ELASTICITY OF DEMAND FOR FOOD AND CLIMATE CHANGE

by

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Abstract

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Medical literature provides evidence that changes in air temperature lead to changes in human body and could lead to a different diet and nutrition. This study examines the hypotheses that an increase in air temperature leads to a decrease in aggregate consumption of fats and proteins, and to a rise in carbohydrates consumption. Three food groups are selected for the analysis as representative of natural substance listed above: animal fats (fat), meat (proteins) and vegetables (carbohydrates). Non-parametric estimation helps to define functional form of the relationship between food consumption and mean seasons temperatures; it turned out to be linear one. The hypothesis is examined with model based on log-linearization version of Almost Ideal Demand System. Results of separate estimation of the selected food groups consumption support the hypotheses about carbohydrate and fats consumption. The elasticity estimates of demand for food to changes in temperature allow to project change in the demand that is associated with the most plausible climate change scenario. It is expected that by 2050, on average, demand for vegetables will increase by 12, 83 % per person per day and demand for fats will decrease by 16, 18 % per person per day.

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C h a p t e r 1

INTRODUCTION

The increase in CO_2 emission rate around the Earth has become evident over the last century. A rise in the amount of carbon dioxide in the atmosphere creates a greenhouse effect that is thought to cause global warming and leads to climate change (Rehdanz and Maddison 2005). A change in the air temperature, sea level and changes in precipitation rates could lead to decreases in yield and productivity level in agriculture. And the worst-case scenario of climate change, that it associated with a substantial increase in food shortage.

Several studies investigate the effect of climate change on agriculture (Mestre-Sanchis and Feijoo-Bello 2008, Nelson et al. 2009, Polsky 2004, Yesuf et al. 2008, Reinsborough 2003). In these articles, the authors examine the influence of changes in the air temperature and level of rainfall on food production, land use and cost of adaptation to the environment. They find a relationship between the climate change and food production in different regions; and predict an increase in prices and compute cost of adaptation due to climate change. While several studies examine the influence of climate change on food production, none of them investigates the impact of climate change on food consumption.

According to a joint report of the World Health Organization and the Food and Agriculture Organization (2002), the human diet has changed in qualitative and quantitative way since the 1960's. Not only has energy consumption level changed, but the structure of the diet has also changed.

Climate change could modify the needs of the human body, leading to a different diet and nutrition, thus changing the consumption pattern. Despite the fact that there is no economic literature on the influence of climate change on food consumption, from the medical point of view there is strong evidence that food consumption is temperature dependent (Babskii et al. 1985, Scmidt et al. 1996, Tkachenko 2005). A lower air temperature typically increases the consumption level while higher temperature decreases it.

Energy consumption of human body increases during physical, intellectual work, psycho-emotional stress, after meals and during decrease of surrounding temperature (Tkachenko 2005). The air temperature, humidity level, and wind influence this demand. To maintain a constant body temperature while it is hot or cold outside, thermoregulation speeds up metabolism processes, increases shivering or sweating to keep levels of heat loss and heat generation equal (Scmidt et al. 1996, Babskii et al. 1985). The rate of metabolism increases if the air temperature deviates from the comfortable temperature downwards (Scmidt et al. 1996). Energy release in the human body occurs through oxidation breakdown of proteins, fats and carbohydrates. All mechanisms that regulate oxidation processes regulate heat generation. If the air temperature goes over +35 C, the body temperature stays constant due to sweating. To evaporate 1 ml of water 0,58 kcal is needed, so metabolism and sweating are connected (Babskii et al. 1985). Thus, the needs for energy increase by about 10 to 15% under cold climate conditions and decrease by about 5% under the conditions of warm climate compared to moderate climate conditions (Gumergriz and Linevskii 1989).

Food contains such nutrients as proteins, fats, carbohydrates, vitamins, dietary fibre and others. As the source of energy nutrients are interchangeable with their kilocalorie values. However, they perform not only energetic function, but also plastic function that is used for secretion and component structure fusion. Thus, a diet should include proteins, fats and carbohydrates. All products can be divided into groups with a high content of proteins, fats and carbohydrates. Meat, milk, fish and eggs are the sources of proteins. Animal fats and vegetable oils provide fats. Vegetables, fruits, cereals and nuts are very good carbohydrates sources (Schmidt et al. 1996). The protein increase in diet may change heat balance of the body and overheat it by specific dynamic protein action (Volovich 1989). As a result it is recommended to lower a level of proteins in the diet under the conditions of warm climate. Volovich (1989) in his book describes negative attitude of the expedition participants to the fat food in the desert and tropics. Carbohydrates play an important role in energetic metabolism. A high intake of carbohydrates reduces water loss of urination. Carbohydrates diet increases body tolerance and slows down overheat (Volovich 1989).

Consequently, there is strong evidence to the fact that the food consumption is sensitive to the air temperature. Despite the mentioned above medical evidence, the link between the human biology and aggregate consumption behavior is not documented. Thus the goal of this research is to test the hypothesis that temperature has an impact on food consumption patterns. Specifically, the hypotheses are that the increase in temperature leads to a decrease in consumption of animal fats, proteins and a rise in carbohydrates consumption. Knowing the elasticity of demand for food to changes in temperature would allow to project change in the demand that is associated with the climate change scenario.

The research focuses on European and South Caucasus countries. National Climatic Data Center and Russian's Weather are the main sources of data on weather variables. While Food and Agriculture Organization provides data on average food quantities consumption per person per day for 1990-1992, 1995-1997, 2000-2002, 2005-2007 years; World Bank provides data on percentage of urban population, Gross domestic product per capita and CPI. Almost Ideal

Demand System provides a framework for the log-linearized econometric model that is estimated by OLS and Fixed Effect for 1990-2007 years.

The paper is arranged as follows. First, literature review of studies on consumer demand theory and impact of climate change on production is provided. Second, details about chosen theoretical model and variables, estimation technique, source of data and variables description are provided. Third, estimation results are presented. Finally, conclusions and implications of the results are discussed.

Chapter 2

LITERATURE REVIEW

Despite the fact that there is no literature on the impact of climate change on food consumption, the studies on consumer demand theory and impact of climate change on production and other processes provide background for this study. The review of studies on impact of climate change on food production gives an idea of possible climate changes measures used in the literature. Considering the studies on consumer demand theory gives an idea of factors that influence the demand for food besides climate change and point to possible methodological issues.

This literature review starts with explaining the existence of different climate change scenarios. Since 1850, 11 hottest years have been 1995 – 2006 (Solomon et al. 2007). Thus, during last years a change of temperature is observed. This rapid change brought a lot of attention to this issue and different climate change projections were developed, which were based on emission scenarios. They make valuable contribution to the investigation of consumption patterns as these scenarios allow to project changes in demand associated with climate change. Uncertainty of future climate change is associated with different levels of CO_2, fossil-fuels production, population growth, land usage, social and economic development. Therefore, many different emission scenarios exist, but they can be combined in 4 families with similar characteristics, such as: A1, A2, B1 and B2 (IPCC Working Group III report 2000).

