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Phillips curve and Google searches

Bachelor's thesis

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Declaration of Authorship

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Abstract

This thesis examines the potential of nowcasting inflation using Google search queries related to unemployment in the Czech Republic. Specifically, the thesis estimates the Phillips curve, which describes the inverse relationship between inflation and unemployment and belongs among key concepts in economics. Using both traditionally obtained and alternative data, simple model of Phillips curve was estimated. The results confirm the presence of Phillips curve in the Czech Republic. Furthermore, the unemployment Google search appears to be a good indicator of inflation development. These findings may be valuable for policymakers, as they enable inflation nowcasting and faster reactions to economic development.

JEL Classification	E21, E23, E24, E31, E37,
Keywords	Google, Econometrics, Job, Market, Phillips curve, nowcasting
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Abstrakt

Tato práce se zabývá předpovídáním aktuálních hodnot (nowcasting) inflace pomocí internetového vyhledávání klíčových slov související s nezaměstnaností v České republice. Využívá Phillipsovu křivku, která popisuje inverzní vztah mezi inflací a nezaměstnaností a patří mezi klíčové ekonomické pojmy. Pro práci s tradičními i alternativními daty byl použit jednoduchý model Phillipsovy křivky. Výsledky potvrzují přítomnost Phillipsovy křivky v České republice. Dále ukázaly, že výsledky hledání nezaměstnanosti prostřednictvím Google jsou dobrým indikátorem vývoje inflace. Tato zjištění mohou být cenná pro politiky a další regulátory, neboť umožňují předpovídat vývoj inflace a rychleji reagovat na ekonomický vývoj.

Klasifikace JEL	E21, E23, E24, E31, E37,
Klíčová slova	Google, ekonometrie, trh, práce, Phillipsova křivka, nowcasting
Název práce	Phillipsova křivka a Google vyhledávání

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Acronyms

BLUE Best Linear Unbiased Estimators

CPI Consumer Price Index

CZSO Czech Statistical Office

GDP Gross Domestic Product

HICP Harmonised Index of Consumer Prices

OLS Ordinary Least Squares

SEI search engine variables for inflation

SEIav arithmetical average searches of keywords for inflation

SEU search engine variables for unemployment

SEUav arithmetical average searches of keywords for unemployment

US The United States

Chapter 1

Introduction

The macroeconomic variables are typically obtained with a significant time lag, often with retrospective corrections. Policymakers and other market players then react to the current development of economy with considerable delay, which reduces the effectiveness of their actions.

This problem may resolve using alternative data from non-traditional sources, such as internet search engines. Search engines, including Google, publicly share the search queries statistics, which can provide valuable insight into current problems of households and consumers. Approach that uses data obtained from Google searches for short-term predictions of macroeconomic variables is often labeled as Google Econometrics.

As confirmed by previous research, Google Econometrics is applicable not only in US, which is the main market for Google, but also in other countries such as the Czech Republic (Platil 2015). Unemployment has been a frequent subject of study in this field (Askitas & Zimmermann 2009) and it has been confirmed, that Google search data improve the models for nowcasting unemployment also in the Czech Republic (Pavlicek & Kristoufek 2015). Unemployment is, among other macroeconomic indicators, related to inflation. The Phillips curve is an economic concept, which describes the inverse relationship between the inflation and unemployment. Based on the Phillips curve relationship, having the data for one of the variables could help in predicting the other variable values.

This thesis aims to examine the Phillips curve presence in the Czech Republic. Furthermore, to provide information, whether and how accurately can search engine data be used for nowcasting inflation using the Phillips curve relationship. In order to cover the Czech search engine market, data from Google

and also Seznam.cz will be examined. Those findings may be relevant mostly to policymakers, as they could nowcast the inflation development and accurately adjust the policies rightaway.

The thesis firstly presents the literature overview of the previous Phillips curve and nowcasting research and explains the related concepts for nowcasting the Czech Phillips curve. Secondly, it presents and describes the traditional and alternative data used in the thesis and the methodology used for the estimation. Lastly, it provides the results overview, its discussion and possible implications from the findings.

Chapter 2

Literature review

2.1 Phillips curve

2.1.1 Formal definition of Phillips curve

The Phillips curve is a widely studied macroeconomic concept that describes the inverse relationship between unemployment and inflation. It was established by Phelps (1967) as a central concept of the macroeconomic theory. The original idea of the Phillips curve was proposed by Phillips (1958) in a paper titled "The Relation between Unemployment and the Rate of Change of Money Wage Rates in the United Kingdom, 1861−1957". This paper demonstrated a negative relationship between unemployment and wage inflation in the United Kingdom over a 90-year period as illustrated in Figure 2.1.

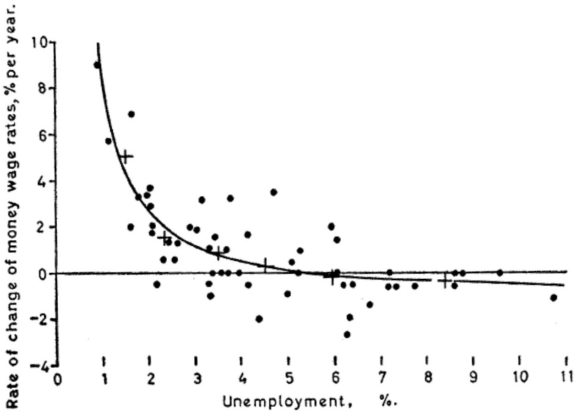

Figure 2.1: The original Phillips curve presenting the relationship between unemployment and rate of change of money wage rates in United Kingdom over the years 1861−1913 (Phillips 1958)

This definition was broadened and generalized by Friedman (1968), who suggested that a short-term tradeoff between unemployment and inflation could be found, but that this relationship breaks down in the long run due to adaptive expectations. In order to describe the rate of unemployment also in the long-run, he introduced the concept of "natural rate of unemployment. Lucas & Rapping (1969) reached the same conclusion regarding the validity of the Phillips curve, but only in the short term.

Over the years, many economists have discussed the concept of the Phillips curve and its usefulness in economic development and increasing available economic instruments. Within this context, Phillips curve was incorporated into a broader macroeconomic perspective, as it was included in the New Keynesian approach. This theory highlights the influence of expectations and other factors that change over time on the Phillips curve in the short run. By accounting for these factors, the theory explains the lags between changes in monetary policy and adjustments in inflation (Blanchard & Watson 1986; Romer 1993)

2.1.2 Usage of Phillips curve in practice

The formal definition and introduction of the Phillips curve generated interest in exploring this phenomenon using real data. Both Okun *et al.* (1973) and Ball & Romer (1990) found stable Phillips curve relationships in US data during the post-World War II period. They pointed out that the Phillips curve could shift in the absence of appropriate measures to control inflation. Its proven persistence in the 1970s and 1980s also indicated the lasting economic impact of monetary policy.

This research also brought considerable suggestions to policymakers. The Phillips curve should be used to set policy targets for both unemployment and inflation (Samuelson & Solow 1960). Policymakers should bear in mind the possibility of its shift over time, which could create obstacles in maintaining stable policy targets. To develop effective policies, policymakers should, therefore, be aware of the shifts in underlying economic conditions, such as changes in inflation expectations or productivity growth, which can affect otherwise stable and predictable Phillips curves (Okun *et al.* 1975).

Tolerating higher inflation up to a certain point could also reduce unemployment (Tobin 1972), however, this approach is a subject of disagreement among authors. The opponents claim that policymakers should rather focus on creating low inflation to shift the Phillips curve down and by that reach the

decrease in both unemployment and inflation. Another approach disagreeing with Phillips curve suggests focusing on creating stable expectations of low inflation to anchor the economy (Lucas Jr 1976; Phelps 1967). Either way, the policymakers should combine monetary and fiscal policy to stabilize the economy while remaining transparent about their policy decisions (Taylor 1979).

Empirical evidence of the Phillips curve relationship has been confirmed by several studies examining data from the United States (Tobin 1972; Gordon 1997; Blanchard & Katz 1999; Sbordone 2002). Later on, the evidence of Phillips curve has been found also in other countries including Canada, Europe, the United Kingdom and Australia (Coenen & Vega 2001; Posen & Kuttner 1999).

Besides the primary official data used for Phillips curve modelling, other factors have significant effects on the relationship between inflation and unemployment. These include inflation expectations, supply shock, the speed of adjusting prices and wages to supply, and demand changes. The importance of these factors varies among different economies (Taylor 1979; Blanchard & Quah 1988). Even in presence of the above-mentioned supply shocks, the Phillips curve is still viewed as a useful framework for understanding inflation dynamics and can be used by central banks while for setting the inflation targets (Ball & Mankiw 1995; Galı & Gertler 1999; Gali & Monacelli 2005). Inflation targeting has been already successfully used in practice to reduce inflation rates and stabilize the output and unemployment (Mishkin & Posen 1997; Levin *et al.* 2004).

2.1.3 Criticism of Phillips curve

While the Phillips curve was initially seen as a useful tool for analyzing the macroeconomy, it has also been subject to criticism. The main critique is that the Phillips curve assumes a fixed tradeoff between inflation and unemployment, and overlooks the fact that workers and firms adjust their expectations and behavior based on changes in monetary or government policies and other factors, as claimed by Phelps (1968); King & Rebelo (1993). This undermines the relationship between inflation and unemployment (Lucas Jr 1976).

Furthermore, Rational Expectations Theory implies that people use all available information to form their behaviour and expectations. Taking this into consideration, policymakers may find it challenging to exploit the trade-

off between unemployment and inflation, as policy changes can affect people's behaviour and future decisions (Sargent & Wallace 1976).

Empirical evidence suggest that the Phillips curve may not be a reliable guide for policy. The relationship described by Phillips curve weakens in the long run, is unstable, and varies over time and across countries. It appears to the monetary policy, what has long-lasting effects on inflation and the economy. Therefore, monetary policy should according to some authors primarily focus on stabilizing the overall level of prices. The natural rate of unemployment is also viewed as consistent with stable inflation in long run and as a primar driver of fluctuations in inflation and unemployment (Ball 2001; Lucas Jr 1976; Goodfriend & King 1997; Friedman 1968; Barro & Gordon 1983).

Inflation dynamics may be influenced by various factors, such as changes in expectations, the natural rate of unemployment, and monetary policy (Galı & Gertler 1999). This summarizes the overall criticism.

2.1.4 Flattening of Phillips curve

With the evolution of the world's economy, the Phillips curve has also evolved. Significant research has shown that it has flattened, meaning the relationship between inflation and unemployment has weakened over time (Blanchard & Katz 1997; Blanchard 2016; Stock & Watson 2016). An example of such flattening in the United Kingdom is shown in Figure 2.2 (PwC 2017).

