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BACHELOR THESIS

Price Elasticity of Electricity Demand: A Meta Analysis

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Declaration of Authorship

The author hereby declares that he compiled this thesis independently, using only the listed resources and literature.

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Prague, July 30, 2014

Signature

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I am also very grateful to prof. Carol Dahl for publishing her dataset that was partly used for this meta-analysis.

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Abstract

During the last decades, one of the most intensively examined statistical relationships in energy economics has been the price elasticity of electricity demand. In this thesis, a quantitative survey of the estimates of price elasticity reported for various countries is provided. The method I use, called meta-regression analysis, indicates that the literature suffers from serious publication selection bias: positive or insignificant estimates of this elasticity are seldom reported, even though questionably large negative estimates are reported commonly. As a result, the average published estimates of price elasticity are greatly exaggerated (more than threefold in the case of short-run elasticity). By utilising the mixed-effects multilevel meta-regression, which is able to correct for publication selection bias, it is shown that the true average elasticity reaches only -0.06 in the short-run, -0.21 in the intermediate-run and about -0.43 in the long-run.

JEL Classification	C52, C81, C83, Q41
Keywords	electricity demand, price elasticity, meta-analysis, publication selection bias

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Abstrakt

Cenová elasticita poptávky po elektřině představuje jednu z nejzkoumanějších proměnných v oblasti energetiky. V této práci se věnuji výzkumům, které se touto problematikou zabývají, a popisuji modely, které byly použity k dosažení prezentovaných výsledků. Metoda, kterou v této práci používám, se nazývá meta-regresní analýza. Tento poměrně silný statistický nástroj nám ukazuje, že literatura prezentující odhady cenové elasticity poptávky po elektřině trpí publikační selektivitou: nesignifikantní nebo kladné odhady cenové elasticity jsou publikovány jen zřídkakdy, zatímco podezřele silně negativní odhady jsou publikovány běžně. Důsledkem toho jsou průměrné odhady cenových elasticit poptávky po elektřině zveličeny v případě krátkého i dlouhého období (v krátkém období dokonce trojnásobně). Využitím víceúrovňového modelu smíšených efektů, který je schopný očistit odhady o zmíněnou publikační selektivitu, jsme dospěli k závěru, že skutečná hodnota cenové elasticity je přibližně -0.43 v dlouhém období, -0.21 v střednědobém období a jen -0.06 v krátkém období.

Klasifikace JEL	C52, C81, C83, Q41
Klíčová slova	poptávka po elektřině, cenová elasticita, meta-analýza, , publikační selektivita

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Acronyms

2SLS Two-Stage Least Squares

3SLS Three-Stage Least Squares

EC Error Components

ECM Error Correction Model

FAIVE Funnel Asymmetry Instrumental Variable Estimator

FAT Funnel Asymmetry test

FIML Full Information Maximum Likelihood

GLS Generalized Least Squares

GMM Generalized Method of Moments

IR Intermediate-run

IV Independent Variable

LR Long-run

LRT Likelihood Ratio Test

ME Mixed-effects

ML Maximum Likelihood

MLE Maximum Likelihood Estimator

MRA Meta-Regression Analysis

OECD Organisation for Economic Co-operation and Development

OLS Ordinary Least Squares

PET Precision-Effect Test

RePEc Research Papers in Economics

SR Short-run

SUR Seemingly Unrelated Regressions

TE True Effect

WLS Weighted Least Squares

Bachelor Thesis Proposal

Author	Přemysl Horáček
Supervisor	PhDr. Tomáš Havránek, Ph.D.
Proposed topic	Price Elasticity of Electricity Demand: A Meta Analysis

Topic characteristics In my thesis, I would like to determine the Price Elasticity of Electricity Demand using the meta-analysis method. First of all, I will explain how meta-analysis works, which advantages it has, why I decided to apply this method and how we can interpret its outcomes. The Price Elasticity of Electricity Demand has already been a subject of many studies. I will examine and evaluate these studies and some of them will be used as resources for my work. Next, I would like to clarify the importance of knowing the correct price elasticity and the possible ways of utilization of its knowledge. After that, the analysis itself will be presented followed up with its evaluation and comparison with the results of former analysis. Finally, conclusion and list of resources will complete my work.

Outline

1. Introduction
2. Theoretical Background
3. Data and Related Work
4. The Model and Empirical Research
5. Conclusion

Core bibliography

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Chapter 1

Introduction

Modelling consumer behaviour when it comes to electricity demand offers crucial information to various agents, be it producers, local distributors, or governments. One of the most descriptive and useful indicators is undoubtedly the price elasticity of electricity demand. Knowing precise estimates of this elasticity is of principal importance for the purpose of government policy concerning optimal taxation, energy infrastructure, nature-friendly legislative and energy security. For example, if we knew that electricity demand is price-inelastic, taxes would be inefficient, and they would not lead to desirable reduction in electricity consumption. Even though economists produced a plethora of price elasticity estimates over the last 60 years, results vary widely, and this heterogeneity needs to be modeled as well. One way how to make use of all these studies is conducting a method called meta-analysis (Stanley 2001). This method, which has greatly evolved over the last decade, offers a powerful tool to understand why these studies come up with different estimates even when they share many common factors. Meta-analysis of price elasticity of electricity demand has been already presented in the study of (Espey & Espey 2004).

Meta-analyses are based on previously published studies, which means that any errors made in those studies will affect its' outcomes. An example of such an error, which is arising quite often, is the sample asymmetry. In that case, estimated values are not spread around the population value evenly. Such an imbalance can emerge when researchers manipulate their models and data in order to achieve more "publishable" results. Luckily, meta-analysis offers several methods of dealing with this issue. The main asset of this thesis is the application of more efficient meta-analytical methods that have been formulated since the latest meta-analysis of price elasticity of electricity demand in

2004. One of those methods, which allows for unobserved between-study heterogeneity, is called Mixed-effects Multilevel Model (Doucouliagos & Stanley 2009). Another asset of this work lies in the use of larger dataset than in the previous work (Espey & Espey 2004). Moreover, this thesis is the first one in terms of price elasticity of electricity demand that accounts for publication bias.

So, the primary objective of this study is to examine whether the estimates published by primary studies are biased because of publication selection. Secondary goal is to search for some characteristic properties of models used by primary studies, regions from which the data came from, and other factors that could somehow influence the final estimates of price elasticities.

The thesis is structured as follows: Chapter 2 gives some valuable information concerning the theory of price elasticity of demand for electricity, its development, and different methods used for its estimation. Chapter 3 summarizes the literature dealing with price elasticity of electricity demand, describes variables of interest and discusses basic futures of the dataset. Chapter 4 begins with an introduction to meta-analysis and publication bias problem. Afterwards, it presents mixed-effects multilevel model and different methods of testing asymmetry of the dataset. Finally, it comments on the results and compares them with previously published studies. Chapter 5 summarizes our findings.

Chapter 2

Price elasticity of electricity demand

2.1 Types of elasticities

Elasticity is a measure of how consumers respond to a change of price of a commodity (price elasticity), disposable income (income elasticity), or any other factor that may be of our concern. For electricity, the most frequently estimated elasticities are those of price and income. As already mentioned, there have been hundreds of studies published over the past several decades. However, the discrepancy between their individual outcomes calls for clarification. Presented meta-analysis will make use of this variability in order to obtain some meaningful results.

2.2 Usage

Estimating electricity demand elasticities helps us understand consumer behaviour in time. There are two basic periods for comparing the results – short- and long-run. Short-run estimates describe the consumer response during the first year since the variable of concern changed. On the other hand, in the case of long-run, the period length is not that uniformly defined. Different studies take different periods as long-run, which is also due to different methods they use. The main purpose of estimating price or income elasticity is forecasting and predicting future demand based on expected inputs. As already said, this information is very useful for various agents, including distributors, producers, governments, exporters, or importers. With the knowledge of precise elasticities, they can adopt their plans and actions because they know what reactions they can expect from consumers when some parameter alters. In this regard, price elasticity is more employed than the income elasticity because end-user prices are easier to manipulate with (be it through taxes, tariffs, or quotas). Another issue that may be of our concern is the ongoing debate over nature-friendly policies, which can also be created much easily with the knowledge of mentioned elasticities. Thanks to them, governments can also adopt their plans of enlargement or restructuring of the energy infrastructure including building new power plants (or deciding which type of power plant should be build).

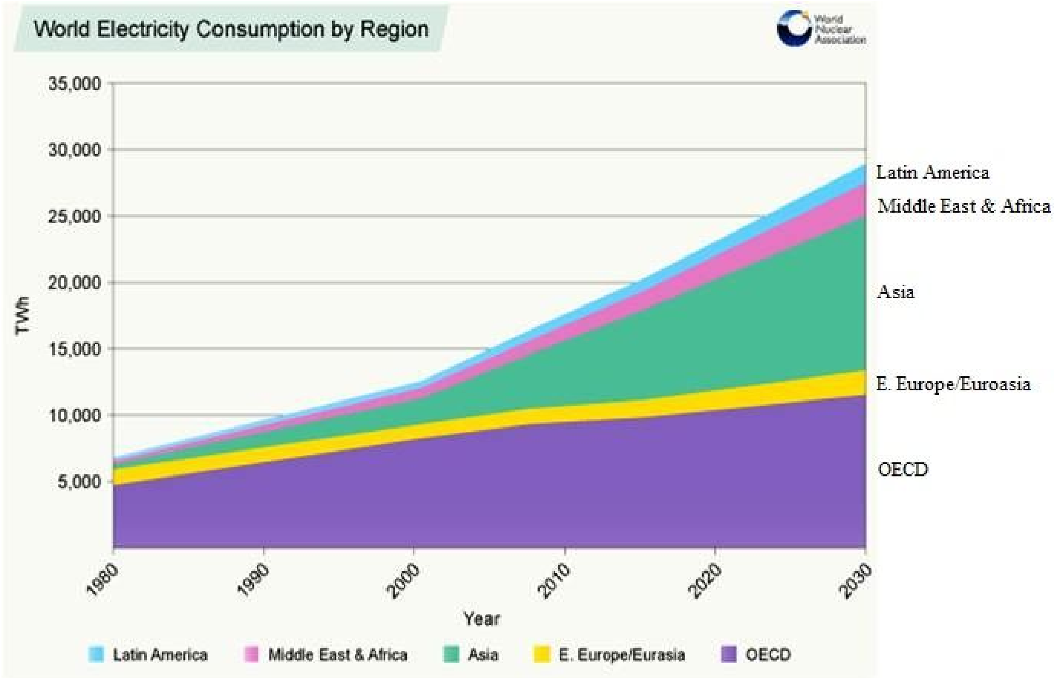
2.3 Decomposition

The distinction between short- and long-run allows us to observe how consumers' adaptation changes over time. It is commonly thought that long-run price elasticities are usually two to four times higher than the short-run ones (Glaister & Graham 2002). Such a phenomenon would suggest that 25-50% of the total adjustment should occur in the first year since the price (or income) change. Users adopt their behaviour differently for each of the periods. It is expectable that they will not be very flexible at changing their habits in the short-run. They may pay higher attention to switching off lights when they do not need them, or using the air conditioner only in those rooms they are currently in. However, in the long-run, the scope of modification possibilities becomes much larger. Consumers can replace their old non-efficient electrical appliances by new energy-saving ones, or they can for example switch from electrical oven to a gas substitute.

2.4 Electricity consumption trends

One stunning fact that I would like to mention here is that world electricity consumption has increased about four times during the last 30 years. That can be seen in the Figure 2.1 below, which also predicts the future consumption till 2030. The enormous increase of consumption is mainly due to the development of countries like China, as the developed regions do not increase their electricity consumption that rapidly. This phenomenon is also observable in the Figure 2.1 – Organisation for Economic Co-operation and Development (OECD) countries increase their consumption negligibly in comparison with Asia.