Table 2.1. SRES (the Special Report on Emissions Scenarios) scenarios description (IPCC Working Group III report 2000)

A1: • "population and economic growth", • modern and advantageous production techniques, • socioeconomic regional cooperation, • decrease in differences between per head earnings	A2: • non-homogeneous self-dependent regions, • constant growing population, • focus on zone "economic development and growth", • low-speed and comparatively less advanced production techniques.
B1: • "population and economic growth", • sharp development in "service and information economy" with decrease in inputs, • rationally constructed production techniques, focusing on sustainable development.	B2: • constant growing population rate, • less advanced production techniques and economic improvement compared to A2 and B1, • focus on sustainable development at local levels.

The A1 scenario can be described as fast "population and economic growth", modern and advantageous production techniques, socioeconomic regional cooperation and decrease in differences between per head earnings. The A1 scenario is divided into 3 groups with different energy systems: Fl – with fossil-fuels, T – fossil-fuels free and B – combination of all possible energy systems. A2 scenario can be described as non-homogeneous self-dependent regions, constant growing population, zone focused on "economic development and growth", low-speed and comparatively less advanced production techniques. B1 scenario can be described as fast "population and economic growth" similar to scenario A1 and sharp development in "service and information economy" with decrease in inputs and rationally constructed production techniques, focusing on sustainable development. B2 scenario can be described as constant growing population rate (not as fast as A2), less advanced production techniques and economic improvement compared to A2 and B1, still focusing on sustainable development, but at local levels (IPCC Working Group III report 2000, p. 4). As a result, all climate change projections are based on different emission scenarios and try to predict future air temperatures and precipitation level as they are appropriate measures of climate change. Hence, different climate change projections predict different temperature and precipitation levels for different parts of the world.

Different climate measures are used in the papers that focus on production effects. Darwin et al. (1995) examine the cost of agriculture adaptation due to change in climate and define average monthly precipitation rate and temperature as main determinants of climate change. Yesuf et al. (2008) determine the mean temperature and rainfall level in the different rain seasons as measures of climate change in their study of food production and climate change in Ethiopia. The effect of climate change on rice production is studied by Srivani et al. (2007) and daily highest and lowest temperatures, precipitation level and solar radiation are defined as climate variables. Different climate measures are used in the paper of Polsky (2004), such as average temperature and rainfall rate for the middle months of each season. Rehdanz and Maddison (2004) investigate the relationship between climate and happiness. The authors use annual average temperature, average temperature during the coldest and warmest months, and the number of months when the temperature is above 20 ˚C and below 0 ˚C, annual average precipitation rate, average precipitation during the wettest and driest months and the number of months when precipitation level is below 100 mm and above 300 mm as measures of climate change. Thuiller et al. (2005) define "the mean annual, winter, and summer precipitation, mean annual temperature and minimum temperature of the coldest month" as measures of climate change in their research of the impact of climate change on different plant species (Thuiller et al. 2005, p. 1).

Considering the literature that investigates the impact of climate change on production, it can be concluded that not only average precipitation level and air temperature are used as climate measures, but also the highest, lowest temperatures and precipitation rate that are below or above some specific level are used.

Several studies examine the demand for food (Dhehibi and Gil 2003, Fan et al. 1994, Sheng et al. 2008, Soe et al. 1994, Wu n.d., York and Gossard 2004, Zhang and Wang 2003). Typical theoretical models used in the papers are an Almost Ideal Demand System (AIDS) model and its variations, Rotterdam, Working's models and Linear Expenditure System (LES) model. While, the price and quantity are jointly determined by supply and demand functions, simultaneous equation model (SEM) can not be applied in the study on impact of temperature on consumption. Typically, temperature is used as instrumental variable for the supply shocks. The weather variable can not be included neither in demand nor in supply equation simultaneously as the weather can not be determined by consumers or producers, thus it is not endogenous in these equations. So, supply and demand equation and the impact of weather on them have to be separated. AIDS, Rotterdam, Working's models and LES allow to estimate demand equation separately.

Almost Ideal Demand System model by Deaton and Muellbauer (1980) is derived from cost/expenditure function and does not depend on the utility function explicitly. It is not linear, but for estimation log-linear form of AIDS can be used. It is based on consumer demand theory and in case of aggregation over consumers, the result is consistent (Dhehibi and Gil 2003). However, AIDS nearly approximates any demand system and it requires summing up the weights of total expenditure to one, and that zero homogeneity in prices and symmetry condition holds. Slutsky symmetry and zero homogeneity conditions can be additionally examined by AIDS model by putting some restrictions on the parameters of the model. Rotterdam model as well can examine these restrictions. Both models are widely estimated and can be used in "linear forms". Barnett (2007) applying Monte Carlo method concluded that AIDS model gives better result when the level of consumer goods substitution is enormously large and both models provide good results when the level of substitution is low and/or moderate.

Working's (1943) model is the basis for Florida (1989) model (Theil et al. 1989). Working assumes the same set of prices for households thus omitting them from the model. Since 1943 the model has been improved a lot. It has been used for cross-country analysis and the assumption about similar prices is no longer relevant. As a result, prices are included in the model. The final model, Florida, requires the information about prices, income level, budget share for good and substitution term (Theil et al. 1989). Absolute prices are converted into relative ones by dividing by the geometric mean. The form of income variable in Florida's model is the same as in the AIDS model. The model consists of linear, quadratic and cubic terms (Regmi and Seale 2010). In addition the model has the same assumptions as AIDS, and other demand models. However, the authors have not developed the extension to the model where other explanatory variables can be included.

Basic variables for all these models are consumer prices, income level, budget share for food and quantities consumed. Zhang and Wang (2003) study Chinese food consumption, applying AIDS model. Besides these variables, the authors define regional and demographic variables ("household size, urbanization level or city size, age and education level of the head of household") as main determinants of consumption (Zhang and Wang 2003, p.5). "Unit values" computed by dividing expenditure on quantities allow to include prices in the model (Zhang and Wang 2003, p.3). However, Beatty (2007) claims that unit values are not appropriate measures of consumer prices as the range of unit values for specific products is extremely wide, given the fact that price and expenditure are endogenous in the demand equation. Wu (n.d.) examines international consumption of food. The author defines country specific factors (geography and culture), income level, population size, expenditure share on food, total expenditure per capita as main determinants of food consumption. The author assumes constant prices. To compare income he uses PPP. The assumption of constant prices is very strong and can not be used when more than 1 period is included in analysis. York and Gossard (2004) include share of population that lives in urban areas and GDP per capita in demand model for fish and meat. The authors found a positive, statistically significant effect of these variables on meat and fish consumption. Dhehibi and Gil (2003) define "habitat persistence" as important variable and include consumption lag in demand function.

The review of different demand models such as AIDS, Rotterdam and Working's models help to define the appropriate model for the research. In comparison with such demand models as Rotterdam, Working's and Linear Expenditure, an estimation of log-linear approximation of Almost Ideal Demand System model is appropriate for the current research as it could be rewritten for cross-country analysis and it can be extended by including different country characteristics (Deaton and Muellbauer 1980). In summary of recent consumer demand studies, consumer prices, country specific factors, GDP per capita and percentage of urban population are identified as main determinants of consumption. Consequently, it is suitable for the study to include them as control variables.

