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THE EFFECT OF ECONOMIC UNCERTAINTY AND E-GOVERNMENT ON PRIVATE INVESTMENT IN THE EUROPEAN UNION

Bachelor's thesis

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I declare that I have compiled the paper independently
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CONTENTS

ABSTRACT

The objective of the thesis is to examine how economic uncertainty and e-government development affect private investment in the European Union. The thesis will identify the most suitable measures of uncertainty in the European Union and then build the model of private investments for the area. The thesis concludes that uncertainty's immediate effect on private investment is positive, however, its economic significance is very low. The effect of e-government development will be found to remain insignificant. This study is based on empirical research, including literature reviews, statistical data and econometric analysis.

Keywords: private investment, economic uncertainty, e-government, European Union

INTRODUCTION

The research on investment is always relevant because investments are the second-largest component of developed countries' GDP. Moreover, according to the Solow theory, investments ensure that the economy grows. Finding the right model that could predict the behaviour of investors is the key not only to economic prosperity but the welfare of citizens and economic stability. The problem is – investors are not always sure in the future, which may cause them to delay their investment decisions. The rightest word for this phenomenon is uncertainty. However, there is a big discussion over how to precisely quantify uncertainty. Depending on a country and other conditions, there are multiple ways to measure uncertainty.

Macroeconomic uncertainty is the key element that impacts the behaviour of investors and firms, forcing them either invest or save their money. The ongoing COVID 19 pandemic increase the influence of uncertainty on investors' attitude towards long-term investments as they do not feel very confident how deeply could the crisis affect the world's GDP and which sectors of the economy will suffer the most. Uncertainty is hard to measure, due to the ambiguity of its meaning. There is a bunch of methods to measure uncertainty proposed by different studies, however, the researches do not agree over which one describes uncertainty best. Also, the researchers are not sure in which direction uncertainty influence investments. More uncertainty could either reduce them, due to the lack of confidence about the future and predicted returns on investments. Or it could increase investments in real assets, because the private sector is reluctant to hold their assets in fiat money, which is not secured by tangibles. Depending on the type of uncertainty (inflation uncertainty, interest rate uncertainty, exchange rate uncertainty *etc.*) used, the research may lead to various outcomes.

The second part of the model is e-government development. The topic of e-government is quite new and has to be researched. There is a lot of different researches performed over the topic, but none of these was finding the connection between private investment and e-government development. According to the hypothesis, e-government should attract investments, since more transparent government and more efficient communication of private sector with the government should reduce the costs of the private sector and make more confident about the future.

The hypotheses of this work are:
1. The influence of uncertainty measured by ex-post approaches on private investment is moderate negative.
2. The influence of uncertainty measured by ex-ante approaches on private investment is moderate negative.
3. The influence of e-government development measured by ex-ante approaches on private investment is a strong positive.

The research questions are:
1. How uncertainty impacts private investment in the European Union?
2. How uncertainty can be measured in the European Union?
3. Are E-government services necessary to attract private investment?

The thesis is divided into two main parts. The first one includes the analysis of related literature and the theoretical part of the connection between private investment and uncertainty and e-government development. The first part also encompasses possible measures of uncertainty. The second part applies the theoretical knowledge obtained in the first part. Firstly, the uncertainty measures are identified and constructed. Secondly, the model of private investment is built.

1. REVIEW OF LITERATURE

Within the framework of the current paper, the factors that could impact private investment are stated to be uncertainty on the macroeconomic level and e-government development (also "maturity"). In Section 1.1. of the current paper the author describes why uncertainty impacts investment, in Section 1.2. the author compares different measures of uncertainty, in Section 1.3. the author explains why e-government initiatives could impact private investment and in Section 1.4. the author compares different measures of e-government development.

1.1. Investment under uncertainty

Theoretical predictions regarding investment under uncertainty are mostly ambiguous and, depending on the assumptions, theories predict either a negative or positive relationship. The majority of works is examining the link between real exchange rate uncertainty and private investment decisions. Servén (2003) finds a negative and highly significant effect of real-exchange-rate uncertainty on private investment in developing countries. However, Servén (2003) concludes that the link might be even positive among highly developed and less trade opened territories with strong financial systems, which economies are so strong that short-term fluctuations of the real exchange rate do not impact the investment decisions made within the country (*Ibid.*).

Also, most empirical studies on this issue have focused on the firm-level impact of uncertainty, due to the complexities associated with the measurement of uncertainty on the macro-level. For example, Kumo (2006) has observed uncertainty on a macroeconomic level in South Africa and found the effect of uncertainty on private investment to be negative.

Pindyck & Solimano (1993) hold that the neoclassical investment theory has so far failed to provide effective and valid models that could describe investment decision making. The neoclassical models tend to over-optimize the forecast of the effectiveness of interest rates and tax policies in stimulating investment. In contrary to the neoclassical theory, the new theory of investment under uncertainty states that if the government is trying to stimulate the short or intermediate-term investments, then it's macroeconomic policy might be more effective if it is concentrated on stability and credibility rather than levels of tax and interest rates. The theoretical ground of Pindyck & Solimano (1993) is based on the real options theory, where also the adjustment costs of investment and irreversibility of most investment decisions are playing major roles. The theory implies that firms become reluctant to invest due to the cost of unexpected negative deviations from an investment plan, so the adjustment costs increase, or the uncertainty that represents the risk that reduces the value of an investment so the return does not achieve the hurdle rate. The theory considers real options to wait, which are the options of deferring an investment decision to the future. If a real option to wait is compared to an ordinary financial option, then it is possible to assume that the price of the real option to wait increases due to the positive changes in a risk rate. Hence, if the risk rate increases, the cost of the real option to wait might reduce the value of either a single investment or a portfolio a lot and render firms reluctant to invest. (*Ibid.*)

Pindyck & Solimano (1993) use the geometric Brownian motion as a model of the price of a real option. The value of investment opportunity is then maximized and it is shown that uncertainty and irreversibility of an investment create an opportunity cost, which increases the required expected returns: "That opportunity cost is an increasing function of the volatility of the project's value, so that an increase in volatility can, in the short run, reduce investment" (*Ibid.*, 262-267). Pindyck & Solimano (1993) try different indicia of economic instability and calculate the corresponding correlation coefficients of volatility with the standard deviation of the marginal profitability of capital and investment, which has appeared to be a good measure of uncertainty according to the theory based on the Brownian motions. Consequently, they find that the most appropriate measures of uncertainty in this context are the volatility of the inflation rate and the volatility of the real exchange rate. The aforementioned measures are significant for both Least Developed Countries (LDC) and the Organization of Economic Co-operation and Development (OECD) member states. They also concluded that strikes, riots and other forms of political turmoil may have either insignificant or no correlation with uncertainty in the context of capital returns. "It may mean that as long as a government can control inflation – an indicator of overall economic stability, and from which exchange rate and interest rate stability tend to follow – it can limit the uncertainty that matters for investment" (Pindyck, Solimano, 1993, p. 286). The overall conclusion is that the model appears significant for both high-inflation LDC and low-inflation OECD countries, however only in the short run that can easily be 10 or 20 years. (*Ibid.*, 297).

The effect of uncertainty mainly depends on how economic agents behave in high-risk economic conditions. If the agents are risk-averse, then under uncertainty the investment can be even lower than if the people were risk-neutral. (Driver, Moreton, 1991)

1.2. Measuring economic uncertainty

To assess the effect of economic uncertainty, it has to be quantified. There are two main types of uncertainty measurements: based on *ex-post* and *ex-ante* approaches. When the *ex-post* approach is used, uncertainty is measured using historical data. The *ex-post* group includes (Lensink, Bo, Sterken, 1999):

1. The normal statistical variance of the variable under consideration;
2. The variance of the unpredictable part of a stochastic process;
3. The conditional variance estimated from the General AutoRegressive Conditional Heteroscedastic (GARCH) models;
4. The variance estimated from the geometric Brownian motion.

On the other hand, the *ex-ante* approach is based on current or future data. This type of data is derived from surveys. The first part of the current section describes the *ex-post* approaches, the second one describes the *ex-ante* approaches.