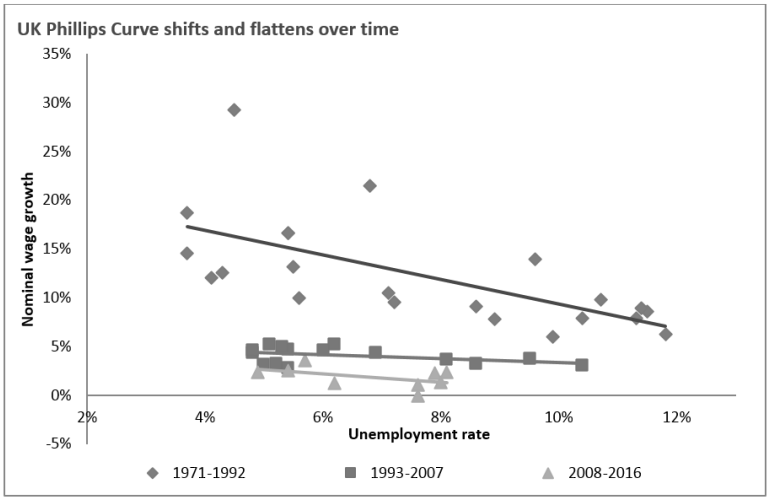

Figure 2.2: The comparison of Philips curve in United Kingdom over three time periods showing the flattening of Phillips curve (PwC 2017)

Empirical evidence has shown that the Phillips curve has flattened in the United States over time with the flattening period between 1980s and early 1990s (Bernanke 2004; Kozicki & Tinsley 2012; Mankiw & Reis 2006; Nakamura & Steinsson 2008; Stock & Watson 2010). In the United States, a more stable inflation after 1990 is also mainly attributed to a firmer anchoring of long-term inflation expectations rather than to the relationship described by the Phillips curve (Hazell *et al.* 2022).

In all advanced economies weakening of the Phillips curve was monitored and dated back to early 1990s (Blanchard *et al.* 2015; Borio & Filardo 2007; Walsh 2009).

The cause of the flattening is a subject of disagreement among authors. Some of them argue that the flattening is related to increased market competition in goods and labor (Borio & Filardo 2007; Walsh 2009). According to others, the flattening is caused by the reduced inflationary sensitivity to changes in the output gap and expectation, due to structural changes in economy including increased competition and greater price flexibility (Mankiw & Reis 2006; Nakamura & Steinsson 2008; Stock & Watson 2010).

Besides identifying the driving causes of the flattening, researches wanted to identify the factors not responsible for this weakening over time. This is not driven by globalization or changes in import prices, changes in the persistence of inflation in the reaction of monetary policy changes in the natural rate of unemployment, or by the degree of price rigidity (Borio & Filardo 2007; Stock & Watson 2010; Kozicki & Tinsley 2012).

The consequences of the flattening of Phillips curve on the effectiveness of monetary policy and macroeconomic stability are not straightforward. It has been suggested to have implications for the conduct of monetary policy, such as the use of forward guidance and the choice of the inflation target (Bell & Blanchflower 2018; Walsh 2009).

Therefore, policymakers should take into account other factors that may be more significant in determining inflation movements and consider inflation expectations when adjusting monetary policy. In terms of inflation, core inflation could be more appropriate indicator of underlying inflationary pressures, as it excludes volatile food and energy prices. As a consequence, the risk of overreacting to short-term fluctuation in headline inflation could be avoided. Further impact of the Phillips curve on monetary policy may be influenced also by factors such as the structure of the economy and the evolution of wages (Stock & Watson 2016; Blanchard *et al.* 2015; Bernanke 2004).

Despite the criticism mentioned above and the Phillips curve flattening, it remains one of the most useful and best documented tools for understanding inflation dynamics. Policymakers should definitely be aware of the declared limitations and complexity of this approach (Galí & Gambetti 2015; Mishkin 2011; Kiley *et al.* 2015).

2.1.5 The most recent studies on Phillips curve

Current research suggests that the Phillips curve is a up to date and valid tool that can be used. Empirical evidence can be found even in very differently structured economies such as Indonesia or Europe (Aginta 2023). For example, European European Central Bank monetary policy in recent years can be partially explained using the concept of structural Phillips curve (Eser *et al.* 2020). The structural Phillips curve describes the relationship between economy-wide easing and inflation as a key element in thinking about the transmission of monetary policy. For the European area, the Phillips curve also helps to explain the fluctuations in weighted median inflation (Ball & Mazumder 2021).

Using of Phillips curve has also resulted in explicit formulations and recommendations. One of them highlights the importance of the global context in Europe, as both domestic and external drivers of inflation should be balanced while dealing with monetary policy (Zobl & Ertl 2021). Empirical evidence has suggested that the Phillips curve without observable flattening applies also to small open economies in Central and Eastern Europe (CEE) (Zobl & Ertl 2021). Similarly, the Phillips curve in Sweden also did not exhibit flattening in recent years, even though its stability over time is questionable (Karlsson & Österholm 2020).

The Phillips curve received attention in other economies worldwide considering the local context. For example policymakers in Indonesia should bear in mind other factors affecting inflation, such as inflation expectations, exchange rate dynamics, and international prices (Aginta 2023). The effect of the inflation changes of unemployment rate have been found also in South Africa, with the exception of some time periods (Buthelezi 2023). In terms of Ghana, no evidence of the Phillips curve has been found. Instead, the policymakers in Ghana have been encouraged to focus on creating job opportunities for both educated and uneducated residents to reduce increasing unemployment (Elliot 2015). However, this particular finding cannot be translated to other countries.

Taking into account that the Phillips curve is a well-known concept, Passamani *et al.* (2022) proposed a model that incorporates the expected inflation as a result of agents using Phillips curve. The model further provides an explanation of the recent "inflation puzzles" as it disentangles the structural component from the expectational effects of the Phillips curve.

2.1.6 Phillips Curve in the Czech Republic

The Czech Republic, being a relatively small country with an economy that cannot compete with the world's largest ones, has not been studied extensively in terms of the Phillips curve phenomenon. However, several Czech authors have addressed this topic and investigated the presence of the Phillips curve on the Czech market in recent years.

Vasicek (2011) proved the validity of the New Keynesian Phillips Curve for four Central European countries, including the Czech Republic, between the years 1995−2008. The evidence showed that inflation is determined by future inflation expectations. There are also indications of the external origin of some short-term impulses due to the economic openness of Central European countries.

The short- and long-run relationship between unemployment and inflation is a subject of debate. Short-term Phillips curve was found to be suitable for application in the Czech economy while maintaining rational expectations. In the long run, the relationship was found to be an irregular curve moving in a clockwise direction (Wang *et al.* 2022). This is in contrast with repeatedly found evidence of a one-directional, indirect, proportional dependence of the inflation rate on the unemployment rate in the long run, (Arlt *et al.* 2022; Vasicek 2009). Krulický *et al.* (2022) recommend considering a growing and strengthening correlation between inflation and unemployment in the future.

The discussion regarding the usage of the Phillips curve in the Czech Republic remains an open area for further research. The existing results have already proved the existence of the Phillips curve; however, they differ in the view of the development of the relationship between unemployment and inflation in the short term and long term.

2.1.7 Benefits of Phillips curve today

The Phillips curve concept can still be used as a framework for analysing the relationship between inflation and unemployment, although the relationship

may not be as stable as it was originally. The evolution of economies since the 1950s must be taken into account, as must the globalisation of the world's economies.

Today, the Phillips curve can still be useful to policymakers in making monetary policy decisions and in understanding the trade-off between inflation and unemployment. At the same time, however, other factors should also be taken into account. Other variables, such as expectations, should be included in the Phillips curve to better capture the dynamics of inflation and unemployment. Considering the variability of these factors in varies economies, it makes sense to apply the Phillips curve for each country separately.

The Phillips curve can also be used for further research, such as analysing the effects of supply shocks in the economy and testing the validity of various economic theories and hypotheses about the behaviour of inflation and unemployment. In this case, it would also be useful to combine the Phillips curve with other models to improve the accuracy of economic forecasts and policy analysis. The concept of economic forecasting is described in the following sections.

2.2 Nowcasting and Google econometrics

2.2.1 Nowcasting

In contrast to the natural sciences, macroeconomic time series data, such as the unemployment rate, are usually available with a significant lag. This is due to the preparation of the data processing and their collection. The process usually takes several months and after corrections to the data (Pavlicek & Kristoufek 2015).

However, the information on the current state of the economy can be very useful both for policymakers and for those who need to make real-time decisions based on the current situation. In this case, forecasting the present value can make a real difference. During the procedure, immediately available data series without delay, which are highly correlated with the variable under study, are processed to obtain the present value of a given variable (Pavlicek & Kristoufek 2015). This type of forecasting for the current period of time is then called "nowcasting" (Del Negro & Schorfheide 2013).

The empirical results of Giannone *et al.* (2008) show that the accuracy of nowcasting generally increases as more new information becomes available

during the current study period. The accuracy of nowcasts depends on the availability and quality of the data used (Croushore 2006).

The data used for nowcasting are available immediately and can be classified as non-traditional data, which includes the search engine queries used in this work. The use of non-traditional data is one of the factors that distinguish nowcasting from forecasting. Forecasting operates with traditional economic indicators in erder to predict its future values.

2.2.2 Google econometrics

"Big Data," publicly available sources of information and insight, is becoming an increasingly important aspect of our daily lives. This data can help provide early indicators of economic and financial trends and activities by offering valuable insights into the unconscious behaviour and subsequent actions of economic agents (Nymand-Andersen & Pantelidis 2018). The big advantage is having access to the undisguised thoughts and current challenges people are dealing with.

Askitas & Zimmermann (2009) demonstrated a strong correlation between keyword searches and unemployment rates in Germany and predicted the great potential of the method used. Since then, the novel data series obtained from Internet platforms have been used intensively and have proven their effectiveness in short-term forecasts of economic and financial indicators (Li *et al.* 2015).

There are several methods for processing Google data. One of them, for example, the one described by Carrière-Swallow & Labbé (2013), works with the search query-based Google Trend Index and incorporates it as a regressor in the simple econometric nowcasting models. Moreover, the simple seasonal autoregressive models that include variables from Google Trends outperform the models without such variables (Choi & Varian 2012).

2.2.3 Google data used for predicting economic trends

Over the past decade, Google data has been used to predict economic variables based on search queries, and the validity of the prediction has been tested against available traditional data.

Baker *et al.* (2011) conducted research that provided the first high-frequency, state-specific measure of job activity, using an index of job searches based on Google data. The idea behind the research assumed that recipients of weekly payments had fewer incentives to engage in job search and related activities.

The job search indicator was suggested to be the best leading indicator for predicting the unemployment rate in the United States, as may be seen in the Figure 2.3 where models augmented with the Google index outperformed traditional ones (D'Amuri & Marcucci 2010). This confirms the earlier weaker claim on a significant positive relationship between job search variables and unemployment data from official sources (Ettredge *et al.* 2005).

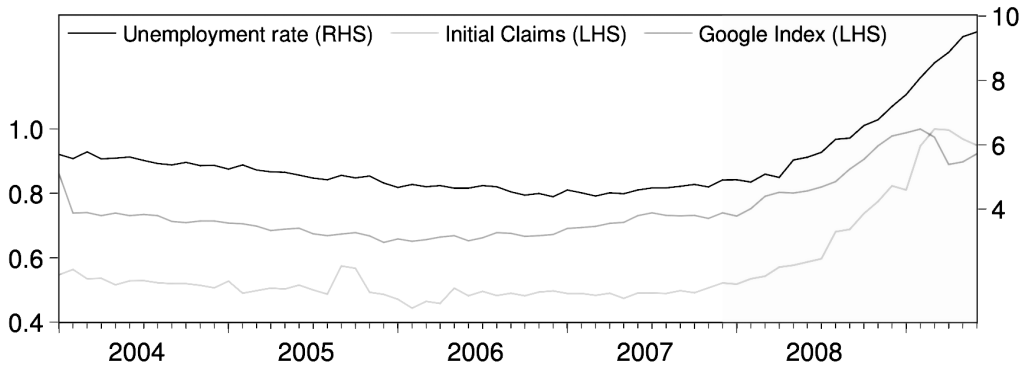

Figure 2.3: The US Unemployment rate (on the right vertical axis) compared with the initial claims (monthly averages rebased on their maximum over the sample 2004:1−2009:6) and prediction based in Google Index (monthly average of Google 'job' searches rebased on their maximum value over the sample 2004:1−2009:6) demonstrating the Google Index as a leading indicator (on the left vertical axis) (D'Amuri & Marcucci 2010)

For the main English-speaking countries and also for the Czech Republic, Krečmer (2018) suggests the inclusion of Google Trends data in some models to improve the prediction of government bond prices and volatility.