Chapter 3

METHODOLOGY AND DATA DESCRIPTION

The standard Almost Ideal Demand System model requires information about consumer prices, total expenditures, and budget shares. Besides, climate change measures and other variables can be included in the model as demand shifters. It can also be extended by including dynamic factors that introduce habit in the model (Blanciforti and Green 1983). Formally, the model of Deaton and Muellbauer (1980) can be presented as follows:

$$X_{it} = \alpha_i + \sum_j \gamma_{ij} \log P_{jt} + \beta_i \log\left(E_t \ / I_t\right) \qquad (1)$$

$$\log I_t = \alpha_0 + \sum_k \alpha_k \log P_{kt} + 1/2 \sum_j \sum_k \gamma_{kj} \log P_{kt} \log P_{jt} \qquad (2)$$

where X_{it} denotes nominal budget share of food item i at time t, $X_{it} = \dfrac{P_{it} Q_{it}}{\sum E_t}$, Q_{it} - quantity of food item i at time t consumed; P_{it} is a consumer price for food item i at time t; E_t is nominal expenditure for food at time t; I_t is an index at time t described by (2). For consumer who maximizes her utility, cost function equals total expenditure. Given this fact, taking the derivative of logarithmic cost function with respect to price gives the equation of nominal budget share and index described by (1) and (2), respectively.

If agriculture price, P_{it} and "real expenditure" for food, E_t / I_t, (nominal expenditure divided by price index) remain the same, nominal budget share per capita of food item i at time t does not change. An increase in the price for food item j at time t followed, on average, by increase in "i_{th} budget share" at time t about $\gamma_{ij}/100$, holding "real expenditure" unchanged. β_i indicates whether food items are necessities or luxuries, having negative or positive sign, respectively (Deaton and Muellbauer 1980, p. 314).

AIDS involves the following restrictions (Deaton and Muellbauer 1980):

$$\sum_{i=1}^{n}\alpha_i = 1,\ \sum_{i=1}^{n}\gamma_{ij} = 0,\ \sum_{i=1}^{n}\beta_i = 0;$$
$$\sum_{j}\gamma_{ij} = 0; \tag{3}$$
$$\gamma_{ij} = \gamma_{ji}$$

If all these restrictions hold, then the weights of total expenditure sum up to one and zero homogeneity in prices and Slutsky condition are satisfied (Deaton and Muellbauer 1980). In demand theory, these conditions define interactions among elastisities. For instance, knowing own-price elasticity and income elasticity, homogeneity condition allows to compute cross-price elasticity (Tewari, Singh 2003). Deaton and Muellbauer (1980) apply special functional form to livelihood and enjoyment costs which are included in cost function. The selection of these functional forms leads to a demand system with the above properties.

Plugging (2) into (1) to receive:

$$X_{it} = \alpha_i - \beta_i\alpha_0 + \sum_j \gamma_{ij}\log P_{jt} + \beta_i(\log E_t - \sum_k \alpha_k \log P_{kt}$$
$$-1/2\sum_j\sum_k \gamma_{kj}\log P_{kt}\log P_{jt}) \tag{4}$$

The model (4) can be estimated by MLE, taking into account the nonlinearity of the model. Given the collinearity in prices, nonlinear model can be transformed into linear one and can be estimated by OLS and Fixed Effect.

Generalization over households requires the presence of a "representative consumer". Following this, the aggregate nominal budget share for food item i, $\overline{X}_{it}$, equals

$$\overline{X}_{it} = \sum_h P_{it} Q_{ith} / \sum E_{th} \equiv \sum_h (E_{th} X_{ith}) / \sum E_{th} \tag{5}$$

Introducing (5) into (1) to receive

$$\overline{X}_{it} = \alpha_i + \sum_j \gamma_{ij} \log P_{jt} + \beta_i \log\left(\overline{E}_t / I_t\right) \tag{6}$$

where $\overline{E_t}$ - mean of total nominal expenditure for food over households h at time t. Therefore, the modified Deaton and Muellbauer (1980) model can be presented in the following form:

$$\overline{X}_{it}^l = \alpha_i + \sum_j \gamma_{ij} \log P_{jt}^l + \beta_i \log\left(\overline{E}_t^l / I_t^l\right) \tag{7}$$

$$\log I_t^l = \alpha_0 + \sum_k \alpha_k \log P_{kt}^l + 1/2 \sum_j \sum_k \gamma_{kj} \log P_{kt}^l \log P_{jt}^l \tag{8}$$

where $\overline{X}_{it}^l$ denotes nominal budget share per capita of food item i in country l at time t, Q_{it}^l - quantity of food item i in country l at time t consumed; P_{it}^l is an agriculture price for food item i in country l at time t; $\overline{E}_t^l$ is nominal expenditure for food per capita in country l at time t; I_t^l is an index in country l at time t described by (8).

The goal of current research is to test the hypotheses that increase in temperature leads to a decrease in consumption of animal fats, proteins and a rise in carbohydrates consumption. Hence the main focus of current research is quantity of food consumed. Almost Ideal Demand System provides a framework for the following econometric model and allows to control for other than weather factors:

$$\frac{P_{it}^l Q_{it}^l}{\sum E_t^l} = f\left(Z_t^l\right) + \varepsilon_{it} \tag{9}$$

where Z_t^l - exogenous variables in country l at time t.

This model shows that nominal budget share per capita of food item i in country l at time t is a function of exogenous variables and error term (ε_{it}). Demand function can be described by log-linearly approximated equation that can be estimated by OLS and Fixed Effect:

$$\ln Q_{it}^{l} = \beta_0 + \beta_1 \ln Z_t^l + \beta_2 \ln P_{it}^l + \beta_3 \ln \sum_i E_t^l + \varepsilon_{it} \qquad (10)$$

where βs are elasticity coefficients.

Aggregation of Deaton and Muellbauer (1980) requires the condition of a "representative consumer" holds. Contrary to this condition, Forni and Lippi (1997) state that agent's heterogeneity is possible. The authors provide evidence that in this case the structure of error term changes and suggest a model which incorporates "common shock and idiosyncratic component". The former affects consumption of food item i in the all countries, for instance, bad harvest and the latter affects the level of consumption in the particular country, for instance, an implication of new policy. The "idiosyncratic component" vanishes if population increases (Forni and Lippi 1997, p.4). Consequently the model (10) can be rewritten in the following form:

$$\ln Q_{it}^{l} = \beta_0 + \beta_1 \ln Z_t^l + \beta_2 \ln P_{it}^l + \beta_3 \ln \sum_i E_t^l + \nu_t + \varepsilon_{it} \qquad (11)$$

where ν_t, ε_{it} - "common shock and idiosyncratic component", respectively.

Food and Agriculture Organization[1] gives data on food groups consumed. The dataset contains such food groups as cereals, starchy roots, sugar, pulses, tree nuts, oil crops, vegetable oils, animal fats, meat, vegetables, fruits, stimulants, milk and fish. However, only three food groups are chosen to perform an analysis. Animal fats, meat and vegetables are selected as representative of fats, proteins

[1] http://www.fao.org/faostat/foodsecurity/FSSDMetadata_en.htm (downloaded in September, 2010)

and carbohydrates, respectively. Table 3.1 presents the descriptive statistics of average per person per day consumption of the selected groups of food in 42 countries over the period of 1990-2007.