1.2.1. *Ex-post* approaches for measuring economic uncertainty

According to Leninsk, Bo & Sterken (1999), the most popular methods to measure of *ex-post* uncertainty are the variance from the GARCH model and the variance of the unpredictable part of a stochastic process. Whereas the GARCH method is more precise as it allows the time dependence of the squared mean (the second moment) of random variables. Although, the GARCH modelling requires long time series and high frequency and is not suitable for panel data unless it is divided into samples grouped by country. The authors conclude that the second popular measurement is more flexible as it allows to use a shorter time period. Also, they conclude that the method „is based on the assumption that either unconditional variable is constant or the conditional variance converges to a constant term, which might not always be the case in practice“ (Lensink, Bo, Sterken, 1999). The study examines 138 countries over the period of 1970-1995 and studies the effect of uncertainty on economic growth. The proxies of uncertainty are based on the following indicators: uncertainty concerning the budget deficit, uncertainty concerning taxes, uncertainty concerning government consumption, uncertainty concerning export sales, uncertainty concerning real interest rate, uncertainty concerning inflation. (*Ibid.*)

One can choose the proxies of economic uncertainty depending on what affects the economy the most. For example, by the change in oil prices, like it was performed by Heybati (2016), where the observed country is Iran. Iran's economy is highly dependent on oil prices, like most of the middle-east countries. Unlike Iran or other middle-east countries, the European economy is more diversified and then more dependent on the overall price change. For example, the work that studies the effect of uncertainty on economic growth in European countries uses total price index (Bredin, Fountas, 2009).

For example, Bonciani & Roye (2016) use The EURO STOXX 50 Volatility Index (VSTOXX) as an uncertainty measure. However, there is a limitation that should be considered using the index. The VSTOXX is measured as volatility of the STOXX 50 index that, in turn, consists of 50 largest and most volatile European stocks. The problem is that stock market volatility is driven not only by macroeconomic risk but also by investors' risk-aversion, investors' attitude and leverage. (*Ibid*.)

1.2.1. *Ex-ante* approaches for measuring economic uncertainty

The widely used *ex-ante* method is the estimation of uncertainty via surveys of professional forecasters (SPF). Conflitti (2011) is investigating the ability of the European SPF to reflect uncertainty. The European SPF is a survey that is conducted once in a quarter by the European Central Bank, on crucial macroeconomic variables such as GDP growth, inflation and the rate of unemployment. The Conflitti (2011) approach is targeted at finding the rate of disagreement between the forecasters. The underlying theory is: a high dispersion of the point forecasts is interpreted as high uncertainty and *vice versa*. However, the author argues that the direct evaluation of forecast uncertainty is accompanied by some methodological problems. First, it should be assumed that uncertainty is a function of the probability distribution of the observable variable. To measure uncertainty using the SPF, one should consider three main approaches (*Ibid*.):

1. To measure the disagreement among forecasters;
2. To measure the mean individual forecast error variance or standard deviation;
3. To measure the variance for the aggregate figures.

The first method is considered to be less suitable as the number of professional forecasters varies from year to year. Also, forecasters could have the same information and agree on forecasts and consequently, disagreement equals to zero (or close to). Conflitti (2011) proposes to measure uncertainty by aggregating the average of individual uncertainty and the disagreement of the mean forecast, that is, by measuring the aggregated standard deviation. (Conflitti, 2011)

However, estimating variances from the SPF histograms represent a methodological issue. Since the forecasters attach probabilities to a specific range, it is not clear how the probability is distributed within the range. In order to measure the individual densities of the probability distribution, one has to consider several approaches of measuring disagreement and uncertainty using probability intervals. First prescribes no assumptions for the probability distribution. The second one assumes that each forecaster's histogram is normally distributed. The second approach suggests that normal distributions are fitted to the histograms by minimizing the sum of the squared differences between the histograms' probabilities and those for the same intervals but coming from the normal distribution and therefore finding the mean and variance. The third, "crude" one, assumes that all the mass are located at the interval midpoints. Giordani & Söderlind (2002) explain that the best method is a normality fitting because all the other methods overestimate the variance. Giordani & Söderlind (2002) have compared the aforementioned three main approaches of uncertainty measures and decided that disagreement is a good proxy. On the other hand, it is less easily available than the others. For further work, Giordani & Söderlind (2002) use the average individual standard deviation as it is highly correlated with the disagreement (correlation = 0.89). Also, Giordani & Söderlind (2002) have compared the SPF approach with the time series models described above. Giordani & Söderlind (2002) summarize that the uncertainty measure based on SPF data is more reliable than that of the time series models. Nevertheless, their conclusion is considered to be problematic due to the poor fit of the normal distribution to individual histograms as well as the derivation of disagreement from the density forecast rather than point estimates (Rich, Tracy, 2010).

Another study engaging the ECB-SPF data examines the point and density forecasts of HICP (Harmonised Index of Consumer Prices) in one-year-ahead and one-year/one-year forward horizons in measuring uncertainty. Firstly, Rich *et al.* (2012) test whether disagreement counts as a good proxy for uncertainty or not. The approach used in the testing is a linear regression modelling with the natural logarithm of uncertainty (measured as the standard deviation of inflation) as a dependent variable and disagreement as a regressor. Rich *et al.* (2012) found the relationship to be weak and that disagreement can only account for 20% of the variation in uncertainty for the moment-based approach (point forecasts) and 1% for the interquartile range (IQR) based approach in one-year-ahead horizons. (*Ibid.*)

Bloom (2009) examines the linkage between several cross-sectional measures of uncertainty and stock market volatility and finds a positive and strong correlation between the two. Uncertainty is measured by the standard deviation of firms' pre-tax profit growth, the standard deviation of stock-returns, the standard deviation of annual 5-factor TFP growth within the NBER manufacturing industry database and the dispersion across macro forecasters over their GDP predictions. (*Ibid.*)

Another way of measuring uncertainty include information-based indicators. Baker *et al.* (2016) develop an uncertainty index for the United States based on the frequency of the newspaper articles that include the following combinations of terms: "economic" or "economy"; "uncertain" or "uncertainty"; and one or more of "Congress", "deficit", "Federal Reserve", "legislation", "regulation" or "White House". (Baker *et al.* 2016)

One contemporary paper develops a Google Trends-based uncertainty indicator. The index is based on the assumption that economic agents refer to the internet and search necessary information in Google when they are uncertain. Using Google Trends, the authors search for the frequency of used terms that were subjectively selected by the authors. Examples of the keywords are: "bankruptcy", "stock market", economic reforms", "debt stabilization". To verify the reliability of the index, Castelnuovo & Tran (2017) calculate the correlations between the Google-Trend index and the alternative ones, which were constructed by other studies. The correlation coefficients are all positive and mainly strong. (Castelnuovo, Tran, 2017)

Uncertainty may also be measured by non-economic variables, both domestic and external. Those disturbances include the security of property rights, measures of corruption, political instability, terrorism, war. Although it is almost impossible to quantify such uncertainties, many studies use crude methods of measuring to capture the impact. (Ahmad, Qayyum, 2008)

1.3. E-government and private investment

Due to the recency of such object of economic research as e-government, there is a lack of literature regarding this topic. Especially the one that examines the link between e-government maturity and private investment directly. The majority of studies highlight increased transparency, reduced corruption and increased effectiveness and efficiency as benefits of the adoption of ICT services in public sector administration.

On the whole, e-government is seen as a positive phenomenon and the majority of governments is taking steps to adopt and develop ICT services. Twizeyimana & Anderson (2019) search for and analyze the literature on e-government and conclude that there has been a growing body of research on this topic. Also, it has been found that research is mainly conducted for developed countries. The findings revealed that the adoption of ICT services improved public services, administrative efficiency, trust and confidence in government, ethical behaviour and professionalism, Open Government capabilities, where the term „Open Government“ stands for an idea that government actions and policies should be designed and operated with transparency, openness, collaboration, participation and inclusiveness. (*Ibid.*)

Mossberger & Tolbert (2005) explain e-government's benefit to entrepreneurs in terms of reduced costs. E-government has the potential to reduce the public service delivery costs, by automating them and making available online 24/7, and „this is also consistent with the philosophy that government that „works better, costs less“ will increase citizen confidence in the government“ (*Ibid.*).

Castelnovo (2013) and Dečman (2010) find the relationship between e-government initiatives and the effectiveness of taxation systems, which leads to reduced transaction costs and a possible lowering of the level of taxation. E-government initiatives contribute to the reduction of the administrative burden on enterprises and allow to achieve better effectiveness in managing a business. The benefits in detail are (Castelnovo, 2013):

1. Increased transparency for starting, transforming or closing a business;
2. Increased inter-agency cooperation;
3. Increased efficiency in the delivery of services to enterprises;
4. Increased ease of doing business and competitiveness.

E-government is seen as a strong and effective solution for increasing trust in government, transparency and accountability. For instance, Halachmi & Greiling (2013) argue that e-government results in better transparency because citizens can access any pertinent information and follow the processes of government in real-time. It is assumed that in developed democracies, the increased use of ICT will lead to less opaqueness since ICT services generate records that are hard to erase or change after publishing and are easy to track back (*Ibid.*).