In the Czech Republic, the applicability of Google Econometrics has also been demonstrated by other authors. Google data has been shown to significantly improve the nowcast in the areas of unemployment, consumer confidence, and the overall economic situation. Figure 2.4 further explores the visual analysis of consumer confidence. The Google Consumer Sentiment Index based on Google queries and shows the similar development to the Consumer Confidence Indicator provided by Czech Statistical Office (Platil 2015). For the unemployment nowcast, the authors use job search-related queries such as "job,", "job offers" or "labor office". Pavlicek & Kristoufek (2015) also confirmed that the Google search data improve the models for nowcasting unemployment in the Czech Republic and Hungary, although they are rather small economies.

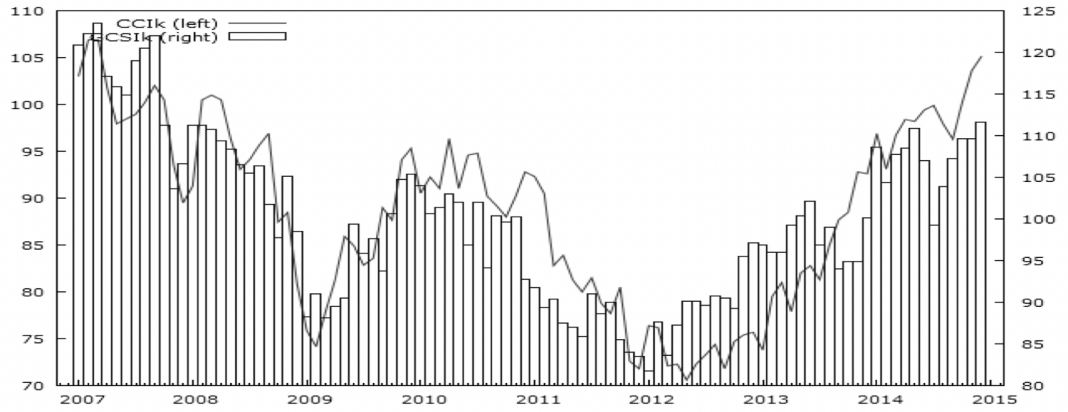

Figure 2.4: Visual analysis of Google Consumer Sentiment Index (bars, values depicted on the left vertical axis) and Consumer Confidence Indicator (continuous line, values depicted on the right vertical axis) river the years 2007−2015 provided by Czech Statistical Office demonstrating the similar development (Platil 2015)

Chapter 3

Theoretical concepts

3.1 The Phillips Curve and its relationship with inflation and unemployment

The Phillips curve describes the relationship between inflation and unemployment and was introduced in the mid-20th century by Phillips (1958), who investigated data on unemployment and nominal wages in the United Kingdom. An inverse relationship was found between the two variables, which in practise explains that lover unemployment leads to higher inflation. Conversely, if the goal was to fight inflation, it was necessary to accept the unemployment.

The concept of a stable trade-off between unemployment and inflation has also been proved successful in several other world economies. This provided policymakers with the opportunity to control these economic variables based on the Keynesian approach. Governments could then tolerate high inflation in exchange for very low unemployment, and vice versa. This made it possible to control movement along the Phillips curve based on monetary and fiscal policy and through it achieve local goals for a given country.

As research progressed and economies changed rapidly since the 1950s, it became apparent that the original Phillips curve was an oversimplified representation of reality. Other variables, such as inflation expectations, were shown to have a large impact and should be taken into account. There have also been found short-term deviations from the Phillips curve caused by supply shocks.

Supply shocks, such as natural disasters or sudden changes in commodity prices, can lead to a short-term increase in inflation, even in the presence of temporarily high unemployment. In such a case, the Phillips curve could move both inward and outward, depending on the nature of the shock, leading to

either low or high values for both variables, followed by a temporary breakdown of the Phillips curve.

In addition to supply shocks, the proxy variables that determine the level of inflation and unemployment can also pose challenges to the estimation of the Phillips curve. Both inflation and unemployment are difficult to measure directly, so proxy variables such as the consumer price index are therefore used as substitutes. However, this may not capture the full extent of interest. Regarding inflation, the consumer price index may not fully capture changes in the prices of goods and services for various interest groups. Similarly, unemployment may not describe the full extent of unemployment because it does not account for discouraged workers who have lost interest in finding work.

In practise, the whole concept of Phillips curves may serve central banks maintain and set their monetary policy strategy. By adjusting interest rates, an appropriate level of inflation can be maintained. In the event of excessively high inflation, raising the interest rate may soothe the state of the economy and reduce inflation. Similarly, if inflation is below the target level, raising interest rates can increase the inflation. The current state of the country's economy, financial market conditions, and global developments should also be considered when setting monetary policy.

Recently, the flattening of the Phillips curve has been demonstrated in several countries (Blanchard & Katz 1997; Blanchard 2016; Stock & Watson 2016; PwC 2017), which may call into question the use of the Phillips curve as a guide for monetary policy. The authors attribute the weakening of the relationship to, among other things, confidence in banks' ability to maintain low inflation and structural changes in the global economy.

Today, the Phillips curve can still be used as a useful tool by policymakers, minding its limitations and any other factors which are necessary to consider (Ball & Mazumder 2021; Eser *et al.* 2020; Aginta 2023). The Phillips curve may differ for each country, as its presence has recently been both confirmed (Vasicek 2009; Zobl & Ertl 2021; Karlsson & Österholm 2020) and rejected as the relationship has weakened (Elliot 2015; Blanchard *et al.* 2015; Borio & Filardo 2007; Walsh 2009). This implies the necessary research be done in each country, as the states of economy may differ rapidly. Future use of the Phillips curve may also involve innovative methods in conjunction with the traditional approach.

3.2 Theoretical framework for using internet data to predict the Phillips curve

The whole concept of nowcasting seems to be self-explanatory, since the name has its origin in connection of the words now and forecasting. This technique aims to estimate present values of economic variables, as opposed to forecasting future outcomes. The predictions should ideally reflect the real-time state of the economy, or they should be as close to the current state as possible. This can be very useful because many economic indicators are usually obtained with a significant time lag, and policymakers need the current variables as soon as possible in order to respond to developments in the economy.

The development of this method was made possible primarily by the amount of real-time data available on the Internet. This data is provided primarily by search engines, social media, and online shopping sites as they collect data on consumer behaviour online. Moreover, the data is collected passively, i.e., without the active participation of consumers. This can contribute to the accuracy of the observation and explain the actual needs and wants.

The data obtained can then be used in econometric models as explanatory variables that provide information about specific behaviours that affect the explained variable. The explanatory variables proven to have a significant effect can then be used for nowcasting economic indicators such as inflation, GDP, and employment. Nowcasting and Google Econometrics can also be used to predict stock and real estate prices and labour market indicators, among others.

As mentioned above, the main advantage of Nowcasting is to improve the speed and accuracy of forecasting and to provide policymakers and economic agents, with real-time information that allows them to make more informed decisions. Also worth mentioning is the cost of the data collected. Since the data is passively collected, the cost of obtaining the data, if any, is very low. This fact makes nowcasting relatively inexpensive and offers great advantages over traditional methods.

Traditionally, the Phillips curve has been obtained using traditional data such as the inflation rate, unemployment rate, and GDP, which can take several months to obtain. With the Phillips curve nowcasting method, the main advantage is likely to be the shortened time required for data processing and the accuracy of the predictions. Data collected from search engines and other sources could provide real-time information on people's concerns about job op-

portunities, salaries, and prices, and provide insight into the current state of household economic conditions. Search engines provide information on search volume and allow job-related keywords and unemployment to be used for regression analysis, with the same being applicable for price-related keywords and inflation. As an example, this relationship in practice can be seen in Figure 3.1, where the inflation and unemployment Google search plots the Phillips curve shape in US in 2020−2022.

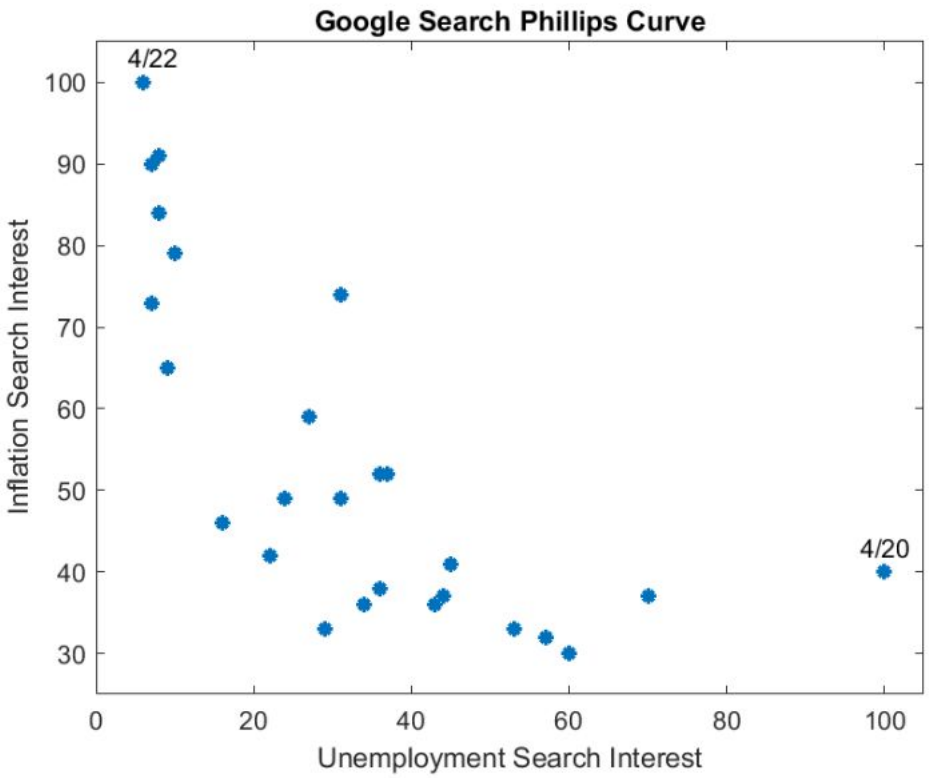

Figure 3.1: The US Phillips curve plotted using the Google search interests for inflation and unemployment in 2020−2022 (Twitter, Inc. 2023)

Potential limitations and challenges associated with the use of internet data include issues related to data quality, sample selection bias, and data aggregation. Among other factors, the quality of data can be affected by spelling errors and language variations across the country. Aside from different dialects, regions may also differ in the likelihood of using search engines for certain purposes, which may lead to sample selection bias. Conversely, since the data are usually collected at the national level, local differences in economic activity may remain unobserved.

Empirically, search engine data has been shown to be capable of predicting various economic variables including unemployment rate, retail sales, consumer confidence, and economic activity. These predictions were also demonstrated to be more accurate than traditional forecasting methods. According to the research, web and search data also have the potential to enhance traditional economic data sources in predicting economic variables by increasing the accuracy of the model. However, there is always a need for proper examination of a particular country and its specific, as the research and web data and their importance may be specific to each country (Choi & Varian 2012; 2009; Goel *et al.* 2010; Carrière-Swallow & Labbé 2013).