Figure 2.1: World Electricity Consumption by Region

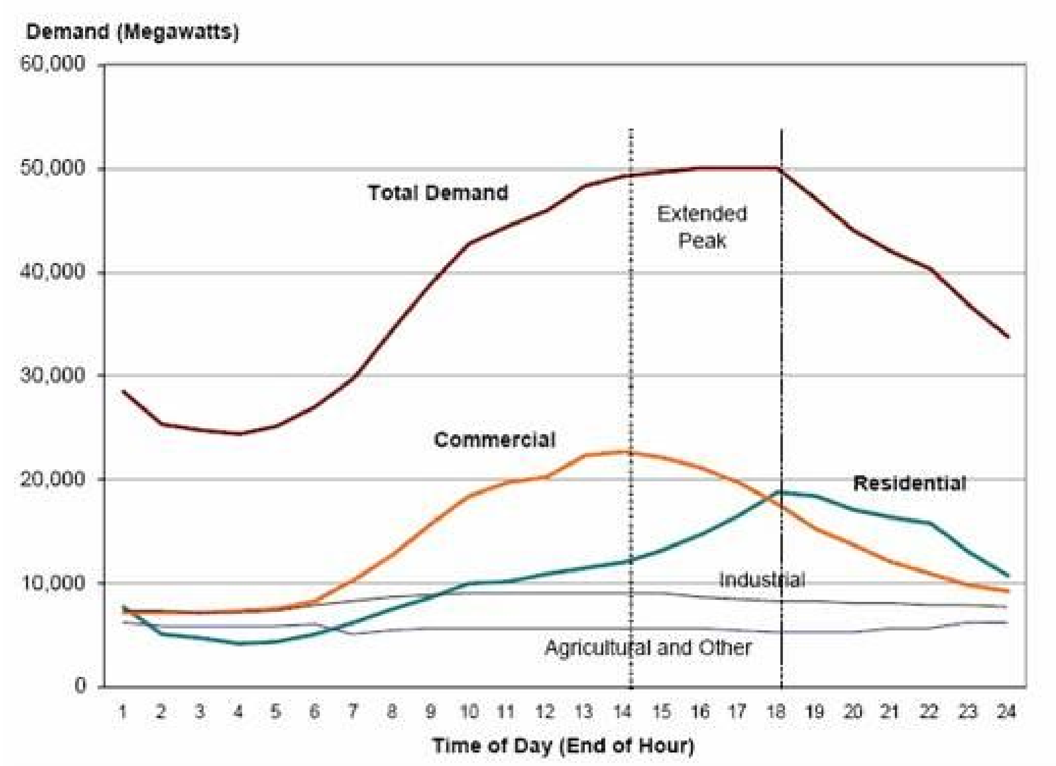


Source: OECD/IEA World Energy Oultook 2009 - Reference Scenario.

Another interesting discussion could be based on the figures representing per capita electrical energy demand for individual countries. The "top" consumer is Iceland, followed by Norway, Canada, Finland and United Arab Emirates. More information about this issue can be found in Figure A.1 presented in Appendix A. Many of the primary studies that were used for this meta-analysis engaged in the area of different electricity demand during the day. A graph describing this problem is shown in Figure 2.2.

Moreover, this graph also includes valuable information about how much electrical energy each sector of the economy uses during the day. The distinction between residential, commercial and industrial sector is very useful because each of those sectors has its own characteristic properties. That is also why I decided to look for information about the sector of the economy the data came from. After that, it was possible to include dummy variables representing the three sectors of the economy into the regression. A graph showing how much electrical energy is demanded by each sector in total is depicted in Figure A.2 in Appendix A.

Figure 2.2: Electricity demand by sector during the day



Source: www.mpoweruk.com

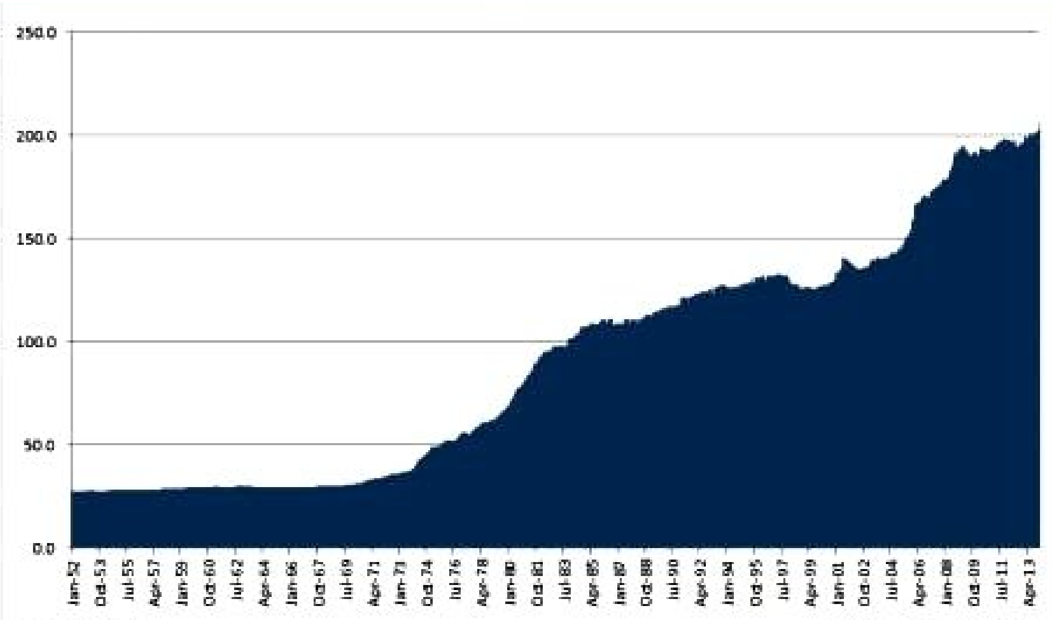
2.5 Price of electrical energy

Another relation can be found between the price of electrical energy and the amount of studies dealing with price elasticity of energy demand. Figure 2.3 and Figure 2.4 below show trends of both price of electrical energy and the amount of studies published for each year.[1] We can see how stable the price of electrical energy was since the 1970's. However, a huge increase in energy prices comes as we move to the 1980's.[2] Now, when taking a look at Figure 2.3 and Figure 2.4, we can identify the relation between the two graphs as we observe a rapid increase of the number of studies published in the 1980's. Another significant change of price was recorded in the period 2004-2008, which also stirred up higher attention of the researchers.

[1] I decided to use electricity price index instead of pure price of electricity for this the graph in Figure 2.3.

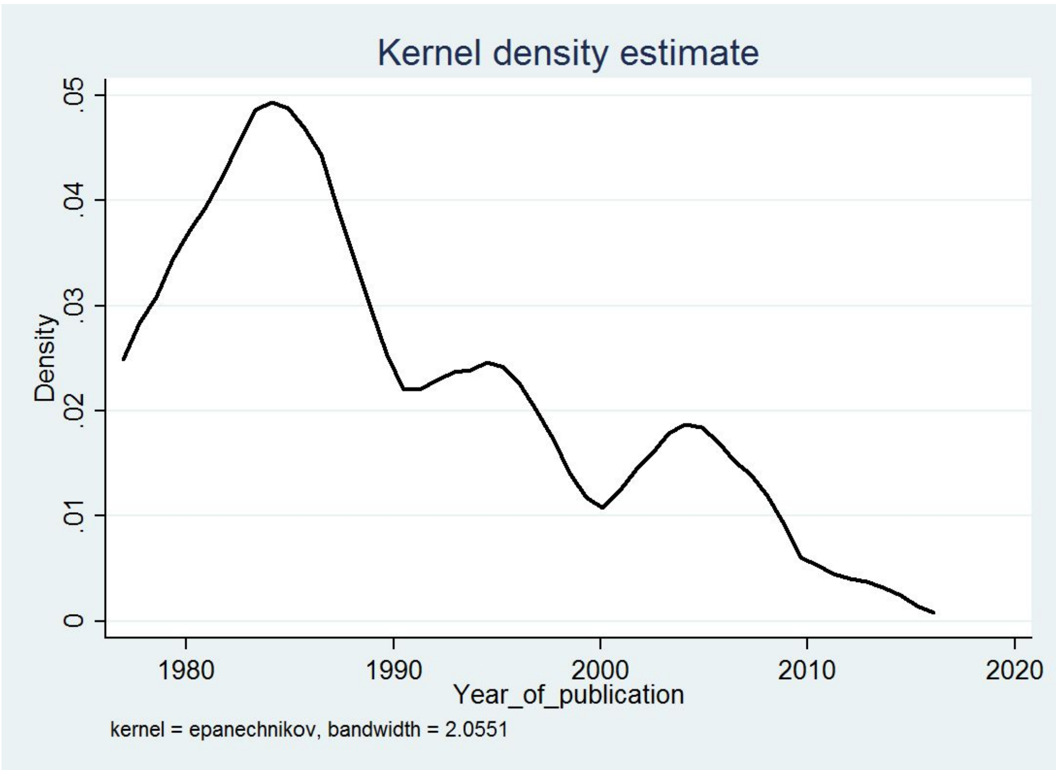
[2] In 1980's the prices of many commodities were rising rapidly – including electricity or oil.

Figure 2.3: Electricity Price Index 1952-2013



Source: Ali Hayer, Bureau of Labour Statistics

Figure 2.4: Density of published estimates during 1978-2014



Source: author's computations.

2.6 Estimation

There has been a significant development of econometric methods during the last decades. This subhead shortly summarizes the most frequent methods and techniques used for estimating different parameters of concern. We will mainly focus on those that were employed by authors of our primary studies, because right understanding of the models presented in primary studies is of value.

The most frequently used method is the standard Ordinary Least Squares (OLS) method. This process serves us well when estimating unknown parameters in a linear regression model. It is based on the idea of minimizing the sum of squared vertical distances between the observed responses in the dataset and the responses predicted by the linear approximation.[3] In order to obtain the most precise estimates, the regressors need to be exogenous, and there should not be any perfect multicollinearity. Moreover, the estimator is unbiased only if the errors are homoscedastic and serially uncorrelated. This method is used quite often, and our dataset only validates this statement as it turns out that more than 38% of our estimates were obtained by this method.

The second most favoured method in our dataset is the Seemingly Unrelated Regressions (SUR) model, which is a generalization of a linear regression model that consists of several regression equations, each having its own dependent variable and potentially different sets of exogenous explanatory variables (Davidson & MacKinnon 1993). This method, proposed by Zellner (1962), allows us to estimate all of those regression equations separately, which is why the system is called seemingly unrelated (Greene 2002). However, some authors suggest that the term *seemingly related* would be more appropriate (Davidson & MacKinnon 1993), since the error terms are assumed to be correlated across the equations. It is worth mentioning, that under certain conditions, SUR and OLS are in fact equivalent.[4] This method has been used in more than 20% of primary studies.

The third most represented method of estimation in our dataset is the Two-Stage Least Squares (2SLS) method that has been presented in more than 10% of primary studies. It is used to calculate Independent Variable (IV) estimates by a two-stage process. A similar process, which adds one more stage, is called

[3]"Least-Squares Regression - The Regression Line." (n.d.). Retrieved from https://www.boundless.com/statistics/correlation-and-regression/the-regression-line/least-squares-regression-1504e377-ae3d-4c8f-9dc2-aac5ed459edc/ .

[4]For further information see Davidson & MacKinnon (1993).

Three-Stage Least Squares (3SLS), and it has been used in about 3% of primary studies.

There are a few more methods, which I will not describe here, that were used in less than 5% of the studies. Among them is a method called Error Correction Model (ECM)[5], Maximum Likelihood (ML) (including Full Information Maximum Likelihood (FIML)), Generalized Method of Moments (GMM), or Generalized Least Squares (GLS).

[5]For further information about this model see Balestra & Nerlove (1966).

Chapter 3

Literature summary, collection and description of the dataset

The first step of every meta-analysis is the collection of data. However, it is not as easy as it could seem to be. It is crucial to filter the "right" data in the means of their usability for the purpose of a meta-analysis. The estimates found in the studies dealing with price elasticity of demand for electricity often differ substantially. To be more concrete, values of estimated price elasticities in the literature vary from -5.7 to 3.7 in the short run and from -7.7 to 3.6 in the long run.

3.1 Literature summary

The data used in the previous study on this theme (Espey & Espey 2004) were available online only partly. Their study was based on 36 studies published between 1971 and 2000. These studies provided 123 estimates of short-run elasticity and 125 estimates of long-run elasticity. It is probable that the 2004 study did not use all of the available information as we see that the dataset was pretty small. That is one of the reasons why I decided to apply the method of meta-analysis to a larger dataset.