Table 3.1. Descriptive statistics of food consumption (g/person/day), 1990-2007, European and South Caucasus countries

Variable	Obs	Mean	Std. Dev.	Min	Max
Animal Fats	164	28.58	18.92	3	79
Meat	164	183.85	75.11	37	397
Vegetables	164	308.23	136.11	94	763

The data shows a lot of variation in food consumption across countries. For instance, the minimum animal fats consumption during these periods is in Georgia and maximum one is in Hungary. The minimum vegetable consumption is documented in Iceland and maximum one is in Greece. The minimum meat consumption is recorded in Azerbaijan and maximum one is recorded in Luxembourg. Preliminary data analysis suggests that the difference in consumption across countries can be explained not only by country specific effects, but also by changes in temperature.

The research focuses on Europe and South Caucasus which have substantially temperate climate zones and more or less the same growing season. The list of European and South Caucasus countries used in the analysis is presented in Appendix in Table A1. The growing season in Europe and South Caucasus usually starts in April when the average daily air temperature goes over +5°C and ends up in November (Wikipedia[2]). Therefore, summer and fall are the seasons when the crops production outcomes are realized. Consequently, the amount of fruits, vegetables, cereals etc that is produced in a season increases during these

[2] http://en.wikipedia.org/wiki/Growing_season (accessed in February, 2011)

months. Thus, to eliminate the impact of production on consumption, it would be appropriate to focus only on winter and spring temperatures, however summer and fall temperatures should be also included in the analysis. Not only plant production depends on a harvest, but also livestock sector is linked to a harvest. Livestock production is affected by the quantity of fodder produced during summer and fall. The less animal feed is grown, the less animal products are available. Therefore, focusing on interpretation of non- growing season months is suitable for plant and livestock products.

Following previous studies on impact of climate change on production, mean seasons' temperatures are chosen as climate measures. National Climatic Data Center[3] provides raw data on mean monthly temperature for large number of stations since 1800. Having an interest in last 20 years, the dataset for 1990-2010 has been extracted. Missing values in this dataset are given as -9999. For practical reasons, they are substituted for empty values that permit to compute mean season temperature properly. To change temperature to degrees Celsius it is divided by 10. Average mean monthly data for each country from different stations is calculated. To replace the missing values, data on mean temperature in European and Caucasus capitals from World Data Center for Meteorology[4] and Russia's Weather Server[5] are used. Russia's Weather Server gives daily temperature mainly since 2000. Thus, dataset for 2000-2007 has been taken and mean monthly has been computed. As the data on consumption are available for four periods 1990-1992, 1995-1997, 2000-2002, 2005-2007; average mean monthly temperature for these periods for each country is constructed (see Table 3.2), observations on 1993, 1994, 1998, 1999, 2003 and 2004 years are excluded. Table 3.2 provides descriptive statistics of mean season temperature in 42

[3] ftp://ftp.ncdc.noaa.gov/pub/data/ghcn/v2/ (downloaded in March, 2011)
[4] http://www.ncdc.noaa.gov/oa/wdc/index.php?name=worldweatherrecords (downloaded in March, 2011)
[5] http://meteo.infospace.ru/wcarch/html/index.sht (downloaded in March, 2011)

selected countries over the period of 1990-2007.The difference in mean monthly temperature can be observed across countries and months: the minimum mean monthly temperature during these periods is documented in Kazakhstan and maximum mean monthly temperature is in Cyprus. In order to explore the impact of climate change on consumption, winter, spring, summer and fall mean temperatures are constructed. Both mean season temperatures and mean year temperature are used in the analysis, but in different specifications. The data on mean year consumption are provided for all those periods mentioned above. For instance, mean consumption of 1990-1992 consists of mean consumption in the winter, spring, summer and fall for this period. Thus, if winter temperature increase influences on mean winter food consumption, it will affect overall consumption during this period.

Table 3.2. Descriptive statistics of mean season temperature, 1990-2007, European and South Caucasus countries

Variable	Obs	Mean	Std. Dev.	Min	Max
Mean winter t ˚C	147	3.044	4.699	-7.311	14.305
Mean spring t ˚C	147	19.552	3.932	10.154	27.9
Mean summer t ˚C	147	9.911	3.818	0.6288	18.158
Mean fall t ˚C	147	10.408	4.459	2.679	21.220

The World Bank[6] provides data on such control variables as urban population (% of total population), GDP per capita (current US$), Consumer price index (2005=100) and total population. For practical reason GDP per capita is divided by 1000 and now it is presented in thousands US$. Observations on 1993, 1994, 1998, 1999, 2003 and 2004 years are excluded; average urban population, CPI,

[6] http://data.worldbank.org/, (downloaded in March, 2011)

GDP per capita for four periods 1990-1992, 1995-1997, 2000-2002, 2005-2007 for each country are constructed.

Cultural differences also may influence on consumption patterns. Thus, inclusion of religion affiliation, which serves as a proxy variable for cultural differences, is relevant. Christianity and Islam are two most popular religions in Europe. Worldmapper[7] gives data on shares of Christians and Muslims in Europe (% of total population) in 2005. The premise of the inclusion of such control variables as GDP per capita and percentage of urban population is discussed in the literature review. Logarithm of GPD is used in the analysis. However, minor changes are introduced in the standard set of variables; instead of consumer prices Consumer Price Index is used. In order to control for time specific unobservable factors, period dummy variables are created for each period. To perform estimation, panel data set is constructed from the set of variables mentioned above and reshaped to the long form. Table 3.3 presents the descriptive statistics of CPI, GDP, share of urban population, percentage of Christians and Muslims in 42 selected countries over the period of 1990-2007.

Table 3.3. Descriptive statistics, 1990-2007, Europe and South Caucasus

Variable	Obs	Mean	Std. Dev.	Min	Max
CPI	147	75.123	30.730	0.000	113.168
Urban population	147	68.065	12.236	42.320	97.320
GDP	147	16.584	16.207	0.407	92.811
Christians	147	77.693	22.179	0.300	98.100
Muslims	147	8.615	20.689	0.000	97.400

[7] http://www.worldmapper.org/display_religion.php?selected=564, (downloaded in April, 2011)