Chapter 4

Data and empirical model

4.1 Traditional inflation and unemployment data

Inflation data from Eurostat and unemployment data from the Czech Statistical Office will be used to verify the presence of the Phillips curve in the Czech Republic based on traditional data. The following section briefly introduces the traditional data and the methods used for obtaining them.

4.1.1 Inflation data from Eurostat

Due to the reformed method of an inflation measurement, the data from CZSO are differently measured for the time period before and after year 2018 (Czech Statistical Office accessed on 22 April 2023). Therefore data on inflation have been obtained from Eurostat, for the purpose of this thesis.

For inflation measurement, Eurostat uses the Harmonised Index of Consumer Prices (HICP), which is a Consumer Price Index (CPI) calculated with a harmonised approach. This method enables the direct comparison between the HICPs of European countries without the need of any additional adjustment. Inflation is defined for this purpose as the price change of consumer goods and services acquired by households in time (Eurostat accessed on 22 April 2023). The inflation data on Czech inflation are available from 1997 until present.

The Eurostat inflation data are available since 1997. As the other data from Google Trends are available since 2004 and the unemployment data from CZSO are available since 2005, the Eurostat inflation data will be in this context also retrieved from the period 2005−2022.

4.1.2 Unemployment data from CZSO

CZSO defines an unemployed person as a citizen of age 15 or more satisfying all of the below-mentioned conditions during the examined period:

- not to be employed;
- to be actively looking for a job;
- to be ready to enter a job position.

Any person older than 15 years that does not meet any of the above-mentioned conditions is considered to be employed or economically inactive. The only exception classified as unemployed is a group of people, who already found a job with a starting date within 14 days.

CZSO gathers the data about unemployment from a quarterly Labour Force Sample Survey, which is being published after every quarter with a significant time lag. The unemployment rate is then measured as a percentage ratio of unemployed people to the total workforce, which includes both the employed and unemployed population.

As a reform in unemployment measurement took place and the measurement of unemployment has changed since 2005, the data for the purpose of this thesis have been obtained in the period 2005−2022. That corresponds also to the Google Trends data availability, which are accessible since 2004.

4.2 Google Trends data

Google search history information for the specific time period and location is freely available on the Google Trends website. Google Trends provides an unfiltered sample of search queries that are anonymized, categorized, aggregated and can provide information about actual search requests. Google provides two types of data samples: one covering real-time Google search data from the last 7 days and the other covering non-real-time data since 2004 up to the 72 hours prior to the search. Google Trends also offers filters enabling to focus on a specific time period, location, category, and particular Google search, such as web search or Google Pictures.

Google normalizes the search data and scales it proportionally to range from 0 to 100 based on comparison to all searches on all topics, allowing thus comparison between keyword searches. Normalization divides each data point

by the total number of searches in different regions and time periods to provide a relative measure of popularity. This approach prevents regions with high search volume from always dominating the rankings (Google Accessed 2023b).

Since the search queries are to be compared with monthly data from the CZSO, there are also obtained monthly data for Czech Republic from Google Trends . In order to examine as long time period comparable to the available traditional data as possible, data from 2005 to 2022 are used. The following 6 keywords are used to query unemployment searches: "práce", "prace" (both Czech equivalents for job), "volná místa" (vacancies), "nabídka práce" (job offer), "životopis" (resume), and "úřad práce" (labour office) in the job category. For obtaining the query on inflation searches, following 6 keywors are used: "inflace" (inflation), "úrokové sazby" (interest rates), "zdražení" (price increase), "spoření" (saving), "investice" (investments), and "úvěr" (credit/loan). All data are provided as a csv file in the form of monthly values in the range from 0 to 100 and downloaded from Google (Accessed 2023a).

4.3 Seznam.cz data

Czech search engine Seznam.cz is along with Google one of the most popular and used search engines in Czech Republic. As this is characteristic for the local search-engine market, the search query data from Google are not the only ones that should be examined (Platil 2015). The comparison of the results from two different search engines may also provide valuable information regarding the users of the particular search engine, as they may differ in their demographical and socio-economical determinants.

The search database of Seznam.cz is not as extensive as Google Trends, however, it may still provide valuable information about consumer behaviour. Seznam.cz provides a database of its searches up to 1 year in the past on a website "Statistiky vyhledávání" (Seznam.cz 2023). Contrary to Google Trends, Seznam.cz does not use any sort of index and rather provides statistics on the actual search volume in real numbers. The Seznam.cz filters enable the distinction between daily, weekly and monthly searches and also between the devices used for the search: PC, tablet, smartphone or other multimedia devices.

For the purpose of this thesis, monthly data on the same keywords for unemployment: "práce", "prace" (both Czech equivalents for job), "volná místa" (vacancies), "nabídka práce" (job offer), "životopis" (resume), and "úřad práce" (labour office) and on inflation: "inflace" (inflation), "úrokové sazby" (interest

rates), "zdražení (price increase), "spoření" (saving), "investice" (investments), and "úvěr" (credit/loan) have been obtained. All data provided are in the form of absolute searches. Considering the other data availability, the data from Seznam.cz are be obtained from the period 2022:5−2022:12 for the purpose of this thesis.

4.4 Data description

4.4.1 Czech inflation and unemployment

The evolution of the inflation and unemployment in Czech Republic may be seen from Figure 4.1. In the period between 2005 and 2021, the highest inflation was 8% in 2008 during the World Financial Crisis. Since 2009 inflation has remained in the interval between slightly bellow 0% and 4%. The level of inflation has significantly increased since the beginning of 2022, which may be caused by very high prices of real estates, increase in energy prices or the budget policy during the Covid-19 pandemic.

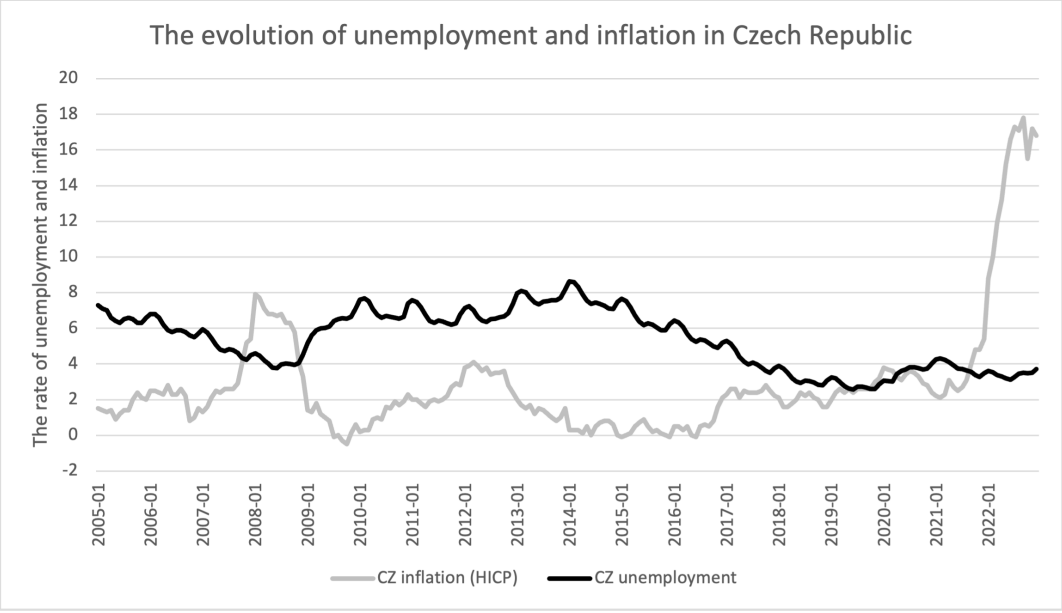

Figure 4.1: The evolution of unemployment (obtained from CZSO) and inflation (obtained from Eurostat, measured by HICP) in Czech Republic over years 2005−2022

The high level of inflation in recent year, which reached 18%, may have probably not bee driven primarily by unemployment, as can be also noticed from the Figure 4.1. Therefore the data from period 2005−2022 and also

2005−2021 will be used for the estimating of the Czech Phillips curve to avoid the possible bias caused by the evolution of inflation in recent year.

4.4.2 Google unemployment searches

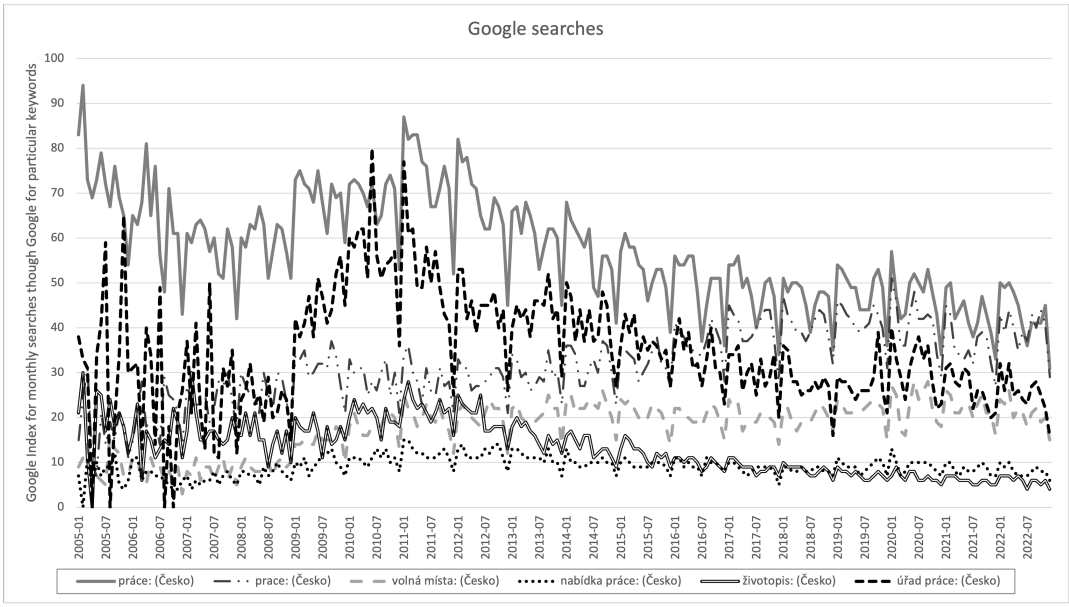

Figure 4.2: The overview of Google searches of particular 6 keywords for unemployment scaled with Google Index over the period 2005−2022

Figure Figure 4.2 depicts the development of Google searches for 6 keywords for unemployment scaled with Google Index during the time period 2005−2022. It illustrates the dominance of 3 keywords: "práce" (labour), "prace" (labour, without diacritics) and "úřad práce" (labour office) above the 3 others.

There may be also seen a similar tendency in the searches fluctuations regarding both the peaks and declines. That may be caused for example by seasonality, as only from the graph there seems to be a regular decline in unemployment searches at the beginning of most years.

The unemployment Google search data depicted on the plot have its peaks in 2005 an in the period 2010−2012 and since 2012, the unemployment search seems to decline. In comparison with the official unemployment data from CZSO depicted on the Figure 4.1, there seems to be a declining tendency in both unemployment keywords Google search and the official unemployment data. The only difference remains in the beginning of the decline, as the Google unemployment search declined since 2011 and the official unemployment fluctuated

between 2010 and 2014 and than had a declining tendency from 2014 until 2020.

The declining tendency of Google unemployment search may be caused by various factors, such as the actual declining unemployment, but also by other possibilities of job search offered by social media such as LinkedIn (2002–present).

