Charles University

Faculty of Social Sciences
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MASTER'S THESIS

Comparison of coherent demand systems: The case of meat demand in the Czech Republic

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Declaration of Authorship

The author hereby declares that he compiled this thesis independently; using only the listed resources and literature, and the thesis has not been used to obtain a different or the same degree.

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Prague, January 6, 2017

Signature

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Abstract

There are many models used to estimate demand elasticities. We present a complex review of these studies in our thesis. Our empirical goal is to compare LES, Translog and QUAIDS demand systems according to their performance. In parallel, we estimate the elasticities of meat demand in the Czech Republic for the period 2010 – 2015 using the data of the household budget survey. Comparing the systems by the Akaike and Schwarz criterion, LES demonstrates the best fit for this kind of data. The average of price elasticity for different kinds of meat in the examined period is -0.99, income elasticity then equals to 1.12. These results can have important implications for tax policy, or for commercial use.

JEL Classification	F12, F21, F23, H25, H71, H87
Keywords	Demand, comparison, LES, Translog, QUAIDS, meat

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Abstrakt

Existuje mnoho modelů zkoumajících poptávkovou elasticitu. V této práci nabízíme komplexní přehled těchto modelů. Cílem pak je porovnání poptávkových systémů LES, Translog a QUAIDS na základě jejich výkonnosti. Souběžně odhadujeme elasticitu poptávky po mase v České republice za období 2010 – 2015 na datech statistik rodinných účtů. Porovnáním systémů pomocí Akaike a Schwarz kritérií vychází LES jako nejlepší pro tento typ dat. Průměrná cenová elasticita pro různé druhy masa za pozorované období je -0.99, příjmová elasticita se rovná 1.12. Tyto výsledky mohou mít významné důsledky pro daňovou politiku, nebo komerční využití.

Klasifikace	C31, C34, D11, D12
Klíčová slova	Poptávka, porovnání, LES, Translog, QUAIDS, maso

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Acronyms

AIC – Akaike Information Criterion

AIDADS – An Implicitly Directly Additive Demand System

AIDS – Almost Ideal Demand System

BTL – Basic Transcendental Logarithmic System

CDE – Constant Difference of Elasticities

COICOP – Classification of Individual Consumption by Purpose

CPI – Consumer Price Index

CSO, ČSÚ – Czech Statistical Office

CZCOICOP – Czech Classification of Individual Consumption by Purpose

CZK – Czech Crown

HBS – Household Budget Survey

IIA – Information Inaccuracy

LES – Linear Expenditure System

MLE – Maximum Likelihood Estimator

OLS – Ordinary Least Squares

PIGL – Price-Independent Generalized Linearity

PIGLOG – Polynomial Price-Independent Generalized Linearity

QES – Quadratic Expenditure System

QUAIDS – Quadratic Almost Ideal Demand System

RMSE – Root Mean Squared Error

RSS – Residual Sum of Squares

SBC – Schwartz’s Bayesian Criterion

SRMSE – System-wide Root Mean Squared Error

SUR – Seemingly Unrelated Regression

USA – United States of America

Master's Thesis Proposal

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Comparison of coherent demand systems: The case of meat demand in the Czech Republic

Motivation:

A paramount subject in consumer demand analysis is exploring association between price and income on one side and demanded quantity on the other side. This association has been measured through elasticities of demand. Expenditure, income, own or cross price elasticities then suggest likely effect of price or income on the quantity (or expenditures) for certain commodity. Knowing those elasticities allow to derive the effect of price-based policies, such as tax or subsidies, and to estimate corresponding distributional effects of benefits and other transfers, which are both very useful information for policy-maker. Also corporate sector can benefit from the knowledge of elasticities in order to analyze how their customers will react to price changes of their products and also possibly differentiate between consumers.

At the beginning, demand analysis were based on a single-equation model. Such analysis could not appropriately reflect the microeconomics foundations and assumptions given by the theory. Also the availability of appropriate time series or panel data was low. A pioneering work in demand system analysis can be seen in the work of Stone (1954), who developed so called Linear Expenditure System (LES). Since that time, many improvements in the demand analysis were made resulting in a development of range of coherent demand systems. In the present Almost Ideal Demand System (AIDS) (Deaton & Muellbauer, 1980) and its modifications are the most widely demand systems used to analyses consumer demand.

The goal of my thesis is to compare the performance of LES, AIDS and AIDADS (An Implicitly, Directly Additive Demand System), presented as the best in recent studies) demand systems. One of the most popular area in demand system analysis is food consumption as most of its items represent the necessity for human survival. The results of empirical studies are however quite inconsistent as different demand model have been are used. In my thesis, specifically, I will analyze meat demand in the Czech Republic, as expenditures on meat present the largest budget share among food items and therefore it is an important commodity in the food industry business.

Hypotheses:

1. Hypothesis #1: Different demand systems have different performance; the AIDADS model has the best performance.
2. Hypothesis #2: Meat demand in Czech Republic has income elasticity close to the unity and demand with respect to own price is inelastic.
3. Hypothesis #3: Own and cross price elasticities vary across different types of meat
4. Hypothesis #4: There is large observed heterogeneity in consumer demand. Elasticities vary across various household segments, as defined by household income, education, age of family head, residence in rural areas and being retired.

Methodology:

The study will consists of the estimation of three different coherent demand systems on meat: Linear Expenditure System, Almost Ideal Demand System, and An Implicitly, Directly Additive Demand System will be estimated using household-level data from Household Budget Survey from the Czech Republic. Those data are collected by the Czech Statistical Office every year and include information about 3,000 households, including sources of income, expenditures and consumed quantities of wide range of food commodities. The analysis will focus on meat demand as a whole and then on all categories of meat included in the HBS dataset. The models will be compared through R-squared, information criteria, nesting or non-nesting tests to identify the best model suitable for this kind of analysis. We aim at estimating the income, own and cross price elasticities for meat and meat categories.

Expected Contribution:

The study will shed a light on the differences between the most widely used demand systems (LES, AIDS and AIDADS) and compare its performance in the case of food demand. As a practical output the meat demand of Czech households will be analyzed and the result will be compared with similar recent studies being conducted abroad and in the Czech Republic. So far, there are only few studies on this topic using Czech data and as far as we know none of them has used the AIDADS model yet.

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Outline:

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Author **Supervisor**

1. Introduction

Elasticity of demand is one of the basic issues of consumer theory. We can count income, own price and cross price elasticities. There exist many ways how to estimate elasticity using econometric methods. The use of single equation model is straightforward and easy to interpret. On the other hand, many coherent demand systems were developed during the 20th century. Those systems better correspond to microeconomics theory. They usually satisfy the conditions of homogeneity, Slutsky conditions on symmetry, or additivity. The demand systems also differ one from the other, and there are already a few studies that have compared different demand systems on different types of data, using various techniques, such as Monte Carlo simulation, Akaike or Schwarz information criteria.

Our aim is to provide a review of demand systems to study household consumption. The proposed estimation of demand system is applied for the case of several kinds of meat, using household-level annual data of about 3,000 Czech households over the period 2010 – 2015. Why did we choose the meat products? First, expenditures on meat and fish represent important portion on household food budget, amounting about 30% in 2015. Meat market therefore represents a significant component of the Czech household budget and hence of the Czech economy (ČSÚ 2016a). Second, additionally to prices and income, meat demand is influenced by many external, as well as internal factors (consumer-specific characteristics or location of residence that determines local food products availability) – both may determine whether a household appear in a market (having nonzero expenditures) and result in preference heterogeneity. While my bachelor thesis (Dlasková 2014) focused on the Czech consumers heterogeneity in meat demand, still using the single equation model, I would like to follow my previous research and focus the same consumption domain in my diploma thesis.[1] Last, Household Budget Survey—the dataset we use in this thesis—records both annual expenditures and quantities for the food items only, allowing us to derive the implicit unit price of meat types for each household.

[1] The primary objective of the master thesis is to compare several demand systems on meat, examining consumers' preference heterogeneity in correcting for zero expenditures only. Comparison of demand systems augmented by household-specific variables will therefore remain for future research.

In our thesis, we have chosen to closely explore three of them. Linear Expenditure System (LES) as the firstly developed demand system (Stone 1954), Transcendental Logarithmic Demand System (Translog) (Christensen et al. 1975), to which the Shonkwiler-Yen zero correction procedure (1999) was firstly applied, and Quadratic modification of Almost Ideal Demand System (QAIDS; Banks et al. 1997), which Smutná (2016) found the best fitting model to the Czech consumer food demand data.[2] Estimation results from these three demand systems are compared and the one with the best fit is identified

We find that according to the Akaike and Schwarz information criterions, LES exhibits the best performance. The demand parameters we estimate from the LES are the following: income elasticities are slightly higher than unity, 1.00 for beef, 1.01 for pork, 1.14 for poultry, 1.19 for fish and 1.25 for other meat, that is not consistent with Engel's law that requires the income elasticity are between 0 and 1. This implies that meat is luxury good with average income elasticity equal to 1.12. Price elasticities have expected values: -1.06 for beef, -0.98 for pork, -0.93 for poultry, -1.00 for fish and -0.99 for other meat and meat products, on average own price elasticity equals to -0.99. Cross price elasticities differ significantly across the meat types and indicate that, on average, pork and beef are complements, the same for fish and beef, fish and poultry and fish and pork. On the other hand, fish and other meat are substitutes. The other estimates of cross price elasticities give mixed results. Our estimates of elasticities are higher than the ones found in previous studies on Czech meat demand, which can be caused by omitted selectivity problem.

In the next chapter we review the literature; it begins with a summary of several demand systems, then it shortly describes the methods of comparison of these systems, and concludes with the empirical literature on estimating demand of Czech consumers. Chapter 3 describes the hypothesis and methodology we use. Chapter 4 describes the data. Next two chapters report the estimation results for each of the three demand models and compare their performance. The last Chapter 7 concludes the thesis.

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[2] Šarlota Smutná in her master thesis aimed at several procedures to treat the selectivity that was applied on several demand systems. The primary goal of the thesis by Smutná (2016) was to compare these procedures, while the goal of my thesis is to compare several demand systems, controlling for the selectivity in QAIDS following the approach as suggested by Smutná (2016).

2. Literature review

Consumer Theory and Demand Systems

Changes of aggregate demand at a basic level, are caused by the changing preferences of consumers. Therefore, the consumer is one of the basic pillars of the market. The first focus on the consumer in economic literature was at the end of the 19th century. Until then, all of economics could have been called macroeconomics. The breakthrough publication was Principles of Economics by Alfred Marshall first released in 1890 (Marshall 2009). It introduces mathematical apparatus to the theory at the level of basic market actors and their interactions for the first time. Many basic theses of microeconomics are summarized in this publication and it is also the origin of Marshallian demand which specifies what the consumer would buy in each price and income wealth situation. The concept of elasticity was also introduced in this book.

To conduct proper research of consumer behavior with mathematical tools we must assume her rationality. A rational consumer takes into account only those alternatives that are available to her. She decides according to available information or she searches for worthwhile information. According to that she classifies the information based on her preferences (fulfilling her particular assumptions) and then chooses the best alternative.

Consumer theory includes many assumptions linked to the models of consumer utility maximization. Thanks to the formation of econometrics we are able to check microeconomic theory with empirical data. But if the assumptions of the microeconomic theory or of the models are not satisfactory, the results can be unreliable.

To analyze consumer demand, it is necessary to first define it. The basic concepts are the utility (u), which is a variable based on consumer preferences, income (M) – money which the consumer has, while individual goods have their prices (p_i). The amount of individual goods, which the consumer chooses is called the demand for them. Microeconomics has two views on the optimization problem which are mutually reciprocal (duality). On one side, we can maximize the consumer's utility while spending her entire given income; from other side, we can strive for a given value of the utility while minimizing income. Demand based on the first approach is called Marshallian demand: $x_i = D_i(p, M)$, where p is the vector of prices of the individual goods. Demand based on the second approach is called Hicksian *xi = Hi (p, u).*

The Engel curve is a graph which illustrates demand for the *i*th good *Di (p, M)* as a function of income, developed early in the second half of the nineteenth century. These curves can have both positive and negative slopes, even for one commodity at the different levels of income. For the category of food (in isolation), empirical studies show a constant negative slope of the Engel curve. In comparison to, for example, alcohol or clothing, where the curve has a positive slope up to the point when a particular limit of income is reached and then it starts to decline. This trend (decreasing share of food in total expenditure with rising income) was confirmed by many empirical studies and it is called Engel's law. Its validity on actual data confirms Syrovátka (2003) and also, ten years later Smutná in her thesis based on different methodologies (Smutná 2013).

“A major concern in the estimation of Engel curves is that the functional form used should be consistent with observed consumer behavior. Engel curves should be able to represent luxuries (commodities whose consumption increases more than proportionally with income), necessities (whose consumption increases less than proportionally with income), and inferior goods (commodities whose consumption decreases as income increases). In addition, Engel curves should allow the same commodity to be a luxury for the poor but a necessity for the rich.” (Cirera and Masset 2010)

According to demand theory, elasticity is the most important factor. It shows us the sensitivity of the consumer to changes of some particular parameter of the good, market or consumer conditions. We usually calculate own price, cross price and income elasticity as they show the change of the purchased quantity of good due to changing parameters of the particular good. For example, the price of other goods or the income of the consumer.

The knowledge of elasticities is useful for governmental or commercial policies. Companies can analyze the impact of price change of their products on consumer demand for them. On the other hand, government can estimate the effect of taxes. Therefore, they can calculate whether the change of price will pay off.

There are many ways to estimate elasticities. One can use single equation models like the Double-Log model or more complex demand systems.

Single equation model

First models of the demand were described by one-equation, omitting some important microeconomic assumptions and relationships. Data availability, having sufficiently large units or panel structure data, was another limiting factor. Thanks to these limitations, first demand studies mainly aimed at the estimation of Engel curves (Aziz and Malik 2006).

Multiple linear regression model

In its constant elasticities form a linear model of the multiple regression is tool useful for the analysis of consumer demand. It is based on the basic principles of econometric analysis, which were laid in the beginning of the 19th century Carl Friedrich Gauss and Andrey Markov (Wooldridge 2008). The only microeconomics restrictions which can be placed on this model is the rule of homogeneity. It is therefore a very simplified version of coherent demand model that in fact does not satisfy the other assumptions given by consumer theory.

The basic form of the model is defined as follows:

$$\ln(x_i) = \sum_{j=1}^{n} \beta_{ij} \ln(p_j) + \beta_m \ln(M) \tag{2.1}$$

where β_{ij} and β_m are parameters to estimate, x_i is the quantity of *i*th good, p_j is price of *j*th good ($j = 1, \ldots, n$) and M are the total expenditures.

Its main advantage is that the parameters β_{ij} directly represent their own and cross-price elasticities and β_m represents income elasticity.

Chern et al. (2003) provides the study of Japanese meat demand using among others also OLS estimation. He compares the elasticities for beef, pork, poultry, ground meat, ham, sausages and bacon. Most elastic is the demand for bacon with the own price elasticity equal to -1.3 on the other hand beef's elasticity equals to -0.6.

Demand systems

The literature on the estimation of demand functions consistent with economic theory has been a heavily published field for the last fifty years. The first models of demand were one-equational, omitting some important microeconomic assumptions and relationships due to a lack of availability of appropriate and sufficiently numerous panel data. Thanks to these factors, the first studies were focused mainly on the estimation of Engel curves (Aziz and Malik 2006).

The limitations of former empirical research in this field have been caused by the limited availability of appropriate functional forms for the demand models. Since 1954 when Stone introduced the first Linear Expenditure System the theory has produced a large number of flexible functional forms. The Linear Inverse Demand System, the Transcendental Logarithmic Demand System, the Quadratic Expenditure System, the Constant Difference of Elasticities demand system, the Generalized Cobb Douglas and Leontief System, the Rotterdam Model, the Almost Ideal Demand System and Normalized Quadratic Demand System. New research has developed more complicated systems, the Asymptotically Ideal Model, different modifications of AIDS (Quadratic AIDS, LA/AIDS, Inverse AIDS, and Directed Graph Model), the Vector Error Correction Model, the Laurent Demand System and An Implicitly Directly Additive Demand System (Barnett 1983; Wang and Bessler 2003).

Flexibility of functional form means using a sufficient amount of parameters for any given vector of prices. This makes it possible to estimate any set of elasticities while the consumers are divided on different income segments. Local flexibility improves the concept of functional forms such as Cobb-Douglas, which do not include complements. In some aspects, even the Double-Log model is locally flexible. On the other hand it does not account for mutual interdependencies of a huge amount of commodities in the consumer basket (Alston et al. 2002).

As illustrated above, there are many demand systems. We have chosen to closely explore three of them. The Linear Expenditure System as the first developed demand system., The Transcendental Logarithmic Demand System on which the Shonkwiler-Yen correction for zeros was first applied and the Quadratic modification of the Almost Ideal Demand System which Smutná proposes as the best fitting system to Czech consumer demand data (Shonkwiler and Yen 1999; Smutná 2016). In this chapter the review of chosen demand systems will be introduced along with the illustrations of their use on food or especially on meat demand data.

Consistency of models

A demand model can be consistent with neoclassical microeconomic theory only if it fulfills following conditions (Stone 1954):

Additivity

Implies that the sum of total expenditures as given in the system is identically equal to total expenditures:

$$p_i x_i = M \tag{2.2}$$

Homogeneity rule

It shows us the relationship between elasticities coming from the Euler rule for homogenous functions (Demand function is homogenous of the degree 0 in prices and income):

$$\sum_{j}^{n} e_{ij} + e_m = 0; (i = 1,2, \dots n) \tag{2.3}$$

Where e_{ij} is price elasticity and e_m is income elasticity.

The rule of homogeneity assumes that only real income and prices are relevant according to explanation of the demand.

Engel aggregation condition

It provides the possibility of the expenditure aggregation of individual functions. We can write it with coefficients of income elasticity and according demand:

$$\sum_{i}^{n} w_i \, e_m = 1 \tag{2.4}$$

Where w_i is the budget share of the expenditures on *i*th commodity.

Upon this condition the individual equation in the demand system should be connected. For this particular equation the homogeneity of zero degree is watched in price and income. The models can be also constructed to fulfill symmetry of cross price elasticities when $e_{ij} = e_{ji}$.

LES (Stone 1954)

The first commonly used demand system is the Linear expenditure system introduced by (Stone 1954). He builds on the cost-of-living index (which is dependent on the measurable prices only and based on the properties of the demand functions) developed by Klein and Rubin (1947). The system of demand equation possesses properties of the neoclassical theory of consumer choice. The idea to consider the goods not in isolation but with the demand for all commodities bought by consumers classified into a number of groups was revolutionary.

From all linear system in expenditure relative to price it is the only one fulfilling the regularity of conditions of demand theory (Meyer et al. 2011). It is easy to apply as it is linear and it has few independent parameters (2n-1) if we take n as the number of commodities. The little number of parameters also provides some restrictions. All goods have to be Hicksian substitutes, expenditure elasticities are always positive – there cannot be any inferior goods, and cross price derivatives are proportional to expenditure derivatives. Engel flexibility is restricted to linear Engel curves because of constant marginal budget share.

A consumer's individual utility function possesses an additive separability and it can be represented by the utility function $U(x_1, \dots, x_n)$ (Chang and Fawson 1994). Where consumption of *i*th good is represented by x_i. After a monotonic transformation it can be represented as the sum of a set of individual utility functions as follows:

$$U = \sum_{i=1}^{n} \beta_i \ln(x_i - \gamma_i) \quad (2.5)$$

β_i and γ_i are parameters of utility function and have to possess: $\beta_i > 0$, $x_i > \gamma_i$ and $\sum \beta_i = 1$. We maximize U subject to the budget constrain that is the total expenditure on all commodities:

$$\sum_{i=1}^{n} p_i x_i = M \quad (2.6)$$

where p_i denotes for price of *i*th good and M is total expenditure on all n goods.