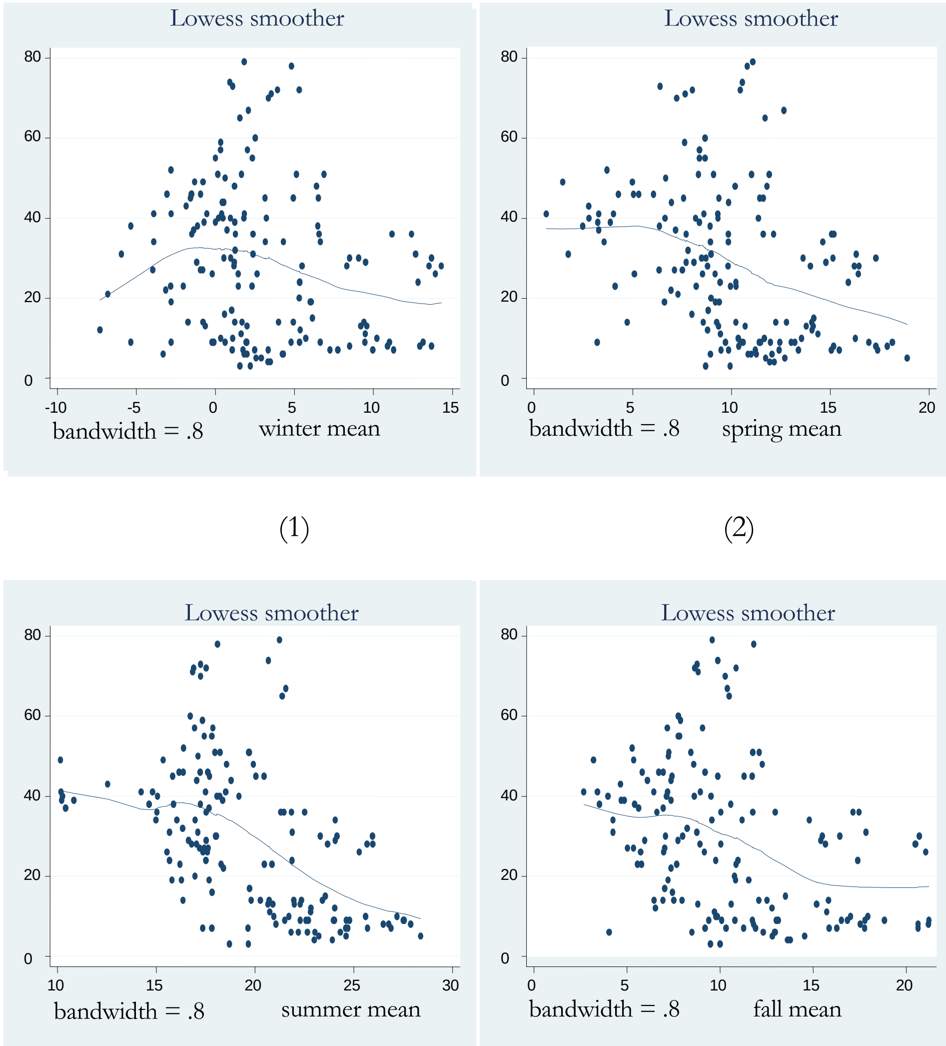
The highest percentage of Muslims is observed in Turkey, the lowest one is in Poland, Slovakia and Czech Republic. The highest percentage of Christians is in Malta and the lowest one is in Turkey. The minimum share of urban population is documented in Albania in the first period and maximum one is in Belgium in fourth period. The difference in CPI and GDP per capita is observed in the data set: the minimum CPI is recorded in Belarus and maximum one is recorded in Moldova; the lowest GDP per capita is observed in Moldova in the first period and highest one is in Luxembourg in fourth period.

Chapter 4

EMPIRICAL RESULTS

This chapter provides the empirical results of testing the hypotheses that the increase in temperature leads to a decrease in consumption of animal fats, proteins and a rise in carbohydrates consumption. Three food groups are selected for investigation the impact of climate change on consumption: animal fats (fats), meat (proteins) and vegetables (carbohydrates).

The first section focuses on discussion of the lowess results. They are the starting point of the analysis as a theory of impact of temperature on consumption does not provide information about the functional form of the relationship. Thus, lowess method is applied. Lowess is a local scatter plot smoothing technique, "$(x_i, y_i), i = 1,..., n$, in which the fitted value at x_k is the value of polynomial fit to the data using weighted least squares", carrying very little weight to x_i if it is far away from x_k, that is non-parametric regression method (Cleveland 1979, p. 829). The default choice of the curve smoothness is 0,8. The higher is the value, the higher is the smoothing. However, slightly lower values of smoothness provide similar pattern. The results of plotting animal fats consumption against mean winter, spring, summer and fall temperature are shown in Figure 1-4.



(1) (2)

(3) (4)

Figure 1-4. Scatter plots of fats consumption against mean winter, spring, summer and fall temperature.

As it is seen from the graphs, the overall trend is downward. However, the lower left half of the Panel 1 is upward sloping for reason of small number of observations where the mean winter temperature is below -2 °C. Thus, this part of the graph can be disregarded. The lower left half of the Panel 3 shows that the relationship between mean summer temperature and animal fats consumption is about constant, but the same reasoning can be applied here. It can be confirmed by the Panel 1, where the number of observations of mean temperature over 0 ˚C and below 7 ˚C (a temperature range which corresponds to constant relationship in Panel 2) is higher and downward trend is observed. Hence, it can be concluded that, in accordance, with theory; increase in the air temperature leads to lower fats consumptions. Moreover, the relationship between animal fats consumption and mean air temperature is close to linear. So, OLS and Fixed Effect estimation are appropriate. Smoothed scatter plots of meat and vegetable consumptions against temperature are presented in the Appendix. These scatter plots show the linear relationship between food consumption and temperature as well, except for some changes in meat consumption graphs. By the same token the relapionship between meat consumption and temperature has unclear pattern, that is not predicted by the theory. Only the effect of mean summer temperature on meat consumption can be explained by the theory. While all the graphs of vegetable consumption and temperature support the theoretical prediction, increase in air temperature leads to rise in vegetable consumption. To check the statistical dependence of consumption and temperature, non-parametic Spearman correlation test is applied. Results are presented in Table 4.1. A negative sign of Spearman's rho on animal fats consumption confirms the negative statistically significant relationship between air temperature and fats consumption. Positive sign of Spearman's rho on vegetable consumption confirms the positive statistically significant relationship between temperature and carbohydrates consumption. However, the hypotesis of meat consumption and temperature independence can not be rejected. Table 4.1 presents the results for spearman correlation between temperature and consumption of animal fats, vegetables and meat in 42 countries over 1990-2007 period.

Table 4.1. Spearman's correlation, Ho: cons and temperature are independent

	Spearman's rho	Prob > |t|
	Animal Fats consumption	
Mean winter temperature	-0.238	0.002
Mean spring temperature	-0.454	0.000
Mean summer temperature	-0.570	0.000
Mean fall temperature	-0.425	0.000
	Meat consumption	
Mean winter temperature	0.319	0.000
Mean spring temperature	0.066	0.402
Mean summer temperature	-0.167	0.036
Mean fall temperature	0.117	0.143
	Vegetables consumption	
Mean winter temperature	0.487	0.000
Mean spring temperature	0.678	0.000
Mean summer temperature	0.694	0.000
Mean fall temperature	0.657	0.000

The second section focuses on pooled OLS and Fixed Effect (FE) estimation as smoothing scatter plots suggest their appropriateness. Non-parametric regression method shows that inclusion of quadratic terms of mean monthly temperature is not necessary. Additionally, hypothesis that second-degree polinomial in mean monthly temperature coefficients are jointly significant is tested and rejected by F-test. Thus, relationship between food consumption and temperature is indeed linear. Besides, Log-linearization of Almost Ideal Demand System allows to use OLS and FE methods. The first step is to estimate the impact of temperature and period dummies on consumption using pooled OLS. The second step is to add control variables to the exogenous variables (mean temperature) and estimate the relationship using pooled OLS weighted with total population and country fixed effect. Different specification estimation of animal fats consumption provides a framework for model specification choice.