4.4.3 Google inflation searches

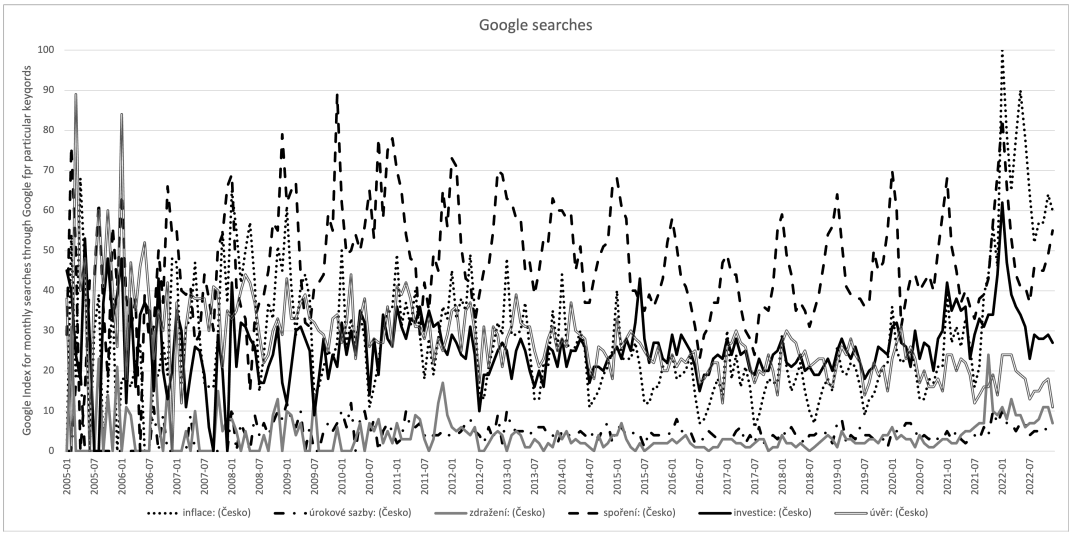

Figure 4.3: The overview of Google searches of particular 6 keywords for inflation scaled with Google Index over the period 2005−2022

Searches for 6 keywords for inflation scaled with Google Index are shown on Figure 4.3. The searches for "spoření" (saving) clearly dominate the searches. It reaches its highest value in 2010 and the searches seem to be very seasonal, as the peaks occur at the beginning of every year and the downs tend to come in the summer months. This can be explained for example by the New Year's resolutions and interest in personal finance, while the summer months are primarily dedicated to vacations.

The development of searches for "inflace" (inflation) seems to coincide with the inflation in Czech Republic (depicted in Figure 4.1), as it had a declining tendency in the period 2008−2020 and rises sharply in the second half of 2021. Together with the high inflation in Czech Republic, the searches for "investice" (investments) also increased sifnificantly.

4.4.4 Seznam.cz unemployment searches

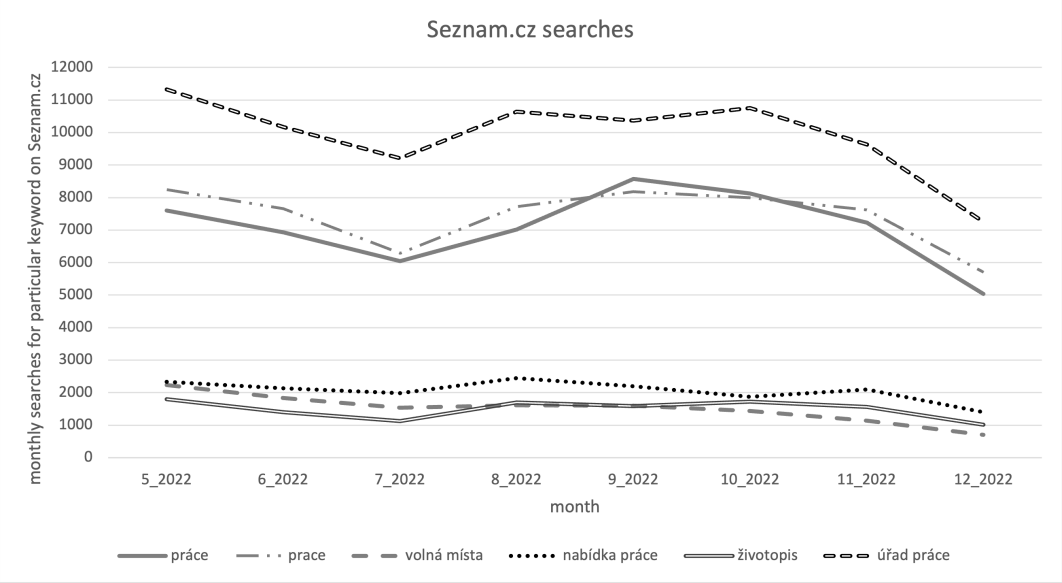

Figure 4.4: Monthly searches though Seznam.cz for particular keywords for unemployment over the period 2022:5−2022:12

The Seznam.cz searches for unemployment do not provide any comprehensive overview, as the observed period is quite short compared with the available Google Trends data or traditional data. Even though there seems to be the same dominance of 3 unemployment keywords "práce" (labour), "prace" (labour, without diacritics) and "úřad práce" (labour office) above the others, as was observed for Google unemployment searches. The development of the searches also seems to have a similar pattern for all of the examined keywords.

The Seznam.cz data may be valuable mostly in the absolute search volume Seznam.cz provided, adding concrete search volume to the whole concept. However, the greatest limitation of this data lies in the very short period available and therefore these data can serve primarily as complementary to the Google Trends data, in order to examine also this popular Czech search engine.

However, as can be seen from the traditional data on unemployment in Figure 4.1 and is proven by further analysis in Chapter 5, the inflation in 2022 in the Czech Republic increased rapidly and was most likely driven by other factors than the Phillips curve relationship. As shown in Chapter 5, the Czech Phillips curve relationship is strongest in 2005−2021 and as Seznam.cz data are available only from 2022, the data analysis of this thesis focuses hereafter only on Google data.

4.4.5 Seznam.cz inflation searches

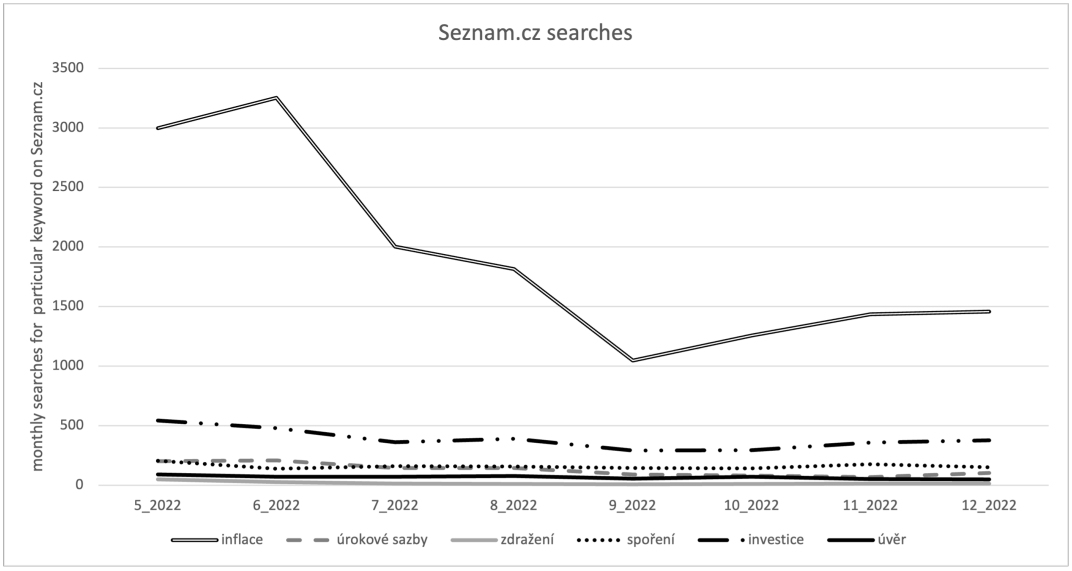

Figure 4.5: Monthly searches though Seznam.cz for particular keywords for inflation over the period 2022:5−2022:12

The searches for keywords connected with inflation on Seznam.cz depicted on Figure 4.5 differ from the Google searches for the same keywords (on Figure 4.3) primarily in the domination in searches for "inflace" (inflation), which dominates the searches. Searches for the other 5 keywords remain very low over the whole time period compared to searches for "inflace" (inflation). This may be caused by various factors, such as different interest of Seznam.cz users than Google users.

The trend for "inflace" (inflation) is declining for almost the whole period depicted, while the searches for other 5 keywords remain nearly constant and only slightly fluctuate.

For the purpose of this thesis, only Google data are used for further analysis and models in Chapter 5, as it is not available in 2005−2021 where the Phillips curve seems to be most pronounced in the Czech Republic. The reasons are discussed in more detail at the end of Subsection 4.4.4.

4.5 Empirical model

The purpose of this thesis is to estimate the Phillips curve and therefore the main used model is the classical Phillips curve model complemented with the

classical OLS model. R Studio was used for the estimation of the below described models and their assumptions.

4.5.1 Simple Phillips curve model

The simple Phillips curve depicts the relationship between two variables, inflation and unemployment, and is linear in parameters. The model consists of only two variables. The explanatory variable is unemployment and the explained variable is inflation. As the simple Phillips curve relationship examines the effect of the unemployment development on the changes in inflation values, the often-used simple Phillips curve model also operates with the changes in both variables (Hazell *et al.* 2022). The changes are within the context of this thesis understood as the difference between the value in time t and the value in time $t-12$, as all the values are measured monthly and the Δ then provides the difference between the value in a particular period and the value in the same month of the previous year. In order to examine which model is better for the application of Phillips curve in Czech Republic, also a model without the changes measurement is used. Both the models, the one using the unemployment and inflation rate in equation Equation 4.1 and the one operating with changes in the variables in equation Equation 4.2, are described below.

$$\pi_t = \beta_0 + \beta_1 u_t + \upsilon_t \tag{4.1}$$

$$\Delta\pi_t = \beta_0 + \beta_1 \Delta u_t + \upsilon_t \tag{4.2}$$

The limitation of the simple Phillips curve model may lie in the simplicity of the model. As stated in Chapter 2 and Chapter 3, the Phillips curve may be affected also by other significant factors, that are not included in this model. Therefore this model is estimated with the acknowledgement of the simplified view and aims to estimate the relationship solely between the unemployment and inflation.

The simple Phillips curve model is estimated firstly for the traditional data in order to examine the presence and development of the Phillips curve in Czech Republic. Secondly this model is used for the estimation of the relationship between the traditionally obtained inflation and the Google search query for the keywords for unemployment. For this purpose, the arithmetic mean from the search engine queries is used in order to keep the relationship of one explanatory

and one explained variable. Finally, the Czech Phillips curve based solely on the search engine queries is estimated, using again the arithmetic mean of the keyword values. The model described in Equation 4.2 is used for the estimations of Phillips curve using the search engine query data, as the Google data already include the change in the search volume, as they are normalised with the Google Index (explained in Section 4.2).

4.5.2 OLS model

The OLS model is used for the estimation of the relationship between the keywords searches and corresponding traditionally obtained variable. The estimation should help to validate, whether the keywords for unemployment and inflation were chosen appropriately and how much the search of the keyword is related to the explained variable development.

The OLS is used for search query for unemployment and inflation obtained from Google. The explanatory variables which refer to **search engine variables for inflation (SEI)** are indexed from 1 to 6 as data queries for 6 keywords from the search engine was obtained.