By solving the maximization problem we get the system of behavioral demand equations:

$$p_i x_i = p_i \gamma_i + \beta_i (M - \sum_{j=1}^{n} p_j \gamma_j) \qquad (2.7)$$

for i = 1, 2, 3, ... n

Where again $\beta i \geq 0$, and $\sum \beta i = 1$. This adding-up condition satisfies the budget constraint. Homogeneity in prices and total expenditure, and symmetry are satisfied automatically. Also $xi > \gamma i$ must hold as the regulatory condition suggest. Therefore the utility function is quasiconcave.

We have γi as the subsistence parameter. If γi is positive, the demand is inelastic and vice versa. $\sum pi\ \gamma i$ is the total cost of subsistence and $M\text{-}\sum pi\ \gamma i$ are “supernumerary expenditure”. Consumer allocation of supernumerary expenditures over different commodities is represented by βi’s.

There cannot be any inferior commodities in the model. If good *j* is price elastic, the cross price elasticity will be positive and vice versa. It means that price effect is always stronger than the substitution effect.

The budget share form of the model can be seen in Table 2.2.

Park et al. (1996) used LES to estimate the food demand on the 1987-88 Nationwide Food Consumption Survey data from USA (United States of America). They distinguished food into 12 categories including beef, pork, chicken and fish and calculated their price and income elasticities looking for differences between income groups of households. Own-price elasticities were similar between the income groups for most commodities. However, income elasticities were consistently higher for the lower-income group.

Rotterdam demand system (Barten 1964; Theil 1965)

The Rotterdam model is consistent with demand theory and it is as flexible as any other local approximation form Kinnucan et al. (1997). Its name comes from the site of its orgin.

It comes from differential approach to demand analysis introduced by Theil (1965). The equation in scalar form is then written as (Barnett and Serletis 2008):

$$dx_i = \frac{\partial x_i}{\partial y} dy + \sum_{j=1}^{n} \frac{\partial x_i}{\partial p_j} dp_j, \qquad i = 1, \dots, n \tag{2.8}$$

Multiplying both sides by p_i/y and using the identity $dz = zd \ln z$, (2.8) can be rewritten in logarithmic differentials as

$$w_i d \ln x_i = \theta_i d \ln y + \sum_{j=1}^{n} \frac{p_i p_j}{y} \frac{\partial x_i}{\partial p_j} d \ln p_j, \qquad i = 1, \dots, n \tag{2.9}$$

Where $w_i = p_i x_i / y$ is the budget share of the *i*th use of income and $\theta_i = w_i \eta_{iy}$ is the marginal budget share of *i*th use of money income ($p_i \partial x_i / \partial y$). The budget shares are always positive and sum to unity. The marginal budget shares are not always positive but also sum to unity. We can define the system for relative or absolute prices.

The model used in Capps Jr and Schmitz (1991) is formulated as:

$$1/2(w_{it} + w_{it-1}) \ln(q_{it}/q_{it-1}) = \propto_i + b_i \left(-\sum_k 1/2(w_{kt} + w_{kt-1}) \ln(p_{kt}/p_{kt-1}) \right) + \sum_j c_{ij} \ln(p_{jt}/p_{jt-1}) \tag{2.10}$$

To insure homogeneity, symmetry and adding up condition, the following assumptions must be fulfilled: $c_{ij} = c_{ji}$ (symmetry), $\sum_j c_{ij} = 0 \; \forall i$ (homogeneity) and $\sum_i b_i = 1$; $\sum_i c_{ij} = 0$ (adding up).

In this study the meat categories are divided to beef, pork, poultry and fish. The data were collected in USA in the period 1966 to 1988 and it is annual data of per capita consumption levels and nominal prices. The aim of this study was to document key issues in considering health and nutrition factors in food demand analysis. Capps Jr and Schmitz (1991) use the cholesterol information index to explore the sensibility employing Rotterdam model. Only in the case of pork the coefficient was statistically different from zero. They also explore the effect of own prices, prices of other exanimated goods and total expenditure. Resulting elasticities are quite low according to other studies. The highest is in the case of pork (-0.45) and the lowest is for poultry (-0.22).

Kinnucan et al. (1997) used the Rotterdam system instead of LA/AIDS because it was more consistent with meat demand behavior in USA. They estimated the effect of advertisement on the demand for meat. They put the attention on the robustness of estimation. The dollar expenditures on advertisement with 3month delay is examined (on the quarterly data from 1976-1993). The results shows that the effect of advertisement is very sensitive on examined period. It can be influenced by the errors in measurements or structural changes, which was recognized in former studies on the same theme.

Translog System (Christensen et al. 1975)

Basic Translog system was developed on the theory of indirect transcendental logarithmic utility function.

"Direct and indirect translog utility functions provide budget share equations which are both flexible and consistent with the theory of utility maximization. These forms are attractive for modelling consumer behavior. Because of their flexibility they are ideal for testing hypotheses such as additivity of preferences". (Christensen and Manser 1977)

The direct utility function is written as:

$$-\ln U = \propto_0 + \sum_i \propto_i \ln x_i + \frac{1}{2} \sum_i \sum_j \beta_{ij} x_i x_j \qquad (2.11)$$

where $\beta_{ij} = \beta_{ji}$, utility maximization subject to the budget constraint $\sum p_i x_i = M$ yields budget share equations:

$$w_i = \frac{p_i x_i}{M} = \frac{\propto_i + \sum \beta_{ij} \ln x_i}{\sum(\propto_i + \sum \beta_{ij} \ln x_i)} \qquad (2.12)$$

The indirect utility function is defined as:

$$\ln V = \propto_0 + \sum_i \propto_i \ln\frac{p_i}{M} + \frac{1}{2}\sum_i \sum_j \beta_{ij}\frac{p_i}{M}\frac{p_j}{M} \quad (2.13)$$

The logarithmic form of Roy's identity can be used to determine the budget shares corresponding to indirect translog form.

$$w_i = \frac{p_i x_i}{M} = \frac{\propto_i + \sum \beta_{ij} \ln\frac{p_i}{M}}{\sum(\propto_i + \sum \beta_{ij} \ln\frac{p_i}{M})} \quad (2.14)$$

The budget share form with household indices of the data can be seen in Table 2.2.

(Christensen and Manser 1977) used the newly developed model to explore the consumption of meat in USA from the period 1947-1971. They divided meat into four categories: beef, pork, poultry and fish. They have estimated own and cross price elasticities for these groups for years 1947, 1969 and 1971. Their results shows high elasticity of fish (around -3) and the elasticity for other meat around minus one.

QES (Howe et al. 1979)

Demand functions in Quadratic Expenditure System are quadratic in total expenditure. It is the generalization of LES. The class of quadratic demand functions has general form:

$$h^i(P,M) = \frac{1}{g^2}\left(\propto_i - \frac{g_i}{g}\propto\right)(M-f)^2 + \frac{g_i}{g}\propto(M-f) + f_i \quad (2.15)$$

where M stands for total expenditures, P is a vector of prices and $f; g; \alpha$ are homogeneous functions of degree one. The budget share form of the model can be seen in Table 2.2.

Nayga (1995) uses QES for the estimation of disaggregated meat demand data. They divide the meat into 14 meat products. They did not use any price information in their model assuming constant price in the examined period. A two-step estimator was used according to Heien and Wesseils (1990) method for dealing with zeros in the sample. Many influences from socio-demographic factors were found.

AIDS (Deaton and Muellbauer 1980)

The Almost Ideal Demand System was developed by Deaton and Muellbauer (1980). The model can be derived from second order approximation of any cost function, which means that it has a flexible functional form. That is extremely useful for estimating a demand system with many properties (Meyer et al. 2011). The model automatically and exactly satisfies the axioms of choice. Also homogeneity and symmetry can be imposed with simple parametric and aggregation restrictions. It is consistent with known household-budget data and can be easily estimated, but the fact that the price index is not linear in terms of parameter estimated can make it more complicated. Therefore the linear approximation of the price index is often used, the model is then called LA/AIDS, it restricts Engel curves to be linear. In recent years, AIDS family models have been very popular especially in food demand modeling and of course in the models of demand for meat.

We start from a specific class of preferences, which leaves exact aggregation to consumers: the market demands representation that is like the outcome of the representative consumer decision (Deaton and Muellbauer 1980). We call these preferences the PIGLOG (Polynomial Price-Independent Generalized Linearity) class. The cost of expenditure function that represents them defines the minimum expenditure necessary to reach a specific level of utility at given prices. The PIGLOG cost function is:

$$\ln c(u,p) = \alpha_1 + (1-u)\ln a(p) + u\ln b(p)$$

Where *a(p)* and *b(p)* are homogenous function of degree 1 in *p* and *u* is the utility with the range from 0 to 1 (Poray et al. 2000). Specific functional forms for ln*a(p)* and ln*b(p)* are:

$$\ln a(p) = \alpha_0 + \sum_{i=1}^{N}\alpha_k \ln(p_i) + \frac{1}{2}\sum_{i=1}^{N}\sum_{j=1}^{N}\gamma_{ij}^{*} \ln(p_i)\ln(p_j) \qquad (2.16)$$

$$\ln b(p) = \ln a(p) + \beta_0 \prod_{i=1}^{N} p_i^{\beta_i} \qquad (2.17)$$

The cost function can then be transferred to:

$$\ln c(u,p) = \alpha_0 + \sum_{i=1}^{N} \alpha_i \ln(p_i) + \frac{1}{2}\sum_{i=1}^{N}\sum_{j=1}^{N} \gamma_{ij}^{*} \ln(p_i)\ln(p_j) + u\, \beta_0 \prod_{i=1}^{N} p_i^{\beta_i} \qquad (2.18)$$

where α_i, β_i, and γ_{ij}* are parameters, the homogeneity in p is fulfilled, as can be seen from the equation, if those restrictions are possessed:

$$\sum_{i=1}^{N} \alpha_i = 1, \sum_{i=1}^{N} \beta_i = 0, \sum_{i=1}^{N} \gamma_{ij} = 0 \ \ (aditivity) \qquad (2.19)$$

$$\sum_{j=1}^{N} \gamma_{ij} = 0 \ (homogeneity) \qquad (2.20)$$

$$\gamma_{ij} = \gamma_{ji} \ (symetry) \qquad (2.21)$$

If we use the logarithmic differentiation on the equation (2.18) we get the function of prices and utility expressed by the budget shares:

$$w_i = \alpha_i + \sum_{j=1}^{N} \gamma_{ij} \ln(p_j) + \beta_i u\, \beta_0 \prod_{i=1}^{N} p_i^{i} \qquad (2.22)$$

where:

$$\gamma_{ij} = \frac{1}{2} \left(\gamma_{ij}^{*} + \gamma_{ji}^{*}\right) \qquad (2.23)$$

We get the budget shares equation in the basic form that can be used for estimation of the model:

$$w_i = \alpha_i + \sum_{j=1}^{N} \gamma_{ij} \ln(p_j) + \beta_i \ln\left(\frac{X}{P}\right) + \varepsilon_i \,, for\ all\ i = 1, \ldots, N \tag{2.24}$$

Where the price index is defined as :

$$\ln(P) = \alpha_1 + \sum_{J=1}^{N} \alpha_J \ln(p_J) + \frac{1}{2}\sum_{i=1}^{N}\sum_{j=1}^{N} \gamma_{iJ} \ln(p_i)\ln(p_j) \tag{2.25}$$

AIDS is the most widely used system for the analysis of meat demand. The original article by Deaton and Muellbauer (1980) was cited 1307 times according to Web Of Science (2016).

One of the most recent studies using AIDS for meat demand analysis is from Slovakia. (Benda Prokeinova and Hanova 2016). It gives complex insight into the Slovakia meat market. The authors point out that the change in consumption patterns after 1990 are caused by the change in taxation. After this year, the state stopped generously subsidizing not only the production of meat, but also its consumption. It is the same case for the Czech Republic. The data set is obtained from the Situation and Outlook Reports of Meat (1997–2014) and from the Slovak Statistical Office. The analyzed commodities were beef, pork, chicken and fish. Own price, cross price and income elasticities were estimated giving the results shown in Table 2.1:.

Table 2.1: Slovakian meat demand elasticities

commodity	beef	pork	chicken	fish	income
beef	-0.4279780	-1.5293130	-0.2455730	0.0413323	2.1615314
pork	-0.1930650	-0.8428750	0.0288189	-0.0202760	1.0273972
chicken	0.1290020	0.8030288	-0.9158260	0.0265370	0.0427420
fish	0.8760695	-0.0668220	0.3938175	-0.8579850	-0.3450800

AIDADS (Rimmer et al. 1992)

One of the recent models is An Implicit Direct Additive Demand System, invented by Rimmer et al. (1992) and simplified for empirical applications by Cranfield et al. (2003). The AIDADS nests the LES and overcomes its limited Engel-flexibility by imposing less restrictive marginal budget shares. The system has the following form:

"AIDADS starts from an implicit directly additive utility function defined by Hanoch (1975):

$$\sum_{i=1}^{n} U_i(x_i, u) = 1 \quad (i = 1,2, \dots, n) \tag{2.26}$$

where {x_1, x_2,…, x_n } is the consumption bundle, u is the utility level. U_i is a twice-differentiable monotonic functions satisfying appropriate concavity conditions and has the following form:

$$U_i = \frac{[\propto_i + \beta_i G(u)]}{[1+G(u)]} ln\left(\frac{x_i - \gamma_i}{Ae^u}\right) \tag{2.27}$$

where G(u) is a positive, monotonic twice-differentiable function, γ_i is the subsistence level of consumption, α_i, β_i and A are parameters. The following restrictions are imposed on the parameters:

:

$$0 \leq \propto_i, \beta_i \leq 1 \sum_{i=1}^{n} \alpha_i = 1, \sum_{i=1}^{n} \beta_i = 1 \tag{2.28}$$

The usual utility maximization yields:

$$x_i = \frac{\Phi_i(M - \gamma' P)}{p_i} + \gamma_i \quad for\ i = 1,2, \dots, n \tag{2.29}$$

where $\Phi_i = \frac{\propto_i + \beta_i e^{u_j}}{1+e^{u_j}}$ $for\ i = 1,2, \dots, n\ \ and\ \gamma' P = \sum_{i=1}^{n} p_i \gamma_i$*."* (Yu et al. 2000)

The budget share form of the model can be seen in Table 2.2

Yu et al. (2004) estimated the AIDADS model on cross-section data from 1985 dividing the groups of food on grains, livestock and meat products, horticulture and vegetable products, fish, and other food. The data was collected worldwide and they divide it into group according to geographical location. For Western Europe the income elasticity for meat was 0.86 in the case of livestock and meat and 0.02 for fish.

QUAIDS (Banks et al. 1997)

The quadratic modification of AIDS is called QUAIDS. It was developed by Banks et al. (1997). The advantage of QUAIDS over AISD is the allowance of Engel curves to be non-linear.

For the QUAIDS system, the indirect utility function *V(p, M)* is defined as Lambert et al. (2006):

$$V(p,M) = \left\{\left[\frac{\ln(M) - \ln(a(p))}{b(p)}\right]^{-1} + \lambda(p)\right\}^{-1} \tag{2.30}$$

Following the notation of thesis. $\ln(M) - \ln(a(p)) / b(p)$ is the indirect utility function of a system with budget shares linear in log expenditure where *a(p)* and *b(p)* are functions of prices. The term *λ(p)* is a differentiable, homogenous function of degree zero in prices.

QUAIDS assumes that the relation between income and expenditure is not linear and has the following budget shares equation applicable for the model:

$$w_i = \alpha_i + \sum_{j=1}^{N} \gamma_{ij} \ln(p_j) + \beta_i \ln\left(\frac{X}{P}\right) + \lambda_i \left(\prod_{k=1}^{N} p_k^{\beta_k}\right)^{-1} \ln\left(\frac{X}{P}\right)^2 \tag{2.31}$$

The additivity condition is extended by

$$\sum_{j=1}^{N} \lambda_i = 0 \tag{2.32}$$

Lambert et al. (2006) estimated QUAIDS on the data from Canada for 1992 and 1996. They explored the probabilities of consumption of beef, pork, chicken, fish and the category of other meats in different regions. They used Heien and Wesseils (1990) correction for censored data. Price and expenditure elasticities were also the goal of this study. For beef, pork, chicken and other meat are the price elasticities close to -1, for fish it is almost -0.5. According to expenditure elasticity, fish has the most inelastic reaction with the value 0.6 and chicken elasticity is highest with 1.4.

Table 2.2: Models comparison

Demand system	**Budget share form**	**Properties**
Linear Expenditure System (LES)	$w_{it} = \frac{p_{it}\gamma_{it}}{y_t} + \beta_i(1 - \frac{p_t^{'}\gamma}{y_t})$	- Rank two demand system. - Limited Engel flexibility- constants marginal budget shares over all income levels - Special case that nests at AIDADS.
Quadratic Expenditure System (QES)	$w_{it} = \frac{p_{it}\gamma_{it}}{y_t} + \beta_i\left(1 - \frac{p_t^{'}\gamma}{y_t}\right) + \left(\frac{p_{it}\gamma_{it}}{y_t} - \beta_i \frac{p_t^{'}\delta}{y_t}\right)\prod_{i=1}^{n}\left(\frac{p_{it}}{y_t}\right)^{-2\beta_1}\left(1 - \frac{p_t^{'}\gamma}{y_t}\right)^2$	- Rank two demand system. - Limited Engel flexibility- produces Linear Engel curves. - Nested at LES.
Almost Ideal Demand System (AIDS)	$w_{it} = \alpha_i + \sum_{i=1}^{n}\ell_{it}\ln(p_{it}) + \beta_i \ln\left(\frac{y_t}{P_t^*}\right)$	- Rank two demand system. - Limited Engel flexibility- produces Linear Engel curves. - Budget share predictions may lie above unity.
Trenscendental Logarithmic System (BTL)	$w_{it} = \frac{a_i + \sum_j \beta_{ij}\ln(\frac{p_{it}}{y_t})}{1 + \sum_k \sum_j \beta_{kj}\ln(\frac{p_{it}}{y_t})}$	- Rank two demand system - Limited Engel flexibility - Transcendental logarithmic utility function

Continue of the table 2.1

Demand system	Budget share form	Properties
Rotterdam demand system	$w_{it}\Delta\ln(q_{it}) = \sum_{j=1}^{n}\gamma_{ij}\Delta\ln(p_{jt}) + \beta_i\sum_{j}^{n} w_{jt}\Delta\ln(q_{jt})$	- Rank two demand system - Limited Engel flexibility - Absolute price version
Quadratic Almost Ideal Demand System (QUAIDS)	$w_{it} = \alpha_i + \sum_{i=1}^{n}\ell_{it}\ln(p_{it}) + \beta_i\ln\left(\frac{y_t}{P_t^*}\right) + \lambda_i\left(\prod_{i=1}^{n} p_{lt}^{\beta_1}\right)^{-1}\left[\ln\left(\frac{y_t}{P_t^*}\right)\right]^2$	- Rank three demand system. - High Engel flexibility – allows non-linear Engel curves and for goods to be luxury at low income levels and normal at high expenditure level. - Budget shares predictions may lie outside the [0,1] interval. - Nested at AIDS
An Implicit Direct Additive Demand System (AIDADS)	$w_{it} = \frac{p_{it}\gamma_{it}}{y_t} + \frac{\alpha_i + \beta_i\exp(u_t)}{1+\exp(u_t)}(1-\frac{p_t^{'}\gamma}{y_t})$	- Rank three demand system. - High Engel flexibility- marginal budget shares are non-linear on income/expenditure, - Budget shares constrained to the interval [0,1] - Nested at LES.

Source: (Cirera and Masset 2010), (Barnett and Seck 2008) , author. *t* is the index of household, *y* are total expenditures and the rest follows the notation of the thesis.