3.2 Collection of data

The main source of my dataset comes from the online available database that is managed by Professor Carol Dahl from Colorado School. The database in its original form contained 5258 estimates from 1951 to 2008. Most of these estimates were published during the 1970's and early 1980's, when electricity prices were increasing considerably. However, many of the estimates had to be left out of the analysis, because they were missing the fundamental "precision" measures (t-statistics or standard errors). Even though I tried to look after every single missing value in the dataset, the information of concern was not included in the relevant study in the majority of cases.

Another asset of this thesis is the enlargement of the mentioned Dahls' dataset in the way of replenishing some missing values and adding about 100 new estimates from studies published in the period 2008-2014. The dataset in its final form provides 834 short-run estimates of price elasticity, 1325 intermediate -run estimates and 231 long-run estimates from 247 different studies published between 1951 and 2014.[1] These data were collected in more than 30 different countries, and the estimates were varying between -5.78 and 0.778 in short-run (from -0.82 to 0.40 after removing outliers), between -12.61 and 9.39 in intermediate-run (from -2.08 to 0.948 after removing outliers) and between -9.32 and 3.62 in long-run (from -2.68 to 1.31 after removing outliers). The weighted average of the estimates is -0.19 for short-run, -0.47 for intermediate-run and -0.51 for the long-run.

3.3 Specification and description of the variables

"The next step is to identify important characteristics of the studies and to code them." (Stanley 2001) This step can be difficult and time-consuming.[2] Stanley is basically saying that in this phase of a meta-analysis it is important to think about what variables should be used and what goal do we want to achieve by including them into our model.

Stanley and his colleague specified the basic model of meta-analysis in this form (Stanley & Jarell 1989):

$$b_j = \beta + \sum_{k=1}^{K} \alpha_k Z_{jk} + e_j, \qquad j = \{1, 2, \ldots, L\} \tag{3.1}$$

where b_j represents the estimate of the parameter β obtained from j-th study, and L is the total number of studies. β stands for the "true" value of the estimated parameter and e_j is the error term. Z_{jk} is a vector including

[1]List of all primary studies can be found in Table B.3 in Appendix B.

[2]Indeed, coding can represent as much as 90–95 percent of the work involved in conducting a meta-analysis (Hunter & Schmidt 1990).

some explanatory variables that are meant to help us explain what drives the heterogeneity of the results of primary studies.

Stanley *et al.* (2008) propose a specific division of the variables included in the vector Z_{jk} into a few groups corresponding to their logical coherence. The first group is the most important, and it includes only the variable describing "precision" of empirical estimates. The second group, they propose, should be made of variables that are describing the model used by individual primary studies. The third one should try to detect the "quality" of the relevant study. For example, in this group we could find variables representing the number of tests the model went through or number of degrees of freedom it had. The fourth and the fifth group would be representing other factors concerning the author (such as age, gender, and profession) and the data used (such as country, year, and period length).

3.4 Precision of estimates

The estimates of price elasticity together with their precision are the two essential variables needed for a meta-analysis. The precision indicator is most frequently given in the form of standard deviation or the relevant t-statistics. Another important "precision indicator" is the number of observations the particular study worked with.

3.5 Geographical origin

As already mentioned, the dataset builds upon observations from more than 30 different countries. Most frequently, we can find data coming from the USA and Europe. Therefore, I decided to create two specific dummy variables. One of them is labelled *USA* and the other one *Europe*. Not surprisingly, the first mentioned is equal one if the data come from the United States, the second one is equal one if the data come from Europe. It would be possible, of course, to include many other dummy variables for each country, but this action would lead to a significant increase of degrees of freedom. Large values of degrees of freedom are undesirable, and that is why I decided to use only two dummy variables for the regions mentioned above.

3.6 Other characteristics

During the creation of the dataset and reading the primary studies, I was already searching for some characteristic attributes of each study in order to include the "correct" variables into this meta-analysis. The main challenge here was to think about whether it is possible to collect given characteristics from a majority of primary studies and whether it will have some meaningful outcome. Including tens of variables would lead to an undesirable increase of degrees of freedom.

Among others, I decided to include the variable *year_of_publication* which refers to the publication of the relevant primary study. This variable could give us some insight into the area of the historical trend of price elasticity of electricity demand.

3.7 Methods used by primary studies

In accordance with the study (Knell & Stix 2003) there should be no systematic influence of the method used on the individual empirical estimates, if the econometric model is specified correctly. However, in praxis, we observe that there are some differences in the elasticity estimates connected with different methods. That mainly occurs when researchers use low numbers of observations.

When collecting the data, I came across more than 20 different methods and techniques of estimating the price elasticity of electricity demand. Some studies were also using more methods at once and comparing the results. In that case, I included both estimates obtained by using different methods into the dataset, and I made a note of which estimate was obtained by which method. In the end, I took a view from above at the dataset and found out which methods were used the most.[3]

3.8 Publication attributes

The last group of factors that could influence the publication selection and the heterogeneity of estimates includes the publication attributes of particular primary studies.

[3]These methods were described in Section 2.6.

In accordance with constantly developing economic and econometric theory, changing economic circumstances and cycles, it is necessary to take the years of publication of primary studies into account. Furthermore, it is also a good idea to look at the "quality" of individual studies. Of course, it is not simple to objectively determine how good the concrete research is. Luckily, we can use a proxy variable in order to represent this "quality". As a common and readily observable proxy variable we collect information about how many times a particular study has been cited. In order to be able to find out this information for the largest possible number of studies, I decided to use Google Scholar.[4] However, we have a problem arising here. The studies carried out long time ago have, in general, larger numbers of citations. The best way how to solve this problem is to divide the number of citations by the age of the study.

[4]This information was collected in the period May-June 2014.

Chapter 4

Meta-analysis of price elasticity

4.1 Meta-analysis

Meta-analysis is a statistical method that combines and contrasts results from various studies and tries to find some patterns and relationships between those results. Most frequently, meta-analysis is used for estimating the true effect size. The simplest way of conducting a meta-analysis is just taking a weighted average of all the previous estimates. The weighting is often determined by the sample sizes of individual studies. Shortly said, meta-analysis can be thought of as "analysis of analyses" (Glass 1976).

Extensive advantages of this method are indisputable. The outcomes of a meta-analysis are more powerful and can be generalized to a larger population than in the case of every single study. Of course, having such a large dataset is a treasure for every statistical research. Larger datasets often provide more accurate estimates, smaller confidence intervals and therefore it is more probable to detect whether there really is an effect of concern. With meta-analysis, we can also more easily analyze the inconsistency of the results across studies (such as sampling errors and between-study heterogeneity). There is another huge advantage of meta-analysis that we make use of: dealing with publication bias problem, which is a big problem of majority of present studies.

Although meta-analysis is very useful, it is not omnipotent. If we run a good meta-analysis of badly designed studies, we will still obtain bad statistics (Slavin 1986). To avoid this pitfall, we should include only methodologically sound studies in our meta-analysis. This practice is called "best evidence synthesis" (Slavin 1986). Another possibility is to include all the studies (even those qualitatively weaker) in our meta-analysis, but then we should add the so-called "study level predictor variable" that would represent the methodological quality of the studies (Hunter & Jackson 1982). On the other hand, some meta-analysts argue that the best approach is to keep and account for all the information about the sample variance as long as setting up some criteria about methodological selection would cause subjectivity and thereby thwart the purpose and strengths of this method. In this thesis, we make use of a combination of methods dealing with this issue (different criterions and dummy variables that will be presented in next sections of the work).

4.2 Introductory analysis of the dataset

If we take a look at the dataset, we will see that it is very usual to have more than one estimate from a single study. Primary studies often present various estimates according to different methods or different data-sorting (such as regions or periods). If we dealt with this issue in the way of choosing only one estimate that would in our opinion be the "best" one, the analysis would lose objectivity, and as Havranek & Irsova (2010) argue in their meta-analysis, it would lead to other distortions of final results. On the other hand, computing a simple average of estimates from one study would cause a loss of information. That is why we include every single estimate of price elasticity together with its "precision" measure presented in a particular study into our initial dataset.

In the end, we have 2390 estimates of price elasticity of electricity demand coming from more than 240 various articles and studies, which were published between 1951 and 2014. Another information that should not be left without attention is that the primary studies were build upon data coming from years 1934–2011.

4.3 Chauvenets' criterion

During the process of editing the dataset, it is always a tough question which observations should be dropped out of the analysis and which should remain. To be able to make consistent and objective decisions, the best option is to follow some well-established rules. When searching for a method that could be used to filter the outliers, I came across the Chauvenets' criterion[1], which we afterwards use. By means of this criterion, a "critical" interval was created. The values

[1] More detailed description and derivation of this method can be found in the work of Lin & Sherman (2007).

that exceeded the upper, or the lower bound of this interval were labelled as outliers. These observations were afterwards dropped out of the analysis. When using the Chauvenets' criterion, it is important to remember that it usually has to be applied several times. That is because it uses the standard deviation of the sample, which, of course, changes after deleting the outliers. Therefore, it is very likely that with the newly obtained standard deviation we will have to drop out "new" outliers as well.[2] After several applications of the method, all the remaining data are included in the necessary intervals created by the newest standard deviations. Due to this multiple-application issue, the procedure of filtering had to be repeated seven times in the case of short-run, eight times in the case of intermediate-run and five times in the case of long-run price elasticity data.

After dealing with outliers included in the price elasticity estimates category, we have to use the Chauvenets' criterion for the "precision" variable *SE_1* (obtained as $\frac{1}{std\_err}$) as well.

Altogether, 114 observations have been dropped out from the short-run dataset (that is 12% of the original data), 189 observations from the intermediate-run dataset (that is 11% of the original data) and 32 observations from the long-run dataset (that is 10% of the original data), by employing this method. The good news here is that standard deviations for each period length improved significantly. To be more concrete: standard deviation of estimates of price elasticity decreased from 0.404 to 0.199 in short-run, from 0.868 to 0.465 in intermediate-run and from 1.125 to 0.629 in long-run. It is noticeable that the Chauvenets' criterion more or less halved the original values. That, of course, should lead to much more precise and consistent outcomes. Almost the same story happened in the case of standard deviations of the variable *SE_1* in individual period lengths: it decreased from 41.01 to 18.64 in short-run, from 24.73 to 6.53 in intermediate-run and from 12.19 to 6.96 in long-run.

The average price elasticity estimate obtained from the final dataset (after deleting outliers) is equal to -0.187 in short-run, -0.469 in intermediate-run and -0.505 in long-run. That corresponds with the economic theory of price elasticities.

[2]Those outliers that were "hidden" and were not dropped out of the analysis during the first application of Chauvenets' criterion are called *shielded* outliers.

Firstly, all the average estimates of elasticities are negative, which is supposed to be consistent with the economic theory as long as electricity is an ordinary good.[3]

Secondly, the averages of the price elasticities for different periods show us that the shorter the period, the more inelastic is the demand for electricity.[4] For most goods, this behaviour is standard. It is commonly thought that the longer a price change holds, the larger the elasticity is likely to be (in absolute value), as more and more consumers have time and inclination to search for substitutes (Parkin *et al.* 2002). As an example, we can imagine the situation of a sudden fuel price increase. In this case, people may still go fill up their tanks in the short-run, but when prices persist to be high over a longer period, more consumers will try to reduce their demand for fuel in the way of switching to public transportation or investing in more fuel-efficient vehicles.

In the case there exists a higher possibility of publishing some "preferable" estimates, the average of the estimates will be different from the "real" value (Havranek *et al.* 2012a).