The first OLS model estimates the relationship between the **arithmetical average searches of keywords for inflation (SEIav)** and the traditionally obtained inflation as depicted in equation Equation 4.3.

$$\pi_t = \beta_0 + \beta_1 \text{SEIav}_t + \upsilon_t \tag{4.3}$$

The second OLS model, described in equation Equation 4.4, estimates the relationship between the **SEI** variables and inflation and it should provide the overview of the particular keyword significance.

$$\pi_t = \beta_0 + \beta_1 \text{SEI1}_t + \beta_2 \text{SEI2}_t + ... + \beta_6 \text{SEI6}_t + \upsilon_t \tag{4.4}$$

For unemployment searches, the OLS models are constructed in the exactly same way as for inflation and listed in the equations Equation 4.5 and Equation 4.6. They only differ in the names of variables, being **search engine variables for unemployment (SEU)** and **arithmetical average searches of keywords for unemployment (SEUav)**.

$$u_t = \beta_0 + \beta_1 \text{SEUav}_t + \upsilon_t \tag{4.5}$$

$$u_t = \beta_0 + \beta_1 \text{SEU1}_t + \beta_2 \text{SEU2}_t + ... + \beta_6 \text{SEU6}_t + \upsilon_t \tag{4.6}$$

The OLS models are desired to be Best Linear Unbiased Estimators (BLUE) and therefore should they meet the necessary Multiple linear regression assumptions (Wooldridge 2016). The random sample assumption should always be met, as the sample is always drawn randomly from the population, the number of observations is greater than the number of estimated parameters and the error terms should be random. The multi-collinearity assumption is tested only for the models containing more than 1 variable, as there cannot be multi-collinearity in the model with only one explanatory variable. The other assumptions are tested for all the above mentioned OLS models.

The limitation of the OLS models include the possibility of not all the Multiple linear regression assumptions to be met and also the linearity, which assumes that the relationship between the variables is linear. If the Seznam.cz data was used for the estimation, the limited sample size may affect the results and lead to obtaining inaccurate estimates.

Chapter 5

Results and discussion

This section contains the presentations and discussion of results for the estimation of the Czech Phillips curve using traditional data and alternative data from Google. The data sources are described together with the used methodology in Chapter 4. The chapter is divided into 3 subsections. The first subsection estimates the Czech Phillips curve using traditional data. The second one estimates the Czech Phillips curve using traditional inflation data and alternative data on unemployment obtained from Google. The third section estimates the Czech Phillips curve using solely Google search queries.

5.1 Czech Phillips curve estimated using traditional data

The first four models estimated the relationship between inflation and unemployment using the simple Phillips curve. The results of the models are presented in Table 5.1 and in Table 5.2.

Czech Phillips curve in the period 2005−2022 is depicted on Figure 5.1. The graph may be on first sight very similar to the original Phillips curve depicted on Figure 2.1. However, a closer look shows that the upper tail consists only of the data from 2022. As already mentioned, the inflation in 2022 was extremely high and probably not driven by the Phillips curve relationship. The trendline shows the expected inverse relationship between the variables. In order to examine data in a more consistent period, Figure 5.2 plots the relationship between the inflation and unemployment in the years 2005−2021. In this time frame, the relationship seems to be more stable and without extreme values and again shows the desired inverse relationship.

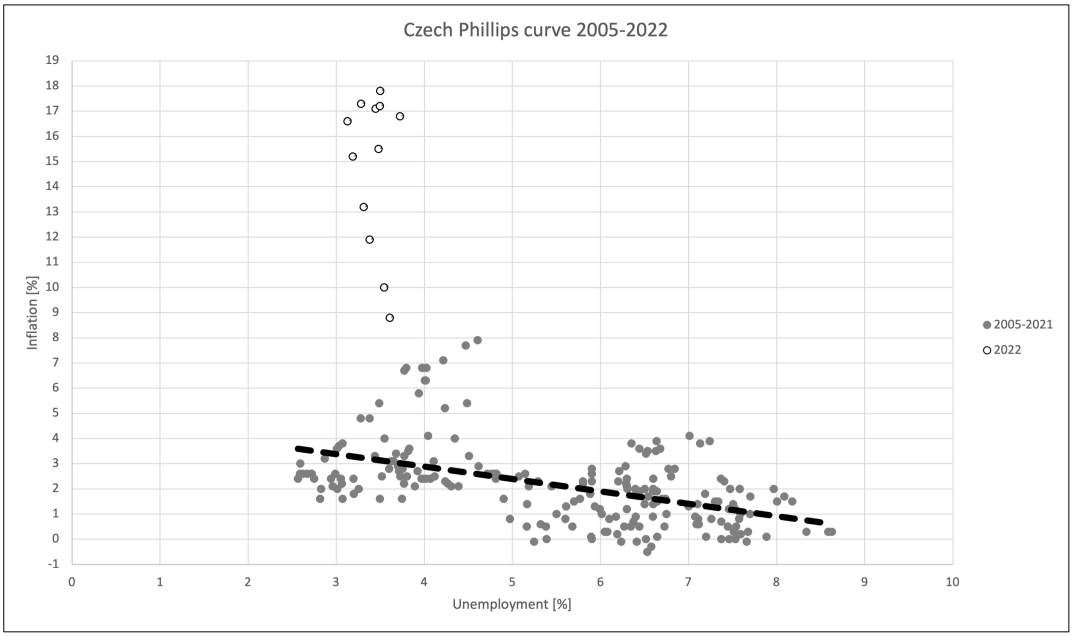

Figure 5.1: Czech Phillips curve in years 2005−2022 constructed using the traditional data on inflation and unemployment

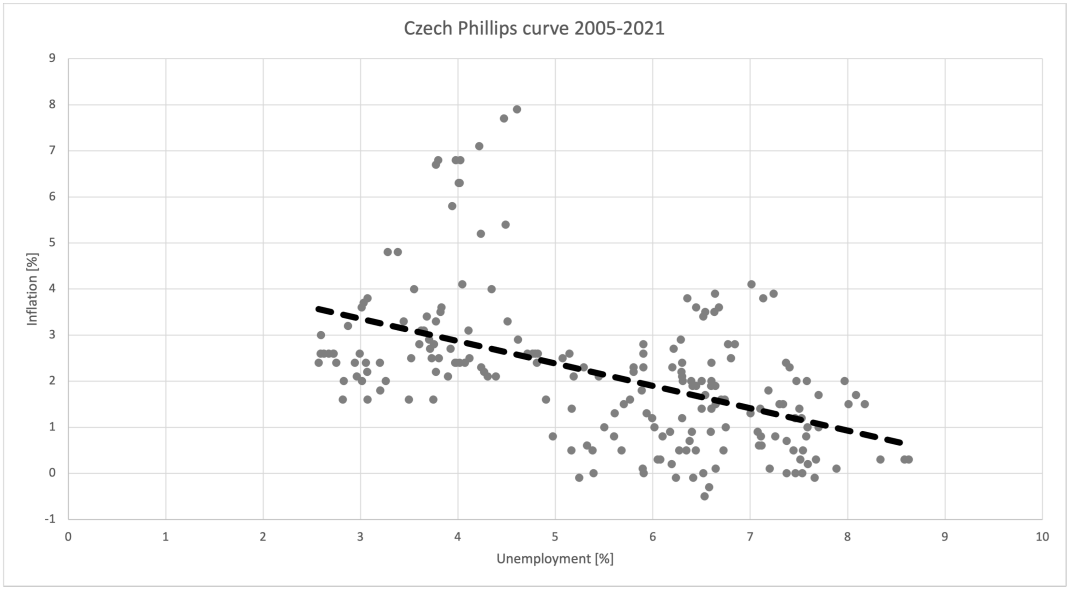

Figure 5.2: Czech Phillips curve in years 2005−2021 constructed using the traditional data on inflation and unemployment

The Table 5.1 presents the results for the simple Phillips curve using percentage values for inflation data from Eurostat and unemployment data from CZSO. Two models in different time periods 2005−2022 and 2005−2021 were estimated in order to compare the results for them. Year 2022 was excluded from the second data set due to the significant increase in inflation, probably originating from reasons other than the ones simple Phillips curve describes, as noted in Chapter 4 and shown in Figure 5.1.

Table 5.1: Coefficients of the basic Phillips curve model for time periods 2005−2022 (1) and 2005−2021 (2)

	Dependent variable:	
	inflation	
	(1)	(2)
	2005−2022	2005−2021
unemployment	−0.964***	−0.494***
	(0.123)	(0.060)
Constant	8.037***	4.867***
	(0.693)	(0.343)
Observations	216	204
R^2	0.222	0.251
Adjusted R^2	0.218	0.247
Residual Std. Error	2.971 (df = 214)	1.384 (df = 202)
F Statistic	61.069*** (df = 1; 214)	67.712*** (df = 1; 202)
Note:		*p<0.1; **p<0.05; ***p<0.01

Basic Phillips curve from both time periods depicts the expected negative relationship between inflation and unemployment with statistically significant results for unemployment estimate. That means, that the unemployment significantly affects the inflation.

In order to find the most relevant simple Phillips curve form for the Czech Republic, the estimation was obtained for the both time periods also with the changes in inflation and unemployment included, as described in Equation 4.2. The results of the estimation are presented in Table 5.2.

Out of the all 4 estimations with results in Table 5.1 and Table 5.2, the results for the basic Phillips curve model including changes in variables in period 2006−2021, depicted in Table 5.2, are described in detail and discussed.

However, it should be noted, that all of the four estimated model proved the statistical significance of the unemployment variable, which in all four cases has an inverse relationship with inflation. The R^2s, with values between 0.172 and 0.395, confirm the relevance of the unemployment influence on the inflation development.

Table 5.2: Coefficients of the basic Phillips curve model with changes (denoted by Δ) in inflation and unemployment for time periods 2006−2022 (1) and 2006−2021 (2)

	Dependent variable:	
	Δ*inflation*	
	(1)	(2)
	2006−2022	2006−2021
Δunemployment	-1.473^{***}	-1.380^{***}
	(0.228)	(0.124)
Constant	0.500^{**}	-0.134
	(0.226)	(0.126)
Observations	204	192
R^2	0.172	0.395
Adjusted R^2	0.168	0.392
Residual Std. Error	3.174 (df = 202)	1.716 (df = 190)
F Statistic	41.911^{***} (df = 1; 202)	124.146^{***} (df = 1; 190)
Note:		*p<0.1; **p<0.05; ***p<0.01

The simple Phillips curve model including yearly changes for the inflation and unemployment values in period 2006−2021 was estimated using 192 monthly observations for both variables. The coefficient for the explanatory variable (Δunemployment) is statistically significant and implies, that if the unemployment rate drops by − 1.38% in comparison to the value in previous year, the inflation rate should rise by 1 % in comparison to the previous year value. As the value of R^2 is 0.395, the Δunemployment explains 39.5 % of the variation in Δinflation. This suggests that the Δunemployment is moderately strong predictor of the Δinflation and proves the presence of the Phillips curve in the Czech Republic. All of these results described can be found in Table 5.2.

As the model includes only one variable and the inflation development is expected to be influenced also by other factors, it does not provide the infor-

mation on the other factors important for the Czech Republic specifically. This could be a meaningful topic for the following research.

For all of the four models, with results in Table 5.1 and Table 5.2, the necessary assumptions for the linear regression have been obtained. The linearity holds for all four models. The random sample and muticollinearity assumptions are satisfied without the need for any tests. The data come from a random sample (even in the shortened period without 2022, all of the data from previous years are included) and there is only one explanatory variable in the model, which excludes the presence of multicollinearity. The residuals follow the normal distribution for the models including changes of the explained and explanatory variables. The residuals of simple Phillips curve model in period 2005−2022 do not follow the normal distribution, however as the period was restricted to 2005−2021, the residuals approximately do follow the normal distribution. The heteroskedasticity was proved by the White test to be present. This suggests, that the variability of inflation is not constant across all the levels of unemployment. That may be explained by the structural changes in economy, such as changes in monetary policy, market expectations and supply shocks, as expected. The results for the assumption testing of the most reliable model (including changes in variables in period 2006−2021) can be seen in Appendix A.