Model selection

In our study we will compare the demand systems by their performance. There are several methods used to compare them.

Rank of the models

Rank of the demand system has many important implications for specification, estimation, aggregation, and welfare calculations (Lewbel 2002). It can be defined as the maximum dimension of the function space by Engel curves demand system. (Lewbel 1991). Other no income parameters have to be fixed (Slottje 2009). The higher order of the rank, the greater variety of shapes of the Engel curves can be displayed.

"A demand system has rank M = 1 if and only if the demands are homothetic, that is, budget shares independent of the level of income. ... A demand system has rank M = 2 if and only if the demands are generalized linear. ... In general, the above results show that the lower the rank, the greater is the degree of utility related structure possessed by aggregate demands. It is therefore important to know the rank of demands to specify aggregate demand equations appropriately." (Lewbel 1991)

Banks et al. (1997) found that while budget shares linear in *M* fits demands for some goods quite well, other goods appear to have budget shares quadratic in ln*M* which implies the need of rank 3 models.

We can divide the models according to their rank as follows:

- Rank one models: Cobb-Douglas and Multiple linear demand system (Lewbel 2002).
- The family of PIGL (Price-Independent Generalized Linearity), PIGLOG and fractional demand systems including AIDS, Translog, Rotterdam, LES and QES belong to the rank two models (Lewbel 1991).
- AIDADS, rank-extended Translog demand system, and QUAIDS belong to the rank three models (Banks et al. 1997, Lewbel 2001). They should be able to display a greater variety of Engel curve shapes than the systems with lower rank.

"These results suggest that for most households demands are reasonably modeled as rank two in general and PIGLOG in particular, but that a more complicated (i.e., rank

three) model is required when households with very low or high expenditures are included in the sample." (Lewbel 1991)

Model comparison

In the case of nesting systems—as it is the case of AIDS vs. QUAIDS—it is enough to find whether the quadratic term as estimated in the QUAIDS model is significantly different from zero.

In the case of not nested models, there are several ways how to compare one demand system to the other. Monte Carlo simulation is used to compare a priori given elasticities with simulated quantities and their estimated values. Other options are not so precise. Results from two or several demand models can be compared through the goodness-of-fit of the underlying models by employing root mean squared error (RMSE), a system-wide RMSE (SRMSE) and the information inaccuracy (IIA) measure. Another option of the model comparison is based on information criterion, specifically on multivariate Akaike information criterion (AIC) and multivariate Schwartz's criterion (SC) account for potential over fitting of models with many parameters.

Monte Carlo simulation

As it is in Meyer et al. (2011) or Barnett and Seck (2008) papers, the best way to compare several different demand models is to use the Monte Carlo simulation, that is a process of generating data following given conditions or strategy. Given conditions (the elasticities), the simulation is based on random sampling to obtain desired dataset (household expenditures and consumed quantities).

For our case we have chosen the LES and Translog models as rank two model and QUAIDS as rank three model.

To compare three demand models with the Monte Carlo simulation (i) we would have to employ three simulations leading to a very similar dataset with given (true) elasticity. Then, (ii) each of the three demand models is estimated using the simulated data, and last (iii) the deviations in the elasticity estimates from the (true) value of the elasticity are derived.

The method introduced in Meyer et al. (2011) describes the strategy of simulation as randomly generating prices and income with given distributions and moments. Total expenditure then depends on income and prices, as it is calculated from these prices and quantities. When we know the true elasticities, we can calculate deviation from estimation results of the demand system.

Akaike information criterion and Bayesian information criterion

AIC measures the relative quality of statistical models for a given set of data. Akaike information criterion can compare the quality of each model that is estimated on the same data, but it cannot tell anything about the quality of the model in general. It was developed by Hirotugu Akaike and first announced in 1971 (Cranfield et al. 2003).

It is not difficult to calculate AIC. The number of parameters, including intercept, in the model *(k)*, number of observations *(n)* and either maximum likelihood estimate *(L)* or the residual sum of squares of the model *(RSS)* is used (Symonds and Moussalli 2011). The formulas are:

$$AIC = -2\ln(L) + 2k \qquad (2.33)$$

or

$$AIC = n\left[\ln\frac{RSS}{n}\right] + 2k \qquad (2.34)$$

If the sample size is small ($n/k < 40$) modified version of AIC, AIC_c, should be used:

$$AIC_c = AIC + \frac{2k(k+1)}{n-k-1} \qquad (2.35)$$

Bayesian information criterion or Schwartz criterion (SBC) is closely related to AIC. They both resolve the problem of overfitting by introducing the penalty term for the number of parameters in the model. It was developed by Gideon E. Schwarz in 1978 (Findley 1991). The formula for calculation is:

$$SBC = -2\ln(L) + k\ln(n) \qquad (2.36)$$

Following the notation of AIC.

Those statistics will be the base of our comparison analysis of LES, Translog and QUAIDS demand system. The best model should have the lowest AIC and SBC.

SBC penalizes the number of parameters strongly than AIC. It can be derived in the same framework as AIC using different prior. Theoretically, AIC has advantages over SBC, because it is derived from the principles of information—SBC is not—and because the derivation of SBC has a prior of *1/R* (where *R* is the number of candidate models) that does not match the intuition that the prior should be decreasing in *k*. (Burnham and Anderson 2003).

Empirical literature on meat demand analysis

Model comparison in empirical literature

Most often compared demand system is the AIDS as it is also the widely used model while estimating demand for consumer goods or services. The AIDS is compared with its modification QUAIDS by the test of the significance of quadratic term (Smutná 2016) Rotterdam model by Monte Carlo simulation (Barnett and Seck 2008), but also with LES (Blanciforti and Green 1983). Empirical studies make also a comparison between QES and Translog demand system by comparicon of likelihood, (Pollak and Wales 1980) or between LES and QES (Pollak and Wales 1978).

Chern et al. (2003) employed a variety of demand systems for estimation of the elasticities. They use OLS, Heckman’s two-step, and Tobit estimators. With respect to the demand system modeling, they utilize the LA/AIDS models with Stone and Laspeyres index, and include the inverse Mills ratio to correct for the zero consumption problem. The full version of AIDS model is also applied, and all results are compared.

Yu et al. (2004) compare LES, CDE (Constant Difference of Elasticities) and AIDADS models, whereas Meyer et al. (2011) perform one of the most complex comparison across the demand systems, including the LES, AIDS, BTL (Basic Transcendental Logarithmic System), QES, QUAIDS and AIDADS, using Monte Carlo simulation.

Meat demand analysis (Dlasková 2014)

Previous chapters illustrated possible methods used to analyze demand. In the empirical part of our study, we will focus on the demand for meat. There are many local studies on this theme from wide scale of states and few of them also from the Czech Republic. In following section income, own and cross price elasticities will be compared internationally and locally based on those studies.

Meat homogeneity as an elasticity estimate factor

While we focus on meat as a good and apply microeconomic analysis of demand the homogeneity of meat is assumed – which means that every unit of meat bought by the consumer has the same price and quality. This assumption is unrealistic as meat can be divided by type (beef, pork, poultry and others) by parts (wings, breast, thigh) and by prerelease treatment of for example processed meat, fresh meat *etc*. These final products differs qualitatively and price also varies accordingly. In common analysis the meat is only differentiated by its type but we can also find a few studies focused on qualitative differences within different kinds of meat. There are studies exploring the impact of nutrition composition (Wang and Chern 1995; Tey et al. 2008) as well. Lopez and Malaga (2009) in their meat demand study in Mexico, deal with individual parts of meat from beef steak to seafood (totaling 18 categories), from the results we can see how heterogenic the commodity meat is. Similar outcomes are provided by a previously undertaken study by Heien and Pompelli (1988) which implies that in the beef category the price demand for beef steaks and processed meat is inelastic while entrecote is elastic. Cross price elasticity also appears to be very strong.

Worldwide meat demand meta-analysis

There are many studies estimating meat price and income elasticities. In the following section we will present the results of meta-analysis using those studies to estimate appropriate value of the elasticity. Meta-analysis of income elasticity from 2010 (exacted from 393 studies hence 3357 estimates) and own price elasticity meta-analysis from 2012 (consisting of 362 studies covering 3755) both performed by Gallet (2010; 2012) illustrates general results and compare the values on different continents and for different types of demand analysis and data (time series vs. cross sectional). The next subchapter is based on the review of the studies estimating the income and price demand elasticity for meat in the Czech Republic. Those studies form the basis for the comparison of our results from the econometric analysis with the results of previous investigations.

Income meat demand elasticity estimates

The worldwide average of income meat demand elasticity from the aforementioned meta-analysis is 0.90 (Gallet 2010). If we compare different kinds of meat we can observe significant decline for pork and poultry. The demand for those types is less sensitive on the change in the level of income than the demand for beef. Gallet compares the influence of functional form on the elasticity estimate. In most cases including double-log and AIDS does not find significant difference compared to the classical linear model. The method of estimation plays an important role. For example the 2SLS method increases the elasticity estimate compared to the use of OLS for

0.744. Data with shorter periodicity (quarterly or monthly versus yearly) also shows slightly higher values. From the regional perspective there is significant difference only for Australia which shows lower elasticity. Also, the Middle East and Central South Asia show a difference, but in the opposite direction, for them income elasticity is lower than the average.

Own price meat demand elasticity estimates

The second paper (Gallet 2012) is focused on differences between three regions – North America, Asia, and Europe. In that context he compares different factors influencing the estimate of overall price elasticity. We can observe average values for different kinds of meat and for given regions. The values move from -0.755 (the fish in Europe) to -1.279 (mutton in North America). Other values are in the table

Table 2.3: Price elasticities of meat

	North Amerika	*Asia*	*Europe*
Beef	-1,084	-0,918	**-0,918**
Pork	-0,913	-0,809	**-0,939**
Mutton	-1,279	-0,992	**-0,948**
Poultry	-0,743	-0,845	**-0,851**
Fish	-1,249	-0,902	**-0,755**
Meat as such	-0,964	-0,848	**-0,831**

Source: Gallet (2012)

Review of the studies of demand for meat in the Czech Republic

After 1989, there are two Czech fellows who have investigated meat demand of Czech households: prof. Janda estimated at first demand for meat, while doc. Pavel Syrovátka, provided an overview of to date available econometric demand models in his 2006 paper. Including non-Czech researchers, literature on meat demand is rare and therefore each contribution will be presented in the following paragraphs.

(Janda 1994) used the AIDS model based on the monthly data from the period 1991-1992 (the source was HBS – Household Budget Survey) using CPI (Consumer Price Index) as the price index. He estimates the demand for the three basic types of meat (pork, beef and poultry, then the commodity meat as such, composed from those three commodities). He used the OLS (Ordinary Least Squares), SUR (Seemingly Unrelated Regression) and MLE (Maximum Likelihood Estimator) to estimate the basic model. His study confirmed price inelasticity of the demand for meat in the Czech Republic in this period. On the other hand, disaggregation of meat to individual kinds shows positive but nonsignificant value of the own price elasticity for meat (Which may be due to, as the author proclaim, small variance of the observations of the quantity and price of poultry, or by the omission of the important unmeasurable explanatory variable in the model.). The values of the own price elasticities for pork and beef are -1.44 and -1.31 (Those goods have elastic reaction on the demand for meat.). Income elasticities confirmed that the individual kinds of meat are the normal good with lower than proportional reaction on the change of income. Alternative specification of the model showed greater value of autocorrelation than original model.

(Brosig 1998) already uses a three-step budget process for analyzing the demand for food in the Czech Republic, a step-by-step modeling of purchased commodities. This approach is based on the theory of weak separability, which assumes that demand for goods in each group influences the demand for commodities in other groups as such (Consumers therefore have a budget for clothing, housing, transportation and services theoretically separate from the budget for food. Further steps divide food categories for each types.) The examined data are a time series of monthly data from the years 1991 to 1995 (the source was HBS), as weight is applied CPI using normalized quadratic cost function estimated by a SUR trough MLE. Analysis provides detailed results for the income and price elasticities. Protein categories (covering meat, offal and eggs) amounted to -0.67 for an own price and 0.83 for income elasticity. For each category of the meat are then: pork -0.83; 0.89, beef-1.27; 0.57; poultry -1.34; 1.00, fish -2.50; 2.02. This thesis also highlights the overall market decline that prevailed at the time.

In 1999 Syrovátka finished his dissertation, which analyzes the impact of the income level of farmers on their purchases and consumption of meat and meat products. Two years later he worked on deeper analysis of the demand for meat on data from the CSO (Czech statistical office) dealing with the standard of living (Syrovátka 2001). The work focuses on the differences between income groups. He differentiates households on: workers, farmers, businessmen and pensioners. An interesting finding of this study is the fact that although pensioner households had the lowest income (15 958 CZK), they spends on meat largest share of revenues, on average, 9.66 % (other categories ranged between 5 % – 6 %) and have the lowest income elasticity of 1.45. Elasticity of other revenue categories have been estimated as follows: employees 1.65, farmers 1.62, and tradesmen 1.53. Data on household budget statistics were used to estimate Engel's model of household demand in its linear form, calculated by OLS.

Czech data was also used to illustrate techniques of estimation of price reactions using unit value data which exploits the implicit links between quantity and unit value choices (Crawford et al. 2003). QUAIDS model was applied to monthly data from the years 1991 to 1992, focusing on married couples. In this study many sociodemographic variables were also included. The presence of women in the household significantly exhibits a distinctly lower quantity demanded (As well as higher education. Interesting is also negative correlation with spending on sanitation and culture.), while the ownership of freezers has a positive effect on demand, as well as the achievement of a basic education. Own price elasticity for meat in this study was -0.968.

Syrovátka (2004) examines the income elasticity of the expenditure for the entire food portfolio (divided into 9 categories). This analysis is conducted through nine single-equation regression models with quarterly data of HBS (1995-2002). He uses the CPI as a unifying price index. His calculations has subsequently been corrected in accordance with the theoretical value of the Engel aggregation condition. For meat and meat products, there is a strong elastic response +2.1291 in income. There was also included categories for fish and seafood with a weak negative reaction -0.2413. This means that an increase in annual household income of 1% would increase annual spending on the category of meat by 2.13%. In addition, meat is on average the highest proportion of spending (27 %) within the category of food.

In his next work in 2007 Syrovátka performs economically-mathematical analysis of exponential model of Engel curve in the analysis of income elasticity of Czech households demand for meat and meat products. He define the function of the income elasticity of demand, which is hyperbolic and static in all its parameters. The value of income elasticity thus depends only on the size of the household income. This function takes exactly unit income-demand elasticity for meat and meat products, including fish, when the overall quarterly income per household is 17 337 CZK. Important fact is that in the reviewed period (1995-2000) was the real quarterly income per capita in the Czech average household in the range <12503; 15288> CZK. By the simulation of the model for these values was determined average income elasticity worth 1.21, examined commodity (meat, dairy products and fish) has therefore an elastic reaction to the change in household income.

Even Janda et al. (2009) later examined demand for food as such and using LA/AIDS model using data from HBS for 2009 and three-stage budget process. The theme was due to the attractiveness of tax policy focused mainly on alcoholic beverages. The meat here is not analyzed as the single commodity and the group of animal foods as such has income elasticity with the value of 0.95 – a normal commodity. (For the group of food is the value 0.60).

In the year 2014 Dlasková examined directly the meat demand elasticity and its development in time on the data from HBS covering the years 2000, 2003, 2006, 2009 and 2012. She also compare the impact of different socioeconomic variables on the demand for meat. She use log-log model estimated by OLS and implicit prices. The estimate of value of own price elasticity was -1.2 and for the income elasticity 1.052. Important factors that influences the meat demand was the household of pensioners decreasing the demand by 12.3 %, the women as the head of the family decreasing the demand by 12.5 %, high education of one member of the family, decreasing the demand by 10.9 % and others. Dlasková examines also the elasticities of different kinds of meat. Own price for beef was 0.131, income elasticity then 0.806, -1.143 and 0.881 for poultry, -0.633 and 0.877 for pork, -0.692 and 0.847 for fish and seafood and -1.282 and 1.002 for other meat products respectively. The elasticity for meat was a little bit declining in time except for the pork and fish. All the income elasticities was declining. The study also shows up that different types of households have the same elasticity for meat.

From the above studies, despite their frequent inaccuracies depending on the availability of data, it is possible to get an overview about what ranges are income and price elasticities of demand for meat in the Czech Republic during the given time period. For own price elasticity of meat or protein foods we observe the range (- 1.2 (Dlasková 2014); -0.67 (Brosig 1998)) and for the income elasticity the range (0.63 (Janda 1994); 1.65 (Syrovátka 2001)). That can be described as approximately corresponding to global averages of meta-analyzes conducted by (Gallet 2010; Gallet 2012) (-0.83 own price elasticity and income elasticity of 0.90). It should be borne in mind that in these studies were tested diverse data in different time periods, as well as meat category definitions differed significantly. Based on studies by Crawford et al. (2003) and Dlasková (2014) we can also observe the influence of sociodemographic factors on this demand.

3. Methodology

Hypothesis

The empirical part aims to those goals:

 To estimate the own, cross price and income elasticity of several kinds of meat using three demand systems covering the period of 2010-2015.

 Compare the result from three used model and identify the model with the best performance.

 Interpret the results from the models and its development in time.

We have those hypothesis:

Hypothesis #1: Different demand systems have different performance; the QUAIDS model has the best performance.

Hypothesis #2: Meat demand in Czech Republic has income elasticity close to the unity and demand with respect to own price is inelastic.

Hypothesis #3: Own and cross price elasticities vary across different types of meat

We have decided to use three types of models: LES, BTL and QUAIDS. LES is chosen as the first and most easies model from all demand systems, Basic Translog is used as it was firstly used (Shonkwiler and Yen 1999) zero correction on it and QUAIDS as it was identified as the best fit for Czech household budged survey data (Smutná 2016). The models were described in Literature review, in this section only concrete specification and results will be introduced. We have decided to not incorporate sociodemographic variables for better comparability of the models.

Treatment of selectivity

Selectivity problem

Smutná (2016) focused her master thesis on the selectivity problem. The selectivity problem occurs when we have zero observations in consumption of and hence expenditures on certain commodity or service. As far as we know it is always a problem of meat demand data, if we decompose it into categories. This is also the case of meat consumption by Czech households if meat.

To clear the terminology, we call the variable limited when it has strictly positive values with a significant portion of zeros. Censored data are those in which the information on the side of the dependent variable is not present. The data where both dependent and independent variables are limited are called truncated. The problem of truncated data can occur when we use a logarithm of the variables – as the whole variable cannot be used when its value is equal to zero. We can avoid this loss by substituting the zero observation by some very small number.

In the case of selectivity, we can incorporate the variety of tools that have been developed over time. We could use: Identical stochastic process: The Tobit model, Different stochastic process with no correlation: The Double hurdle model and Different stochastic process with correlation: Sample selection model which parametric (Heien and Wesseils 1990, Shonkwiler and Yen 1999) or semi-parametric (Cosslett 1991) estimators .

Dealing with zeros

We use Shonkwiler and Yen (1999) method according to Smutná (2016) to dispose of selectivity problem among the available methods. It is a two-stage estimator and its performance is appropriate in the contrast of Heien and Wessels estimator. This method consist of probit estimation for each household and each meat item first. Explanatory variables are denoted as Z and corresponding coefficients η. In the second stage, it reformulates dependent variable y_{ih} as:

$$y_{ih} = \Phi(Z'_{ih}\hat{\eta}_i) f(X_{ih}\beta_i) + \delta_i \phi(Z'_{ih}\hat{\eta}_i) + \varepsilon_{ih} \tag{3.1}$$

where X is the vector of explanatory variables in the second stage and β are corresponding coefficients and δ are coefficients to be estimated, $i = 1, \dots, K$ denotes ith commodity and $h = 1, \dots, N$ denotes hth household.