4.4 Epanechnikov kernel density

Another analytical tool that is commonly used in the scope of an analysis is the density plot. In order to make the analysis as precise as possible, the decision of not including all observations into one graph has been made. Instead, we divide them into three previously used groups (short-run, intermediate-run and long-run) and create a separate graph for each of them. These three graphs are presented below in Figure 4.1, Figure 4.2 and Figure 4.3. For the purpose of describing the density of the estimates, we use the so-called Epanechnikov kernel density function.[5]

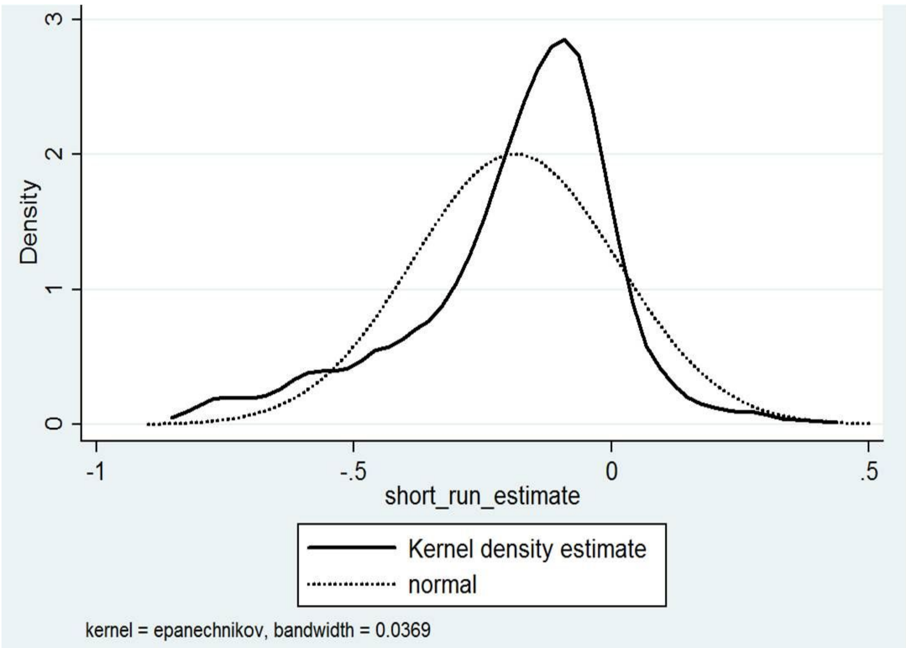
For comparison, a dotted line representing the normal distribution is included in each graph. The normal distribution lines were created by using

[3] An ordinary good is defined as a good which becomes more demanded when its price decreases and vice versa. On the contrary, a Giffen good is the opposite of ordinary good (i.e. people consume more of it as its price rises – this violates the "law of demand").

[4] In general, the demand for a good is said to be relatively inelastic when the price elasticity of demand is less than one (in absolute value): that is, changes in price have a relatively small effect on the quantity of the good demanded. On the opposite, the demand for a good is said to be relatively elastic when its price elasticity of demand is greater than one (in absolute value).

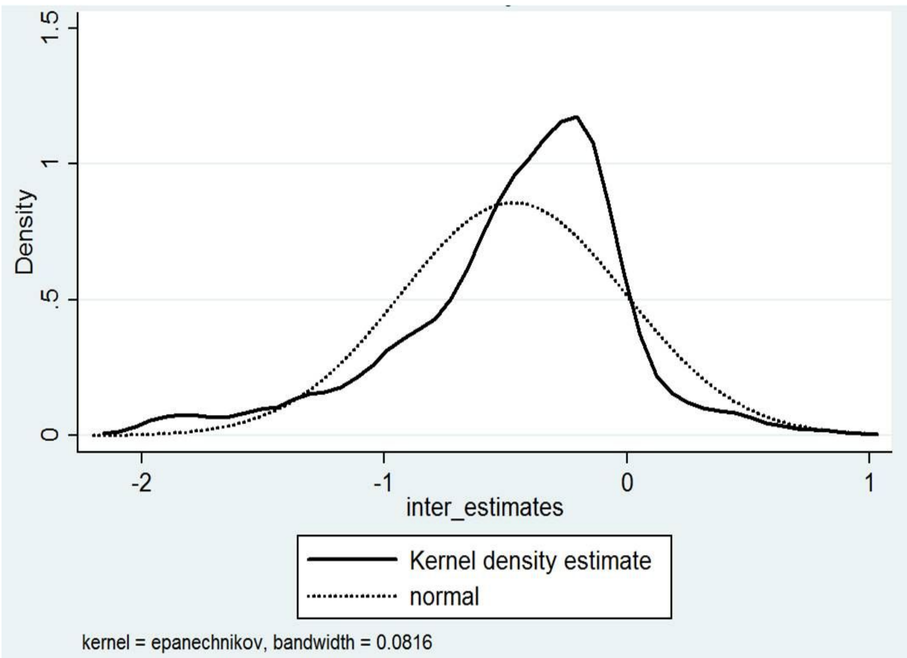
[5] This function is named after its creator V. A. Epanechnikov. For further information about this method see Epanechnikov (1969).

Figure 4.1: Epanechnikov kernel density - short-run



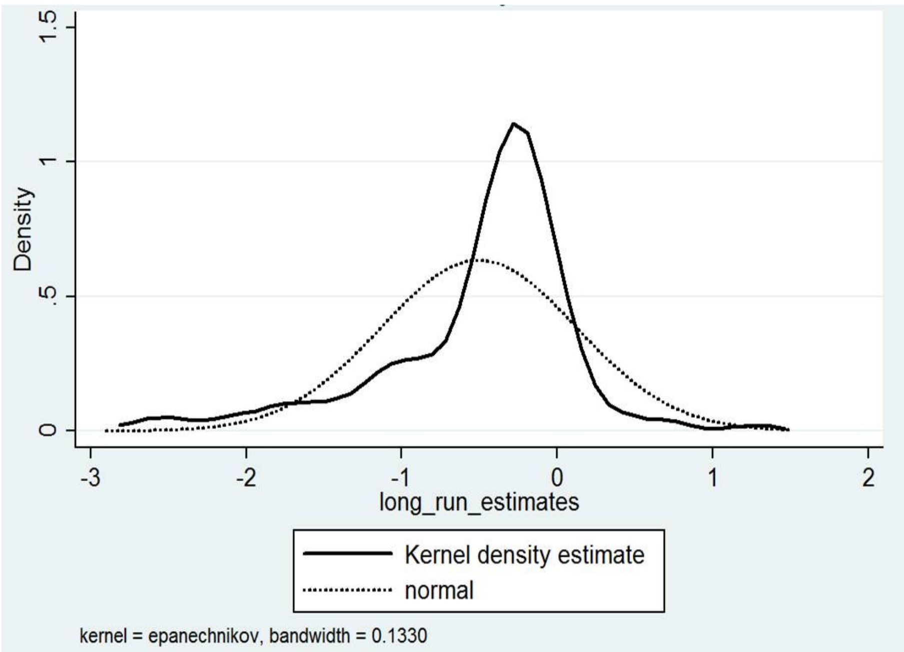
Source: author's computations.

Figure 4.2: Epanechnikov kernel density - intermediate-run



Source: author's computations.

Figure 4.3: Epanechnikov kernel density - long-run



Source: author's computations.

the means and standard deviations of the price elasticity estimates related to individual time periods. It is obvious that the distribution is not very symmetrical in any graph. That could speak for the fact that there exists some kind of publication bias. When taking a closer look at the kernel densities, we can see how "abhorrent" the zero-value is for the authors. This phenomenon is depicted by the highly sloped decreasing density line when approaching the zero estimated elasticity. That, of course, leads to asymmetry which could be explained by the unwillingness of the authors to bring up positive elasticities or by the unwillingness of the publishers to publish those positive results. Due to these suspicions, we will focus on publication bias more deeply in next parts of the work.

4.5 Publication bias

One of the most serious problems, when conducting a meta-analysis, is the dependence and reliance on the available set of published studies. This pitfall is commonly called publication selection bias, and it often leads to false results. Publication selection bias occurs when studies that present outcomes which are insignificant, counter-intuitive or inconsistent with the theory are less likely to be published. That is undoubtedly also the case of energy economics, which we are going to study. It is well known that publication selection can seriously bias the estimates of price elasticities because positive estimates are usually inconsistent with theory (Havranek *et al.* 2012a). However, not only price elasticities suffer from publication selection bias. Stanley and his colleague (Stanley *et al.* 2008) warn that publication selection bias has been found in many areas of empirical economics. This phenomenon is studied by many researchers, and I would like to mention one deterrent fact that Stanley published in his work in 2005. In that study, he documents how the price elasticity of water demand is exaggerated fourfold because of publication bias (Stanley 2005). This problem is hard to solve as long as we do not know how many of these counter-intuitive studies were put under the table or ended in the researchers' "file drawer".[6]

As a result, the distribution of estimated effect sizes is biased, skewed or even completely one-sided. That means that we overestimate the significance of the published studies because the "unwanted" estimates were rejected and not published. Therefore, it is highly recommended to consider this carefully when interpreting the outcome of a meta-analysis (Hunter & Schmidt 1982).

Although the publication bias is most often related to journal practices of placing significant outcomes before insignificant ones, there is another issue we should be worried about. Unfortunately, researchers sometimes want to achieve the publication of their work without respect for the methodological rightness. That happens because they know that insignificant results will not shock anybody and most probably will not be published. They usually use incorrect practices to obtain some significant and surprising outcomes. Stanley points out that this social aspect is closely connected to the publication bias problem (Stanley *et al.* 2008). He says that economists are usually "rewarded" for the volume of studies they published and not for their quality. These "unfair" practices include remaking their models, changing variables, changing hypotheses or leaving out unfavourable "inconvenient" observations. Of course, these questionable practices are not implicitly sample size- or precision- dependent and, therefore, hardly detectable on a funnel plot or by using any other detection methods currently available. However, considering how often publication bias occurs, Stanley (2005) recommends we should include the assumption of the presence of publication bias into every meta-analytical study.

[6] This is why publication bias is sometimes called "the file drawer effect". This term was coined by psychologist Robert Rosenthal (1979).

4.6 Graphical testing of publication selection bias

A very simple method used to detect possible publication selection bias is a graphical image of the dataset, which can serve us as a primal visual check. There is a couple of these graphical methods. Funnel plot and Galbraith plot are used most frequently.

4.6.1 Funnel plot

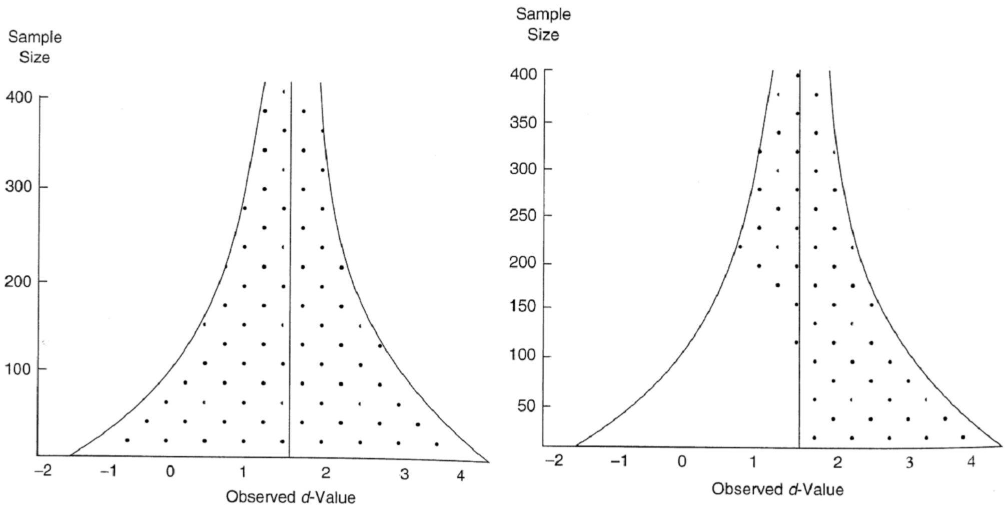
Funnel plot is a very simple point-graph that visualizes the distribution of effect sizes and their precision. We have the estimated values from individual primary studies on the x-axis and their precision on the y-axis. The precision parameter can be determined many ways. The commonly used form is the multiplicative inverse of standard errors ($\frac{1}{se}$). If these standard errors are not available, the precision can also be determined with the help of the size of the sample[7] (n) or its square root ($\sqrt{n}$) (Stanley 2005). The ideal funnel plot should be balanced and should look like an upturned funnel (this is why it is called "funnel" plot). Such an ideal plot is displayed in the left part of Figure 4.4. The distribution in the left part of Figure 4.4 supports the idea that larger studies often show results close to null, and smaller studies suffer from higher random variability. On the right hand side of Figure 4.4, we can see an example of a funnel plot that is heavily influenced by the file drawer problem. We observe a clear bias (one side is almost missing), which can lead to incorrect hypotheses and interpretations.