5.2 Traditional inflation data estimated using Google unemployment data

The presence of the Czech Phillips curve has been confirmed by resultes presented in Section 5.1. This section presents the results for estimating the traditionally obtained inflation on the average Google search for unemployment keywords. The model was estimated in two time periods, 2005−2022 and 2005−2021, as the models in the previous section. That is due to the inflation development in year 2022, which is described in more details in Subsection 4.4.1.

In both estimated time periods, there can be found statistically significant inverse relationship between the average unemployment Google search and the traditionally obtained inflation. Due to the inflation development in 2022, the second model estimated in 2005−2021 may be more relevant for answering the question, whether and how does the unemployment Google search explain the inflation development.

As presented in Table 5.3, during the years 2005−2021, the inverse relationship between the average unemployment Google search explained 8.6% of the inflation development. The relationship was very proportioned, as the drop in average unemployment Google search by −0.996 (measured by the average value of Google Index for 6 keywords, described in details in Section 4.5) implied the increase in inflation rate by 1%. For both models, the necessary assumptions for linear regression were tested. For the described model in the period 2005−2021, the assumptions for linearity, random sample, no multicollinearity and zero conditional mean holds. The heteroskedasticity is present, which can be explained similarly as in Section 5.1. The inflation is expected to be affected primarily by other factors in economy, than the Google unemployment search. The results of the assumption tests are attached in Appendix A.

Table 5.3: Coefficients of the basic Phillips curve model using traditional inflation data (from Eurostat) and alternative unemployment data obtained from Google in time periods 2005−2022 (1) and 2005−2021 (2)

	Dependent variable:	
	inflation (Eurostat data)	
	(1)	(2)
	2005−2022	2005−2021
average unempl. G search	−2.071***	−0.996***
	(0.452)	(0.229)
Constant	83.156***	47.348***
	(12.530)	(6.382)
Observations	216	204
R^2	0.089	0.086
Adjusted R^2	0.085	0.081
Residual Std. Error	32.435 (df = 214)	16.003 (df = 202)
F Statistic	20.977*** (df = 1; 214)	18.974*** (df = 1; 202)
Note:		*p<0.1; **p<0.05; ***p<0.01

These results prove, that the Google search queries for unemployment may be used for predicting the inflation development in the Czech Republic, using the Phillips curve concept. Forecasting inflation dynamics may be valuable especially for the policymakers and authorities, who need to have up-to date

information about the inflation development and adjust the policies accordingly. The forecasts could be then also shared with public, so the households can also adjust to the current market situation.

The further research can examine the relationship also in the more complex Phillips curve models, which can provide more accurate information and also offer more comprehensive base for the inflation predicting. Furthermore, the keywords for obtaining Google search queries may be extended and the results for various keyword combination may be investigated in order to find the most reliable and significant combination.

5.3 Czech Phillips curve estimated using only Google data

As a complementary analysis, the relationship between the Google searches for inflation and unemployment was estimated. Similarly to the previous sections, the model was estimated in two time periods, 2005−2022 and 2005−2021, and the results are presented in Table 5.4.

Table 5.4: Coefficients of the basic Phillips curve model using alternative inflation unemployment data obtained from Google in time periods 2005−2022 (1) and 2005−2021 (2)

	Dependent variable:	
	average inflation Google search	
	(1)	(2)
	2005−2022	2005−2021
av. unempl. Google search	0.232***	0.295***
	(0.076)	(0.069)
Constant	16.451***	14.188***
	(2.099)	(1.932)
Observations	216	204
R^2	0.042	0.082
Adjusted R^2	0.038	0.078
Residual Std. Error	5.433 (df = 214)	4.844 (df = 202)
F Statistic	9.413*** (df = 1; 214)	18.113*** (df = 1; 202)
Note:		*p<0.1; **p<0.05; ***p<0.01

The estimates for average unemployment Google search are significant for both time periods. Considering the second time period 2005−2021, according to the R^2 value, the average unemployment Google search explains 8.2% of the average inflation Google search. However, the relationship between the variables is positive in both time periods, contrary to the results in Section 5.1 and Section 5.2 and the Phillips curve theory. The necessary assumptions for the linear regression were tested with similar results as in Section 5.1 and Section 5.2. The assumptions for linearity, random sample, no multicollinearity and zero conditional mean holds and heteroskedasticity is present. That may be caused by the evolving usage of Google in Czech Republic. Also, Google search for inflation is probably driven primarily by other factors than the unemployment Google search.

The difference in the average Google search query behaviour may be caused by various factors and it is important to note, that the relationship between two Google search queries is estimated. Its behaviour may be explained for example by the increased household interest in the economic situation during the period a member of the household is unemployed. So as unemployment rises, together with the unemployment Google searches, the consumers may become more pessimistic about their financial situation and search for corresponding information.

5.4 Analysis of Google inflation and unemployment search keywords

Additionally, the relevance of the keywords used for obtaining Google search query data was examined in order to evaluate the significance of particular keywords. As the time period 2005−2021 was evaluated in the previous sections as a more relevant for testing the Phillips curve relationship and the results for models in this time period were most relevant, the models were estimated only in this period.

The estimate for average unemployment Google search is significant and explains 24.9% of the unemployment trend. The data from Google regarding the unemployment search can therefore be used for predicting the unemployment rate in Czech Republic. This also supports the earlier claims of Zacha (2015), who already examined this relationship. The most relevant and statistically significant keywords for the unemployment search are "práce"

(labour), "prace" (labour), "volná místa" (vacancies), "životopis" (resume) and "úřad práce" (labour office). In other words, the only statistically insignificant keyword used for the search was "nabídka práce" (job offer). The 0.632 R^2 value for the relevance of the keywords indicates the strong relationship between the unemployment rate and the chosen keywords. From these results can be concluded, that the keywords were chosen well in advance for the purpose of this thesis. The results of the estimation can be found in Table A.3 and Table A.4 in Appendix A.

The estimate for average inflation Google search is also significant, however, it explains only 1.6% of the inflation trend. These results are not surprising, as inflation may not be as connected with the Google search like unemployment. The most relevant and statistically significant keywords for the inflation search are "inflace" (inflation) and "spoření" (saving). The other four keywords "úrokové sazby" (interest rates), "zdražení (price increase), "investice" (investments), and "úvěr" (credit/loan) are statistically insignificant. From these results can be concluded either the inappropriate choice of keywords for inflation, or the insignificance of the Google search queries for the inflation development. The results of the estimation can be found in Table A.3 and Table A.6 in Appendix A. The estimatioins for both unemployment and inflation Google keywords relevance were tested for the Multiple linear assumptions.

Chapter 6

Conclusion

Macroeconomic indicators are often obtained with a time lag, making it difficult for policymakers and economists to react immediately to current economic situation. This problem can be improved by using real-time Internet data to nowcast the current values of such variables. Google Econometrics focuses on working with Google data, which can provide valuable insights into the current issues people are dealing with, as the statistics are available almost daily. The applicability of Google Econometrics on the Czech Republic has already been proven.

This thesis focused on presence and slope of the Phillips curve in the Czech Republic and aimed to describe the relevance of Google searches for its estimation. For this purpose, traditionally obtained data on inflation and unemployment were collected, together with search queries from Google and Seznam.cz for keywords related to inflation and unemployment. The data were estimated and examined in R Studio using the simple Phillips curve model and the OLS method.

The results confimed statistically significant negative relationship between inflation and unemployment in Czech Republic using data from 2005 to 2022. Due to unusually high inflation rate during 2022, the Phillips curve concept was most relevant during the more stable time period 2005−2021. In this time period, the Google search for keywords connected to unemployment, such as "práce" (labour) or "volná místa" (vacancies), was linked to the inflation with statistical significance.

Based on the findings of this thesis, the Google search for unemployment in the Czech Republic could serve for nowcasting the inflation rate development and providing the overview of current state of the economy. That could en-

able faster response to the latest economy development, which can be later on updated by traditionally obtained macroeconomic data.

Despite the use of up-to-date tools and data, there might be several limitations of this thesis. The basic Phillips curve model, used for the estimations, describes only the linear relationship between inflation and unemployment omitting any other variables, which impact the inflation development. The inflation is affected not only by unemloyment rate development, but also by various other factors, such as the monetary policy of supply shocks, which should not be omitted in predictions. The results are relevant only for the Czech Republic, as the Phillips curve presence and usage of Google may differ across countries.

The future research could expand and examine the relevance of Google Econometric for nowcasting inflation using the unemployment search in other countries, e.g. of the Czech Republic neighbours such as Slovakia or Poland. On the home turf, the data from Seznam.cz, which are not publicly available more than a year ago, could be investigated in the same matter. Moreover, other factors influencing the inflation could be brought up together with Google searches for unemployment to enable more precise inflation nowcasting.

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Appendix A

Additional models and assumptions tests results

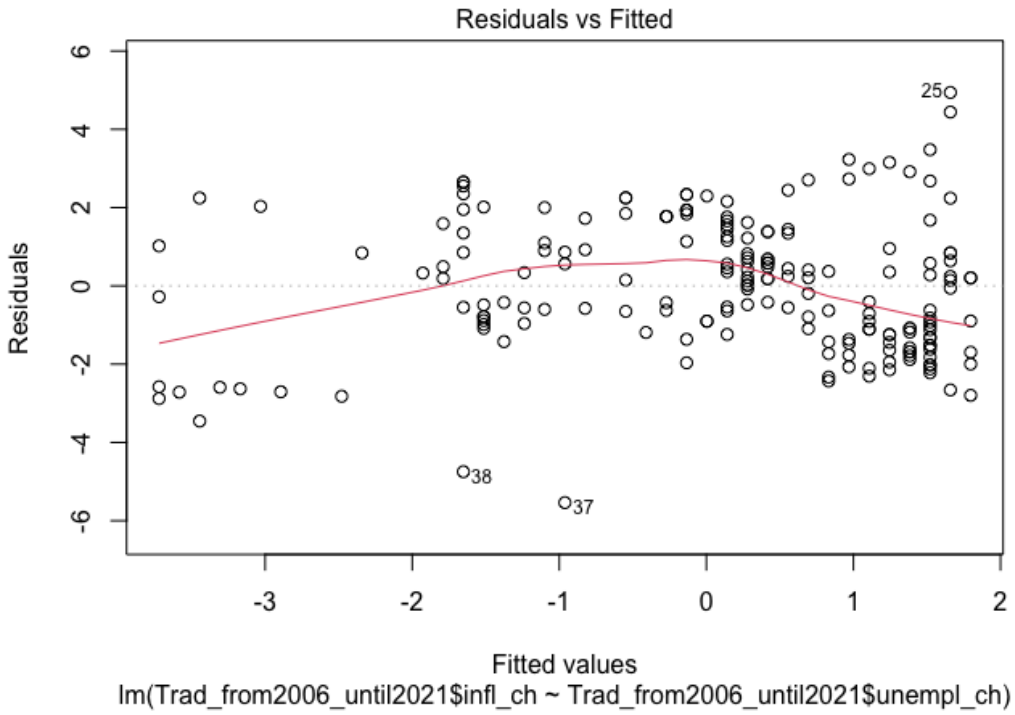

Figure A.1: The results of linearity assumption test for the simple Phillips curve model including the changes in inflation and unemployment in period 2006−2021