There are several bases of trust generated by the digital government. For example, process-based trust means that citizens get faster and more transparent ways of communication with the government. Also, it means that government services and databases are made easily and always accessible. Institutional based trust is making citizens feel the government more transparent and responsible. Institutional based trust is achieved when government securely handles personal information, posts relevant data such as policies, laws, contacts, agendas and minutes. Process-based trust encompasses efficient and effective government, which is possible by using the latest automatic technologies such as online transactions and downloadable forms, and participatory government, which is reached by engaging and drawing citizens´ attention to government processes and political life. (Mossberger, Tolbert 2006)

Ahn & Bretschneider (2011) have proved that e-government performance significantly improves the transparency of bureaucracy. On the other hand, more transparency doesn't mean that the outcome will be positive. Some areas of government should be restricted and confidential. For example, the work of security services, military and certain aspects of foreign policy, which need secrecy in order to operate effectively and follow national interests. (Emery 2003)

In the case of private investment, transparency plays a significant role. Transparency has both direct and indirect effects on investment. Lack of transparency can cause asymmetric information to influence firm investment strategy. As it has been shown by Malesky (2015), a less transparent government tends to create information asymmetry over laws and regulations that concern business operations. For example, if a firm has been operating over some period and a change in law has occurred, but the information regarding this change is not readily available, the firm can operate in ignorance further. Eventually, the firm finds itself operating illegally, which will cost the firm some recourses in terms of money or time. This lack of transparency also creates an opportunity for corrupt officials to exploit asymmetric information about the legal code to their advantage. Lack of transparency can also render government policy unpredictable, which makes firms unable to forecast changes in laws and regulations and build new developments into their investment plans. The indirect impact is through the equitable use of provincial resources. (*Ibid.*)

E-government is also an effective strategy to grapple with corruption. Less commonly, government digitalization reduces the contact between corrupt officials and citizens and makes bribery less plausible. According to Andersen (2009), increases in the use of ICT in government processes have led to significant reductions in corruption. Andersen (2009) observes the effect of e-government on the levels of corruption in non-OECD countries because countries with low levels of corruption struggle in reducing them further. And OECD countries are those that have low corruption levels and high of e-government (*Ibid.*). There is strong evidence that corruption levels impact private investment. For example, Campos *et al.* (1999) distinguish less predictable corruption from the more predictable one. But eventually, he finds that independently from the degree of predictability, more corruption necessarily means less investment (*Ibid.*).

1.4. How to measure e-government development

The abstractness and ambiguity of the term “e-government” represent some challenges in measuring its fair and reliable values by country. Also, there are not enough data to precisely assess the performance of already existing e-government indices.

E-government development measures can be split into several categories. Firstly, e-government development is assessed depending on the territory: at the local, state, federal levels. Secondly, measurements can be categorized depending on a qualitative or quantitative approach. Thirdly, e-government development can be evaluated with the supply-side focus, it means that the quantity and quality of services and service delivery are assessed. Or it can be measured with the demand-side focus, it refers to the assessment of the public views of and their interaction with the government via online services. (Whitmore 2012; Gauld *et al.* 2010)

For instance, Andersen (2009) uses the supply-side focused index that was developed by a research team at Brown University. The team has assessed e-governments in 198 nations around the world. Government web sites have been analyzed in order to get a sense of what services are available and what features the site offers, such as information availability, service delivery and public access. Also, Andersen (2009) states that there are no data regarding e-government dating back to 1996. (*Ibid.*)

In order to find the relationship between national culture and e-government development, Zhao (2011) uses the OECD index of government development, which is a composite index of the scores of e-services.

United Nations (UN) survey-based e-government ranking is supply-side focused, intended to measure e-government development for 192 member states. Each year the data regarding the availability of online government services and telecommunications infrastructure is collected and then compiled into an aggregate index called E-government Development Index (prior to 2010 E-government Readiness Index). Whitmore highlights that the surveys are widely read and highly cited among e-government researches. (Whitmore 2012)

For example, Gauld *et al.* (2010) use a demand-side approach for measuring e-government. In that particular case, the demand-side measure is a telephone survey of 933 respondents overall in New Zealand and Australia, where people are being asked about how frequently they use e-government services and for what purposes. Also, it has been found that the use of ICT is in strong positive correlation with e-government use. (*Ibid.*)

2. EMPIRICAL STUDY

2.1. Data description

The overall sample is quarterly, for the EU-28 countries and in the period from the first quarter of 2000 to the fourth quarter of 2019. However, some of the data were not found to be in the same period and is either temporarily disaggregated or the missing values are generated following the methods described further.

Private investment is defined as gross fixed capital formation, measured as chain-linked volumes (with the 2015's base) to exclude the effect of inflation. The data come from the Eurostat database. Inflation is measured as the monthly seasonally adjusted percentage change of the Harmonized Consumer Price Index calculated by the ECB; the monthly data are retrieved from the ECB database for the period from December 1999 to December 2019. The point-estimates of the forecasters about their outlook for inflation in the one-year-ahead horizon are derived from the SPF, the source of the quarterly data is the ECB database. The EURO STOXX 50 Volatility Index (VSTOXX) daily data for the period from the January 1'st 2000 to December 31'st 2019 are found on the STOXX website and then transformed into the quarterly by averaging daily values, see Figure 2. The Economic Policy Uncertainty index (EPU) comes from the Economic Policy Uncertainty database, see Figure 1.

Although the sample is the EU-28 countries, the SPF is conducted for the Euro area countries and the EPU is estimated for the five countries with the biggest contribution to the overall GDP of the EU. Those countries are the United Kingdom, Germany, France, Italy and Spain (the total contribution is 70% as for the year 2019). The index is constructed by validating the frequency of newspaper articles on the topic of economic uncertainty. The topic is identified using category-specific keywords, which meaning varies by country, in different languages in the preliminarily chosen newspapers. The index observes two major newspapers per country: Le Monde and Le Figaro for France, Handelsblatt and Frankfurter Allgemeine Zeitung for Germany, Corriere Della

Sera and La Stampa for Italy, El Mundo and El Pais for Spain, and The Times of London and Financial Times for the United Kingdom. The graph of EPU is provided in Figure 1.

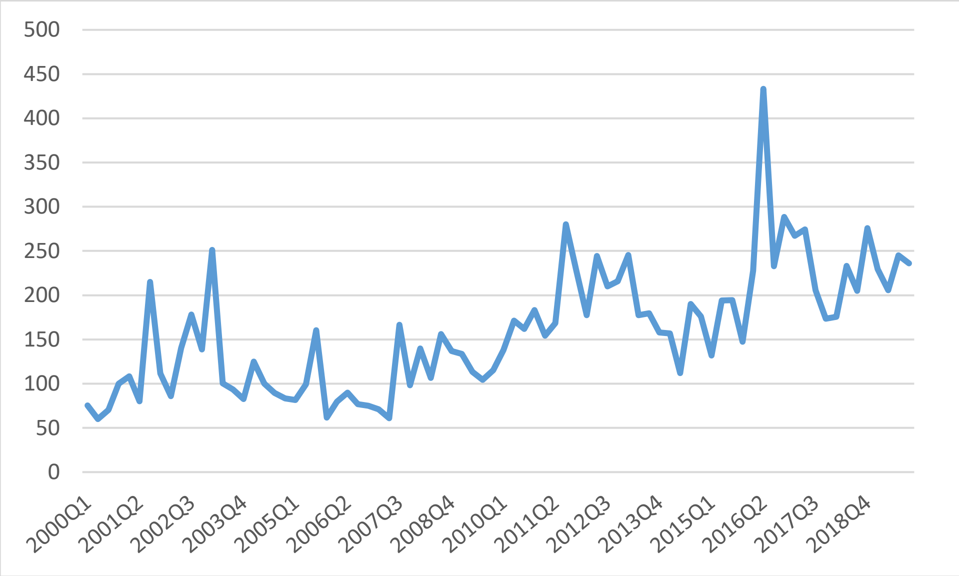

Figure 1. EPU index
Source: the author's calculations from econometric software EViews

Also, the EURO SOXX 50 index includes 50 largest enterprises of 8 countries of the Euro area: Belgium, Finland, France, Germany, Ireland, Italy, Luxembourg, the Netherlands and Spain. It is wise to point out that the choice of the sample assumes that economic events happening in the biggest European countries strongly impact the economy of the rest. The graph of VSTOXX is provided in Figure 2.