The concentrated log-likelihood function then looks like:

$$L_N = -\frac{NK}{2}\ln(2\pi - 1) - \frac{N}{2}\ln(|S|) \tag{3.2}$$

It then changes the equation of budget shares we already know and the equation of elasticities for every estimated model as will be showed in next section.

Probit estimation

As a first stage of selectivity problem solution we have to estimate probit model with different sociodemographic variables. This estimation gives us the input to Shonkwiler and Yen (1999) estimator which we then use in estimation of particular models. The description of chosen sociodemographic variables can be seen in the Table 3.1 along with the expected effect on the consumption of meat.

Table 3.1: Variables for Probit model

Variable	Description	Expected effect
size	number of members living in the household	+
age	age of the principal of the households which is taken to approximate the age category of the household	+
woman	dummy variable equal to 1 if there is a woman in the household	-
children	dummy variable equal to 1 if there is at least one child in the household	+
retired	dummy variable equal to 1 if there is a retired person in the household	-
natural	dummy variable equal to 1 if the household consume something from the subcategory i which has not been purchased but obtained from the kept animals or as a gift, for instance	-
highschool	dummy variable equal to 1 if the education is on the secondary level	+
graduate	dummy variable equal to 1 if the education is on the tertiary level	+
income_cap	yearly income of the household in the Czech crowns divided by the number of household members	+

We have used this variables to estimate probit models for every year (2010-2015) and every (five) kind of meat. The exception were other kinds of meat and meat products, where some variables were omitted.

Models

Elasticities

In this study, we are interested in the own and cross price and income elasticity. We can define the elasticity as a measure of the responsiveness of the quantity demanded of that good to changes in its price/ price of other goods/ consumer income.

The formulas for Marshallian (uncompensated) elasticities are:

$$e_i = \frac{\frac{\partial D_i(p,M)}{\partial p_i}}{\frac{D_i\ (p,M)}{p_i}} \tag{3.3}$$

$$e_{ij} = \frac{\frac{\partial D_j(p,M)}{\partial p_i}}{\frac{D_j\ (p,M)}{p_i}} \tag{3.4}$$

$$e_m = \frac{\frac{\partial D_i(p,M)}{\partial M}}{\frac{D_i\ (p,M)}{M}} \tag{3.5}$$

Where $D_i\ (p, M)$ is the demand function for *i*th good with respect to price vector (*p*) and income (*M*).

According to the Slutsky equation, the compensated elasticities are:

$$e_{ij}^c = e_{ij} + e_m w_i \tag{3.6}$$

In every model, the calculation of elasticities is based on estimated parameters. The formulas for individual models with incorporated Shonkwiler and Yen (1999) correction for zero observations are in following part of the thesis.

LES

We use this specification to estimate the model:

$$w_{ih}^{*} = \Phi(Z_{ih}'\hat{\eta}_i)\left[\frac{p_i x_i}{M} + \propto_i \left(1 - \frac{\sum_k p_k \beta_k}{M}\right)\right] + \delta_i \phi(Z_i'\hat{\eta}_i) + \varepsilon_i, i = 1 \dots n \quad (3.7)$$

where ε_i is an error term and *n* is equal to the number of commodities.

From this model, we will get five times α, five times β and five times δ.

Marshallian price elasticity:

$$e_{ii} = -1 + \frac{1}{w_i^*}\Phi(Z_{ih}'\widehat{\eta_\iota})\,\frac{\beta_i p_j}{M_i} \quad (3.8)$$

$$e_{ij} = -\frac{1}{w_i^*}\Phi(Z_{ih}'\widehat{\eta_\iota})\,\frac{\alpha_i \beta_i p_j}{M_i} \quad (3.9)$$

Income elasticity:

$$e_m == \Phi(Z_{ih}'\widehat{\eta_\iota})\frac{\alpha}{w_i^*} + 1 \quad (3.10)$$

where δ_{ij} is the Kronecker's delta, that is $\delta_{ij} = 1$ if $i = j$ and $\delta_{ij} = 0$ otherwise (Yen et al. 2002, Yen 2016).

Translog

We use this specification to estimate the model:

$$w_{ih}^{*} = \Phi(Z_{ih}'\hat{\eta}_i)\left[\frac{\propto_i + \sum_j \beta_{ij} \ln\frac{p_i}{M}}{\sum_j(\propto_j + \sum_i \beta_{ij} \ln\frac{p_i}{M})}\right] + \delta_i \phi(Z_{ih}'\hat{\eta}_i) + \varepsilon_i, i = 1 \dots n \quad (3.11)$$

From this model, we will get five times α, twenty-five times β and five times δ.

Marshallian price elasticity:

$$e_{ij} = \frac{\Phi(Z'_{ih}\hat{\eta}_i)\left(\beta_{ij} - w_i \sum_k \beta_{kj}\right)}{\left(-1 + \sum_j \sum_i \beta_{ij} \log(\frac{p_i}{M})\right) w_i} - \delta_{ij} \tag{3.12}$$

Income elasticity:

$$e_m = \frac{\Phi(Z'_{ih}\hat{\eta}_i)\left(-\sum_j \beta_{ij} - w_i \sum_k \sum_j \beta_{kj}\right)}{\left(-1 + \sum_j \sum_i \beta_{ij} \log(\frac{p_i}{M})\right) w_i} \tag{3.13}$$

(Yen et al. 2002)

QUAIDS

We use this specification to estimate the model:

$$\mathrm{w}^*_{ih} = \Phi(Z'_{ih}\hat{\eta}_i)[(\propto_i - \beta_i \alpha_0) + \sum_j \gamma_{ij} \ln p_j +$$

$$\beta_i \left[\ln(M) - \sum_j \alpha_i \ln p_j - \frac{1}{2}\sum_j \sum_k \gamma_{jk} \ln p_j \ln p_k\right] +$$

$$\lambda_i \left(\prod_i p_i^{\beta_i}\right)^{-1} \left[\ln(M) - \sum_j \alpha_i \ln p_j - \frac{1}{2}\sum_j \sum_k \gamma_{jk} \ln p_j \ln p_k\right]^2]$$

$$+ \delta_i \phi(Z'_{ih}\hat{\eta}_i) + \varepsilon_i, i = 1 \dots n \tag{3.14}$$

From this model, we will get six times as α, five times β, twenty-five times γ, five times δ and five times λ.

Marshallian price elasticity:

$$e_{ij} = \frac{1}{w_i} \Phi(Z'_{ih}\hat{\eta}_i) \left\{ - \left(\beta_i + 2\lambda_i \left(\prod_i p_i^{\beta_i} \right)^{-1} \ln\left(\frac{M}{P}\right) \right) \left(\propto_j \right. \right.$$

$$\left. + \sum_k \gamma_{kj} \ln(p_k) \right) - \lambda_i \beta_j \left(\prod_i p_i^{\beta_i} \right)^{-1} \left(\ln\left(\frac{M}{P}\right) \right)^2 \tag{3.15}$$

$$\left. + \gamma_{kj} \right\} - \delta_{ij}$$

Income elasticity:

$$e_m = 1 + \frac{1}{w_i} \Phi(Z'_{ih}\hat{\eta}_i) \left(\beta_i + 2\lambda_i \left(\prod_i p_i^{\beta_i} \right)^{-1} \ln\left(\frac{M}{P}\right) \right) \qquad (3.16)$$

(Smutná 2016)

4. Data description

Household budged survey

HBS is an annual review of incomes and expenditures of Czech households and provides, inter alia, information on the amount of selected types of food purchased for individual households. It is therefore an irreplaceable source of primary data, which are used to calculate other CSO statistics for other scientific and commercial analysis, serving as a basis for informed decisions regarding the social policies of the state and also for international comparisons (ČSÚ 2015).

HBS history dates back to the year 1931 when it was included among the official government statistics and surveys conducted in the Czech Republic since the mid-50s. Its methodology, however, has changed course several times and minor adjustments takes place to adapt to changing structure of the population or international standards almost every year. Yet it remains well suited to monitor consumption trends and their properties in time. The primary unit of the household budget survey is the household - a group of people who share the budget and live together (an exception are the children living in different place in part of the week). The household can be also made up of individual, living alone.

The basic set of 3 000 households is constructed so that its composition by selected sampling attributes corresponds to the household structure in the country. The quota micro census results (sample survey carried out by random sampling, which is designed to obtain representative data on the level and structure of income and basic socio-demographic characteristics of the households) and Housing Census (Sampling attribute municipality size and type of house). Household income distribution is reviewed annually by income trends identified in the sectional statistics.

When analyzing this data, so we take into account that the results apply only to a small, though representative, group of the population and income categories are determined in advance. Expenditure items are since 1999 divided according to the classification CZCOICOP derived from international standard COICOP (classification of individual consumption by purpose).

Data for food are collected from each household for two months only, attributed to each unit to cover entire year. The results therefore have to be interpreted according to these information.

Since 2006, the pattern already includes all types of households, e.g. as yet unobserved jobless households, households of pensioners with economically active members or households with no economically active person. The head of household in two-parent families is always male, in incomplete families mostly parent. In non-family households the person in the head of household is the person with the highest income.

For some years it was also collected an additional set of 400 households, used for data security for minimum income households, whose representation in the population would not guarantee adequate representativeness.

The intent in preparing the data for analysis was to ensure the best possible comparability of different years and to capture trends in demand for meat. Supplementary file was not used.

Quantities

The thesis deals with the relationship between the amount of purchased meat and its price. It is suitable to watch these variables and their development in detail. Another reason to explore these statistics is the inconsistency of definitions of meats in previous studies on this feld. Variable definitions for each category are explained in Table 4.1.

Table 4.1: Description of quantity explanatory variables

The name of the variable	Description of the variable
beef_q	Amount of beef bought by the household (kg per year)
pork_q	Amount of pork bought by the household (kg per year))
poultry_q	Amount of poultry bought by the household (kg per year)
fish_q	Amount of fish and seafood bought by the household (kg per year)
other_q	Amount of sausages, canned food, other kinds of meat, bacon and other meat products bought by the household (kg per year)

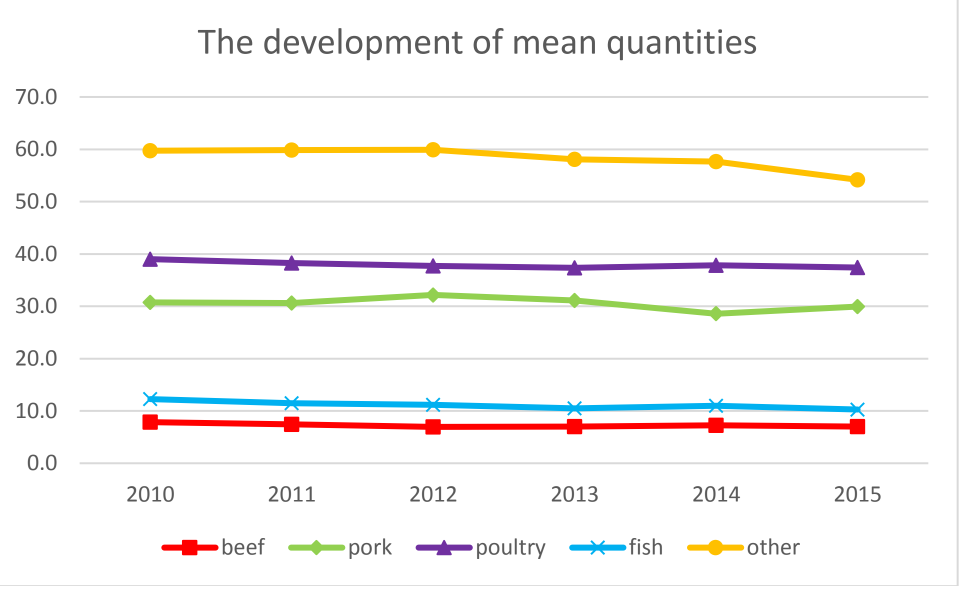
The first thing we are interested in is how many of households consumes given kind of meat or in other words, how many zeros are in observations. It is because we have to explore if there is a possibility of selectivity problem. In Table 4.2 we can see the percentage of zero observations for given kinds of meat. The least consumed meat is beef with in average 45 % of zero observations followed by fish with 19 % and pork with 14 %. On the other hand poultry with 6 % and other types of meat with 0.37 % are mostly consumed meals. Those values clearly shows that usage of censoring method is appropriate. The households with zero consumption of all kinds of meat were deleted from the sample as their elasticities are obviously zero. Maximum of deleted households was three.

Table 4.2: Zeros in observations in %

year	beef	pork	poultry	fish	other
2010	42.97	14.98	5.66	17.53	0.34
2011	43.32	13.26	6.03	18.15	0.34
2012	45.82	13.05	6.32	18.85	0.28
2013	45.64	14.36	6.43	18.93	0.24
2014	45.31	14.85	6.65	17.96	0.45
2015	46.84	13.79	6.96	22.74	0.58
mean	44.98	14.05	6.34	19.03	0.37

Next question we are interested in is the quantity of meat consumed by households in observed years. From Figure 4.1 we can see that the quantity differs very little by the time. Moreover in the case of other meat and meat products and fish and seafood, there was a change in categorization that may cause a little deviation from previous years.

Figure 4.1: The development of meat quantities

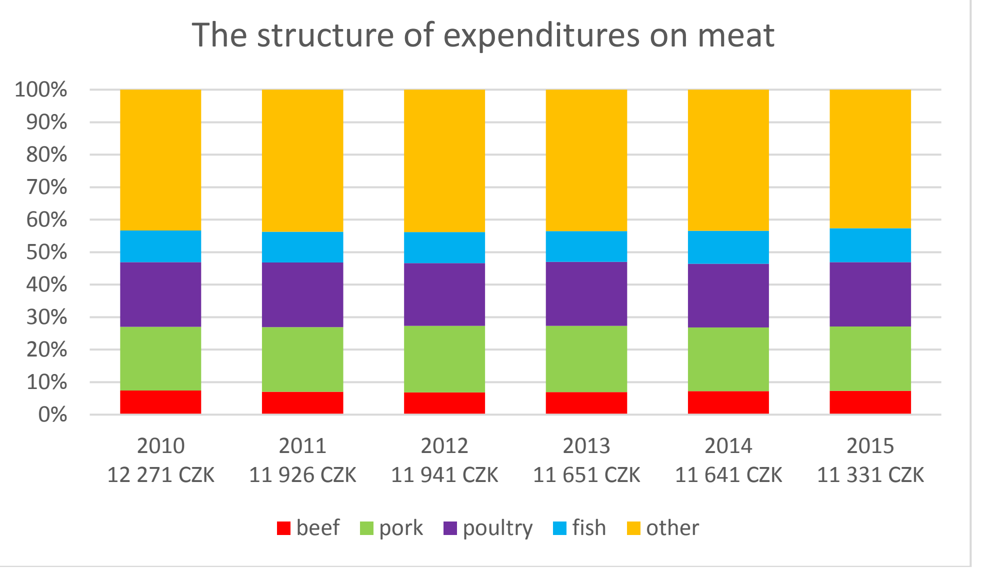


The average quantities of consumed meat are 7.3 kg per year of beef if we count the non-consuming households, among households that have positive consumption it is 13.2 kg. Median is significantly different with the values 3 kg and 9.3 kg respectively—standard deviation was high (14kg). Maximum of consumed beef was 490 kg in 2010. More details can be seen in A 2. In A 3 we can see the descriptive statistics of pork for every year. Average consumption of pork for all households was 30.5 kg, for consuming households it was 35.5 kg median was 21.5 kg and 26 kg respectively. Maximum value of consumed pork was in 838 kg in 2010. Standard deviation quite high with the values 40.1 kg and 41.2 kg respectively. A 4 shows us that poultry was the most consumed single kind of meat with the average of 37.9kg for all households and 40.5 for consuming one. Median was a little lower with 31.4 kg and 33.5 kg respectively. Maximum of consumed poultry was in 2015, 419.4 kg. Standard deviation was almost as high as median (31.3 kg and 30.7 kg). Overall consumption of fish shows the value of 11.1 kg, for the consuming households only it was 12.4 kg. Median was 7.9 kg and 9.1 kg respectively. Maximum of consumed fish was in 2011 with the value of 153.2 kg. Standard deviation was close to mean (11.4 kg in both cases). For more details see A 5. In A 6 are shown the values for other meat and meat products. It is the largest category with minimum of zero observations so if we round to whole numbers we can interpret only one value for consuming and non-consuming households. The mean is 58 kg, median 50 kg, maximum value 372 kg in 2015 and standard deviation is 39 kg.

Expenditures

All expenditures were weighted by CPI for food and nonalcoholic beverages with the basic year of 2005 (A1). Regarding the structure of expenditures, there is just small difference from the quantities purchased. It almost does not differ in time with in average 43 % for other meat and meat products, 20 % for pork and poultry, 10 % for fish and 7 % for beef, total average expenditures are 11 640 CZK per year. The structure of expenditures in times together with total expenditures on meat in given year can be seen on Figure 4.2. For more information about expenditures on different kinds of meat see in A 2 to A 6.

Figure 4.2: The structure of expenditures on meat



Descriptive statistics for total expenditures for households, that consumes meat and expenditures for all households can be seen in Table 4.3 and Table 4.4. We can see that standard deviation moves around median value, averadge minimum for consuming households is 291 CZK, maximum reached on averadge the value of 104 990 CZK.

Table 4.3: Expenditures statistics for consuming households

e	mean	median	min	max	sd
2010	13667.97	11037.29	301.8868	133142.9	11036.52
2011	13224.44	10850.52	284.3643	95309.28	10135.99
2012	13297.35	9851.406	320.4819	79718.07	8971.084
2013	13034	10540.2	276.4165	109759.6	10321.68
2014	13057.46	10708.71	298.048	113596.1	10272.25
2015	12772.42	10288.32	266.3126	98411.23	10119.98
mean	13175.6	10546.07	291.2517	104989.5	10142.91

Table 4.4: Expenditures statistics with zero observations

e with 0	mean	median	min	max	sd
2010	12271.41	9652.291	0	133142.9	10827.12
2011	11926.78	9566.151	0	95309.28	10069.57
2012	11583.94	9219.679	0	91119.68	9840.872
2013	11223.91	8815.084	0	106281.8	9871.203
2014	11149.65	8770.27	0	105294.3	9723.909
2015	11683.17	9374.052	0	96006.83	11861.96
mean	11639.81	9232.921	0	104525.8	10365.77

Prices

The price used in the models is the implicit price calculated from data on the expenditures and purchased quantities. The description of prices as explanatory variables is in Table 4.5. Prices were weighted using the CPI for food and nonalcoholic beverages with the base year of 2005, in the same way as expenditures. For the observations with zero consumption of particular kind of meat is used average price otherwise the observation of household would be omitted.

We are using implicit prices as is usual in the analysis of HBS data. This is in contrast to Jánský (2014) or Smutá (2015), who used CPI as a source of price information. This approach has some advantages if the data for explored commodities are available. Dividing expenditures on the particular commodity by its quantity gives us household-specific prices in very detailed form. By this we get prices depending not only on quantity, but also on quality of the commodity which is not desired. On the other hand using of CPI aggregates the prices to one number losing the information about the price of specific household bud dealing with problem of quality influence on the price.