Let us turn the view towards funnel plots representing our data recorded in Figure 4.5 and Figure 4.6. Figure 4.5 displays the funnel plots for the three periods that were obtained before removing the outliers. It is obvious that working with such data would not bring any rational outcomes. On the other hand, we still can discover some interesting characteristics of the data. For example, in Figure 4.5 (with outliers) in the case of intermediate run, we observe a weird "double top" assemblage. It seems like authors of primary studies preferred values close to 0 and -1 for some reason. However, statements based on Figure 4.5 should not be overvalued as long as these data clearly include many outliers.

Nevertheless, after using the Chauvenets' criterion described earlier, outliers were dropped out, and our funnel plots became much more representative. This improvement can be seen in Figure 4.6, which depicts the characteristics

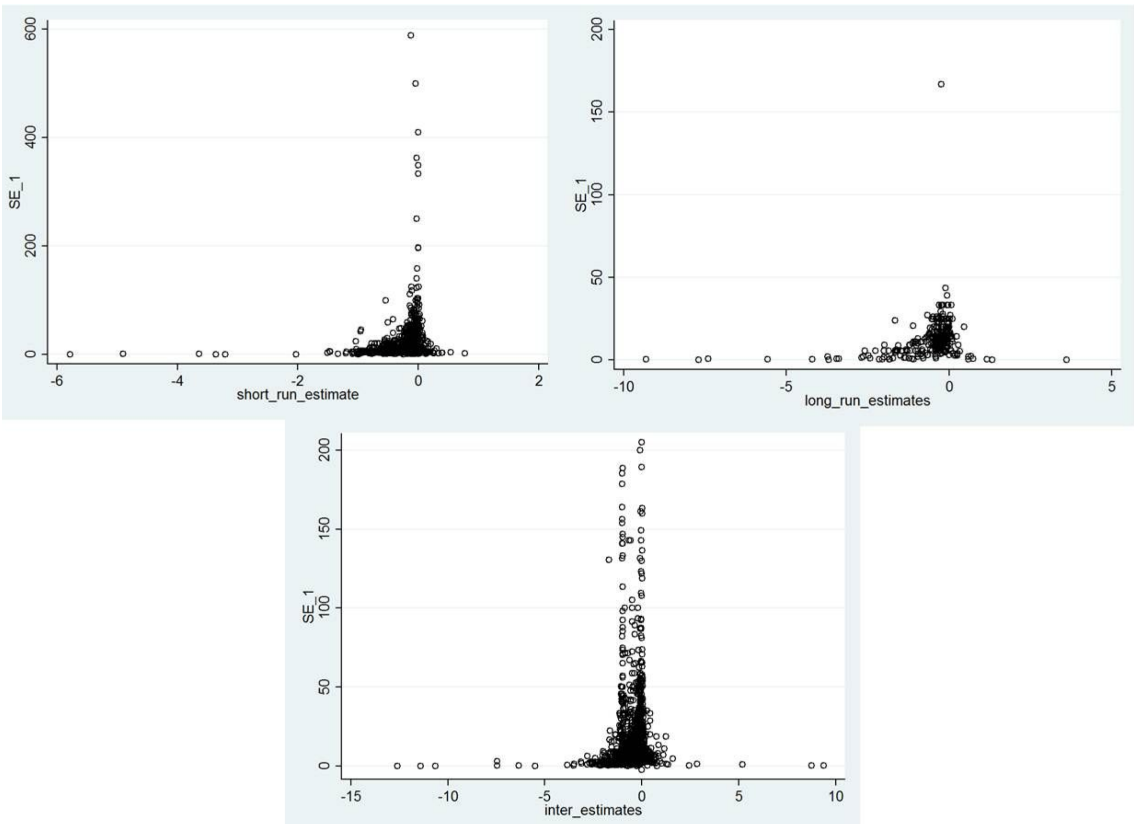
[7] Light & Pillemer (1984) suggest that if no publication bias is present, there should be no relation between the size of the sample size and the size of the effect.

Figure 4.4: Ideal vs. biased funnel plot



Source: S. Scherer (2012).

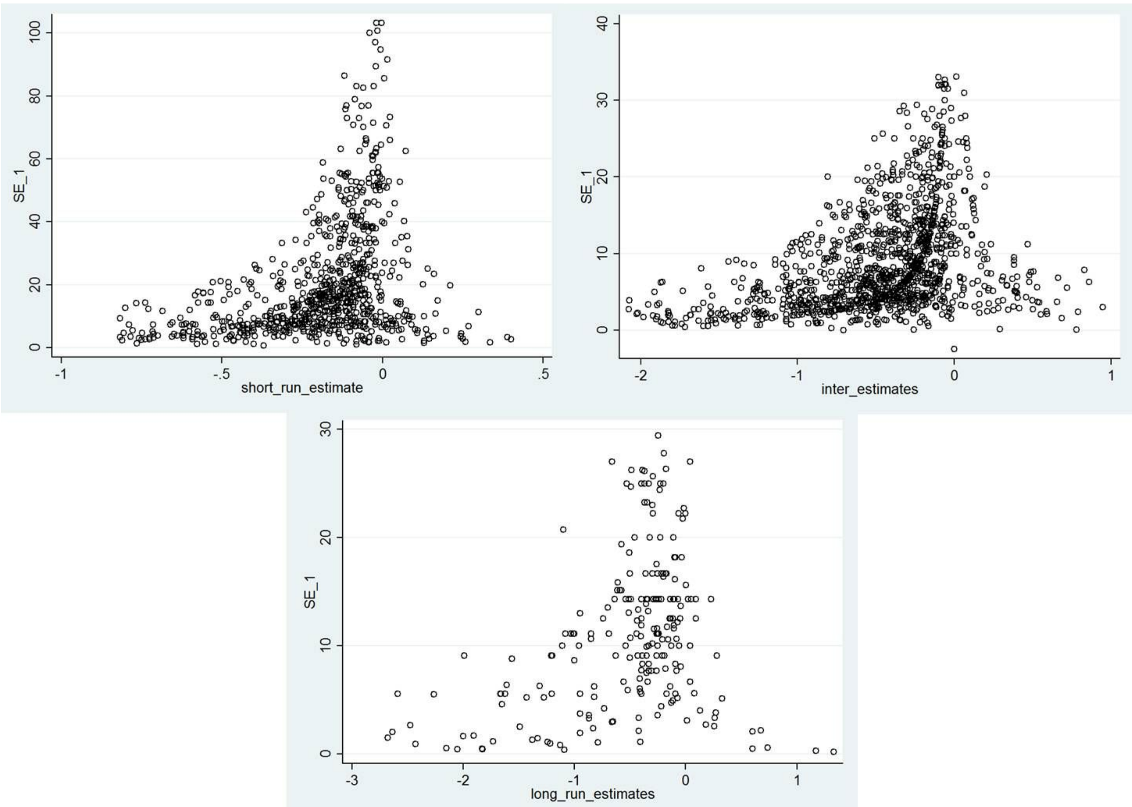
Figure 4.5: Funnel plots (with outliers)



Source: author's computations.

of the final datasets for each period. Each of these periods will be shortly discussed. Starting with short-run period, the funnel plot does not look very skewed. It is almost symmetrical, but it is possible to see that the zero value is somehow "scaring" the publishers again. We see that the left tail (negative) side is significantly longer and "denser". In the case of intermediate-run we also observe a pretty symmetrical funnel plot, but the "zero-issue" is present in this graph too. Besides that, it is worth mentioning that the "double-top" presented in Figure 4.5 has disappeared after carrying out the Chauvenets' criterion filtering. Finally, taking a look at the long-run funnel plot, we see how sparser the dataset in comparison with short- and intermediate-run is. Moreover, this graph seems to have a few horizontal clusters that are caused by studies presenting the same precision for all their estimates.[8] It is questionable whether these observations should or should not be dropped out. However, the decision here was to strictly follow the "one and only" method (Chauvenets' criterion) for filtering outliers in order to keep the objectivity as high as possible.

Figure 4.6: Funnel plots (without outliers)



Source: author's computations.

[8]This phenomenon occurred mainly in the oldest studies.

In the end, we may sum up the funnel plots to be approximately symmetrical with some expectable preference of left-tail outcomes. On the other hand, this suspicion is not sufficient to justify the statement saying there is a publication bias problem.

4.6.2 Galbraith plot

There is a specific type of publication selection that arises when only significant results are preferred, irrespective of their direction. In that case, large t-values (in magnitude) will be over-reported. T. D. Stanley calls this phenomenon "publication selectivity type II" and he refers to it as to "excess variation" issue (Stanley 2005). This selectivity can be detected with the help of another graphical tool called Galbraith plot. The selectivity can be identified by investigating whether there is an excessive likelihood of reporting significant results. In general, the t-statistic obtained from the formula $t = \mid \frac{effect_i - TE}{se_i} \mid$ should not exceed the value 1,96 in more than 5% of observations.[9] The abbreviation TE in the formula above stands for the "True Effect" of our price elasticity (Stanley 2005).[10] The Galbraith plot displays these t-statistics (standardized estimates) on the vertical axis against the "measurement precision" $\frac{1}{se}$ on the horizontal axis. "Essentially, it is a funnel graph rotated 90° and adjusted to remove its obvious heteroscedasticity ($\frac{effect_i}{se_i}$) (Stanley 2005). When there is no genuine effect, points should be distributed randomly around the zero value, with no systematic relation to precision.

When we look at Figure 4.7, we conclude that this does not occur in our case. In every single time-period we recognize that as measurement precision increases, t-statistics are further from zero.[11] Moreover, it is detectable at first sight, that there are many points exceeding the critical value 1.96. In accordance with Stanley (2005), this value should not be exceeded by more than 5% of observations. However, in our analysis, it is exceeded by around 38% of observations in case of short-run, by around 45% of observations in case of intermediate-run and by around 63% of observations in case of long-run. In

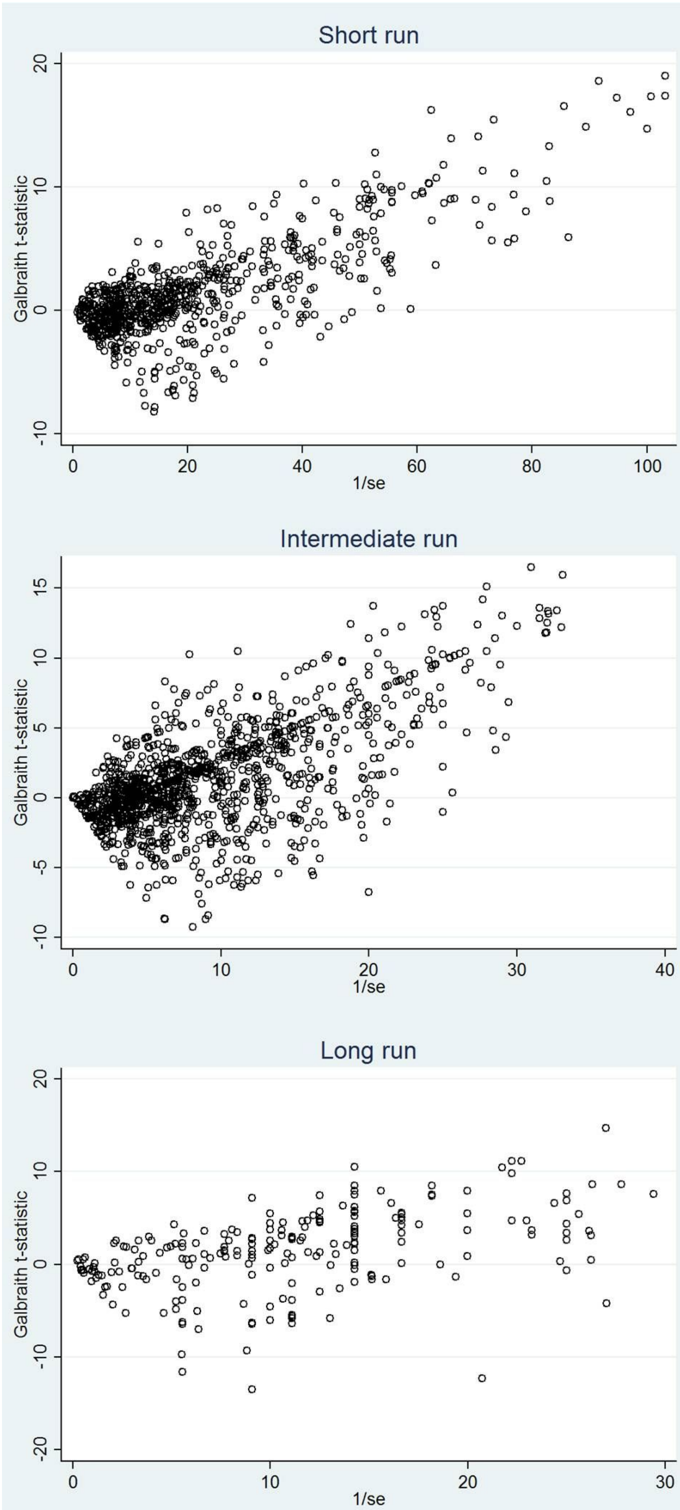
[9] This rule can be used only with sufficiently big samples. If the sample is small, the critical value can be slightly larger.