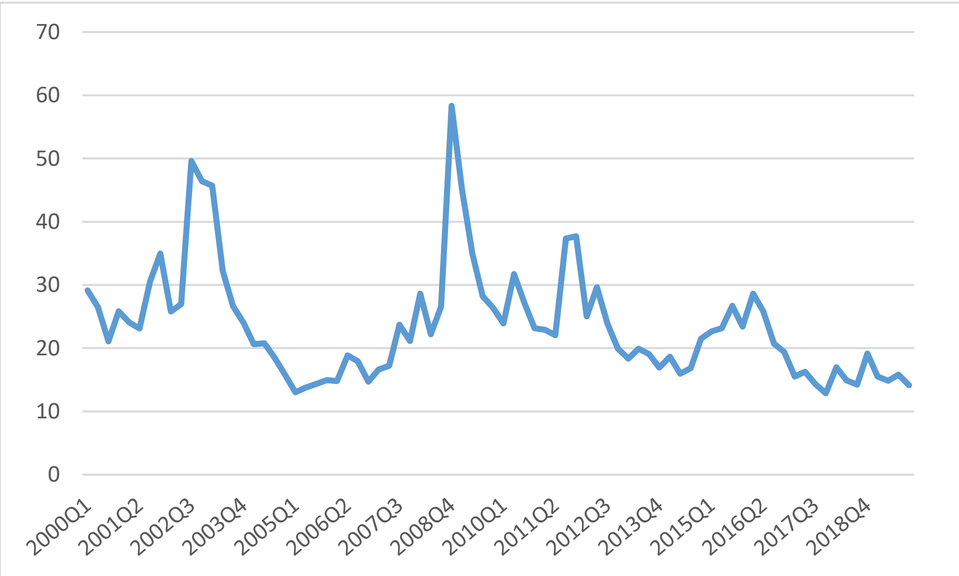

Figure 2. VSTOXX index
Source: the author's calculations from econometric software EViews

Figure 2 exhibits a positive shock of uncertainty during the Great Recession, which happened in the period from the year 2008 to 2009. However, Figure 1 exhibits only a relatively slight increase in uncertainty during these years, but then reaches its peak in 2017. Analyzing the graphs, *ex-ante* and *ex-post* uncertainties may behave differently because are affected by different factors.

As it was already mentioned, there are no long time-series, not to speak of quarterly data, of e-government data yet. For example, the data of the percentage of people who have interacted with public authorities using e-channels for the last 12 months could be used as a variable describing the demand-side e-government development. However, it is available only in the period from 2008 to 2019, so in the model, the incomplete data are used. In order to convert the data into quarterly, the author performs Chow-Lin temporal disaggregation using statistical software JDemetra+, proposed by the Eurostat.

Following the literature and general economic sense, the control variables are listed below. The first ones are short- and long-term real interest rates, adjusted by GDP deflator and aggregated using by country's GDP, the data are retrieved from the AMECO database for the period from the year 2000 to the year 2018 in the EU-28 countries, the data were transformed into quarterly using the aforementioned method – temporal disaggregation in JDemetra+ (the value for 2019 was extrapolated using the same software). The second is seasonally and calendar adjusted real GDP measured as chain-linked volumes with the 2015 year's base, which data are retrieved from the Eurostat database. The third additional variable is seasonally and calendar adjusted general government budget deficit, the data are retrieved from the Eurostat database for the period from the first quarter of 2002 to the third quarter of 2019. The fourth variable is the average real effective exchange rate, the data are retrieved from the ECB database. The last variable, which describes opened economy is the current account, which is measured in current prices and is seasonally and calendar adjusted, the data are retrieved from the ECB database. In order to eliminate the effect of inflation, the values are multiplied by the corresponding HICP values and then divided by 100.

2.2. Measuring economic uncertainty

As discussed in Section 1.2., the researches on uncertainty do not have a common opinion about how to measure uncertainty the best. Some argue that *ex-ante* approaches are more precise, whereas others hold that *ex-post* approaches are more easily available and better, because of their quantitativeness (see Section 1.2). In order to avoid this ambiguity and give a more precise measure of uncertainty, the author of the thesis first tried to design an aggregate uncertainty indicator.

However, it will be shown in Subsection 2.2.3 that all the uncertainty measures have a weak correlation between each other. The uncertainty measures are based on both *ex-ante* and *ex-post* approaches. The *ex-ante* variables used in the indicator are as follows: the EPU index, disagreement among forecasters based on the ECB SPF data. The *ex-post* variables used to create the indicator are as follows: the conditional variance of inflation estimated from the GARCH model and the VSTOXX. The access to VSTOXX and EPU index data can be easily obtained through the websites of statistical organizations that compute both indicators.

Moreover since conditional variance and disagreement data cannot be straightforwardly obtained it should be computed manually, which is done for both variables in Subsection 2.2.1. and Subsection 2.2.2. respectively. The evidence of the irrelevance of constructing a composite indicator is provided in Subsection 2.2.3. The factor analysis performed has proven the existence of two types of uncertainty indicators – *ex-ante* and *ex-post*. Both two are influenced by different factors (see Appendix 4).

2.2.1. GARCH model

Karanasos & Schurer (2008) illustrated a parametric power ARCH model (PARCH) as a possible way to estimate uncertainty for Germany, the Netherlands and Sweden. Karanasos & Schurer (2008) use the first difference of the logarithm of monthly, seasonally unadjusted consumer price index (CPI) as proxies for the inflation.

Viorica *et al.* (2014) analyzed different GARCH models for the inflation of the new European Union member states. As inflation measurement, Viorica *et al.* (2014) use annualized monthly growth rates of the Consumer Price Index provided by International Financial Statistics. The results showed that inflation uncertainty could be measured by the conditional variance estimated from ARCH (1), GARCH (1, 1), EGARCH (1, 1, 1) and PARCH (1, 1, 1) where the mean equation is an AR (p) model and p takes values within 1 an 12. Because the testing is performed for each country individually, the best model is specific for each country. For the five countries under analysis, the EGARCH (1, 1, 1) model was validated and GARCH (1, 1) for the rest.

In order to estimate the conditional variance, the author uses simple GARCH (1, 1) model, as it has been proven to be the most suitable model for modelling volatility of differenced log of consumer price indices (Shaikh *et al.* 2014).

The measure of inflation used in the paper is the first difference of the logarithm of seasonally adjusted monthly HICP. The monthly data are used because GARCH modelling requires long time series. The descriptive statistics of the inflation is provided in Table 1.

Table 1. Descriptive statistics of inflation

Variable	Inflation
Mean	0.001
Median	0.001
Maximum	0.006
Minimum	-0.004
Std. Dev	0.002
Skewness	-0.168
Kurtosis	3.775
Observations	251

Source: the author's calculations from econometric software EViews

The first step is to estimate a mean-equation. It is crucial to test the data for the stationarity and the presence of a unit-root because the mean-equation is an autoregressive model, which in turn assumes that the time series is stationary. The author uses the augmented Dickey-Fuller (ADF) test with the null hypothesis that a unit root is present in a time series sample. The results of the ADF test are provided in Table 2.

Table 2. Results of the ADF test

	ADF unit-root test	
Variable	t-statistic	probability
ADF test statistic	-11.096	0.000
Constant	7.225	0.000

Source: the author's calculations from econometric software EViews

The results provided in Table 2 show that a unit-root does not exist in the time series. Also the constant is statistically significant, therefore an autoregressive model should be modelled with a constant. The next step is to find the most suitable ARMA model, the author follows the Box-Jenkins method and performs Ljung-Box Q-test to do that. The correlogram of the time series with test statistics and probabilities (see Appendix 1) indicates that the most suitable model is AR(1). The formula of the mean-equation is provided below:

$$y_t = 0.004 + 0.166y_{t-1} + \varepsilon_t \quad (1)$$

where

y – monthly inflation rate,

t – is the period within the range of January 2000 to December 2019,

ε – residuals that are normally distributed.

Since the residuals are assumed to be normally distributed, the Jarque-Bera normality test is performed. The Jarque-Bera test statistic is 6.557 with the p-value of 0.038, which indicates that the null hypothesis of a normal distribution is accepted with the significance level of 1%. The author then tests the data for autoregressive conditional heteroskedasticity (ARCH) effects. The test used to detect ARCH processes is Engle Lagrange Multiplier (ARCH-LM) test. The presence of ARCH effects is tested using the AR (1) model with a constant. The results of the test are provided in Table 3.

Table 3. Results of the ARCH-LM test (mean equation)

	Heteroscedasticity test: ARCH			
Variable	coefficient	std. error	t-statistic	probability
Constant	$3{,}05*10^{-6}$	$4{,}41*10^{-7}$	6,899	0,000
$RESID(-1)^2$	0,145	0,066	2,194	0,053
F-statistic	-	-	-	0,053
Chi-Square statistic	-	-	-	0,053

Source: the author’s calculations from econometric software EViews

As can be concluded from Table 3, the time series contains ARCH effects with the confidence level of 90%. The next step is to find the most suitable ARCH type model. The author tries GARCH (1, 1) model estimated with Student’s t distribution, which is presented in Table 4.