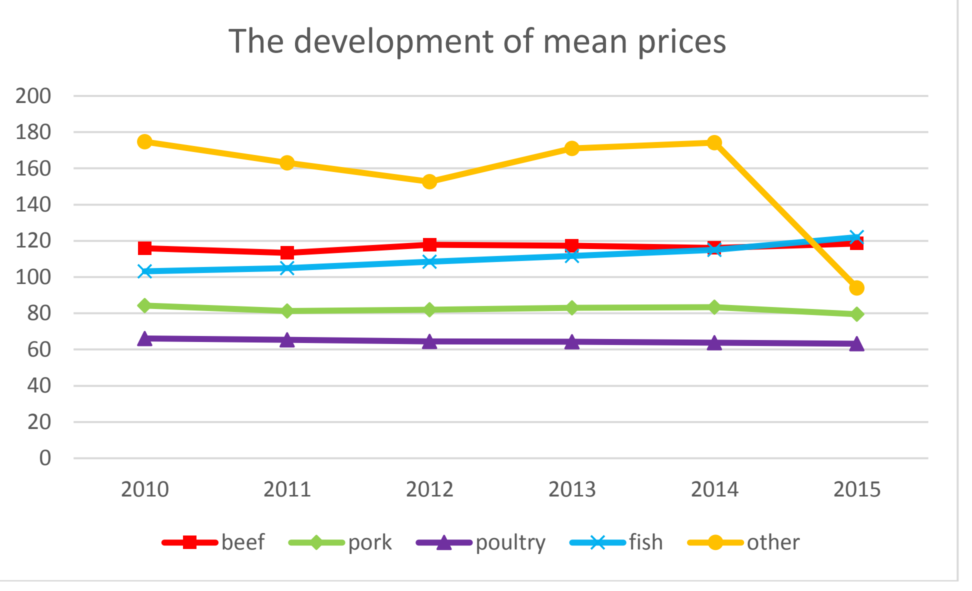
Given the heterogeneity of meat as a commodity, however, the implicit price may be affected by other factors. Different households may choose different meats with different quality of different cuts of meat, whose price is also different. In regression, we use this implicit price households partially elected themselves, not the one actually from the market. Although consumers do not have the power to affect the market price of meat, the price can be calculated in the manner of endogeneity.

Table 4.5: Description of price explanatory variables

The name of the variable	Description of the variable
beef_p	The implicit price of 1 kg of beef, weighted by CPI in CZK
pork_p	The implicit price of 1 kg of pork, weighted by CPI in CZK
poultry_p	The implicit price of 1 kg of poultry meat, weighted by CPI in CZK
fish_p	The implicit price of 1 kg of fish and seafood, weighted by CPI in CZK
other_p	The average implicit price of one kilogram price of other kinds of meat, offal, sausages, meat products, lard and bacon, weighted by CPI in CZK

On Figure 4.3 we can see the development of average meat prices. There is big drawdown in the price of other meat and meat products in 2015. That can be caused by the change of the methodology of gathered data in this year. On the other hand, the rest of the prices is stable. The average of years 2010 to 2015 is 117 CZK for beef, 82 CZK for pork, 65 CZK for poultry, 111 CZK on fish and seafood and 155 CZK on other meat and meat products. Given that we are also counting on median for the prices the difference from mean is not very large. Only in the case of other meat the price is lower by 42 % with the final median number of 89 CZK. That can be caused by the change in categorization, mentioned in the section about quantities and expenditures. The details about prices can be seen in A 2 to A 6.

Figure 4.3: The development of mean prices of meat



Socio-demographical variables

The input variables for probit model are closely described in A 7 to A 12. In Table 4.6 we can see the average values for all 6 years. The mean size of household does not change over time very much with the value close to 2.39 people. It seems like the population is growing older with increasing years from 49.52 average age to 51.83. The percentage of households with the presence of women stays around 93 %, in 43 % there is a child in the household, we have 28 % of retired households in the sample, 44 % of all households have some natural sources of food consumption, 79 % reached high school education and 19 % of household includes someone who graduated.

Table 4.6: Descriptive statistics of probit variables (mean for exanimated period)

	SIZE	AGE	WOM.	CHILD.	RET.	NATU.	HIGH.	GRAD.
mean	2.39	50.94	0.93	0.43	0.28	0.44	0.78	0.19
median	2.00	50.00	1.00	0.00	0.00	0.00	1.00	0.00
min	1.00	19.17	0.00	0.00	0.00	0.00	0.00	0.00
max	7.13	90.00	1.00	1.00	1.00	1.00	1.00	1.00
se	1.17	14.48	0.25	0.49	0.45	0.50	0.42	0.39

Income is distributed among population with the average of 11 205 CZK, median value is slightly lower with 9 937 CZK, minimum is 735 CZK, maximum 185 279 CZK and standard deviation equals to 6 753 CZK.

Table 4.7: Descriptive statistics of monthly household income

	2010	2011	2012	2013	2014	2015	mean
mean	10829	11361	11491	11228	11499	10824	11205
median	9728	10123	10006	9977	10205	9580	9937
min	1463	1234	1068	301	206	137	735
max	80522	135650	333259	228801	204463	128980	185279
sd	5892	6122	8221	7341	6828	6112	6753

5. Estimation results (LES, Translog, QAIDS)

All demand systems were estimated trough MLE method described in Smutná (2016). The estimation was proceed for all observed (six) years for each (three) model and every (five) meat item separately, yielding the results for overall 90 models. According to that, the results will be described individually for each demand system and then the comparison of them will be made. In this section individual income, own and cross price elasticities will be presented.

Probit

We can find the expected and final mean estimated effects of the variables in Table 5.1. The results were not always significant for the types of meat with low number of zero observations.

According to that in the case of other meat and meat products, we have chosen to restrict the probit model only on: size, age, children, natural and income_cap, as there is minimum of zeros in the sample. Even then, all variables were insignificant after estimations. As there is 30 estimations of probit model (that is, 5 types of meat for 6 years) these results are available on request from the author.

Table 5.1: Average results from probit model

variable	Estimated effect	Expected effect
size	+	+
age	+	+
woman	+	-
children	-	+
retired	-	-
natural	-	-
highschool	-	+
graduate	+	+
income_cap	+	+

Overall we can say that the presence of children lowers the probability of consumption of meat as well as the natural consumption. Other interesting thing is that people with secondary and tertiary education buys the fishes significantly more than those with primary education. The count of persons in the household naturally brings higher probability of buying the meat. Other variables are either insignificant or its influence differs by the kind of meat and year. But if we take the average values, we can say that the effect of size, age, retired, natural, graduate and income_cap are as we expected. On the other hand, woman has positive effect, children and highschool has negative effects.

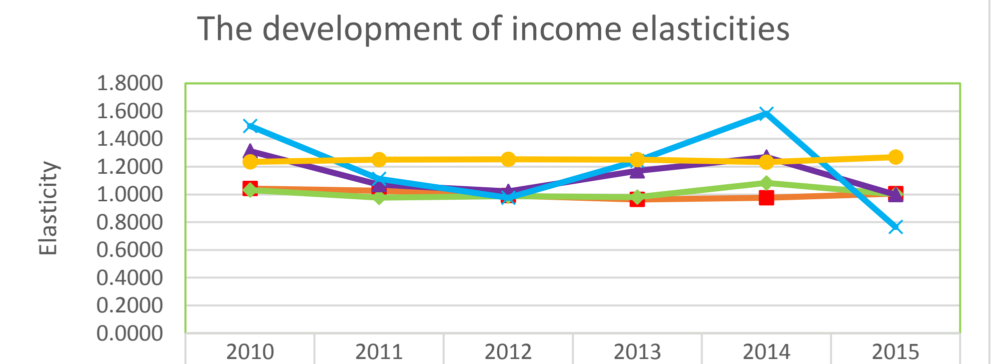
Demand estimation

LES

The Linear Expenditure System is chosen as the first and easies model from all demand systems. We expect that LES will have the worst performance among used demand models as it is the oldest one and it is only rank two model.

In the case of LES, income elasticities are quite uniform in time and close to each other for different kinds of meat. The lowest elasticity for a whole period is for beef and pork. Fish and poultry have the lowest elasticity in the year 2012, then the elasticity increases back to values of 2010 if we don’t count for the jump down in fish income elasticity in 2015. Highest elasticity in the long run has other meat and meat products. More details can be seen in Figure 5.1.

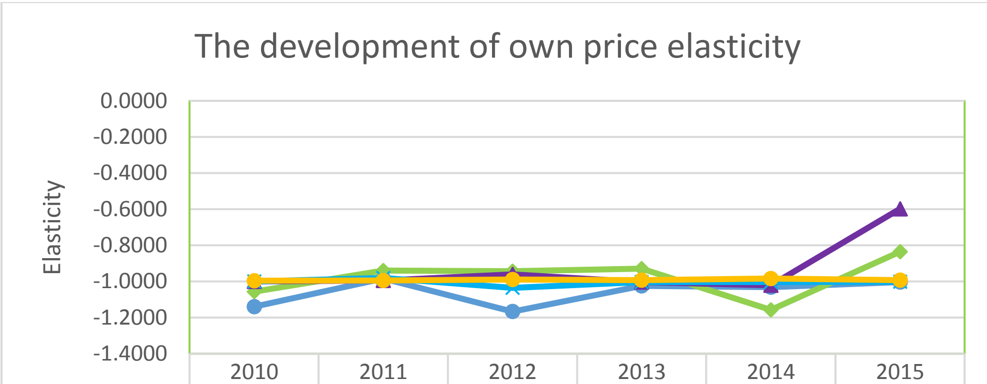
Figure 5.1: Income elasticities for LES



	2010	2011	2012	2013	2014	2015
beef	1.0421	1.0271	0.9926	0.9633	0.9754	1.0066
pork	1.0316	0.9770	0.9868	0.9815	1.0828	1.0019
poultry	1.3120	1.0706	1.0231	1.1704	1.2693	0.9979
fish	1.4929	1.1132	0.9754	1.2422	1.5815	0.7650
other	1.2333	1.2505	1.2526	1.2502	1.2328	1.2683

Own price elasticities are even more uniform across time and meat kinds. They are very close to one in all cases except the jumps down (in absolute value) for pork and poultry. That means that in 2015 the reaction of one 1% increase in price of poultry caused 0.59% decrease in purchased volume. More details can be seen in Figure 5.2

Figure 5.2: Own price elasticities for LES



	2010	2011	2012	2013	2014	2015
beef	-1.1400	-0.9840	-1.1669	-1.0240	-1.0315	-1.0026
pork	-1.0561	-0.9398	-0.9439	-0.9299	-1.1576	-0.8357
poultry	-0.9998	-0.9952	-0.9605	-1.0030	-1.0216	-0.5978
fish	-1.0007	-0.9807	-1.0356	-1.0037	-1.0030	-1.0011
other	-0.9957	-0.9950	-0.9899	-0.9925	-0.9839	-0.9923

As we have used Shonkwiler and Yen (1999) modification of LES, the cross price elasticities are not symmetric any more as they should be in the case of basic LES. We can say that on average, pork and beef are complements, the same for fish and beef, fish and poultry and fish and pork. On the other hand, fish and other meat are substitutes. The values of other elasticities give mixed results. More details can be seen in Table 5.2.

Table 5.2: Cross price elasticities for LES

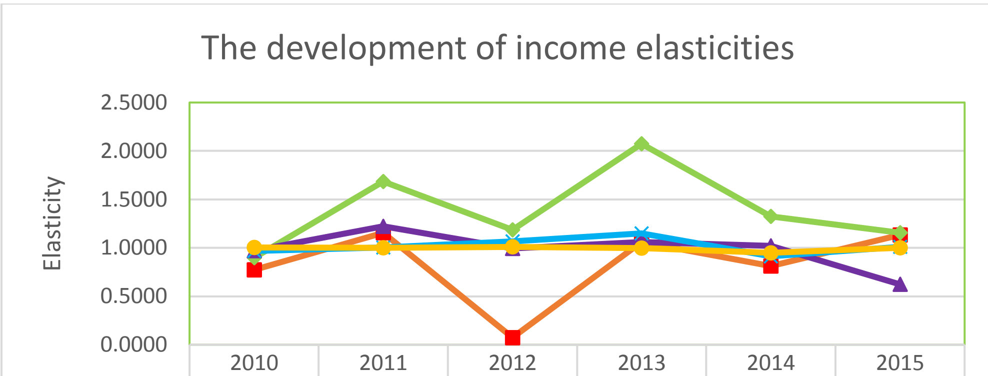
comodity	beef	pork	poultry	fish	other
beef	-	-0.1284816	0.0178883	-0.0283368	0.2434624
pork	-0.3512803	-	0.1034663	-0.0431757	0.1489440
poultry	-0.1719603	-0.0523899	-	-0.0774601	-0.0119115
fish	-0.1681097	-0.0428454	-0.0329007	-	0.0598964
other	-0.1221776	-0.0853253	0.0267636	0.2690800	-

Translog

Basic Translog is used as it was firstly used Shonkwiler and Yen (1999) zero correction on it. We expect it to be the second best models among chosen demand systems as it was developed after the LES model and it is of rank two.

The elasticities in translog shows some jumps across years. The income and own price elasticity of pork acts oddly. Even so we can interpret the results. The lowest income elasticity is performed by beef, but in almost every year except 2012 it is very close to elasticity of poultry, fish and other (close to unity). In 2012 the jump down occurred. Pork income elasticity shows more jumps. It grows up in 2011 and even more in 2013. The income elasticity of poultry drops down a little bit in 2015. More details can be seen in Figure 5.3.

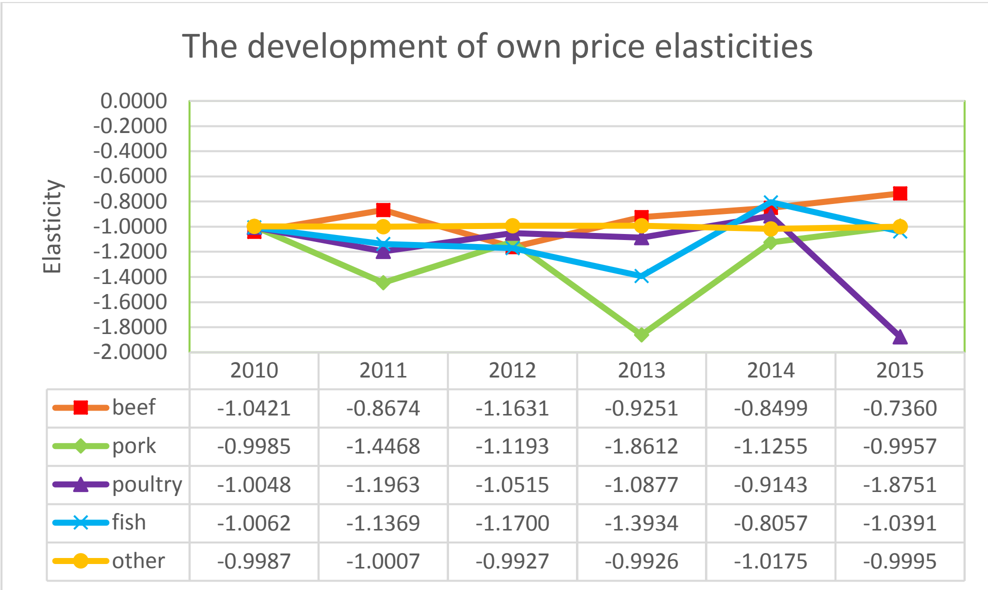
Figure 5.3: Income elasticities for BTL



	2010	2011	2012	2013	2014	2015
beef	0.7718	1.1549	0.0739	1.0614	0.8126	1.1323
pork	0.8977	1.6857	1.1847	2.0735	1.3239	1.1562
poultry	0.9723	1.2225	0.9947	1.0610	1.0212	0.6228
fish	0.9687	1.0041	1.0672	1.1493	0.9127	1.0097
other	1.0045	0.9992	1.0094	0.9985	0.9489	1.0006

In the case of own price elasticity, the estimation in 2010 are almost the same for every type of meat and equal to minus one. It also met in 2012 and 2014. In even years, we can see the variance of own price elasticities among different kinds of meat. It is higher (in absolute value) for pork and fish. In 2015 we also observe jump down for poultry. More details can be seen in Figure 5.4.

Figure 5.4: Own price elasticities for BTL



In the case of cross price elasticities, we can see mixed results. Poultry and beef, poultry and other meat and fish and pork are complements. On the other hand poultry and pork, poultry and fish and other and fish are substitutes. Other results are inconsistent with the assumption of symmetry. More details can be seen in Table 5.3.

Table 5.3: Cross price elasticities for BTL

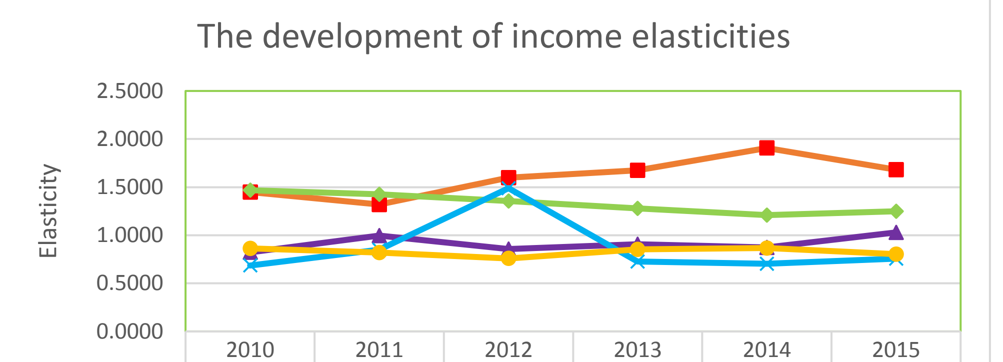
comodity	beef	pork	poultry	fish	other
beef	-	0.6068005	-0.2762956	-0.1470658	-0.0365416
pork	-0.3851894	-	0.5691026	-0.7129990	0.0718486
poultry	-0.1801073	0.4688106	-	0.0591751	-0.1392445
fish	0.0254790	-0.0091137	0.4242117	-	0.0612122
other	0.0040987	0.0022161	-0.0034870	0.1406089	-

QUAIDS

The Quadratic Almost Ideal Demand System is used as it was identified as the best fit for Czech household budget survey data by Smutná (2016). We expect it to be the best among estimated models as it is the newest model and it has rank three.

The income elasticities for QUAIDS shows straight development in time and differs across meat kinds. The value is highest for beef, lower for pork and lowest for poultry, fish and other meat. We can observe jump to higher values in the case of fish for 2012. More details can be seen in Figure 5.5.

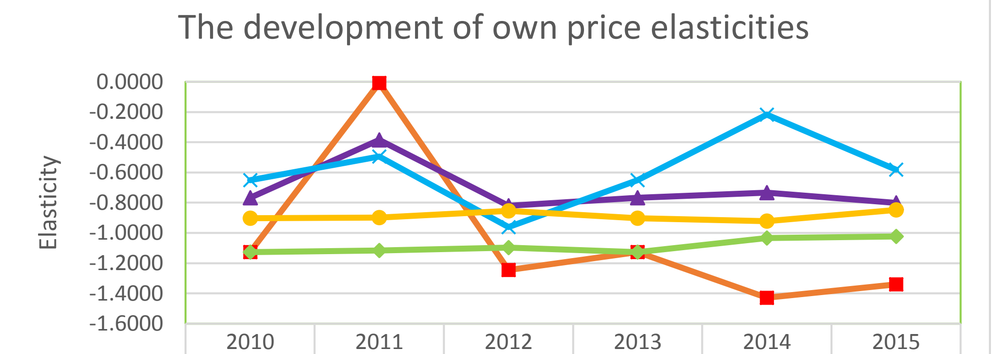
Figure 5.5: Income elasticities for QUAIDS



	2010	2011	2012	2013	2014	2015
beef	1.4491	1.3198	1.5996	1.6749	1.9067	1.6819
pork	1.4680	1.4256	1.3566	1.2781	1.2093	1.2508
poultry	0.8226	0.9973	0.8581	0.9059	0.8749	1.0295
fish	0.6854	0.8508	1.4892	0.7284	0.7025	0.7578
other	0.8621	0.8207	0.7585	0.8549	0.8676	0.8044

The values for own price elasticity are more divergent across observed years. We can see that in the absolute value beef has the higher elasticity except for year 2011 which exhibits big jump to zero. Pork and other meat shows straight and stable development in time where pork has higher elasticity than other meat. For both fish and poultry we can also see the jump in 2011 to smaller values (in absolute value). It repeats for fish in 2014. More details can be seen in Figure 5.6.

