.70 (2.43)
Difference period 3–period 1	-8.51 (3.92)	-7.94 (4.26)	-6.89 (4.36)	-5.62 (4.29)	-4.40 (4.15)
Period 3–period 2	-4.30 (2.89)	-4.26 (2.94)	-3.97 (2.85)	-3.52 (2.72)	-3.03 (2.62)

Note: The estimation results are based on 500 bootstraps. Standard deviations in parentheses

Discussion

The decline in potato production and consumption is an unwanted development because the potato is one of the most environmentally friendly crops⁷. It has a low CO₂ emission. It requires less area than other crops. It is vegetatively propagated (only one plant is involved and the offspring is the result of only one parent). The advantage of this is that commercial growers can reproduce the highest quality plants and ensure consistency of a variety of crop for sale (Science Learning Hub 2013)⁸. The potato is calorie-rich and nutritious, and it will play a potentially important role in feeding an increasing world population. It is important regarding food security. It means that we should be eating potatoes more often, not less.

The results in Table 3 and Table 4 together with Fig. 4 show that the consumption frequency of table potatoes is expected to decrease further in the future. That is because the consumption frequency in older cohorts is higher than in younger cohorts. That means that as earlier generations of potato eaters are replaced by following generations, the aggregate consumption frequency is expected to decrease. And the decrease in consumption frequency over the life cycle contributes to the downturn. This development is not surprising, however. The implication of Engel's law is that within the food budget, cheaper and more starchy foods, as rice, potatoes and bread, are predominant for the poor (Clements and Si 2017). The consequence of income increase is that the

⁷ However, heavy pesticide usage is a potential problem.

⁸ The main disadvantage of vegetative propagation is tuber borne diseases and the potential to impact on biodiversity (Science Learning Hub 2013).

demand for higher quality food will increase at the expense of the staple food. And this is what happened in Norway all the years after the WW2. The decrease in potato consumption was offset by an increase in other staples, but also more diversity. Wandel et al. (2001) indicate that 60–70 percent of the decline of potato consumption (by energy) in Norway between 1976 and 1997 was compensated by alternative staple foods, but the remaining 30–40 percent was made up by ready-made foods such as pizza, hamburgers, rice, porridge and omelets. Wood et al. (2017) suggest that the main reason for decline in potato consumption among Australian consumers was that “potatoes are high in carbohydrates” and that “starchy vegetables are not healthy”.

So, what can be done to reduce the downturn in potato consumption? From Table 4, we see that prices and income have small and unsure effects. In addition, we see that university-educated individuals eat potatoes less often than non-university-educated individuals. This indicates that table potatoes have low status in the population. The potato gained a bad reputation through the introduction of various low-carb diets, like the Atkins diet⁹. In addition, research linking the potato to obesity, diabetes and cardiovascular disease has further increased the potato’s bad reputation. For example, Ek et al. (2014) and Muraki et al. (2016) associated the potato with weight gain and the risk of type 2 diabetes. But other studies contradict this: Linde et al. (2006) found that potato consumption is not associated with obesity and Attah et al. (2017) found that diabetes, overweight and obesity were associated with low potato consumption. Borch et al. (2016) did a systematic review of the existing observational studies linking potatoes to obesity, diabetes and cardiovascular diseases. The studies were observational so no conclusion can be drawn relative to causality. In addition, the studies found both positive, negative and zero associations between potato consumption and these diseases. It means that these studies may not be used as evidence linking potato to human diseases.

An obvious policy instrument that should be used to increase the frequency of potato consumption is to talk positively about potato production and consumption, i.e. to do public promotions about the advantages of increased potato consumption. Especially, young consumers should be informed about the environmental advantages of changing the diet towards more frequent potato consumption. Potatoes should be promoted more in TV shows, cooking programs etc. to contribute to elevate the status of the potato. In addition, the nutrition organizations and the environmental organizations should be more active in supporting the potato.

Conclusion

In this paper, we have estimated the conditional frequency of potato consumption using an age-period-cohort approach with a doubled censored beta regression model. The analysis showed that the frequency of table potato consumption is declining in all generations, and it is declining over the life cycle. That means that the aggregate sale of potatoes is expected to continue to decline in the future, as older generations of potato eaters are replaced by younger generations who eat potatoes less frequently. This is an unwanted situation because the potato is healthy; it is good for the environment and for food security. The decline in the frequency of potato consumption is probably offset by

⁹ https://en.wikipedia.org/wiki/Atkins_diet

increase in other staple foods but also more diversity. What can be done to halt a continuous decline? The potato probably recently got a bad reputation due to suggestions in scientific journals that it contributes to obesity and diabetes 2. The suggestion in this paper is that governmental organizations, potato producers and environmentally friendly organizations need to work to increase the status of the potato.

Abbreviations *FAO*, Food and Agriculture Organization of the United Nations; *CO₂*, carbon dioxide; *GHG*, greenhouse gas; *NM*, Norwegian Monitor database; *GAMLSS*, Generalized Additive Models for Location, Scale and Shape

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