Table 4. GARCH (1, 1)

	GARCH(1, 1)			
Variable	coefficient	std. error	t-statistic	probability
Constant (mean-equation)	0.001	0.000	9.732	0.000
AR (1)	0.334	0.059	5.621	0.000
C (Variance equation)	0.000	0.000	2.103	0.035
$RESID^2(-1)$	0.038	0.025	1.526	0.127
GARCH(-1)	0.860	0.055	15.568	0.000
Akaike info criterion	-10.076	-	-	-

Source: the author's calculations from econometric software EViews

As can be seen from Table 4, the ARCH part of the model is statistically insignificant. The author then tries to fit T-GARCH (1, 1) model, accordingly to Giordani & Söderlind (2003) who found the measures of uncertainty based on it more preferable than the GARCH based ones. The uncertainty estimated with T-GARCH model is different from that estimated by the standard GARCH. T-GARCH assumes that positive inflation shocks increase uncertainty, while negative shocks decrease uncertainty. The mean equation is still AR (1) and the model is estimated with a normal distribution. The model is provided in Table 5.

Table 5. T-GARCH (1, 1)

	T-GARCH(1, 1)			
Variable	coefficient	std. error	t-statistic	probability
Constant (mean-equation)	0.001	0.001	9.668	0.000
AR (1)	0.339	0.061	5.563	0.000
C (Variance equation)	0.000	0.000	2.443	0.015
$RESID^2(-1)$	0.059	0.031	1.893	0.058
$RESID^2(-1)*(RESID(-1)<0)$	0.057	0.033	-1.718	0.086
GARCH(-1)	0.898	0.042	21.420	0.000
Akaike info criterion	-10.077	-	-	-

Source: the author's calculations from econometric software EViews

The formula for the model is provided below:

$$h_t = 1{,}72 \cdot 10^{-7} + 0.898 h_{t-1} + (0.057\gamma + 0.059) u_{t-1}^2 + \varepsilon_t \quad (2)$$

where

h – conditional variance,

u – error term,

γ – the asymmetric term (0 or 1, if equals to one then the shock is negative),

t – is the period within the range of January 2000 to December 2019,

ε – residuals that are normally distributed.

According to Table 5, it can be concluded that the model became better since the Akaike information criterion decreased. All the components are statistically significant with the significance level of 10%. Also, it is necessary to complete all formal procedures and test the reliability of the model by testing the performance of the residuals. The first test to be performed is the Jarque-Bera normality test since the model was estimated using a normal distribution. The Jarque-Bera test statistic probability is 0.17 indicating that the null hypothesis of a normal distribution is accepted with the significance level of at least 5%. The next step is to test the autocorrelation in the residuals, performing the Ljung-Box Q-test. According to the p-values of Q-statistics, the null hypotheses of autocorrelation is rejected for all 36 lags.

Additionally, ARCH effects should not exist in the residuals. The ARCH-LM test is performed and the p-value of F-statistic is 0.635 indicating that the series of the residuals exhibit no conditional heteroscedasticity. All the tests performed indicate that the model is reliable and can be used in estimating conditional variance. Also, it is worth to point out that the coefficient of the asymmetric term is positive, which means that bad news has more effect on uncertainty than good news.

The conditional variance estimated by the model is provided in Appendix 2. The graph for the estimated conditional variance (multiplied by 10 000 for ease of reading) is provided in Figure 3.

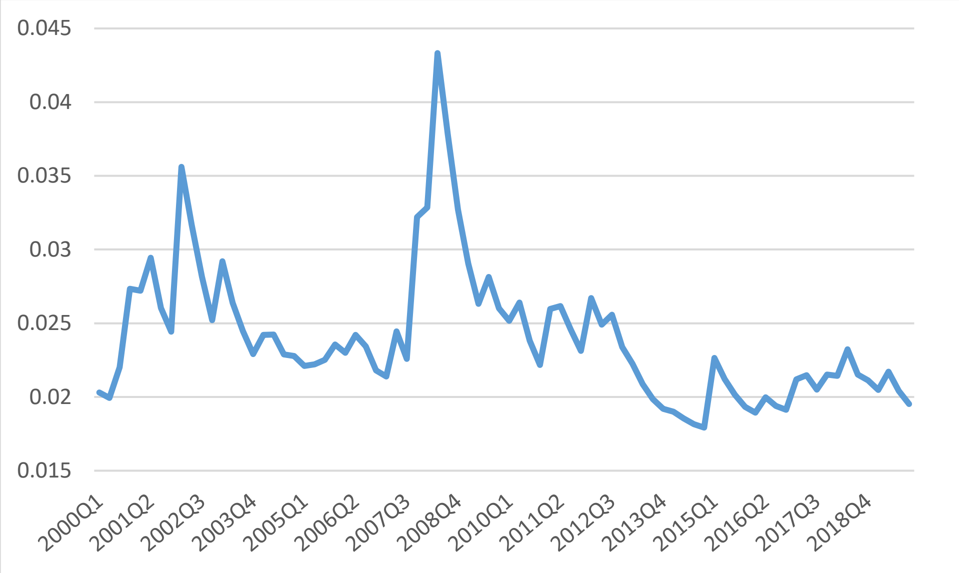

Figure 3. Conditional variance (multiplied by 10 000)
Source: the author's calculations from econometric software EViews

It can be seen from Figure 3 that the conditional variance follows the Great Recession and the early 2000's recession that affected mainly the European Union and the 2014's Ukrainian Crisis. According to Figure 3, uncertainty during crises is increased.

2.2.2. Disagreement among forecasters

Disagreement among forecasters can be calculated as a standard deviation of the forecasters' point estimates in each survey round (Leduc et al. 2009). The data used in the paper covers the period from the first quarter of 1999 to the fourth quarter of 2019. The descriptive statistics of the uncertainty measure is provided in Table 6. The graph of the disagreement is given in Figure 4.

Table 6. Descriptive statistics of disagreement

Variable	Disagreement value
Mean	0.281
Median	0.269
Maximum	0.558
Minimum	0.156
Std. Dev	0.079
Skewness	1.069
Kurtosis	4.300
Observations	83

Source: the author's calculations from econometric software EView

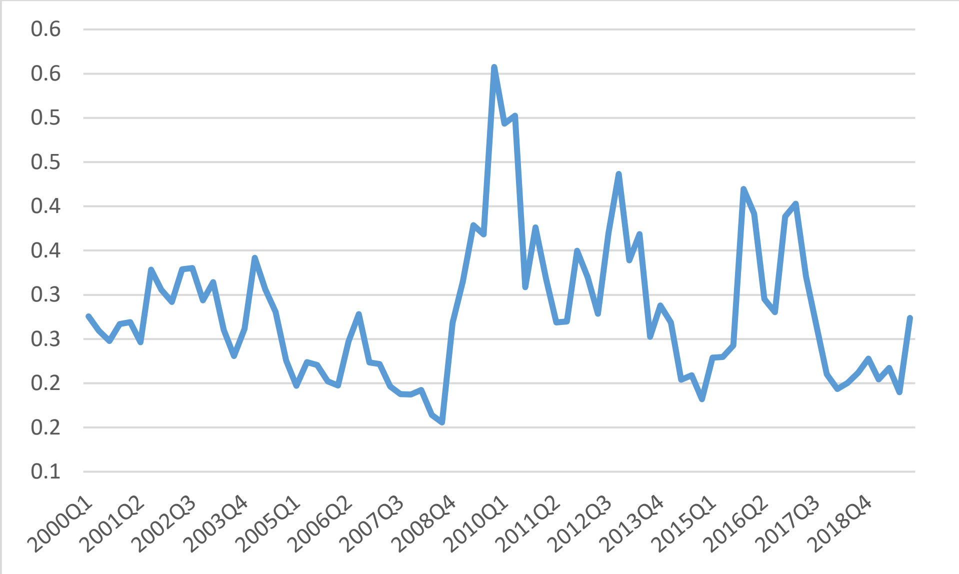

Figure 4. Disagreement among forecasters
Source: the author's calculations from Excel.

According to Figure 4, the dynamics of disagreement follows the dynamics of VSTOXX and the EPU index during the Great Recession (see Figures 1 and 2). Also, it follows the dynamics of the EPU index during the Ukrainian crisis, however, is not so sensitive to that event. The possible reason is that the experts who participate in the survey tend to be influenced in their judgements by political events, which in turn impacts their estimates of the future inflation rate. Hence, standard deviation rises because the experts do not share the same opinion about political events.