The results of OLS weighted with total population and FE estimation of animal fats consumption and variables of interest are presented in Table 4.2 below. Table 4.2 presents the results for selected coefficients of OLS and country fixed effect estimations for animal fats consumption in 42 contries over period of 1990-2007. The full versions of tables with estimates are presented in Appendix in Table A2. The dependent variable is logarithm of animal fat consumption. First, the influence of mean temperature of all four seasons and period dummies on animal fats consumption is estimated (see Column 1). The signs of coefficients on mean temperatures differ within the food group that contradicts to the theory. Possible explanation is that effect of production on consumption is present in coefficients of mean summer and spring temperature. Second, control variables (GDP per capita, CPI, shares of urban population, Muslims and Christians) are added to this specification. Results are presented in Column 3. The incorporation of control variables into the model affects the significance level and the signs of coefficients still preserve within food group. Although CPI controls for production effect, it might be that it does not capture the effect completely and coefficients on mean summer and fall temperature bias upwards. In the last column these specification is estimated by country fixed effect. The coefficients are statistically insignificant at 10% level of significance and have different signs of coefficients on mean winter and summer temperatures than in Column 3, where the same specification is estimated by OLS. Next step, to exclude production effect, summer and fall temperature are not included in the analysis. The Column 2 includes only mean winter and spring variables, and period dummies. The coefficients on these variables are statistically significant at 1 % level of significance; the coefficient on mean spring temperature has predicted negative sign while the coefficient on mean winter temperature is positive. However, once GDP per capita, CPI, percentage of urban population and religious affiliation are added (see Column 4), the coefficient on mean winter temperature becomes negative and statistically insignificant at 10% level of significance. The coefficient on mean spring temperature is statistically insignificant at 10% level of significance, as well. Carrying out a check on correlation between mean season's temperatures indicates the presence of high correlation. The results are provided in Table 4.3. Thus, inclusion of not only mean winter and spring temperatures, but also mean summer and fall temperatures is important for the analysis. Consequently, the specification with mean winter, spring, summer and fall temperatures, GDP per capita, CPI, share of urban population and religious affiliation is the most suitable for testing the hypotheses that the increase in temperature leads to a decrease in consumption of animal fats and proteins, and to a rise in carbohydrates consumption. However, the presence of strong and significant correlation between mean season's temperatures does not allow to estimate the coefficients precisely. Therefore, the specification with mean year temperature is appropriate one and is applied in OLS and country fixed effect estimation for animal fats, vegetables and meat consumption.

There is one more point should be made. Examining the data carefully gives evidence that there are few outliers in CPI and GDP data sets. However, exclusion of these values does not change the results of estimation at all.

The selected coefficients of the results from OLS and country fixed estimation for vegetables, meat and animal fats consumption in the complete specification are presented in the Table 4.4. The full versions of tables with estimates are presented in Appendix in Table A3. As discussed previously, if temperature increases, on average, vegetable consumption will increase and animal fats consumption will decrease. Thus, the obtained results confirm predicted by the theory pattern of change in carbohydrates and fats consumption given change in temperature. The relationship between meat consumption and temperature stays unclear, that is also shown by non-parametric estimation. In fact, the coefficients' sign on year mean temperature differs from the theory prediction. Possible reasons for such result are seasonality in meat consumption, cycles in production and countries specific factors associated with meat consumption.

Table 4.2. OLS, FE estimates, selected coefficients. Dependent variable: log of animal fats consumption

	(1)	(2)	(3)	(4)	(5)
	POLS1	POLS2	POLS3	POLS4	FE1
Mean winter t ˚C	0.028	0.106	-0.017	-0.020	0.007
	(0.056)	(0.035)***	(0.042)	(0.031)	(0.023)
Mean spring t ˚C	0.217	-0.219	0.073	-0.063	0.003
	(0.089)**	(0.051)***	(0.068)	(0.040)	(0.037)
Mean summer t ˚C	-0.239		-0.084		0.028
	(0.068)***		(0.044)*		(0.031)
Mean fall t ˚C	-0.106		-0.059		-0.020
	(0.074)		(0.049)		(0.029)
Controls	No	No	Yes	Yes	Yes
Observations	147	147	147	147	147
R-squared	0.43	0.23	0.72	0.70	0.17
Number of Country					41

Robust standard errors in parentheses

* significant at 10%; ** significant at 5%; *** significant at 1%

Table 4.3. Coefficients of correlation for mean season's temperature

	Mean winter t ˚C	Mean spring t ˚C	Mean summer t ˚C	Mean fall t ˚C
Mean winter t ˚C	1			
Mean spring t ˚C	0.820	1		
Mean summer t ˚C	0.580	0.890	1	
Mean fall t ˚C	0.903	0.924	0.816	1

Table 4.4. OLS, FE estimates, selected coefficients. Dependent variable: log of meat, animal fats and vegetable consumption

	(1)	(2)	(3)	(4)	(5)	(6)
	POLS Animal Fats	FE Animal Fats	POLS Vegetables	FE Vegetables	POLS Meat	FE Meat
Mean year t˚C	-0.087	0.010	0.069	-0.030	0.016	-0.005
	(0.015)***	(0.024)	(0.007)***	(0.027)	(0.007)**	(0.012)
Constant	5.988	2.734	4.341	6.737	5.311	5.098
	(0.770)***	(1.009)***	(0.371)***	(0.786)***	(0.358)***	(0.634)***
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	147	147	147	147	147	147
R-squared	0.71	0.15	0.71	0.36	0.87	0.23
Number of Country		41		41		41

Robust standard errors in parentheses

* significant at 10%; ** significant at 5%; *** significant at 1%

Estimation of semilog models gives the coefficient on mean year temperature, which is semielasticity of food consumption with respect to temperature. It measures the relative change in food consumption taking in account absolute change in temperature, holding the values of control variables constant. The interpretation of OLS results is that for 1990-1992, 1995-1997, 2000-2002, 2005-2007 periods, on average, 1˚C increase in temperature is associated with 6, 9 % increase in daily vegetable consumption and 8, 7 % decrease in daily animal fat consumption per person. The results are statistically significant at 1 %. Results for meat consumption can not be correctly interpreted for reasons indicated above. Country fixed effect estimation results are statistically insignificant for all food groups and the signs of obtained coefficients on mean year temperature differ from OLS results (column 2, 4 and 6).

C h a p t e r 5

CONCLUSIONS ANS IMPLICATIONS

This study explores the influence of climate change on protein, carbohydrates and fats consumption. Mean season's temperature is considered to be a suitable climate change measure. Despite the fact that CPI is used to control for the production effect. This effect could not be completely eliminated. Mean temperature in harvest seasons does not come to the primary focus of the analysis. Research concentrates on Europe and South Caucasus where harvest time is summer and fall. Mean summer and fall temperatures are included in the analysis, hence, they might capture the impact of production on consumption. Thus, mean winter and spring temperature are the variables of interest. An investigation is conducted for three selected food groups which are representative of natural substance listed above: animal fats (fats), meat (proteins) and vegetables (carbohydrates).

Non-parametric estimation suggests functional form of the relationship between food consumption and temperature and it turns out to be linear one. Log-linearization of Almost Ideal System allows to use OLS and country fixed effect estimation methods. Different specification estimation of animal fats consumption provides a framework for model specification choice, where mean seasons' temperatures and mean year temperature serves as different specification for temperature variable. After careful examination of results, mean year temperature is proved to be the most suitable temperature variable as high correlation between mean season's temperature does not allow to estimate the coefficients precisely in the specification with mean seasons' temperature.