[10] True Effect (TE) can be estimated many ways. The most common processes are using FAT (funnel asymmetry test – will be discussed later) or FAIVE (funnel asymmetry instrumental variable estimator. However, for simplicity, we use a simple sample average for individual time-periods, which is also acceptable.

[11] Data used for creating the Galbraith plot depicted in Figure 4.7 were obtained after removing the outliers.

conclusion, we can state that after looking at our Galbraith plots it is very probable that some considerable publication bias is present.

Figure 4.7: Galbraith plots



Source: author's computations.

4.7 Funnel asymmetry test (FAT) and Precision-effect test (PET)

Even though graphical testing of the publication selection bias is very simple, and possible selection can be detected at first sight, it is necessary also to include some explicit regression tests. Moreover, graphical tests are usually not able to find all types of the publication selectivity (Görg & Strobl 2001). "In econometrics, the starting point for modeling publication selection has been the simple MRA between the study's reported effect (such as estimated elasticities and regression coefficients) and its standard error." (Ashenfelter *et al.* 1999).

Another tool that will be described in next few rows is the so-called Funnel Asymmetry test (FAT) which is based on the same idea as the funnel plot discussed earlier. At this point, it is important to consider one fact: In general, studies based on smaller samples of data suffer from larger standard deviations and that often leads to misspecification of those models in order to achieve the largest possible estimates (in absolute value). This way, authors can obtain some statistically significant results. On the other hand, authors of studies using larger samples of data tend to publish smaller empirical estimates, because estimates based on larger datasets are usually more precise (they have smaller standard deviations). Therefore, these larger studies do not ordinarily need a deeper and more sophisticated analysis regarding their models to achieve significance. After all, some types of publication selectivity can be detected through investigating the relation between the size of estimates and their standard errors (Stanley *et al.* 2008). This relationship can be tested by using a simple OLS regression for this regression model:

$$\hat{\gamma}_j = \beta + \beta_0 se_j + \epsilon_j, \tag{4.1}$$

where $\hat{\gamma}_j$ denotes the estimate of the price elasticity and se_j stands for its standard error. In the absence of publication selection, observed effects should vary randomly around the "true" value, β_0, independently of the standard error. For stringent selection, publication bias will be proportional to the standard error, $\beta_0 se_j$ (Stanley 2005). Besides that, we also have to deal with heteroscedasticity. Those random estimation errors, ϵ_j, will be heteroscedastic because primary studies use different sample sizes and modelling variations (Doucouliagos & Stanley 2009). Due to these complications, the equation (4.1) is usually estimated by using the method of Weighted Least Squares (WLS):

$$\frac{\hat{\gamma}_j}{se_j} \equiv t_j = \beta_0 + \beta(\frac{1}{se_j}) + \xi_j, \qquad \xi_j \mid se_j \sim N(0, \sigma^2), \tag{4.2}$$

where t_j denotes the approximate t-statistic of a particular estimate and the new measurement error ξ_j has constant variation – homoscedastic. In the equation (4.2) of funnel asymmetry testing, the intercept β_0 measures the publication bias.[12] With the help of coefficient β, we are then able to measure the true underlying price elasticity of demand for electricity, corrected for publication selection (Havranek *et al.* 2012b).

The results of running a publication selection bias test in the form of a regression presented in the equation (4.2) are displayed in the Table 4.1 below. Like before, data are divided into three periods.[13] Looking at the results, we see the coefficient of β_0 (intercept) in the short-run to be very significant, which justifies the decision of rejecting the null hypothesis of no publication selection in the sample ($H0 : \beta_0 = 0$). In the intermediate-run, intercept has almost the same significance and so we reject the null hypothesis as well. In the case of long-run, the significance of β_0 coefficient is much smaller (t-statistic is about 4 times smaller than in shorter periods), but it is still significant enough to reject the null hypothesis once again. In the end, we conclude that our inference of the existence of publication selection made after graphical analyses proved to be valid also after the FAT.

Table 4.1: Publication selection bias test - OLS

	$short - run$	$intermediate - run$	$long - run$
β(TE)	-0.034***	-0.119***	-0.220***
	(0.005)	(0.012)	(0.036)
β_0(bias)	-1.849***	-1.929***	-1.821***
	(0.126)	(0.130)	(0.474)
N	834	1325	231
Number of Studies	121	164	26
R^2	0.062	0.070	0.138

Source: author's computations.

[12] Testing the significance β_0 of in this specification is analogous to testing the asymmetry of the funnel plot – it follows from rotating the funnel plot and dividing the values on the new vertical axis by se_j.

[13] The data without outliers were used for this regression. A regression counting with raw data including outliers was also performed, but the results were not significant because the method of weighted least squares assigned very high weights to only a few outliers.

One fact that is obvious, but should be mentioned here, is that simple means used previously in the analysis were relatively larger (in absolute values) than the estimates of β in Table 4.1. That encourages further attention to the publication bias issue as it seems to be pretty large. The "true" values of price elasticity estimated by the FAT-PET model are following: approximately -0.034 in the short-run, approximately -0.119 in the intermediate-run and approximately -0.220 in the long-run.[14]

4.8 Mixed-effects multilevel model

In a meta-analysis, we have to take into consideration that estimates coming from one study are likely to be dependent. To be more concrete, in this meta-analytical study, we use data that often include multiple observations from a single primary study (prospectively more studies from one author). That is why we presuppose that individual observations could be seriously correlated.[15] This strong correlation would most probably distort our results heavily if we used the traditional OLS method for the equation (4.1) or its modified version (4.2). A common way how to cope with this problem is to employ mixed-effects multi-level model proposed by Doucouliagos & Stanley (2009), which allows for unobserved between-study heterogeneity. The model is specified this way (Havranek *et al.* 2012b):

$$t_{ij} = \beta_0 + \beta(\frac{1}{se_{ij}}) + \alpha_j + \epsilon_{ij}, \qquad \alpha_j \mid se_{ij} \sim N(0,\theta), \qquad \epsilon_{ij} \mid se_{ij}, \alpha_j \sim N(0,\psi). \tag{4.3}$$

In this equation, i denotes the estimate subscript, and j is a subscript of the related primary study. The overall error term ξ_{ij} now breaks down into study-level random effects α_j and estimate-level disturbances ϵ_{ij}. The interesting point here is that variance of these error terms is additive because both components are assumed to be independent: $Var(\xi_{ij}) = \theta + \psi$, where ψ denotes between-study variance (that is, between-study heterogeneity) and θ within-study variance. When ψ approaches zero, the benefit of using mixed-

[14]The Precision-Effect Test (PET) is rejecting the null hypothesis ($H0 : \beta = 0$) in every period and confirms the significance of "true" values of price elasticity.

[15]A lot of primary studies also used at least partly the same data, sometimes they use the same econometrical models and other similar analytical tools.

effect multilevel estimator instead of simple OLS becomes negligible (Havranek *et al.* 2012a). To examine this condition, we will use some likelihood tests.

The mixed-effects multilevel model is a bit similar to a random effect model that is used for analyses of panel data. The mixed-effects model is based on a combination of fixed (β) and random (α_j) effects. Nonetheless, for the purpose of our meta-analysis, the mixed-effects model using the method of Maximum Likelihood Estimator (MLE) is much more suitable than the random effects counterpart (which uses GLS method), because it allows us to work with between-study (or between-author) heterogeneity and thereby eliminates the influence of primary studies that include large amounts of estimates in comparison with other "poorer" studies (Havranek *et al.* 2012a).

The results of the publication selection bias test based on multilevel model presented in equation (4.3) are displayed in the Table 4.2.[16] As we can see, the estimated "true effect" is almost the same in short-run as for WLS estimation, but the publication bias estimated by mixed-effects multilevel method shows to be higher.[17] In intermediate-run, we observe the same situation.[18] Finally, in long-run, we have somewhat different results than obtained by the WLS method. The "true effect" is estimated to be about 20% larger with use of mixed-effects model than presented by the WLS method in Table 4.1.[19] Another issue that should be considered is that dataset for long-run price elasticity is about five times smaller than those for short- and intermediate-run. That, of course, leads to lower significance (however, it is still significant on all reasonable levels of significance). For all periods, the Likelihood Ratio Test (LRT) strongly rejects the null hypothesis of independent estimates within individual primary studies ($H0 : \rho = 0$). In other words, OLS version of the model is not suitable, and we should prefer the mixed-effects multilevel model.

On the other hand, both methods have one thing in common – they both signal the presence of publication selection in all periods. Moreover, coefficients for β_0 are statistically significant even at 1% significance level according to both methods and for all periods.[20]

[16] The study-level effect was used for this mixed-effect analysis.

[17] There are 834 observations in the short-run dataset coming from 121 different studies. That means that one study presented about seven different estimates on average.

[18] There are 1325 observations in the intermediate-run dataset coming from 164 different studies. That means that one study presented about eight different estimates on average.

[19] There are 231 observations in the long-run dataset coming from 26 different studies. That means that one study presented about nine different estimates on average.

[20] Null hypothesis of independent estimates within individual primary studies was also rejected when modelling the short-, intermediate- and long-run estimates together.

Table 4.2: Publication selection bias test - Mixed-Effects

	$short-run$	$intermediate-run$	$long-run$
β(TE)	-0.033***	-0.121***	-0.268***
	(0.005)	(0.012)	(0.037)
β_0(bias)	-2.268***	-2.412***	-2.247***
	(0.217)	(0.228)	(0.773)
N	834	1325	231
Number of Studies	121	164	26
χ^2	329.3***	495.3***	50.4***

Source: author's computations.

As we expected from the very beginning of this work, publication bias proved to be oriented towards negative results. In other words, authors of primary studies tended to publish more negative results at the expense of the positive ones.[21] Of course, such a bias leads to inaccurate outcomes when using basic methods like simple averages for estimating the TE.

4.9 MRA and heterogeneity of estimates

As already said, publication selection bias makes it impossible to estimate the true effect by simple averaging. However, it is not the only reason simple averaging is not suitable. Besides publication bias, it does not consider the heterogeneity of other characteristics of primary studies. To be more concrete, different methods of estimation, starting assumptions, data and other factors make the simple averaging method less useful.

In this section, we will deal with those shortcomings. Moreover, we will also discuss *which* concrete characteristics of primary studies affect the estimates and *how* they affect them. At first, WLS method[22] will be used for an enhanced model of equation (4.2). This model is suggested to have the following form (Doucouliagos & Stanley 2009):

$$\frac{\hat{\gamma}_j}{se_j} \equiv t_j = \beta_0 + \beta(\frac{1}{se_j}) + \sum_{k=1}^{K} \frac{\beta_k Z_j k}{se_j} + \xi_j, \qquad \xi_j \mid se_j \sim N(0, \sigma^2), \qquad (4.4)$$

[21] This statement holds for every period.

[22] Alternatively OLS used after the "manual" weighting of all the explanatory variables as described in equation (4.2).

where Z denotes a vector of all meta-independent variables (these variables are described in Table B.1 in Appendix B).