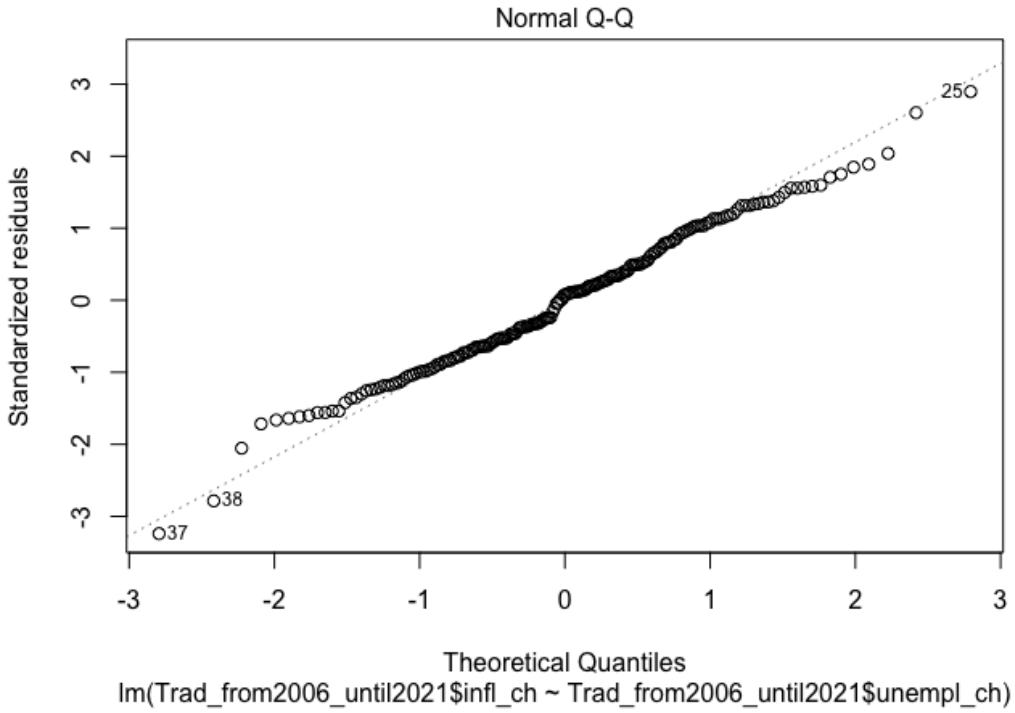

Figure A.2: The results of zero conditional mean assumption test for the simple Phillips curve model including the changes in inflation and unemployment in period 2006−2021

Table A.1: The results of White test for heteroskedasticity for the simple Phillips curve model including the changes in inflation and unemployment in period 2006−2021

	Dependent variable:
	residuals^2
Δinflation	0.082
	(0.110)
$(\Delta\text{inflation})^2$	0.398^{***}
	(0.023)
Δunemployment	-0.490^{**}
	(0.240)
$(\Delta\text{unemployment})^2$	-0.700^{***}
	(0.181)
Constant	1.620^{***}
	(0.256)
Observations	192
R^2	0.639
Adjusted R^2	0.631
Residual Std. Error	2.492 (df = 187)
F Statistic	82.797^{***} (df = 4; 187)
p-value	$< 2.2e-16$
Note:	*p<0.1; **p<0.05; ***p<0.01

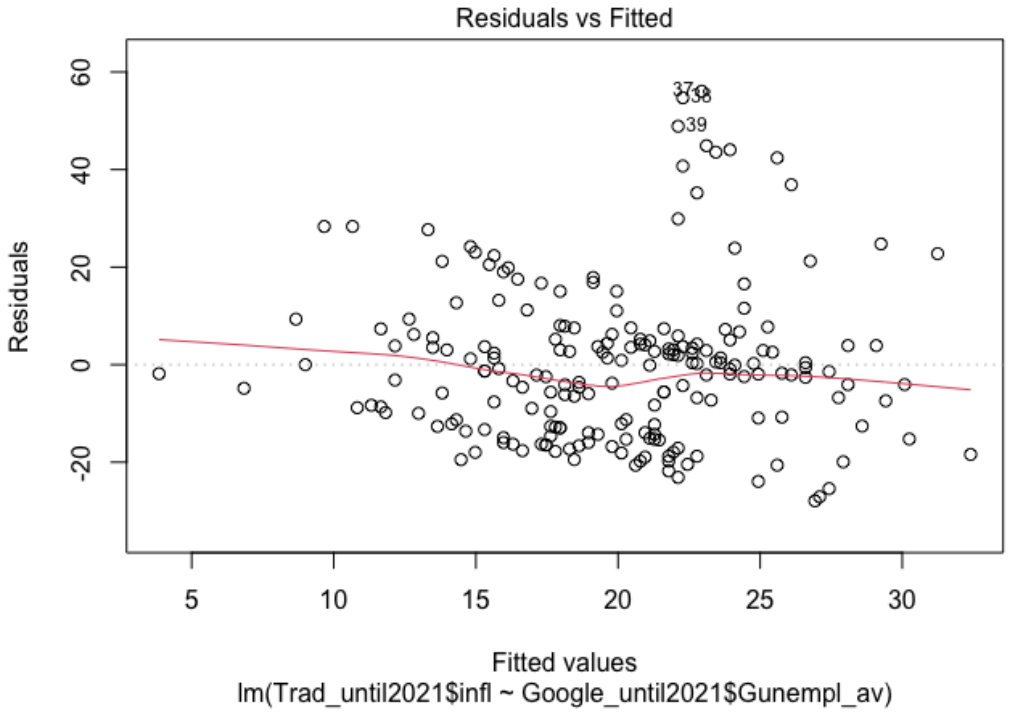

Figure A.3: The results of linearity assumption test for the simple Phillips curve model using traditional inflation and alternative unemployment data in period 2005−2021

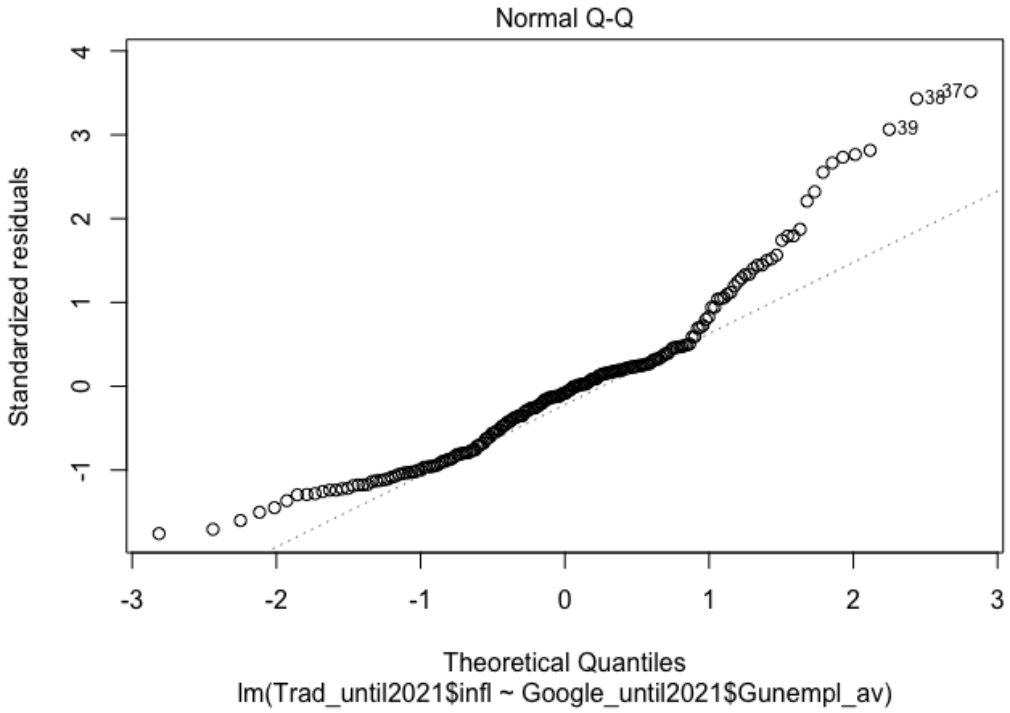

Figure A.4: The results of zero conditional mean assumption test for the simple Phillips curve model using traditional inflation and alternative unemployment data in period 2005−2021

Table A.2: The results of White test for heteroskedasticity for the simple Phillips curve model using traditional inflation and alternative unemployment data in period 2005−2021

	Dependent variable:
	residuals^2
inflation	-33.239^{***}
	(1.382)
inflation^2	0.844^{***}
	(0.021)
average unemployment Google search	18.920
	(14.608)
average unemployment Google search^2	-0.361
	(0.259)
Constant	108.207
	(205.252)
Observations	204
R^2	0.928
Adjusted R^2	0.927
Residual Std. Error	126.963 (df = 199)
F Statistic	643.847^{***} (df = 4; 199)
p-value	$< 2.2e-16$
Note:	*p<0.1; **p<0.05; ***p<0.01

Table A.3: Coefficients of the OLS regression examining the relationship between the average unemployment Google search and the traditional unemployment data

	Dependent variable:
	unemployment (CZSO)
	2005−2021
average unemployment Google search	0.164^{***}
	(0.020)
Constant	0.974^{*}
	(0.561)
Observations	204
R^2	0.249
Adjusted R^2	0.245
Residual Std. Error	1.406 (df = 202)
F Statistic	66.875^{***} (df = 1; 202)
Note:	*p<0.1; **p<0.05; ***p<0.01

Table A.4: Coefficients of the OLS regression examining the relevance of unemployment keywords for the Google search queries for the traditional unemployment data

	Dependent variable:
	unemployment (CZSO)
	2005−2021
práce	0.023^{**}
	(0.011)
prace	-0.137^{***}
	(0.015)
volná místa	0.124^{***}
	(0.025)
nabídka práce	0.076
	(0.049)
životopis	0.048^{**}
	(0.022)
úřad práce	0.018^{**}
	(0.008)
Constant	4.278^{***}
	(0.560)
Observations	204
R^2	0.632
Adjusted R^2	0.621
Residual Std. Error	0.996 (df = 197)
F Statistic	56.366^{***} (df = 6; 197)
Note:	*p<0.1; **p<0.05; ***p<0.01

Table A.5: Coefficients of the OLS regression examining the relationship between the average inflation Google search and the traditional inflation data

	Dependent variable:
	inflation (Eurostat)
	2005−2021
average inflation Google search	0.421*
	(0.231)
Constant	10.606**
	(5.277)
Observations	204
R^2	0.016
Adjusted R^2	0.011
Residual Std. Error	16.602 (df = 202)
F Statistic	3.317* (df = 1; 202)
Note:	*p<0.1; **p<0.05; ***p<0.01

Table A.6: Coefficients of the OLS regression examining the relevance of inflation keywords for the Google search queries for the traditional inflation data

	Dependent variable:
	inflation (Eurostat)
	2005−2021
inflace	0.493***
	(0.100)
úrokové sazby	−0.418
	(0.375)
zdražení	0.203
	(0.240)
spoření	−0.220**
	(0.086)
investice	−0.081
	(0.140)
úvěr	−0.076
	(0.106)
Constant	22.747***
	(5.761)
Observations	204
R^2	0.129
Adjusted R^2	0.102
Residual Std. Error	15.821 (df = 197)
F Statistic	4.848*** (df = 6; 197)
Note:	*p<0.1; **p<0.05; ***p<0.01