Results of separate estimation of the selected food groups consumption support the hypotheses about carbohydrate and fats consumption. In particular, on average, 1˚C increase in temperature lowers demand for fats by 8, 7 % per person and increase daily vegetable consumption by 6, 9 % per person, holding GDP, CPI, period dummies, share of urban population and religious affiliation constant. However, the protein consumption hypothesis is not fully supported. Possible explanations for the meat consumption estimation results are seasonality in meat consumption, cycles in production and countries specific factors associated with meat consumption. Assuming that the same results hold for all countries, these findings allow to project changes in demand for food with respect to climate change. Oak Ridge National Laboratory[8] reports that A1Fl is the most likely SRES scenario. According to IPCC report the best estimates of average surface air temperature change is 1, 86 ˚C in 2050 and 4, 49 ˚C in 2100 (Solomon et al, 2007). Thus, it is expected that by 2050, on average, demand for vegetables will increase by 12, 83 % per person per day and demand for fats will decrease by 16, 18 % per person per day.

It is worth mentioning that, typically, weather is used as instrumental variable for the supply shocks. The important implication of the current findings is that it invalidates weather as supply instrument since it affects demand for food.

The possible extension to this study is to examine the impact of humidity and temperature on food consumption. The level of relative humidity may change the human's feeling about actual air temperature and as a result the needs of human body may change.

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[8] http://www.ornl.gov/sci/knowledgediscovery/QDR/global.html (accessed in May, 2011)

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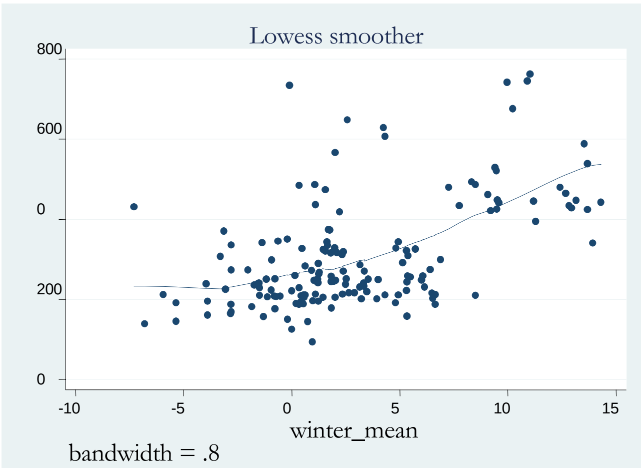
APPENDIX

Table A1. European and South Caucasus countries used in the analysis

Albania	France	Netherlands
Armenia	Georgia	Norway
Austria	Germany	Poland
Azerbaijan	Greece	Portugal
Belarus	Hungary	Romania
Belgium	Iceland	Serbia and Montenegro
Bosnia and Herzegovina	Ireland	Slovakia
Bulgaria	Italy	Slovenia
Croatia	Kazakhstan	Spain
Cyprus	Latvia	Sweden
Czech Republic	Lithuania	Switzerland
Denmark	Luxembourg	Turkey
Estonia	Malta	Ukraine
Finland	Moldova	United Kingdom



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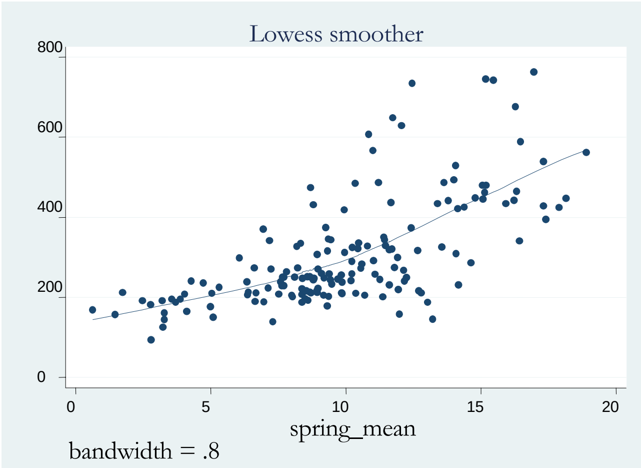
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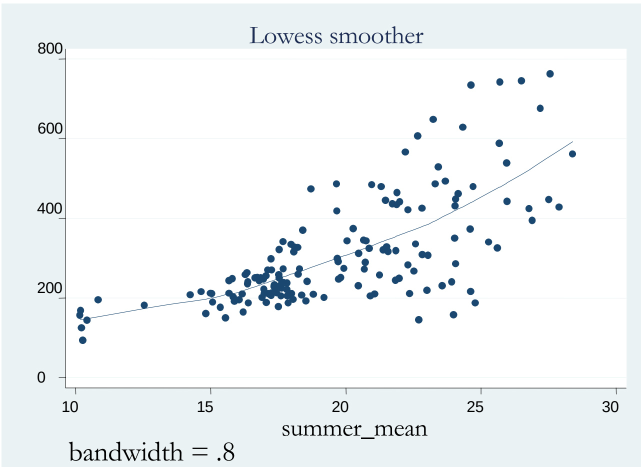
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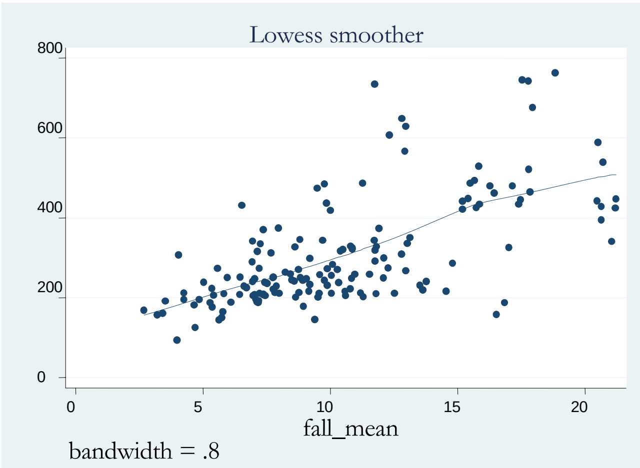
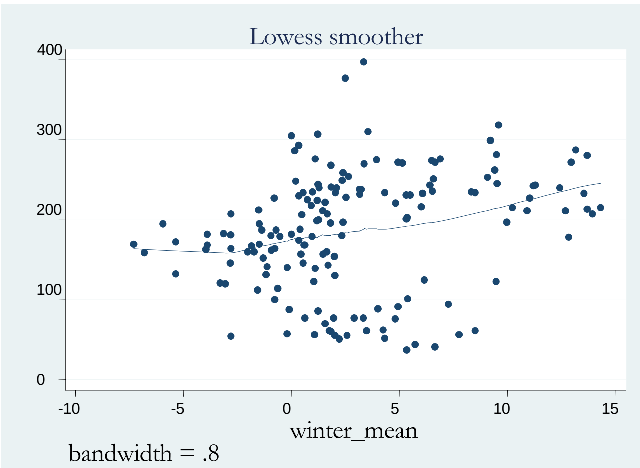


(A4)

Figure A1-4. Scatter plots of vegetable consumption against mean winter, spring, summer and fall temperature.