In accordance with previous findings of publication bias, we also utilize the enhanced version of mixed-effects multilevel model from equation (4.3) formulated by Havranek *et al.* (2012b):

$$t_{ij} = \beta_0 + \beta(\frac{1}{se_{ij}}) + \sum_{k=1}^{K} \frac{\beta_k Z_j k}{se_j} + \alpha_j + \epsilon_{ij}, \quad (4.5)$$

$$\text{where} \qquad \alpha_j \mid se_{ij} \sim N(0, \theta), \qquad \epsilon_{ij} \mid se_{ij}, \alpha_j \sim N(0, \psi).$$

4.9.1 Initial model

In the first step, all variables described in Table B.1 in Appendix B were included into our meta-regression model. In view of the fact that many of the variables turned out to be insignificant, some of them had to be dropped out of the model, because they distorted the analysis.[23]

Although primary studies were gone through carefully in order to rightly assign dummy variables representing the methods used in those studies, a little disappointment arose as our regressions showed results indicating there is almost no significant influence of methods on the price elasticity estimates. There are only two methods that seem to present somewhat (but only negligibly) more negative estimates (ML) and (IV), and one method that resulted into slightly more positive estimates (GMM). This statement is based on results for individual periods and the entire dataset as well. However, the complete sample is more representative for this purpose, as it contains more data, and as period distinction does not matter in this case. Results for the complete dataset are displayed in Table B.2 in Appendix B.

Another characteristic of our concern is the dependence of estimates stemming from the geographical origin of the data. It turned up that price elasticity estimates based on data coming from Europe tend to be slightly higher (in absolute value) than in the case of the USA or the rest of the world. That, again, can be seen in Table B.2.

[23]Besides observing the significance of single variables, tests for testing joint significance of groups of variables were also performed.

4.9.2 Results for different time periods

Now, we will focus on individual periods starting with short-run (Table 4.3). The most important statement here is that short-run price elasticity is estimated to be very close to zero by both methods of estimation (OLS and Mixed-effects (ME)). In accordance with ideas we earlier came up with (adopting electricity demand in short-run is difficult), the results are understandable. Additionally, we must say that the estimated publication bias is relatively large. In the case of mixed-effects model, it is even exceeding the critical value 2 (in absolute value), which, according to Stanley (2005), indicates a serious publication bias.

Table 4.3: MRA model results - Short-run

Variable	*OLS*	*ME*
β(True Effect)	-0.065***	-0.055***
	(0.006)	(0.006)
β_0(bias)	-1.665***	-2.210***
	(0.117)	(0.209)
indust_se	0.052***	0.034***
	(0.006)	(0.007)
commer_se	0.034***	0.025***
	(0.007)	(0.007)
GMM_se	0.051***	0.030**
	(0.013)	(0.015)
IV_se	-0.038***	-0.006
	(0.008)	(0.010)
N	834	834
Number of Studies	121	121
R^2	0.220	
χ^2		219.960***

Source: author's computations.

Proceeding to intermediate-run (Table 4.4), we observe somewhat more negative results concerning the estimated "true" price elasticity. However, in comparison with most studies, it is still pretty small (in absolute value), which is again in accordance with a serious publication that is also found in this period. We also see there are more significant variables than in the short-run outcome, which may be caused by a larger dataset available for intermediate-run. Even though OLS method estimated some relation between the results of primary studies and its presence in RePEc respectively Scopus database, mixed-effects method rejects this hypothesis. Another phenomenon depicted in Table 4.4 is that data collected in Europe seem to produce more negative estimates than those from the USA or the rest of the world.

Table 4.4: MRA model results - Intermediate-run

Variable	*OLS*	*ME*
β(True Effect)	-0.210***	-0.160***
	(0.032)	(0.039)
β_0(bias)	-1.787***	-2.118***
	(0.126)	(0.237)
indust_se	0.064**	0.015
	(0.030)	(0.034)
resid_se	-0.040	-0.068**
	(0.029)	(0.033)
GMM_se	0.458***	0.382***
	(0.146)	(0.117)
ML_se	-0.053**	-0.020
	(0.026)	(0.211)
USA_se	0.063***	0.116***
	(0.017)	(0.024)
Europe_se	-0.101***	-0.028
	(0.026)	(0.034)
Scopus_se	-0.040**	0.000
	(0.018)	(0.026)
Repec_se	0.085***	-0.011
	(0.017)	(0.024)
N	1325	1325
Number of Studies	164	164
R^2	0.161	
χ^2		409.62***

Source: author's computations.

Finally, we comment on the Table 4.5 that displays results for the long-run. As for long-run, we expected the estimated "true effect" to be the most negative of all the periods, which proved as a correct reasoning. As the true price elasticity of electricity demand is assumed to be the most negative, authors do not seem to exaggerate it that much as in previous cases. However, there is obviously still some publication bias in the data because the coefficient of β_0 is significant and larger than one (in absolute value).[24] We should take the large

[24]This classification is based on the idea of Stanley (2005).

estimates of "method-effects" (GMM, IV) with a grain of salt, as we have to consider the smallness of the dataset (especially the small amount of studies).

Table 4.5: MRA model results - Long-run

Variable	*OLS*	*ME*
β(True Effect)	-0.431***	-0.431***
	(0.047)	(0.060)
β_0(bias)	-1.258***	-1.309**
	(0.421)	(0.617)
indust_se	0.218***	0.190***
	(0.044)	(0.063)
commer_se	-0.020	-0.068
	(0.102)	(0.125)
GMM_se	0.388***	0.388***
	(0.083)	(0.100)
IV_se	-0.604***	-0.618***
	(0.108)	(0.173)
N	231	231
Number of Studies	26	26
R^2	0.387	
χ^2		3.60**

Source: author's computations.

In every period, there were only two dummies (out of three) representing the sector-based division into residential, commercial and industrial demand for electricity. That is because including all of them would lead us to a "dummy variable trap" (Greene 2003).[25]

4.9.3 Insignificant variables

At the beginning of this study, it was necessary to decide which particular variables could have some significant effect on the estimates of price elasticity of electricity demand. Even though there may be some reasonable arguments for their significance, many of them proved insignificant in this analysis. For example, year-of-publication was not significant in any reasonable model during the whole analysis, which indicates that price elasticity of electricity demand should not be changing over time.

[25] The decision which two dummy variables should be included in the concrete period was based on their significance.

Another variable that did not show any significance is the variable *Citations* representing the number of citations of individual primary studies. That is rejecting the hypothesis that studies presenting more negative results are being cited more frequently. The concern of insignificant method-variables was already discussed subsection 4.9.1.

4.10 Comparison with previous meta-analysis

In this subhead, a brief comparison with the previously published meta-analysis study (Espey & Espey 2004) will be made. Firstly, Espey&Espey did not present a single result concerning the price elasticity of electricity demand. They used six different methods of estimation, and that is why they obtained six different estimates for both short- and long-run. As for short-run, they presented estimates between -0.35 and -0.70, which are somewhat larger (in a negative sense) than results obtained in our analysis. However, this is not very surprising, since their study did not account for the publication selection bias. The most comparable short-run estimation result of their study is the value -0.38 that has been obtained with the use of a model that took intra-study error correlation into account.

Regarding the long-run, Espey & Espey (2004) suggested the true value of price elasticity of electricity demand to be somewhere between -0.49 and -0.67. Our result misses this interval only by six-hundredths. That, again, can be explained by the words of publication selection bias, which we have accounted for. Moreover, one positive point can be mentioned here: the "distance" between our estimates and the suggested corresponding intervals by Espey&Espey is much larger in the case of short-run, which is consistent with our findings of severer publication bias in the case of the shorter period.

The study from 2004 also examined the influence of some data characteristics as we did. Moreover, in some cases, it was concerned with exactly the same variables, namely with *US* and *non-US* origin of the data, *publication year* and *OLS* estimation technique. Although our conclusions are corresponding with theirs in the cases of OLS estimation (they also did not find any significant influence of this method on estimates) and the *US* vs. *non-US* origin of data (they also found more positive results when using the US data), they are not presenting the same statements in the last common variable. To be concrete, Espey&Espey argue there is a slight decrease of estimated price elasticities over time. Nonetheless, they obtained significant estimates of this variable only in one-half of methods they used.

Chapter 5

Conclusion

One of the main objectives of this work was to collect sufficiently large sample of data, which would worthily represent the voluminous literature engaging in the area of electricity demand.

After going through more than 300 papers and researches, I chose 247 of them that included the necessary information for the purpose of a meta-regression analysis. Reading those studies and searching for desirable information that afterwards had to be manually organised into a large dataset was the most time-consuming part of this work. As a result, this analysis is eligible to work with almost 2400 different estimates of price elasticity of electricity demand coming from more than 30 countries.

As next, we were able to study the large variation between different estimates of elasticities with the use of some meta-analytical and graphical methods. In accordance with those methods, we set up some basic assumptions and hypotheses about the true value of the price elasticity of electricity demand and about factors that could cause its improper estimation.

At the beginning of this meta-analysis, we were prosily describing the publication selection issue and its consequences. In connection with price elasticity of electricity demand, the publication bias problem was never studied before. That is why examining its size in this area of energy research was the main purpose of this thesis. Various models and methods have been used in order to be able to state whether there exists some kind of publication selectivity. In the end, we figured out that serious publication bias burdens the price elasticity of electricity demand.

This problem was not allowed for in the previous study dealing with the topic of meta-analysis of price elasticity of demand for electricity led by Espey

& Espey (2004). In comparison with that study, this one is making use of new, more efficient meta-analytical tools such as the mixed-effects multilevel method. Moreover, this analysis works with more than nine times larger dataset than the previous study did.

After taking the publication bias into account, we obtained the "true" price elasticities, which were estimated to be about -0.06 in the short-run, between -0.16 and -0.21 in the intermediate run, and approximately -0.43 in the long-run.

The powerful mixed-effects multilevel model also detected significant between-study heterogeneity. Besides the publication selection bias, we also examined other factors influencing outcomes of primary studies. Country of origin of our data is one of them. However, due to the quantity of different regions, we only examined the variation stemming from the three most represented ones - Europe, the USA and the rest of the world. Our analysis showed that data from Europe lead (on average) to more negative estimates than data from the rest of the world. On the contrary, data coming from the USA tend to result in more positively oriented estimates.

We also examined the possible influence of methods used by authors of primary studies on their estimates. In general, there were no earthshaking relations found in this field of analysis. There is only one method that seems to steadily present somewhat more negative results (IV) and one that seems to produce slightly more positive results (GMM). However, this statement is of low relevancy as the dataset is not large and representative enough for the purpose of this examination.

Last but not least, demand for electricity initiated from the residential sector of the economy appears to be more price-elastic than demand originating from the commercial or industrial sector. On the contrary, demand for electricity of the industrial sector seems to be the most price-inelastic.

Despite the fact that meta-analysis is considered to be a very powerful and efficient tool, it is not possible to designate its outcomes as definitive or irrefragable. As mentioned at the beginning of our analysis, MRA is dependent on many factors, including the correctness of methods used in primary studies or techniques of data collection and organization. Moreover, electricity demand is a complicated concept and including all the necessary variables and observations is not always possible.