2.2.3. Uncertainty indicator

Firstly, before constructing any sort of composite indicator, the correlation matrix should be assessed (Joint Research Centre-European Commission, 2008). The correlation matrix of the uncertainty variables described in Section 2.1 is provided in Table 7.

Table 7. Correlation matrix

	Correlation matrix			
	disagreement	conditional variance	EPU	VSTOXX
Disagreement	1.000	-0.035	0.181	-0.301
Conditional variance	-0.035	1.000	-0.260	0.437
EPU	0.181	-0.260	1.000	0.032
VSTOXX	-0.301	0.437	0.032	1.000

Source: the author's calculations from econometric software EViews

As can be concluded from Table 7, the variables have a weak correlation, therefore the construction of a composite index is not rational. Four different specifications of the model should be constructed and tested instead.

2.3. The model

For the model to be closer to reality, more components describing private investment should be added. For example, real interest rate (Muhammad et. al, 2013) and government budget deficit (Bahmani-Oskooee et. al 2006) are usually seen as variables that impact private investment, all the variables added are described in Section 2.1. The initial intention to construct an uncertainty indicator including four distinct variables is found to be inappropriate in the EU context, so four different specifications of the model should be constructed, encompassing all four measures of uncertainty separately, if they are in correlation with the residuals of the baseline model (see Table 9).

The econometric model should be constructed as an autoregressive model since there is a reason to believe that real capital formation data exhibit autocorrelation (see Graph 5). ARMAX models are being assessed further in Subsection 2.3.1. Also, all the variables (excluding the real interest rate) are logarithmized in order to make the interpretation of the model easier. Government budget deficit is naturally represented as a negative value, and hence all values are negative, the data can be multiplied by minus one to make it possible to logarithm the values. The current account cannot be logarithmized without additional adjusting, because its data contain both positive and negative values. Hence, it is mathematically correct to add a constant, which is equal to the modulus of the minimum value plus one (in that case, the constant is equal to 86 759). The mathematical method described is suitable since it doesn’t change the variance (only the mean).

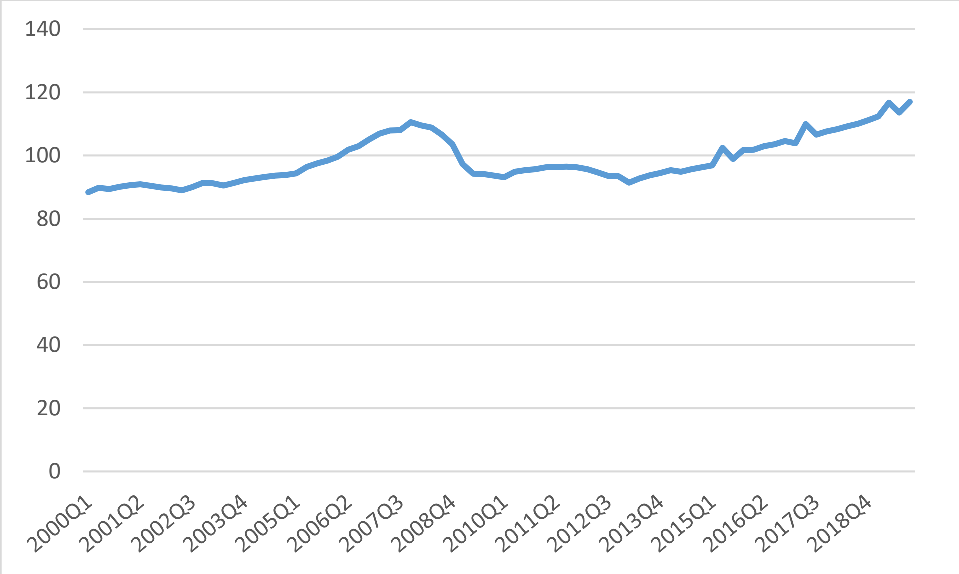

Figure 5. Real fixed capital formation (chain linked volumes)
Source: the author's calculations from Excel.

Firstly, the ADF unit-root test is performed for the dependent variable and the regressors, in order to assess their stationarity. The respective ADF tests' results could be seen in Table 8.

Table 8. ADF tests (11 lags)

	ADF unit-root	
	Original, test-statistic (p-value)	1'st difference, test-statistic (p-value)
l_CapFormAdj	1.386 (0.959)	-2.773 (0.005)
l_CondVar	0.008 (0.682)	-10.047 (0.000)
l_VSTOXX	-0.670 (0.424)	-9.661 (0.000)
l_Disagreement	-0.625 (0.444)	-9.325 (0.000)
l_EPU	0.789 (0.883)	-3.992 (0.000)
l_Egov	0.566 (0.839)	-1.035 (0.272)
RealInterest	-0.912 (0.321)	-2.244 (0.024)
l_Deficit	-0.369 (0.552)	-3.420 (0.001)
l_CA	0.193 (0.740)	-7.658 (0.000)
l_GDPReal	2.114 (0.992)	-3.455 (0.001)
l_REE	-0.101 (0.649)	-7.375 (0.000)

Source: the author's calculations from econometric software EViews

The graph of differenced investments is given in Graph 6.

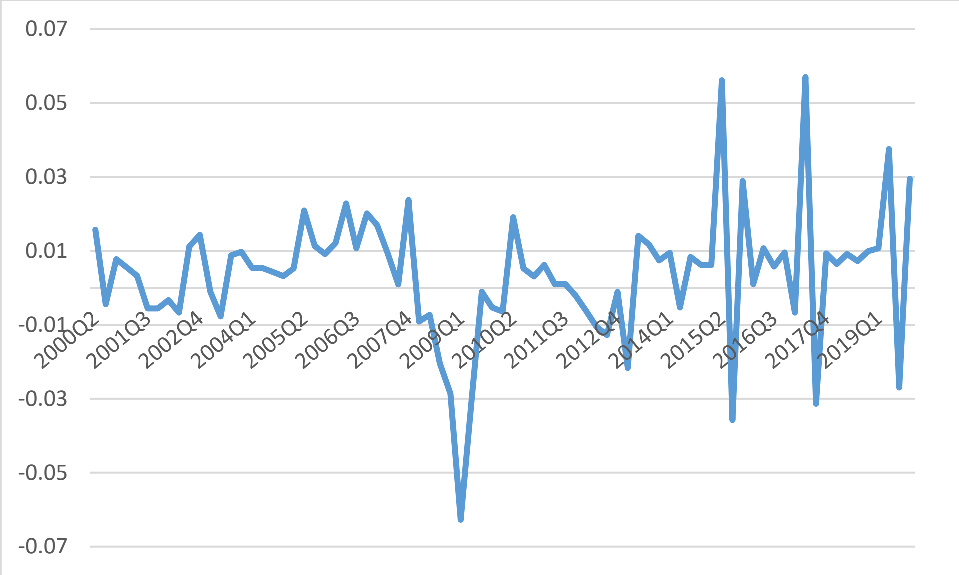

Figure 6. The growth rate of real fixed capital formation
Source: the author's calculations from Excel.

As can be seen from Figure 6, the growth of real capital formation exhibits deep negative shock in the period from the fourth quarter of 2007 to the first quarter of 2010. It is also the case in Figure 3 and Figure 2. Moreover, the growth is more volatile after the fourth quarter of 2014, when the Ukrainian crisis took place.

One of the methods to ensure if the model needs additional variables is to build the model without them and assess the correlation coefficients of the residuals of the model with additional variables. For that purposes, the author builds the best ARMA model, which is chosen based on the smallest Akaike criterion. The Akaike criteria in the range of ARMA (4, 4) are provided in Appendix 2. According to the Akaike criteria, the best model is ARMA (2, 4). Consequently, the next step is to find the most relevant regressors by deriving the residuals from ARMA (2, 4) model and assessing its correlation coefficients with all the regressors listed in Section 2.1. The correlation matrix is provided in Table 9.

Table 9. Correlation matrix of residuals with the regressors

	Correlation
Short-term interest rate	0.387
Long-term interest rate	-0.176
Budget deficit	-0.026
Current account	-0.298
Conditional variance	0.144
VSTOXX	-0.007
Disagreement	-0.049
EPU	0.053
Real GDP	0.542
REE	-0.116
E-government	-0.001

Source: the author’s calculations from econometric software EViews
Notes:

1. All variables are the first differences of the original variables; E-government is the second difference of the original variable.