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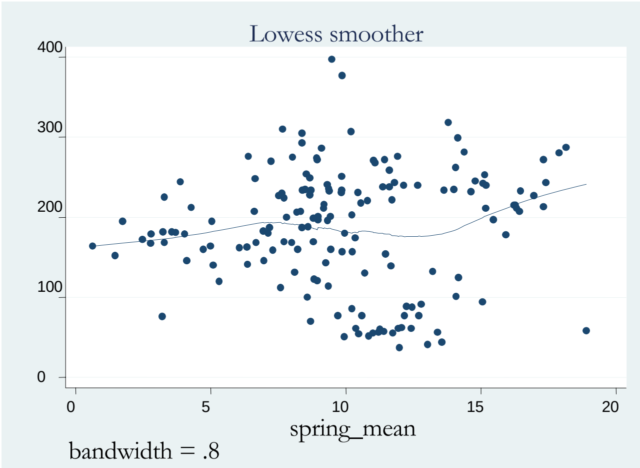

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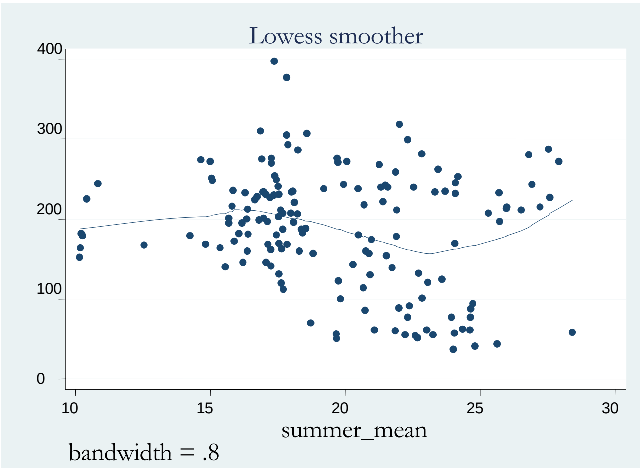

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summer_mean
bandwidth = .8

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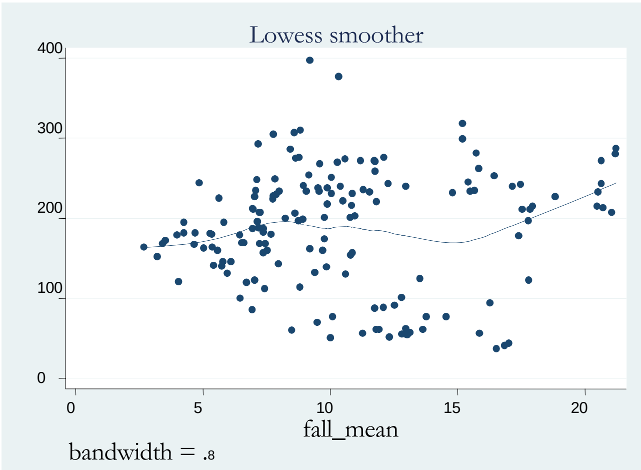

(A8)

Figure A5-8. Scatter plots of meat consumption against mean winter, spring, summer and fall temperature.

Table A2. OLS, FE estimates. Dependent variable: log of animal fats consumption

	(1)	(2)	(3)	(4)	(5)
	POLS1	POLS2	POLS3	POLS4	FE1
Mean winter t °C	0.028	0.106	-0.017	-0.020	0.007
	(0.056)	(0.035)***	(0.042)	(0.031)	(0.023)
Mean spring t °C	0.217	-0.219	0.073	-0.063	0.003
	(0.089)**	(0.051)***	(0.068)	(0.040)	(0.037)
Mean summer t °C	-0.239		-0.084		0.028
	(0.068)***		(0.044)*		(0.031)
Mean fall t °C	-0.106		-0.059		-0.020
	(0.074)		(0.049)		(0.029)
Period 1, dummy	-0.025	0.048	0.202	0.229	0.005
	(0.231)	(0.259)	(0.165)	(0.169)	(0.074)
Period 2, dummy	0.009	-0.072	0.141	0.110	-0.024
	(0.222)	(0.272)	(0.158)	(0.162)	(0.065)
Period 3, dummy	-0.199	0.012	0.141	0.233	-0.063
	(0.233)	(0.271)	(0.140)	(0.143)	(0.058)
Urban population			-0.023	-0.020	0.008
			(0.007)***	(0.007)***	(0.015)
CPI			-0.002	-0.002	-0.002
			(0.002)	(0.002)	(0.001)*
Ln(GDP)			0.396	0.414	-0.000
			(0.064)***	(0.057)***	(0.077)
Christians			-0.013	-0.015	
			(0.007)*	(0.007)**	
Muslims			-0.022	-0.026	
			(0.006)***	(0.006)***	
Constant	6.739	5.059	6.751	5.821	2.433
	(0.694)***	(0.456)***	(1.069)***	(1.076)***	(1.107)**
Observations	147	147	147	147	147
R-squared	0.43	0.23	0.72	0.70	0.17
Number of Country					41

Robust standard errors in parentheses

* significant at 10%; ** significant at 5%; *** significant at 1%

Table A3. OLS, FE estimates. Dependent variable: log of meat, animal fats and vegetable consumption

	(1)	(2)	(3)	(4)	(5)	(6)
	POLS Animal Fats	FE Animal Fats	POLS Vegetables	FE Vegetables	POLS Meat	FE Meat
Mean year t ˚C	-0.087	0.010	0.069	-0.030	0.016	-0.005
	(0.015)***	(0.024)	(0.007)***	(0.027)	(0.007)**	(0.012)
Period 1, dummy	0.225	0.011	-0.108	-0.105	0.056	0.002
	(0.165)	(0.068)	(0.086)	(0.092)	(0.062)	(0.054)
Period 2, dummy	0.123	-0.023	-0.103	-0.073	0.036	-0.009
	(0.159)	(0.060)	(0.072)	(0.064)	(0.055)	(0.043)
Period 3, dummy	0.211	-0.056	-0.048	0.038	0.081	0.026
	(0.139)	(0.051)	(0.046)	(0.058)	(0.049)*	(0.042)
Urban population	-0.021	0.007	-0.003	-0.015	-0.005	-0.002
	(0.006)***	(0.014)	(0.002)	(0.010)	(0.002)**	(0.009)
CPI	-0.002	-0.002	-0.001	0.001	-0.002	-0.001
	(0.002)	(0.001)*	(0.001)	(0.001)	(0.001)	(0.001)
Ln(GDP)	0.418	-0.013	-0.005	0.119	0.249	0.148
	(0.045)***	(0.082)	(0.030)	(0.083)	(0.027)***	(0.059)**
Christians	-0.014		0.011		-0.004	
	(0.007)**		(0.003)***		(0.003)	
Muslims	-0.024		0.014		-0.015	
	(0.006)***		(0.003)***		(0.003)***	
Constant	5.988	2.734	4.341	6.737	5.311	5.098
	(0.770)***	(1.009)***	(0.371)***	(0.786)***	(0.358)***	(0.634)***
Observations	147	147	147	147	147	147
R-squared	0.71	0.15	0.71	0.36	0.87	0.23
Number of Country		41		41		41

Robust standard errors in parentheses

* significant at 10%; ** significant at 5%; *** significant at 1%