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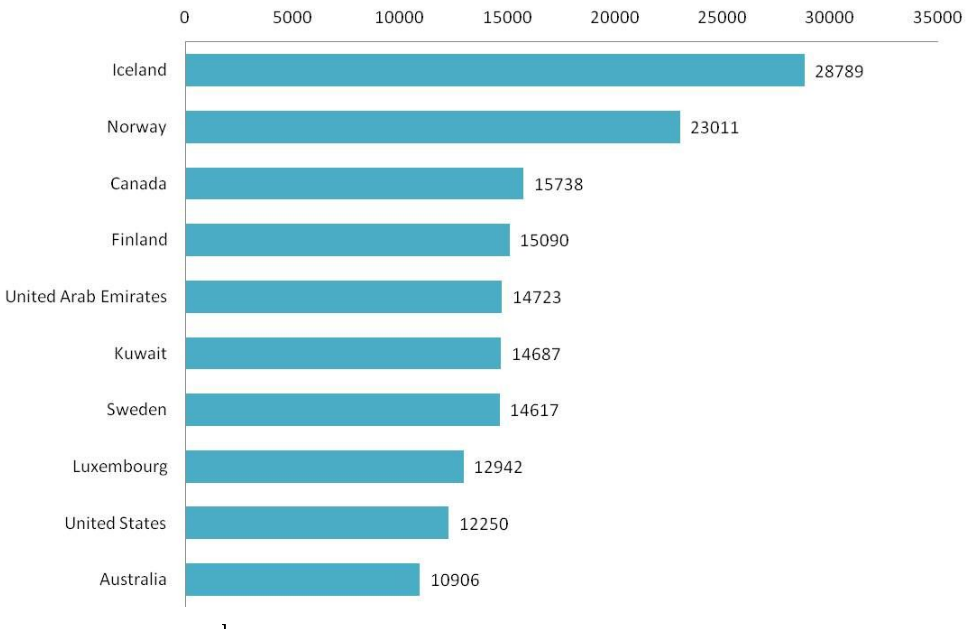
Appendix A

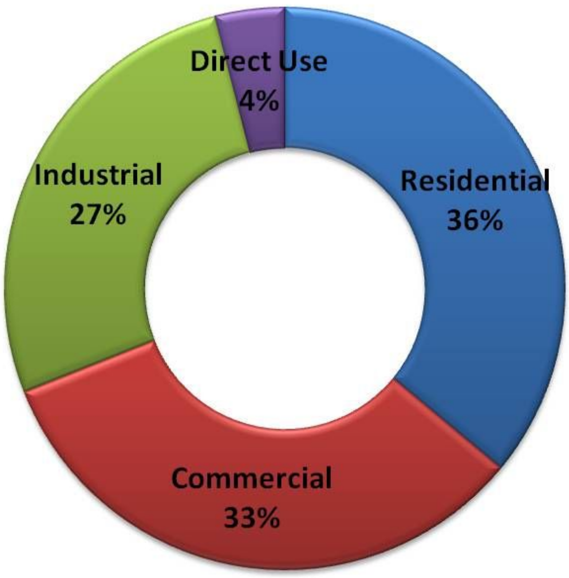
Electrical energy demand and consumption - additional figures

Figure A.1: Per capita Electrical Energy Demand (KWh)



Source: www.mpoweruk.com.

Figure A.2: Electricity Consumption by Application (USA)



Source: www.mpoweruk.com.

Appendix B

Description of Variables and additional tables

Table B.1: Description of Variables

Abbreviation	*Dummy*	*Description*
short_run_estimate	no	estimate of short-run price elasticity of electricity demand
inter_estimate	no	estimate of intermediate-run price elasticity of electricity demand
long_run_estimate	no	estimate of long-run price elasticity of electricity demand
std_err	no	size of the standard error of given estimate
t_stat	no	size of relevant t-statistics (for H_0 : price elasticity equal to 0
industrial	yes	=1 if the estimate is based on industrial data
commercial	yes	=1 if the estimate is based on commercial data
residential	yes	=1 if the estimate is based on residential data
Scopus	yes	=1 if the primary study is included in Scopus database
Repec	yes	=1 if the primary study is included in RePEc database

The table continues on the next side.

USA	yes	=1 if primary study used only data from the USA
Europe	yes	=1 if primary study used only data from Europe
Citations	no	number of times the study has been cited according to Google Scholar
year_start	no	year representing the oldest data used by given primary study
year_end	no	year representing the newest data used by given primary study
FIML	yes	=1 if the estimate was obtained by FIML method
ML	yes	=1 if the estimate was obtained by other ML method than FIML
EC	yes	=1 if the estimate was obtained by EC method
GMM	yes	=1 if the estimate was obtained by GMM method
OLS	yes	=1 if the estimate was obtained by OLS method
GLS	yes	=1 if the estimate was obtained by GLS method
SUR	yes	=1 if the estimate was obtained by SUR method
twostage	yes	=1 if the estimate was obtained by 2SLS method
threestage	yes	=1 if the estimate was obtained by 3SLS method
newML	yes	=1 if the estimate was obtained by any ML method
newIV	yes	=1 if the estimate was obtained by 2SLS or 3SLS method

Source: author's computations.

Table B.2: MRA model - all periods

Variable	*OLS*	*ME*
β(True Effect)	-0.065***	-0.431***
	(0.006)	(0.060)
β_0(bias)	-2.266***	-1.309**
	(0.083)	(0.617)
indust_se	0.06***	0.190***
	(0.007)	(0.063)
commer_se	0.034***	-0.068
	(0.008)	(0.125)
GMM_se	0.068***	0.388***
	(0.016)	(0.100)
IV_se	-0.042***	-0.618***
	(0.009)	(0.173)
ML_se	-0.072***	-0.020
	(0.020)	(0.211)
Europe_se	-0.089***	-0.028
	(0.012)	(0.034)
N	2390	2390
Number of Studies	247	247
R^2	0.103	
χ^2		424.28***

Source: author's computations.

Table B.3: List of primary studies

Acton *et al.* (1976)	Acton *et al.* (1980)
Akmal & Stern (2001)	Anderson (1974)
Anderson (1973a)	Anderson (1973b)
Anderson (1971)	Andrikopoulos *et al.* (1989)
Ang *et al.* (1992)	Apte (1983)
Archibald *et al.* (1982)	Arsenault *et al.* (1995)
Asadoorian *et al.* (2006)	Atakhanova & Howie (2005)
Atkinson (1979a)	Atkinson (1979b)
Badri (1992)	Baker & Blundell (1991)
Balabanoff (1994)	Bandaranaike & Munasinghe (1983)
Barnes *et al.* (1981)	Basu (1976)
Baughman *et al.* (1979)	Beenstock *et al.* (1999)
Beierlein *et al.* (1981)	Bernard *et al.* (1996)
Bernard *et al.* (1987)	Berndt *et al.* (1977)
Berndt & Samaniego (1984)	Bernstein & Griffen (2005)
Betancourt (1981)	Bigano *et al.* (2006)
Bjerkholt & Rinde (1983)	Bjorner *et al.* (2001)
Blundell & Robin (1999)	Botero *et al.* (1987)
Branch (1993)	Brenton (1997)
Bye (1986)	Cargill & Meyer (1971)
Carlevaro & Spierer (1983)	Cavoulacos & Caramanis (1983)
Chang & Chern (1981a)	Chang & Chern (1981b)
Chang & Hsing (1991)	Chern (1978)
Chern (1975)	Chern & Bouis (1988)
Chishti (1993)	Choi (2002)
Christodoulakis & Kalyvitis (1997)	Christopoulos (2000)
Chung & Aigner (1981)	Cian *et al.* (2007)
Cicchetti & Smith (1975)	Cohn (1980)
Considine (2000)	Coughlin (1991)
Dahan (1996)	Delfino (1992)
Denton *et al.* (2003)	Denton *et al.* (1999)
Dergiades & Tsoulfidis (2008)	Diabli (1998)
Dobozi (1988)	Dodgson *et al.* (1990)
Donnelly (1987)	Donnelly (1985)
Donnelly (1984b)	Donnelly (1984a)
Donnelly & Diesendorf (1984)	Donnelly & Saddler (1984)
Douthitt (1989)	Dubin (1985)
Duncan & Binswanger (1976)	Dunstan & Schmidt (1988)
Eltony (2006)	Eltony (2004)
Eltony (1995)	Eltony & Awadhi (2007)
Eltony & Hajeeh (1999)	Eltony & Hoque (1997)

The table continues on the next side.

Eltony & Mohammad (1993)	Eskeland *et al.* (1994)
Faisal & Eatzaz (2011)	Fan & Hyndman (2011)
Faris & Abdul (2002)	Fatai *et al.* (2003)
Filippini (1999)	Filippini (1995b)
Filippini (1995a)	Fisher & Kaysen (1962)
Fouquet (1995)	Fuss (1977)
Garbacz (1984a)	Garbacz (1984b)
Garbacz (1984c)	Garbacz (1984d)
Garbacz (1983b)	Garbacz (1983a)
Garcia & Miguel (2000)	Gill & Maddala (1978)
Glakpe & Fazzolare (1985)	Gollnick (1975)
Green *et al.* (1986)	Griffin (1974)
Guo & Tybout (1994)	Hall (1986)
Halvorsen & Larsen (2001)	Halvorsen (1977)
Halvorsen (1976)	Halvorsen (1975)
Halvorsen & Ford (1979)	Hartman & Werth (1981)
Hausman (1979)	Hawkins (1978)
Hawkins (1978)	Hawkins (1975)
Henderson (1983)	Henriksson *et al.* (2014)
Henson (1984)	Herriges & King (1994)
Hesse & Tarrka (1986)	Hill *et al.* (1983)
Hirschberg & Aigner (1983)	Hogan (1989)
Holtedahl & Joutz (2004)	Horowitz (2007)
Houthakker (1980)	Houthakker *et al.* (1974)
Houthakker (1951)	Hsiao & Mountain (1994)
Hsiao *et al.* (1989)	Hsueh & Gerner (1986)
Hughes-Cromwick (1985)	Ilmakunnas & Torma (1989)
Inglesi-Lotz (2011)	Inglesi-Lotz & Blignaut (2011)
Iqbal (1986)	Ishiguro & Akiyama (1995b)
Ishiguro & Akiyama (1995a)	Ito & Matsui (1978)
Jaffee *et al.* (1982)	Jones (1995)
Jungeilges & Dahl (1986)	Kamerschen & Porter (2004)
Karbuz *et al.* (1997)	Kaserman & Mayo (1985)
Keng (1991)	Khazzoom (1986)
Kohler & Mitchell (1984)	Kokkelenberg & Mount (1993)
Kolstad & Lee (1993)	Kumar & Shukla (1999)
Labandeira *et al.* (2005)	Lareau & Darmstadter (1982)
Larrson (2006)	Laumas & Williams (1981)
Lee & Chiu (2011)	Lim *et al.* (2014)
Liu (2005)	Lohani (1992)
Lyman (1994)	Maddala *et al.* (1994)

The table continues on the next side.

Maddigan *et al.* (1983)	Maddock *et al.* (1992)
Mansur *et al.* (2005)	Matsukawa (1994)
Matsukawa *et al.* (1993)	Mcfadden *et al.* (1977)
Mchugh (1977)	Mendoza & Vargas (1987)
Micklewright (1989)	Moghaddam (2003)
Moghimzadeh & Kymn (1986)	Mount & Chapman (1979)
Mount *et al.* (1974)	Mountain (1989)
Mountain & Hsiao (1989)	Mountain *et al.* (1989)
Munley *et al.* (1990)	Murray *et al.* (1978)
Nagata & Sonoda (2000)	Nan & Murry (1991)
Narayan *et al.* (2007)	Narayan & Smyth (2005)
Okajima & Okajima (2013)	Otero & Diego (1984)
Parhizgari & Davis (1978)	Parti & Parti (1980)
Pesaran *et al.* (1998)	Pindyck (1980)
Pitt (1985)	Poyer & Williams (1993)
Rahman (1982)	Ramcharran (1988)
Reilly & Shankle (1988)	Rossi & Tansini (1989)
Roth (1981)	Roy (1986)
Ryan *et al.* (1996)	Saddler & Donnelly (1983)
Sahlawi & Mohammed (1999)	Salgado & Verdugo (2007)
Schwarz (1984)	Shi *et al.* (2012)
Shin (1981)	Shin (1985)
Silk & Joutz (1997)	Smith (1980)
Sterner (1989)	Sterner (1985)
Sutherland (1983a)	Sutherland (1983b)
Taylor (1977)	Terza (1986)
Tserkezos (1992)	Urga & Walters (2003)
Uri (1977-78)	Uri (1983)
Uri (1982)	Uri (1979a)
Uri (1979b)	Uri (1979d)
Uri (1979c)	Uri (1978)
Vashist (1984)	Veall (1987b)
Veall (1987a)	Velez *et al.* (1987)
Verleger (1973)	Vita *et al.* (2006)
Vlachou & Samoulidis (1986)	Walfridson (1987)
Walker (1979)	Wang (1985)
Westley (1992)	Westley (1989b)
Westley (1989a)	Westley (1984)
Wijemanne (1987)	Wilson (1974)
Yang (1978)	Yoo *et al.* (2007)
Young *et al.* (1983)	Zachariadis & Pashourtidou (2007)
Ziramba (2008)	