The only measure of uncertainty that can be added is conditional variance. The rest have a relatively smaller correlation with residuals. The control variables that should be added are short-term interest rate, real GDP and current account. E-government development seems to be uncorrelated with private investment. The next step is to build the model based on the discovered. The initial ARMAX (2, 4) model is provided in Table 10.

Table 10. ARMAX (2, 4)

Variable (T = 79)	coefficient	std. error	t-statistic	probability
AR(1)	−0.913	0.244	−3.734	0.000
AR(2)	0.080	0.227	0.355	0.723
MA(1)	0.125	0.195	0.642	0.521
MA(2)	0.023	0.170	0.137	0.891
MA(3)	−0.176	0.174	−1.015	0.310
MA(4)	−0.972	0.177	−5.504	0.000
Real GDP (1st difference)	1.700	0.091	18.740	0.000
Current account (1st difference)	−0.082	0.004	−18.450	0.000
Short-term interest (1st difference)	−0.002	0.008	−0.303	0.762
Conditional variance (1st difference)	0.032	0.009	3.705	0.000
Akaike criterion	-466.23	-	-	-
R-squared	0.562	-	-	-

Source: the author’s calculations from econometric software EViews

It can be seen from Table 10 that some AR and MA terms are not statistically significant thus have to be eliminated. Sequential elimination of insignificant AR and MA terms leads to the next ARMAX (1, 0) model provided in Table 11.

Table 11. ARMAX (1, 0)

Variable	coefficient	std. error	t-statistic	probability
AR(1)	-0.560	0.095	-5.874	0.000
Real GDP (1st difference)	1.410	0.150	9.369	0.000
Current account (1st difference)	-0.004	0.004	-0.945	0.345
Short-term interest (1st difference)	0.018	0.005	3.533	0.000
Conditional variance (1st difference)	-0.005	0.013	-0.351	0.726
Akaike criterion	−466.232	-	-	-
R-squared	0.562	-	-	-

Source: the author's calculations from econometric software EViews

It is crucial to point out that the conditional variance has its standard error higher than the coefficient. It might be that the uncertainty shocks, which happened during the Great Recession and early 2000s recession, exaggerate the standard error. To eliminate these extreme values the sample should be restricted. The new defined sample is the period from the first quarter of 2010 to the fourth quarter of 2019. The adjusted model is provided in Table 12.

Table 12. ARMAX (1, 0) with restricted sample (2010Q1 – 2019Q4), version 1.

Variable	coefficient	std. error	t-statistic	probability
AR(1)	-0.707	0.121	-5.838	0.000
Real GDP (1st difference)	1.585	0.194	8.186	0.000
Current account (1st difference)	-0.073	0.013	-5.848	0.000
Short-term interest (1st difference)	-0.006	0.011	-0.590	0.555
Conditional variance (1st difference)	0.018	0.021	0.889	0.374
Akaike criterion	−249.240	-	-	-
R-squared	0.722	-	-	-
Adjusted R-squared	0.690	-	-	-

Source: the author's calculations from econometric software EViews

According to Table 12, the short-term interest rate is no longer statistically significant, so it should be eliminated first since its probability is higher than that of conditional variance. The model without short-term interest rate is provided in Table 13.

Table 13. ARMAX (1, 0) with restricted sample (2010Q1 – 2019Q4), version 2.

Variable	coefficient	std. error	t-statistic	probability
AR(1)	-0.804	0.109	-7.371	0.000
Real GDP (1st difference)	1.782	0.222	8.026	0.000
Current account (1st difference)	-0.054	0.014	-3.831	0.001
Budget deficit	0.020	0.006	3.132	0.004
Conditional variance (1st difference)	0.031	0.015	2.042	0.049
Akaike criterion	−249.667	-	-	-
R-squared	0.748	-	-	-
Adjusted R-squared	0.719	-	-	-

Source: the author's calculations from econometric software EViews

According to Table 13, the model is now improved, since adjusted R-squared is higher and the Akaike criterion is minimized. The short-term interest rate variable is substituted by government budget deficit because it is significant now. In the second version of the model, all the standard errors are lower than the corresponding coefficients. Moreover, the conditional variance is now statistically significant.

The next step is to test the performance of the model. Firstly, the Jarque-Bera test for normality of residuals is performed. The Jarque-Bera test statistic is 7.606 and p-value 0.022, which indicates that the residuals are normally distributed with the significance level of 1%. Secondly, the residuals should not exhibit autocorrelation. By looking at the correlogram and corresponding Q-statistics, provided in Appendix 3, all of them are statistically insignificant through the lag 36 with the significance level of 5%. Furthermore, the model was estimated using the least-squares method, thus, it is crucial to test for heteroskedasticity. The White test is performed to test for heteroskedasticity. The respective F-statistic is 1.758 with the p-value of 0.148, which indicates that the null-hypothesis of homoskedasticity can be accepted with the significance level of at least 5%. The formula of the model is provided below:

$$y_t = -0.804y_{t-1} + 1.782x_1 - 0.054x_2 + 0.020x_3 + 0.031x_4 + \varepsilon_t \quad (3)$$

where

y – monthly inflation rate,
x_1 – real GDP,
x_2 – current account,
x_3 – government budget deficit,
x_4 – conditional variance,
t – is the period within the range of the first quarter of 2000 – fourth quarter of 2019,
ε – residuals that are normally distributed.

The model has been proven to be valid and its performance is good. According to the model provided in Table 13, the real GDP is the most influential variable and increases the private investment by 1.782 percentage points when is raised by one percentage point. When the current account rises one percentage point, capital formation decreases on average by 0.054 percentage points. Uncertainty, measured by conditional variance, raises investment by 0.031 percentage points when rises by one percentage point. Government budget deficit raises capital formation by 0.020 percentage points when is increased by one percentage point. Real fixed capital formation is negatively influenced by its previous value. The previous value decreases the capital formation by 0.804 percentage points when raises by one percentage point.

All the coefficients are barely economically significant. However, the effect of the regressors shown is only short-term or immediate. It can be captured from the model that the AR term is negative, hence an increase in the dependent variable in the previous period decreases the value in the current. The coefficient of the uncertainty is positive and the coefficient of AR (1) term is negative, then an increase in uncertainty by one percentage point may cause the growth of investments to decrease in the next period. The further work done may engage the Finite Distributed Lag (FDL) type model by adding the lags of independent variables in order to calculate the long-run effect.

2.4. Discussing the results

According to the last ARMAX model that has been built in Section 2.3, none of the hypotheses was confirmed. The hypothesis about the *ex-post* uncertainty measures and their impact on private investment was partially confirmed. The impact is positive and weak in the EU-28 countries. It may raise the question, why the impact is positive. One of the possible reasons is that European investors are risk lovers and agree to take more risks in exchange of greater profitability. Another answer lies in the ECB strong economic policy so that investors are sure about economic future uncertainty notwithstanding. The second possible reason is that uncertainty doesn’t impact investment in the same period, because investors make their decisions based on historical data. Thirdly, uncertainty may impact investments only during prominent economic crises, such as the Great Recession and early 2000’s economic crisis, which were excluded from the model, due to the enormous standard error of conditional variance. Nevertheless, the uncertainty measure based on the real inflation rate is relevant. European investors are influenced by unstable inflation and use it in their decision-making as a risk measuring tool.

The measures of uncertainty based on *ex-ante* approaches has not been proved to be relevant in the context of the EU-28 countries. The result may mean that the European investors' decision-making is not influenced by non-economic events and politics, or the European foreign policy is extremely stable and has not demonstrated such events that could theoretically impact investors' decisions.

A possible nuance with the uncertainty measures that have been estimated in the paper is an aggregated sample. In some countries across the European Union, uncertainty may positively influence private investment, whereas in other countries negatively and the overall result may be misleading because the data of smaller economies is crowded out by the bigger ones. Also, uncertainty may not impact investments in the same period, since investors operate with historical data.

E-government development has not found its place in the model due to its extremely weak correlation with the dependent variable. The reason may be that the European governments do not develop e-services properly. As it was mentioned in Section 1.3, the private sector may struggle when the information about new laws and regulations is not up to date. The absence of the connection with private investment may mean that the information about new regulations is not always updated, but the e-government measurement used does not consider that.

CONCLUSION

The thesis was aimed at understanding the influence of uncertainty and e-government development on private investment in the European Union. The thesis has explained how both factors affect the investors' decisions and how economic uncertainty for the area can be measured. The evidence provided in the thesis is a sign of the European Central Bank's and European central governments' strong performance.