Figure 5.6: Own price elasticities for QUAIDS



	2010	2011	2012	2013	2014	2015
beef	-1.1274	-0.0083	-1.2445	-1.1274	-1.4283	-1.3398
pork	-1.1269	-1.1165	-1.0962	-1.1269	-1.0341	-1.0233
poultry	-0.7679	-0.3845	-0.8203	-0.7679	-0.7330	-0.8013
fish	-0.6516	-0.4940	-0.9611	-0.6516	-0.2173	-0.5803
other	-0.9026	-0.8991	-0.8540	-0.9026	-0.9222	-0.8478

In the case of QUAIDS cross price elasticities, pork and beef, pork and fish, beef and fish and poultry and fish are complements. Only other meat and fish appears as substitutes. More details can be seen in

Table 5.4.

Table 5.4: Cross price elasticities for QUAIDS

comodity	beef	pork	poultry	fish	other
beef	-	-0.1284816	0.0178883	-0.0283368	0.2434624
pork	-0.3512803	-	0.1034663	-0.0431757	0.1489440
poultry	-0.1719603	-0.0523899	-	-0.0774601	-0.0119115
fish	-0.1681097	-0.0428454	-0.0329007	-	0.0598964
other	-0.1221776	-0.0853253	0.0267636	0.2690800	-

6. Comparison (across the demand models) and Discussion

Fit of the models

As we have calculated all three models with MLE, we have got three vectors of parameters and three values of likelihood for every exanimated year. The parameters can be seen in A 13, A 14 and A 15. Calculation of information criteria is based on number of estimated parameters of the model, the value of likelihood and in the case of SBC also on the number of observations as was described in Literature review. We can see the numbers of observations in Table 6.1 and the numbers of parameters in Table 6.2. The values of log likelihood are in Table 6.3, the values of AIC are in Table 6.4 and the values of SBC are in Table 6.5 for every year.

The highest number (46) of parameters has QUAIDS, second is Translog (35) and least parameters have LES (15). Log likelihood is lowest for QUAIDS and almost the same for LES and Translog preferably for BTL. Thanks to the lowest number of parameters, LES exhibits the best fit according to AIC and SBC. We can therefor say that LES has most probably the best fit among the estimated models.

Table 6.1: Number of observations

	2010	2011	2012	2013	2014	2015
N	3251	2904	2896	2910	2889	2929

Table 6.2: Number of estimated parameters

	LES	BTL	QUAIDS
parameters	15	35	46

Table 6.3: Log likelihood of models

	LES	BTL	QUAIDS
2010	33231.53	33362.76	28656.10
2011	32794.69	32839.38	25937.34
2012	34187.37	28067.38	25575.21
2013	30203.50	30296.19	25666.88
2014	27251.80	26497.98	25308.81
2015	32378.96	32083.51	25578.19

Table 6.4: AIC results

	QUAIDS	BTL	LES
2010	82.96	60.95	21.09
2011	82.97	60.97	21.17
2012	82.93	61.10	21.18
2013	83.04	61.04	21.18
2014	83.13	61.15	21.19
2015	82.98	60.99	21.18

Table 6.5: SBC results

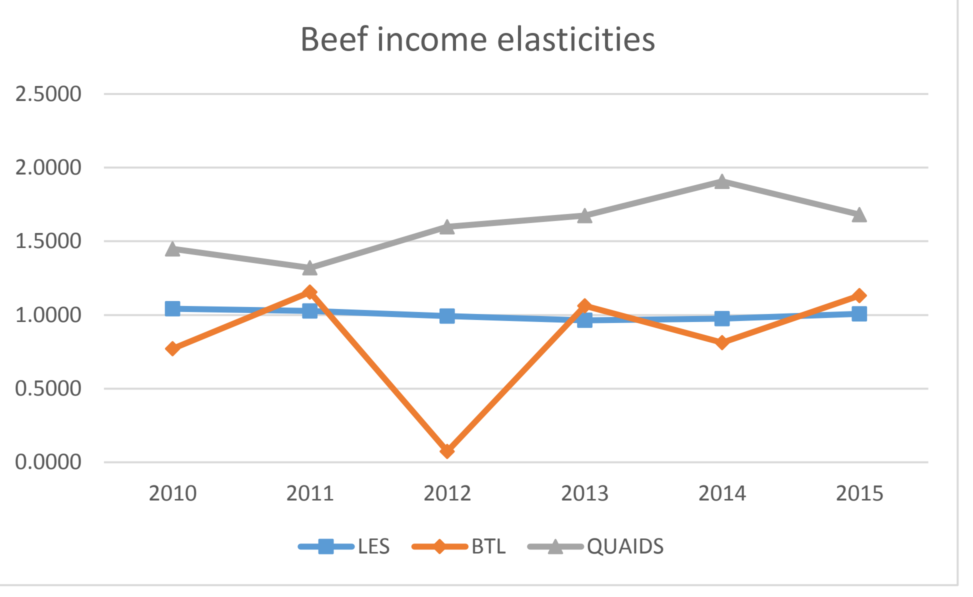
	QUAIDS	BTL	LES
2010	152.51	113.87	43.77
2011	150.27	112.17	43.12
2012	150.18	112.27	43.11
2013	150.38	112.27	43.14
2014	150.32	112.28	43.10
2015	150.45	112.32	43.19

Elasticities estimated by the models

Income elasticities

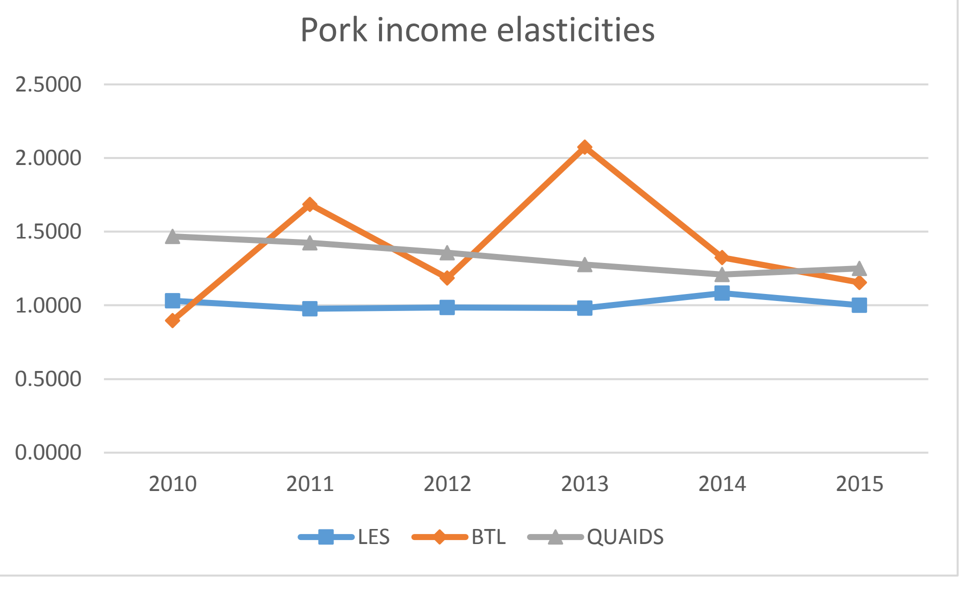
From Figure 6.1 to Figure 6.5 we can see the comparison of income elasticities across LES, BTL and QUAIDS in time. The results differs quite significantly for different models. In the case of beef we can observe values close to one for all years if estimated by LES. Translog gives as the most scattered results (for all the kinds of meat except others), but for beef, if we do not count the result for 2012, the elasticities from BTL are close to the one of LES. On the other hand, QUAIDS gives higher elasticities with increasing trend in time.

Figure 6.1: Comparison of income elasticities for beef



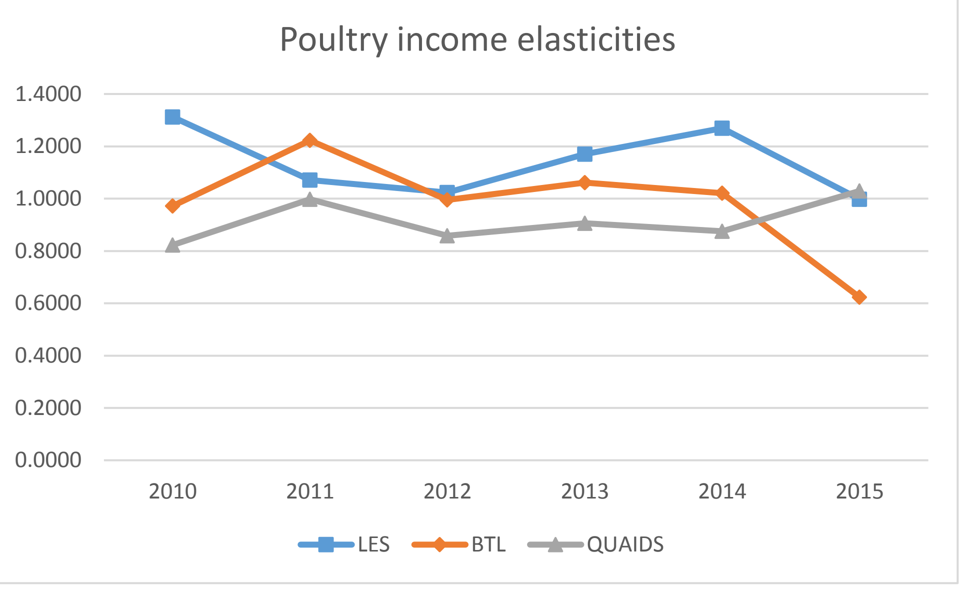
For pork, LES and QUAIDS have convergent results—the elasticities form QUAIDS are decreasing and the one for LES are almost stable. Translog also gives messy results with high values for years 2011 and 2013 in this case.

Figure 6.2: Comparison of income elasticities for pork



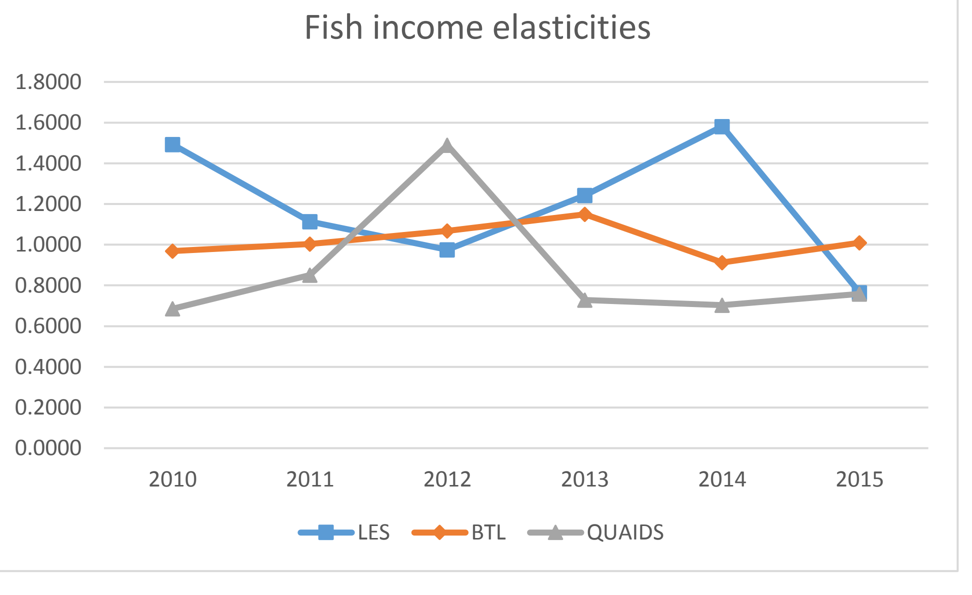
In the case of poultry the results differs. For 2010 the values of LES are higher and the ones of BTL and QUAIDS are lower. On the other hand, in 2015 the values for LES and Translog goes down and for QUAIDS they grows. In other years we can see decreasing trend from 2011 to 2012 and then increasing to 2014. The lowest values gives QUAIDS, the highest are the ones from LES.

Figure 6.3: Comparison of income elasticities for poultry



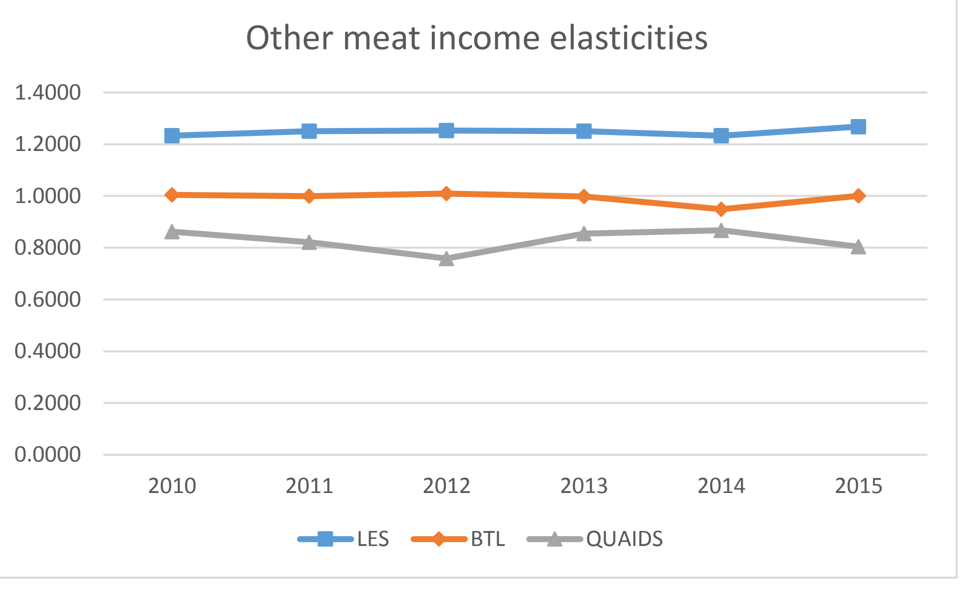
For fish, we can see the unusual phenomenon—BTL gives quite straight results but LES and QUAIDS exhibit some deviations. Interesting also is that those deviations has opposite directions. We can see jump up in 2012 in QUAIDS results (in other years they are stable) and downward trend in the case of LES for 2012. On the other hand, LES jumps up in 2014 significantly. In 2015 the results of all three models are closest to each other.

Figure 6.4: Comparison of income elasticities for fish



In the case of other meat and meat products, the results are most convincing for all the models (as they are all without deviations), which can be caused by the minority of zero observations in the sample. The highest values gives LES, BTL is in the middle and QUAIDS exhibits lowest elasticities.

Figure 6.5: Comparison of income elasticities for other meat



As we wanted to analyze the elasticities, we would like to get to some straight-forward results. We have averaged the values of elasticities from all the years for all three models and for every kind of meat. We also got the mean of all meat kinds. The results can be seen in Table 6.6. At the end, the results for the meat as whole does not differ model from model very much. The mean for LES is almost the same as for QUAIDS (1.12 and 1.10 respectively). The value for BTL is quite smaller (1.04).

Table 6.6: Mean income elasticities

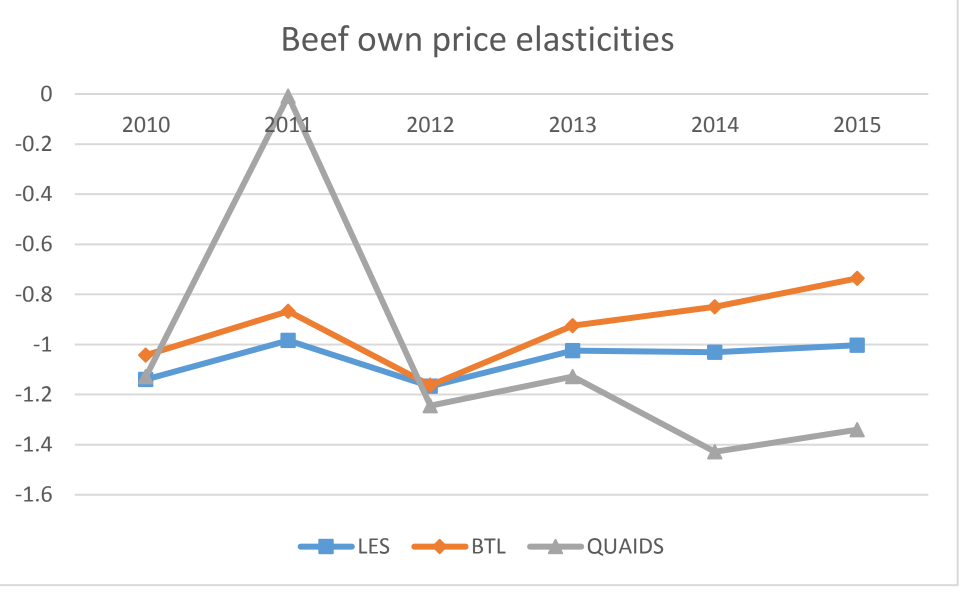
	beef	pork	poultry	fish	other	mean
LES	1.0012	1.0103	1.1405	1.1950	1.2479	1.1190
BTL	0.8345	1.3869	0.9824	1.0186	0.9935	1.0432
QUAIDS	1.6053	1.3314	0.9147	0.8690	0.8280	1.1097

Own price elasticities

On the Figure 6.6 to Figure 6.10 we can observe the differences between the estimates of own price elasticities. If we look at them, we can see the same pattern like in the case of income elasticities. Translog gives us messy results. But in this case, also QUAIDS shows some jumps over different kinds of meat. As in the case of income elasticities, the ones for other meat are most straight and does not differ among models very much.

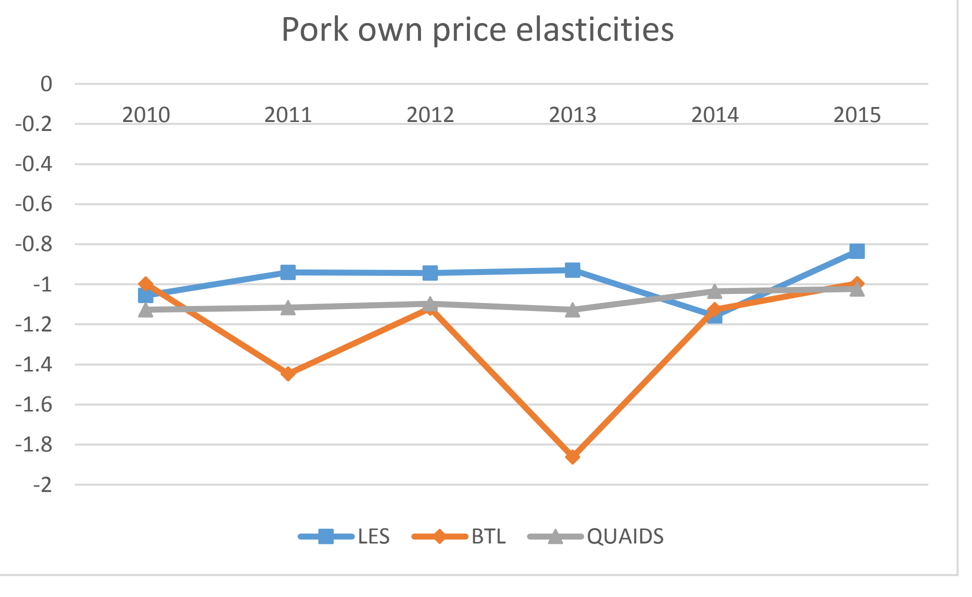
In the case of beef, we can observe big jump up in the year 2011 for QUAIDS and small jumps for LES and BTL. The further development is divergent across models. Most stable are the results of LES.

Figure 6.6: Comparison of own price elasticities for beef



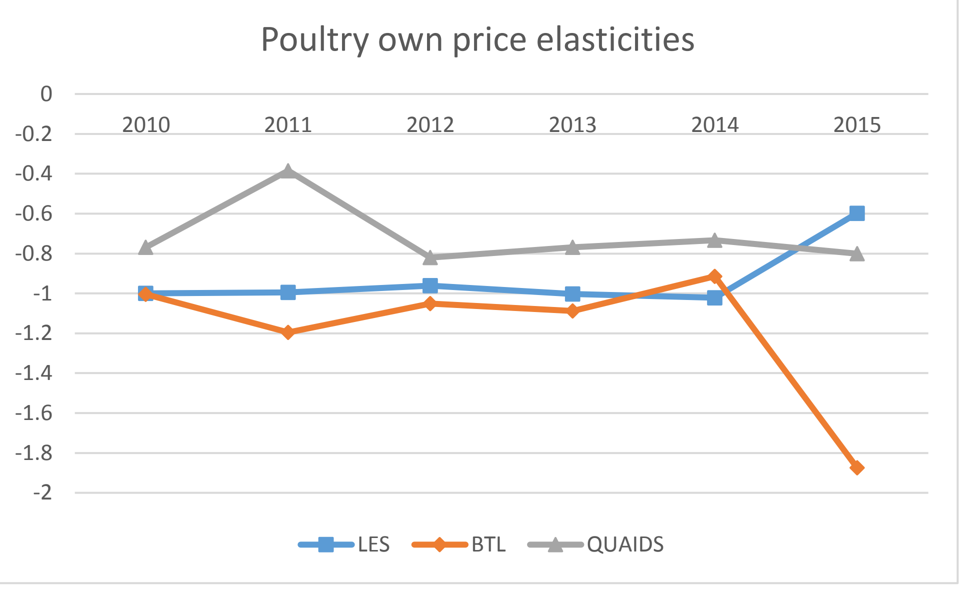
In the case of pork, Translog is totally out of the scale. Its value in 2013 gets to -2. On the other hand, LES and QUAIDS gives the results close to each other. QUAIDS is stable over time with small increasing trend and LES exhibits small decrease in 2014 and the return back and little bit higher in 2015.

Figure 6.7: Comparison of own price elasticities for pork



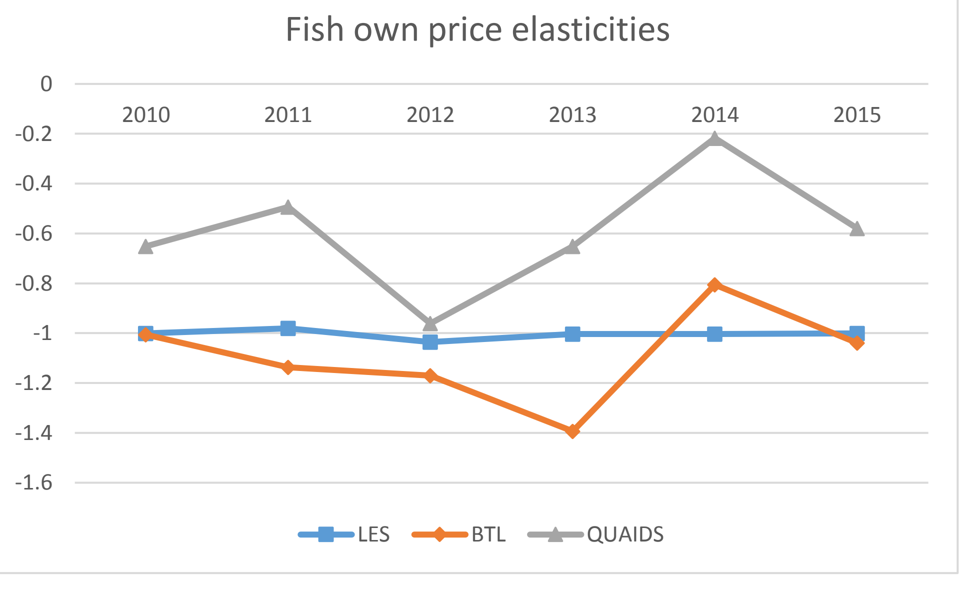
Estimates for poultry gives us inconsistent results for all three models. We can see the jump up from the trend in 2011 in the case of QUAIDS, jump up for LES in 2015 and in the same year big jump down close to -2 in the case of BTL. In other years the elasticities stays stable. Translog and LES gives similar results and QUAIDS exhibits lower values in the absolute value.

Figure 6.8: Comparison of own price elasticities for poultry



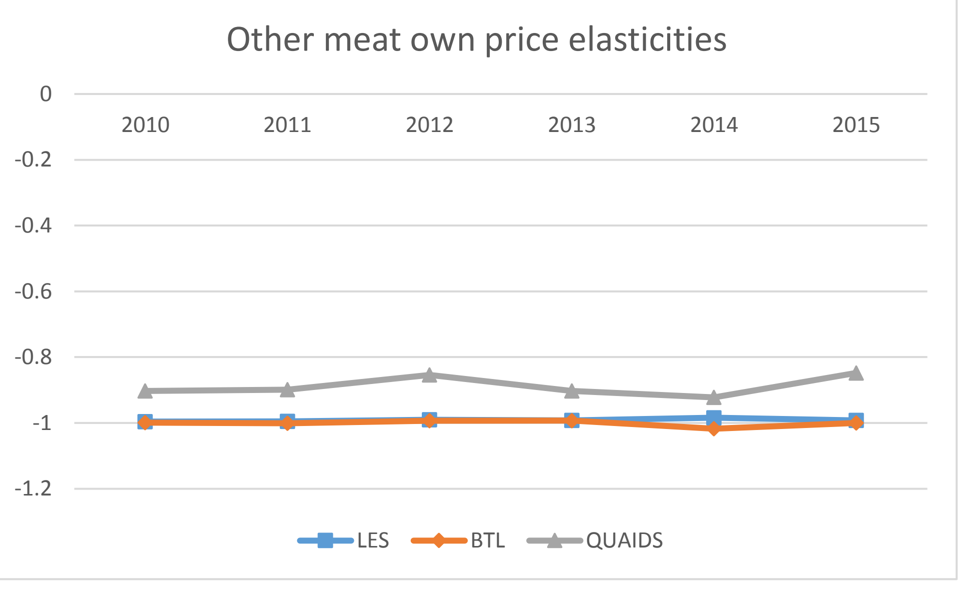
Fish gives also scatter results for BTL and QUAIDS, LES stays stable over time with the value of -1. QUAIDS goes up in 2011, down in 2012, it is highest in 2014 and then it goes down in 2015. Translog on the other hand decreases from 2010 to 2013, then jumps up in 2014 and goes down on the starting value -1 in 2015.

Figure 6.9: Comparison of own price elasticities for fish



For other meat and meat products the results does not differ very much across the years and models. For LES and BTL in stays on -1 for all observed periods. QUAIDS gives little lower results in absolute value.

Figure 6.10: Comparison of own price elasticities for other meat



The difference between models in the case of own price elasticity is higher than for income elasticity. The final results of mean meat price elasticity are -0.99 for LES, -1.09 for BTL and -0.87 for QUAIDS.

Table 6.7: Mean own price elasticities

	beef	pork	poultry	fish	other	mean
LES	-1.0582	-0.9772	-0.9297	-1.0041	-0.9915	-0.9921
BTL	-0.9306	-1.2578	-1.1883	-1.0919	-1.0003	-1.0938
QUAIDS	-1.0459	-1.0873	-0.7125	-0.5927	-0.8880	-0.8653

Cross price elasticities

On Table 6.8 we can see the result of cross price elasticities for all combinations of meat. The only relationship that holds for every estimate is that fish and other are substitutes (+++ and +++ signs). Other results differs a lot. LES exhibits lower values in absolute value than BTL and QUAIDS. Overall the effects are quite small.

Table 6.8: Cross price elasticities

	LES	BTL	QUAIDS	sign
beef-pork	-0.0090100	-0.3851894	-0.3512803	- - -
beef-poultry	0.0092897	-0.1801073	-0.1719603	+ - -
beef-fish	0.0051540	0.0254790	-0.1681097	+ + -
beef-other	0.0004066	0.0040987	-0.1221776	+ + -
pork-beef	-0.0101878	0.6068005	-0.1284816	- + -
pork-poultry	0.0025403	0.4688106	-0.0523899	+ + -
pork-fish	-0.0053054	-0.0091137	-0.0428454	- - -
pork-other	0.0005629	0.0022161	-0.0853253	+ + -
poultry-beef	-0.0002759	-0.2762956	0.0178883	- - +
poultry-pork	-0.0025953	0.5691026	0.1034663	- + +
poultry-fish	-0.0035515	0.4242117	-0.0329007	- + -
poultry-other	-0.0003551	-0.0034870	0.0267636	- - +
fish-beef	0.0105015	-0.1470658	-0.0283368	+ - -
fish-pork	0.0049545	-0.7129990	-0.0431757	+ - -
fish-poultry	-0.0076097	0.0591751	-0.0774601	- + -
fish-other	0.1400836	0.1406089	0.2690800	+ + +
other-beef	0.0845164	-0.0365416	0.2434624	+ - +
other-pork	0.0722382	0.0718486	0.1489440	+ + +
other-poultry	0.0324203	-0.1392445	-0.0119115	+ - -
other-fish	0.0371520	0.0612122	0.0598964	+ + +

Discussion

We have estimated three demand systems (LES, BTL and QUAIDS) to gain three sets of estimates for income, own and cross price elasticity for five kinds of meat. That represents a huge amount of information closely explained above. Overall, we can say that according to information criteria, LES gives the best fit, BTL is the second one, and QUAIDS does not perform very well thanks to high number of parameters and the similar likelihood as other models. On the other hand, QUAIDS has higher rank than other two models so we have expected it to have better fit as it allows higher Engel flexibility.

If we look at the results of elasticities, LES gives the most uniform results across time. In the case of income elasticities we can see differences in the values among different types of meat. On average, beef is the least elastic kind of meat in income (1.00) followed by pork (1.01), poultry (1.14), fish (1.19) and other (1.25), as can be seen in Table 6.6. Average result for meat as a whole is then 1.12.

In the case of price elasticity, LES gives the results close to the unity in absolute value. The least price responsive is demand for poultry (-0.92) and the most responsive is beef (-1.05). Price responsiveness of pork (-0.98), other (-0.99) and fish (-1.00) demands are in between. On average price elasticity is -0.99, as reported in Table 6.7.

Cross price elasticities are quite low in absolute value for LES (Table 5.2) meaning that there are just weak price relations among different kinds of meat.

The estimates for BTL vary over time in their magnitude. Income elasticities are in a range of 0.83 for beef and 1.39 for pork. In the case of own price elasticities the largest difference is found for between beef (-0.93) and pork (-1.26). More details can be seen in Table 6.6 and Table 6.7. Cross price elasticities can be seen in Table 5.3.

QUAIDS also exhibits big differences among elasticity estimates among different kinds of meat but it is not so scattered in time. Income elasticities are in the range from 0.83 (other) to 1.61 (beef) (Table 6.6), cross price elasticities range between -0.59 (fish) to -1.09 (pork) (Table 6.7). The results for cross price elasticities can be found in Table 5.4.

If we compare the results from LES with the results of previous studies for Czech Republic (Table 6.9) the income elasticities and in most cases also the own price elasticities are higher in our study.

Table 6.9: Estimates of elasticities of meat for Czech Republic

Author	Data	Category	Income el.	Own price el.
(Janda 1994)	1991 - 1992	beef	0.91	-1.44
		pork	0.51	-1.31
		poultry	0.87	0.36
(Brosig 1998)	1991 - 1995	beef	0.57	-1.27
		pork	0.89	-0.83
		poultry	1.00	-1.34
		fish	2.02	-2.50
(Dlasková 2014)	2000 - 2012	beef	0.81	0.13
		pork	0.85	-0.69
		poultry	0.87	-0.63
		fish	0.85	-0.69
		orher	1.00	-1.28

Overall the averaged values of income elasticities for all kinds of meat and all years does not differ so extremely between models as can be seen in Table 6.10. The values of own price elasticities are more different (the difference is 0.23 from the value of BTL to the value of QUAIDS, LES is in the middle).The results confirms our second hypothesis that meat demand in Czech Republic has income elasticity close to the unity and demand with respect to own price is inelastic, but with the reserve of 0.01 to unit elasticity. Our results are slightly higher than international ones (Gallet 2010; Gallet 2012).

Table 6.10: Average elasticities for meat

	income elasticity	own price elasticity
LES	1.118988448	-0.992128017
BTL	1.043198445	-1.093783905
QUAIDS	1.109698657	-0.865296973

7. Conclusion

The thesis consists of theoretical and empirical part. In the theoretical part, we describe several models for estimation of consumer demand in coherent and theoretically sound way. Specifically, several complex demand systems are presented: Linear expenditure system (LES), Rotterdam demand system, Translog system (BTL), Quadratic expenditure system (QES), Almost ideal demand system (AIDS), An implicit direct additive demand system (AIDADS), and Quadratic almost ideal demand system (QUAIDS). We provide examples of their application. Methods, how these demand systems be compared, is presented. A review of empirical literature on estimating meat demand closes this pat, including a meta-analysis of meat demand and empirical results provided for demand for meat of the Czech consumers.

In our empirical part, we choose three demand systems that are estimated on household-level data for the Czech consumer—LES, Translog and QUAIDS. We choose these three models, since a] LES was the firstly developed system for demand analysis, b] the Translog was for the first time corrected by Shonkwiler and Yen method to treat the selectivity, and c] QUAIDS is recently widely used demand model, allowing also the Engel curves to be non-linear. Two stage procedure was used to deal with the selectivity, i.e. zeros in observations (for example, only 55% of households consumes beef). The selectivity problem was treated by Probit model that was augmented by socio-demographic variables, however, the demand models were estimated as a basic systems, without such augmentation.

Household budget survey data from Czech Republic for the period 2010 to 2015 was used for the estimation of income, own and cross price elasticities of several kinds of meat. We divide meat aggregate category into five subcategories—beef, pork, poultry, fish, and other meat and meat products.

As we have estimated Akaike and Schwarz Bayesian information criterions for all three models we have concluded that LES gives the best fit to Czech HBS data. It gives those results: income elasticities are slightly higher than unity, 1.00 for beef, 1.01 for pork, 1.14 for poultry, 1.19 for fish and 1.25 for other meat. According to Engel's law requires the income elasticity are between 0 and 1, our results does not confirm this law finding that meat is a luxury good with average (from elasticities for different types of meat) income elasticity equal to 1.12. Price elasticities have expected values: -1.06 for beef, -0.98 for pork, -0.93 for poultry, -1.00 for fish and -0.99 for other meat and meat products, on average own price elasticity equals to -0.99. Cross price elasticities differ significantly across the meat types and indicate that, on average, pork and beef are complements, the same for fish and beef, fish and poultry and fish and pork. On the other hand, fish and other meat are substitutes. The other estimates of cross price elasticities give mixed results. Our estimates of elasticities are higher than the ones found in previous studies on meat demand conducted in the Czech Republic. It can be caused by the fact that we are the only one using the techniques for treatment of zero in the case of meat demand.Our results are slightly higher than international ones (Gallet 2010; Gallet 2012).

As far as we know, there have never been attempts to use LES and Translog on Czech demand data. Despite QUAIDS provides more flexible Engel curves and should be more accurate, LES was the best fitting model for this case. This anomaly could be caused by possible lack of households with very low or high expenditures in the sample. The comparison of the three chosen models used on meat demand is very important for future analysis of this particular kind of data.

The knowledge of elasticities is useful for governmental or commercial policies. Companies can analyze the impact of price change of their products on consumer demand for them. On the other hand, government can estimate the effect of taxes and improve its fiscal policies.

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Appendix

A1: CPI weights for meat expenditures

year	2010	2011	2012	2013	2014	2015
CPI for food and nonalcoholic beveradges	1.113	1.164	1.245	1.306	1.332	1.318
Overall CPI	1.149	1.171	1.21	1.227	1.232	1.236

(ČSÚ 2016b)

A 2: Descriptive statistics for beef

q	mean	median	min	max	sd	N
2010	13.76581	9.55	0.48	490.7	16.84193	1853
2011	13.14501	9.75	0.64	136.12	12.43318	1645
2012	12.82249	9.13	0.9	122.77	11.88278	1568
2013	12.90121	8.655	0.61	293.96	14.68625	1581
2014	13.27402	9.125	0.39	345.63	15.40827	1579
2015	13.20661	9.35	0.58	124.48	12.61538	1556

q with 0	mean	median	min	max	sd	N
2010	7.850452	3.56	0	490.7	14.42914	3251
2011	7.450651	3.39	0	136.12	11.40376	2904
2012	6.946992	2.79	0	122.77	10.83129	2896
2013	7.013646	2.905	0	293.96	12.59164	2910
2014	7.259588	2.91	0	345.63	13.17213	2889
2015	7.020379	2.72	0	124.48	11.31502	2929

e	mean	median	min	max	sd	N
2010	1604.081	1089.398	67.38544	40123.09	1887.743	1853
2011	1485.384	1085.052	59.27835	15414.09	1449.599	1645
2012	1504.47	1057.028	82.73092	10527.71	1391.585	1568
2013	1496.388	1017.611	64.31853	27010.72	1645.091	1581
2014	1533.985	1052.928	48.04805	38497.75	1794.402	1579
2015	1560.913	1086.495	44.00607	13144.92	1501.988	1556

e with 0	mean	median	min	max	sd	N
2010	914.7852	367.4753	0	40123.09	1631.813	3251
2011	841.922	354.811	0	15414.09	1316.355	2904
2012	815.0944	279.5181	0	10527.71	1269.28	2896
2013	813.5002	289.4334	0	27010.72	1423.658	2910
2014	838.9394	289.039	0	38497.75	1531.032	2889
2015	1181.385	805.0076	0	10740.52	1256.052	2929

p	mean	median	min	max	sd	N
2010	115.936	113.0966	38.76971	517.2611	34.42294	1853
2011	113.3688	111.0454	34.36426	345.5443	30.31605	1645
2012	117.8491	115.235	45.20816	488.1395	33.08306	1568
2013	117.3171	114.3578	32.05242	387.3437	31.86417	1581
2014	116.0248	112.6126	36.25336	463.9255	32.88217	1579
2015	118.5291	114.1584	36.08224	599.1601	34.7026	1556

A 3: Descriptive statistics for pork

q	mean	median	min	max	sd	N
2010	36.14067	25.98	1.15	838.94	45.63962	2763
2011	35.26318	26.67	0.62	626.81	37.20268	2518
2012	36.99946	26.645	1.04	777.42	45.32903	2517
2013	36.32956	25.72	0.95	1034.5	49.31856	2491
2014	33.55061	25.345	1.32	386.4	30.94851	2459
2015	34.7399	25.91	1.13	637.16	38.63924	2524

q with 0	mean	median	min	max	sd	N
2010	30.72679	20.55	0	838.94	44.01473	3251
2011	30.58814	22.195	0	626.81	36.65447	2904
2012	32.17011	22.575	0	777.42	44.06688	2896
2013	31.11109	21.47	0	1034.5	47.38447	2910
2014	28.56854	20.65	0	386.4	30.95015	2889
2015	29.94819	21.77	0	637.16	37.8228	2929

e	mean	median	min	max	sd	N
2010	2823.874	2149.146	80.86253	39039.53	2600.524	2763
2011	2726.542	2086.77	53.2646	30486.25	2446.252	2518
2012	2819.456	1057.028	82.73092	10527.71	1391.585	2517
2013	2768.715	2141.271	91.11792	31150.08	2489.881	2491
2014	2678.387	2144.52	117.8679	17710.96	2204.926	2459
2015	2600.427	2009.863	106.9803	25320.18	2274.54	2524

e with 0	mean	median	min	max	sd	N
2010	2400.858	1734.052	0	39039.53	2601.014	3251
2011	2365.069	1777.921	0	30486.25	2458.801	2904
2012	2451.447	1828.514	0	23328.51	2506.089	2896
2013	2371.01	1748.469	0	31150.08	2500.391	2910
2014	2280.662	1713.964	0	17710.96	2246.517	2889
2015	2247.182	1840.668	0	20494.69	1945.367	2929

p	mean	median	min	max	sd	N
2010	84.27603	81.96011	27.37536	199.1817	17.32059	2763
2011	81.23292	78.92282	27.01455	199.9583	16.20602	2518
2012	82.00903	79.78705	24.38086	239.5629	15.69451	2517
2013	83.06517	81.45962	21.19909	183.5468	15.93728	2491
2014	83.47815	81.70286	22.33788	180.2463	16.13392	2459
2015	79.49695	77.38343	15.14093	180.8784	16.75581	2524

A 4: Descriptive statistics for poultry

q	mean	median	min	max	sd	N
2010	40.17575	32.78	0.71	419.36	31.75121	3066
2011	40.72014	33.92	0.52	251.19	30.50717	2728
2012	40.22727	34.1	0.96	202.59	29.27649	2712
2013	39.91397	32.67	0.81	315.07	30.47614	2722
2014	40.50162	33.42	0.85	271.04	30.65851	2696
2015	40.17575	32.78	0.71	419.36	31.75121	2724

q with 0	mean	median	min	max	sd	N
2010	39.00478	32.34	0	293	32.20635	3251
2011	38.26627	31.96	0	251.19	31.12078	2904
2012	37.68528	31.715	0	202.59	29.97911	2896
2013	37.34905	30.745	0	315.07	31.06295	2910
2014	37.80992	31.04	0	271.04	31.29296	2889
2015	37.37757	30.67	0	419.36	32.28797	2929

e	mean	median	min	max	sd	N
2010	2588.946	2123.091	67.38544	16599.28	1925.415	3066
2011	2524.461	2100.515	56.70103	17418.38	1875.004	2728
2012	2455.684	2064.257	25.70281	27068.27	1819.41	2712
2013	2446.999	2024.502	54.36447	17659.26	1847.187	2722
2014	2451.773	2021.772	51.8018	17927.93	1842.091	2696
2015	2415.412	1965.099	53.8695	20494.69	1913.484	2724

e with 0	mean	median	min	max	sd	N
2010	2442.417	2009.883	0	16599.28	1963.489	3251
2011	2372.332	1981.959	0	17418.38	1914.336	2904
2012	2300.508	1947.39	0	27068.27	1859.586	2896
2013	2289.752	1891.271	0	17659.26	1884.911	2910
2014	2288.83	1893.393	0	17927.93	1881.683	2889
2015	2241.748	1694.234	0	25320.18	2294.343	2929

p	mean	median	min	max	sd	N
2010	66.12192	63.04157	10.74152	201.1289	21.4615	3066
2011	65.45457	63.24525	17.31533	157.0595	21.43111	2728
2012	64.50182	61.56581	13.17669	158.6037	20.5727	2712
2013	64.38637	62.12797	14.82537	331.9136	20.99152	2722
2014	63.70618	61.15045	15.01502	159.5802	20.06506	2696
2015	63.21454	60.60844	11.83279	178.441	20.88483	2724

A 5: Descriptive statistics for fish and seafood

q	mean	median	min	max	sd	N
2010	13.56476	9.97	0.22	114.21	12.53366	2936
2011	12.78609	9.59	0.32	153.21	11.52388	2604
2012	12.49031	9.14	0.28	95.42	11.21918	2589
2013	11.75181	8.58	0.31	111.01	10.95252	2590
2014	12.33347	9.07	0.39	114.9	11.27375	2574
2015	11.68145	8.445	0.27	97.61	10.90518	2573

q with 0	mean	median	min	max	sd	N
2010	12.2546	8.83	0	114.21	12.56882	3251
2011	11.46962	8.175	0	153.21	11.58559	2904
2012	11.17054	7.845	0	95.42	11.28329	2896
2013	10.46355	7.34	0	111.01	10.96756	2910
2014	10.99297	7.8	0	114.9	11.31457	2889
2015	10.26564	7.15	0	97.61	10.9107	2929

e	mean	median	min	max	sd	N
2010	1324.055	988.3199	35.04043	10476.19	1223.498	2936
2011	1260.609	938.1443	33.50515	9469.072	1103.246	2604
2012	1274.296	971.8876	25.70281	9138.956	1144.808	2589
2013	1235.665	891.2711	25.26799	10388.97	1148.384	2590
2014	1326.728	980.4805	35.28529	11476.73	1204.256	2574
2015	1344.319	982.5493	28.07284	10740.52	1255.476	2573

e with 0	mean	median	min	max	sd	N
2010	1196.17	861.6352	0	10476.19	1226.921	3251
2011	1130.815	822.5945	0	9469.072	1112.927	2904
2012	1139.65	836.5462	0	9138.956	1151.328	2896
2013	1100.209	760.3369	0	10388.97	1150.325	2910
2014	1182.528	828.8288	0	11476.73	1209.599	2889
2015	1181.385	805.0076	0	10740.52	3183.099	2929

p	mean	median	min	max	sd	N
2010	103.0792	94.79611	38.07784	514.4679	37.19838	2936
2011	105.015	96.16864	22.42243	513.0539	39.30559	2604
2012	108.5352	100.1019	33.88337	750.3183	43.74461	2589
2013	111.6368	101.8019	34.56844	610.9454	44.24084	2590
2014	114.9742	103.9659	14.81216	474.788	46.77055	2574
2015	122.061	109.8077	43.02051	651.8968	51.21643	2573

A 6: Descriptive statistics for other meat and meat products

q	mean	median	min	max	sd	N
2010	59.83226	51.64	0.57	300.57	40.23919	3244
2011	59.95802	52.68	0.68	262.84	39.08873	2897
2012	60.00493	52.42	1.54	280.1	39.32132	2890
2013	58.19345	50.25	0.54	291.86	38.48917	2904
2014	57.79923	49.55	0.51	291.63	38.9074	2879
2015	54.389	46.26	0.36	372.28	38.01337	2916

q with 0	mean	median	min	max	sd	N
2010	59.72184	51.62	0	300.57	40.28397	3251
2011	59.83414	52.6	0	262.84	39.14312	2904
2012	59.90133	52.29	0	280.1	39.36626	2896
2013	58.09346	50.185	0	291.86	38.53154	2910
2014	57.61917	49.44	0	291.63	38.98006	2889
2015	54.16617	45.9	0	372.28	38.09417	2929

e	mean	median	min	max	sd	N
2010	5327.011	4687.332	51.21294	26904.76	3399.336	3244
2011	5227.441	4640.034	81.61512	22521.48	3261.889	2897
2012	5243.443	4701.205	103.6145	22455.42	3223.695	2890
2013	5086.238	4465.544	41.34763	23550.54	3191.133	2904
2014	5066.584	4509.009	45.04505	27982.73	3226.572	2879
2015	4851.345	4244.31	33.38392	28710.93	3174.489	2916

e with 0	mean	median	min	max	sd	N
2010	5317.179	4679.245	0	26904.76	3403.885	3251
2011	5216.64	4628.866	0	22521.48	3267.151	2904
2012	4877.245	4327.711	0	21056.22	3054.589	2896
2013	4649.441	4125.574	0	20072.74	2911.917	2910
2014	4558.686	4045.045	0	19680.93	2855.078	2889
2015	4831.47	4229.135	0	28710.93	3183.099	2929

p	mean	median	min	max	sd	N
2010	92.9661	91.09029	27.37652	229.2479	19.91171	3244
2011	91.2079	88.90299	19.43331	223.4795	19.384	2897
2012	91.92916	89.70066	33.94114	400.5158	21.02898	2890
2013	91.77975	89.87454	17.96578	224.4884	19.61718	2904
2014	92.32354	90.55494	30.08537	270.0753	20.36312	2879
2015	93.80658	91.825	35.44728	235.092	20.89389	2916

A 7: Descriptive statistics of probit variables - 2010

	size	age	wom.	child.	ret.	natur.	high.	grad.	Income_cap
mean	2.47	49.52	0.94	0.47	0.26	0.46	0.79	0.17	10828.90
median	2	48	1	0	0	0	1	0	9728.13
min	1	19	0	0	0	0	0	0	1463.05
max	8.08	90	1	1	1	1	1	1	80521.76
sd	1.19	14.31	0.24	0.50	0.44	0.50	0.41	0.37	5891.88

A 8: Descriptive statistics of probit variables - 2011

	size	age	wom.	child.	ret.	natur.	high.	grad.	Income_cap
mean	2.38	50.57	0.93	0.43	0.29	0.45	0.79	0.18	11360.67
median	2	50	1	0	0	0	1	0	10123.29
min	1	19	0	0	0	0	0	0	1234.27
max	7	90	1	1	1	1	1	1	135649.87
sd	1.16	14.48	0.25	0.49	0.45	0.50	0.41	0.38	6122.29

A 9: Descriptive statistics of probit variables - 2012

	size	age	wom.	child.	ret.	natur.	high.	grad.	Income_cap
mean	2.39	51.00	0.94	0.42	0.29	0.45	0.78	0.19	11491.43
median	2	50	1	0	0	0	1	0	10006.28
min	1	19	0	0	0	0	0	0	1067.93
max	7	90	1	1	1	1	1	1	333258.68
sd	1.16	14.43	0.25	0.49	0.45	0.50	0.41	0.39	8221.15

A 10: Descriptive statistics of probit variables - 2013

	size	age	wom.	child.	ret.	natur.	high.	grad.	Income_cap
mean	2.38	51.24	0.93	0.42	0.29	0.42	0.78	0.19	11227.45
median	2	50	1	0	0	0	1	0	9976.85
min	1	19	0	0	0	0	0	0	301.34
max	6.67	90	1	1	1	1	1	1	228801.34
sd	1.16	14.47	0.25	0.49	0.45	0.49	0.42	0.39	7342.09

A 11: Descriptive statistics of probit variables - 2014

	size	age	wom.	child.	ret.	natur.	high.	grad.	Income_cap
mean	2.35	51.49	0.93	0.41	0.29	0.44	0.76	0.20	11498.51
median	2	51	1	0	0	0	1	0	10205.47
min	1	19	0	0	0	0	0	0	206.03
max	7	90	1	1	1	1	1	1	204463.34
se	1.16	14.54	0.25	0.49	0.45	0.50	0.42	0.40	6828.38

A 12: Descriptive statistics of probit variables - 2015

	size	age	wom.	child.	ret.	natur.	high.	grad.	Income_cap
mean	2.35	51.83	0.93	0.40	0.29	0.42	0.76	0.21	10824.09
median	2	51	1	0	0	0	1	0	9579.70
min	1	20	0	0	0	0	0	0	137.28
max	7	90	1	1	1	1	1	1	128980.16
sd	1.16	14.65	0.26	0.49	0.45	0.49	0.43	0.41	6112.12

A 13: Parameters estimates for LES

	2010	2011	2012	2013	2014	2015
beta1	0.01355	0.003198	0.002151	0.010947	0.047937	-0.00033
beta2	-0.03467	-0.0262	-0.01954	-0.02953	-0.12658	0.008095
beta3	0.001358	0.006813	0.019518	-0.00904	-0.12169	-0.02424
beta4	-0.00248	0.012288	0.003988	-0.0038	-0.01107	0.001267
beta5	0.032641	0.042012	0.088254	0.059118	0.118595	0.062531
alfa1	0.004341	0.002802	-0.00079	-0.00371	-0.00252	0.000766
alfa2	0.004909	-0.00341	-0.00212	-0.00297	0.01303	0.000312
alfa3	0.049784	0.010626	0.003291	0.025902	0.042042	-0.00032
alfa4	0.039693	0.006902	-0.00146	0.015259	0.053062	-0.01525
alfa5	0.090251	0.098312	0.10007	0.096707	0.09017	0.101491
delta1	-0.00888	2.93E-05	0.00076	-0.00638	-0.03058	0.001736
delta2	0.007123	-0.00226	-0.00434	-0.0039	-0.00304	-0.00126
delta3	0.036751	0.010359	0.002976	0.01344	0.045978	0.000574
delta4	0.034444	0.00626	-0.00092	0.00581	0.047748	-0.01542
delta5	0.424468	0.397378	0.376298	0.436712	0.469229	0.423908

A 14: Parameters estimates for BTL

	2010	2011	2012	2013	2014	2015
beta11	-0.00021	-0.00058	-0.00088	0.000659	-0.00767	-0.00054
beta12	0.001704	-0.00062	-0.00252	-0.00092	-0.01528	-0.00168
beta13	8.97E-05	0.00252	0.012731	0.001975	0.010327	0.000891
beta14	-0.00011	-0.0018	-0.00232	-0.00225	0.013129	0.001086
beta15	-0.00033	0.001139	-0.00221	-2.2E-05	-0.01008	0.000509
beta21	-0.00049	-0.0039	0.004685	0.007499	0.006955	0.00069
beta22	1.34E-05	-0.00158	-0.0105	-0.00173	0.016982	0.000178
beta23	-0.00056	-0.00414	-0.01746	-0.00508	0.016991	-0.00126
beta24	0.000325	0.002313	0.002633	0.003976	-0.00757	-0.00108
beta25	-0.00041	0.004891	0.004937	-0.00683	0.011074	-9.1E-05
beta31	7.64E-05	-1.10E-03	-0.01227	-0.0092	0.008346	-0.00156
beta32	0.000695	-0.00291	0.009257	0.004935	0.003025	0.00348
beta33	0.000363	0.002224	0.008858	0.002596	-0.01692	-0.00191
beta34	-0.00277	0.002186	-0.0043	-0.00761	0.007921	0.001564
beta35	-0.0005	0.002071	-0.00237	0.011003	0.002225	-0.00074
beta41	-0.00073	0.003814	-0.00979	-0.00903	0.022919	-0.00054
beta42	-0.00387	0.0061	-0.00024	0.001229	0.011487	-0.0006
beta43	5.47E-05	-0.00221	-0.00225	0.001083	-0.00672	0.000827
beta44	0.00035	0.000943	0.011139	0.006039	-0.02522	-0.00081
beta45	0.002367	-0.00861	0.005566	0.002955	-0.0137	0.000914
beta51	0.001293	0.00151	0.017276	0.009965	-0.0299	0.001796
beta52	0.001628	-0.00105	0.00295	-0.00369	-0.01719	-0.00173
beta53	2.98E-05	0.001813	4.8E-05	-0.00037	-0.0011	0.001616
beta54	0.002103	-0.00378	-0.00719	-0.00033	0.013025	-0.00058
beta55	-0.00121	0.000764	-0.00558	-0.0071	0.008419	-0.00044
alfa1	-0.0084	-0.01138	-0.02585	0.007238	0.11826	-0.00126
alfa2	-0.00011	0.019538	0.084201	0.017975	-0.10753	0.007598
alfa3	-0.03892	-0.03203	-0.08381	-0.05111	0.143242	-0.00124
alfa4	-0.0259	-0.01127	-0.05269	-0.03272	0.144623	0.017099
alfa5	-0.62143	-1.95548	-0.45077	-1.32211	0.592323	-0.99118
delta1	-0.01352	0.001063	-0.00157	-0.00705	-0.05646	0.003091
delta2	0.01086	-0.00176	0.002819	-0.00323	0.141549	-0.00263
delta3	0.052389	0.010966	0.117522	0.015028	0.216542	-0.00028
delta4	0.04388	0.005336	0.037706	0.005387	0.156126	-0.01851
delta5	0.41101	0.401069	0.134745	0.44189	0.334793	0.423024

A 15: Parameters estimates for QUAIDS

	2010	2011	2012	2013	2014	2015
gama11	-0.0295	-0.08953	-0.02208	-0.05331	-0.07643	-0.04048
gama12	-0.02778	-0.0916	-0.01898	-0.02917	-0.06347	-0.03316
gama13	-0.0172	0.009227	-0.01672	-0.0177	-0.01237	-0.023
gama14	-0.02614	-0.01908	-0.01565	-0.02303	-0.01418	-0.02002
gama15	-0.0175	-0.03628	-0.01991	-0.01568	-0.02813	-0.01627
gama21	-0.02034	-0.03384	-0.01145	-0.01636	-0.03604	-0.00433
gama22	-0.01827	-0.02261	-0.01317	-0.02541	-0.01965	-0.00959
gama23	-0.0156	0.010961	-0.01731	-0.01547	-0.00546	-0.01662
gama24	-0.01389	-0.00731	-0.01332	-0.00511	0.004607	-0.01408
gama25	-0.0205	0.001622	-0.01778	-0.01144	-0.01471	-0.01819
gama31	0.010432	-0.00639	0.003344	-0.00269	0.007352	-0.00809
gama32	0.011136	0.021709	0.003836	0.006541	0.013719	-0.00447
gama33	0.029207	0.085385	0.012129	0.034513	0.038652	0.023541
gama34	-0.01303	-0.0069	-0.00602	-0.01822	-0.01411	-0.00705
gama35	0.002041	-0.02321	-0.00464	-0.00151	0.012954	-0.01008
gama41	-0.01104	-0.03177	-0.01323	-0.01021	-0.01415	-0.01022
gama42	-0.01081	-0.00033	-0.01173	-0.01013	-0.02168	-0.00946
gama43	0.000379	-0.00943	-0.0139	-0.01306	-0.00675	-0.01044
gama44	0.008593	0.030173	0.000338	0.023868	0.037771	0.01614
gama45	0.002917	0.031962	-0.01023	-0.0008	0.003447	0.001741
gama51	0.029658	0.100742	0.040045	0.047615	0.066211	0.041675
gama52	0.027584	0.057653	0.034049	0.031976	0.050134	0.031133
gama53	-0.00881	-0.08012	0.016378	-0.00435	-0.01672	0.007227
gama54	0.026026	-0.00241	0.022036	0.005466	-0.02233	0.007157
gama55	0.013608	0.00917	0.01966	0.004753	0.002261	0.021722
alfa0	-0.01353	-0.10892	0.007232	-0.00917	-0.02693	-0.0024
alfa1	-0.01405	-0.096	0.00377	-0.01904	-0.04504	-0.00812
alfa2	0.021463	0.066025	0.014844	0.017798	0.017614	0.020456
alfa3	0.033893	0.092367	0.018781	0.027027	0.037731	0.022452
alfa4	0.019387	0.04455	0.012902	0.01483	0.005833	0.015516
alfa5	0.042789	0.125992	0.025802	0.037013	0.048038	0.032774
beta1	0.075012	0.206853	0.028263	0.070669	0.099665	0.048576
beta2	0.038012	0.009027	0.040686	0.049737	0.057293	0.047651
beta3	0.023872	-0.03857	0.045706	0.031079	-0.00368	0.036063
beta4	0.043385	-0.00011	0.032608	0.037961	0.034196	0.041288
beta5	0.051243	0.046618	0.06353	0.056719	0.054907	0.059956
lambda1	-0.00201	-0.0124	0.002424	-0.00016	-0.00046	0.002133
lambda2	0.002469	0.003926	0.00112	-0.00035	-0.00163	-0.0005
lambda3	-0.00357	0.002769	-0.00454	-0.00307	-0.00096	-0.00225
lambda4	-0.00442	-0.00064	-0.00025	-0.00365	-0.00347	-0.004

lambda5	-0.00752	-0.00855	-0.01101	-0.00783	-0.00717	-0.00956
delta1	0.102349	0.108313	0.104527	0.060015	0.046132	0.105854
delta2	0.171471	0.165542	0.153227	0.192764	0.141412	0.153417
delta3	0.194492	0.171596	0.118592	0.20547	0.24958	0.174662
delta4	0.087737	0.077504	0.097832	0.082724	0.125402	0.120468
delta5	0.040505	0.132543	0.014431	0.082654	0.125192	0.024861