The model of private investment was built using ARMAX type model, since real fixed capital formation data exhibit autocorrelation. The initial sample was restricted since the shocks happened in the early 2000s have exaggerated the standard error of the conditional variance. The model's control variables were real GDP, current account, government budget deficit and conditional variance with real fixed capital formation as a dependent variable. The uncertainty was measured as the conditional variance of inflation estimated by TGARCH (1, 1) model. Other measures of uncertainty provided have been found to be unable to describe the behaviour of private investment. The immediate effect of the uncertainty has been found to be positive. However, its economic significance is low. According to the results, e-government development does not influence private investment in the European Union as an aggregated sample.

Regarding what could be made additionally is the sample. One could omit using an aggregated sample and perform the analysis with the biggest European economies such as Germany, France, Italy, Spain and the smallest, such as Malta, Estonia and Latvia. However, such an approach is more time-consumable but could lead to more reliable results. Further work may be performed with uncertainty measures. Instead of the conditional variance of inflation, one may use the conditional variance of either real exchange rate or interest rate. Also, instead of disagreement among forecasters, the mean individual variance could be used, by using the individual histograms provided with quarterly SPFs. The last model can be transformed into FDL type model with the lags of explanatory variables, since uncertainty may not influence investments in the same period. Additionally, e-government development indicator can be added or changed to some supply-side indicator, such as the quality of e-government services. Although e-government development may not influence private investments, it could make the economy more attractive to foreign investors. One could examine the linkage between foreign direct investment and e-government development.

The work may be useful to the ECB and the European Parliament. Even if the results do not support the initial hypothesis, the uncertainty measure used in the thesis is suitable for the European Union. It may also be tried to use in the European Union member countries individually. In addition to the aforementioned, European investors may use the research and provided methodology to calculate the risk associated with uncertainty.

KOKKUVÕTTE

Erainvesteeringud, olles SKP suuruselt teise komponendina, on väga olulised riigi heaolu ning kasvu toetamiseks. Seni on ilmunud palju teooriaid, nt Solow kasvumudel, mis tõendavad, et majanduskasvuks on investeeringud hädavajalikud. Kuid need teooriad eeldavad, et majanduslikku ebakindlust ei ole, mis ei vasta tegelikule elule. Majanduslik ebakindlus võib mõjutada investeeringuid oluliselt ning mõju vektor sõltub investorite riski võtmisest. Kui investorid on riski armastajad, siis ebakindlus mõjutab investeeringuid positiivselt ja vastupidi. COVID19 pandeemia ajal on ebakindluse tähtsus oluliselt suurenenud, kuna investorid veel ei tea kuidas kriis mõjutab maailma majandust ja milliseid ärisektoreid rohkem. E-riigi arendatavuse tase peab mõjutama investeeriguid ka, kuna pakutavad teenused vähendavad kulusid, mis on seotud ettevõtte suhtlemisest avaliku sektoriga.

Töö põhilisteks uurimisküsimusteks on:

1. Kuidas majanduslik ebakindlus mõjutab erainvesteeringuid Euroopa Liidus?
2. Kuidas ebakindlust saab mõõta Euroopa Liidus?
3. Kas e-riigi teenused on vajalikud investeeringute tagamisek?

Antud töö eesmärgiks oli uurida seost erainvesteeringute ja majandusliku ebakingluse ning e-riigi arendatavuse vahel. Tulemuseks on tuvastatud nõrk positiivne seos erainvesteeringute ja ebakindluse vahel. Selline tulemus võib olla põhjendatud asjaoluga, et Euroopa Liidu investorid on riski armastajad ning on väga kindlad Euroopa Liidu tulevikus. E-riigi arendatavuse seos erainvesteeringutega on statistiliselt ebaoluline. Ebakindluse mõõtmiseks on kasutatud tingimuslik dispersioon arvutatud TGARCH (1, 1) mudeli abil. TGARCH mudel on valitud tuginedes sellele, et head ja halvad uudised mõjutavad dispersiooni asümmeetriliselt, mis on tõendatud asümmeetrilise tunnuse statistilise olulisega. Teised töös arvutatud ebakindluse indikaatorid ei saa kirjeldada erainvesteeringute käitumist. Erainvesteeringute mudel on ehitatud ARMAX (1, 0) mudeli baasil, kus regressoriteks on riigi defitsiit, reaalne SKP, jooksevkonto saldo ning tingimuslik dispersioon.

Võimalikeks arengukohtadeks on valimi muutus individuaalseteks riikideks ehk võib testida Euroopa Liidu suurimaid riike (vastavalt SKP osakaalule) ning väiksemaid, kuna agregeeritud valim võib näidata teist tulemust. Samas, ex-post ebakindlust võib mõõta intressimäära või reaalvahetuskurssi tingimusliku dispersioonina. Ex-ante ebakindlust aga võib mõõta prognoosijate erimeelsuse asemel (disagreement among forecasters) nende individuaalse dispersiooni keskmisena, kasutades individuaalseid histogramme. E-riigi arendatavuse taset võib mõõta ka e-riigi teenuste kvaliteedi tasemena.

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APPENDICES

Appendix 1. Correlogram of monthly seasonally adjusted HICP

	Correlogram			
Lag	AC	PAC	Q-Stat	Probability
1	0,337	0,337	28,850	0,000
2	0,157	0,049	35,141	0,000
3	0,050	-0,019	35,777	0,000
4	0,051	0,037	36,448	0,000
5	0,008	-0,022	36,463	0,000
6	0,102	0,112	39,168	0,000
7	0,110	0,054	42,328	0,000
8	0,064	-0,010	43,386	0,000
9	0,077	0,054	44,957	0,000
10	0,082	0,037	46,713	0,000
11	0,169	0,141	54,268	0,000
12	0,049	-0,067	54,912	0,000
13	-0,007	-0,056	54,927	0,000
14	0,020	0,043	55,035	0,000
15	0,006	-0,023	55,045	0,000
16	-0,039	-0,050	55,460	0,000
17	0,030	0,031	55,708	0,000
18	0,019	-0,023	55,806	0,000
19	0,058	0,068	56,729	0,000
20	0,012	-0,039	56,772	0,000
21	0,051	0,035	57,490	0,000
22	0,080	0,062	59,247	0,000
23	-0,014	-0,076	59,300	0,000
24	-0,015	0,019	59,364	0,000
25	0,002	-0,003	59,365	0,000
26	0,034	0,032	59,696	0,000
27	-0,031	-0,036	59,970	0,000
28	-0,039	-0,075	60,399	0,000
29	-0,005	0,038	60,407	0,001
30	0,015	0,012	60,473	0,001
31	-0,005	-0,022	60,481	0,001
32	-0,041	-0,058	60,973	0,002
33	0,036	0,054	61,353	0,002
34	0,004	0,025	61,357	0,003
35	0,020	0,024	61,470	0,004
36	0,091	0,074	63,906	0,003

Appendix 2. Akaike criteria

Model	Akaike criterium
ARMA(0,0)	-410.05
ARMA(0,1)	-406.94
ARMA(0,2)	-416.65
ARMA(0,3)	-417.79
ARMA(0,4)	-416.69
ARMA(1,0)	-406.96
ARMA(1,1)	-409.37
ARMA(1,2)	-418.67
ARMA(1,3)	-416.67
ARMA(1,4)	-414.70
ARMA(2,0)	-417.34
ARMA(2,1)	-416.71
ARMA(2,2)	-416.67
ARMA(2,3)	-418.95
ARMA(2,4)	-421.52
ARMA(3,0)	-417.23
ARMA(3,1)	-415.23
ARMA(3,2)	-414.68
ARMA(3,3)	-417.45
ARMA(3,4)	-421.02
ARMA(4,0)	-415.24
ARMA(4,1)	-413.98
ARMA(4,2)	-414.75
ARMA(4,3)	-416.43
ARMA(4,4)	-419.20

Appendix 3. Correlogram of the private investment model

	Correlogram			
Lag	AC	PAC	Q-Stat	Probability
1	1	-0.063	-0.063	0.173
2	2	0.128	0.125	0.899
3	3	0.104	0.121	1.386
4	4	-0.340	-0.353	6.767
5	5	0.033	-0.035	6.820
6	6	0.126	0.262	7.605
7	7	-0.123	-0.053	8.380
8	8	0.152	-0.073	9.588
9	9	-0.122	-0.133	10.397
10	10	0.043	0.214	10.500
11	11	-0.059	-0.098	10.703
12	12	-0.021	-0.084	10.730
13	13	0.053	0.038	10.902
14	14	-0.046	0.052	11.036
15	15	-0.027	-0.081	11.085
16	16	0.223	0.197	14.554
17	17	0.001	0.180	14.554
18	18	0.196	0.064	17.492
19	19	-0.122	-0.344	18.678
20	20	-0.080	0.024	19.218

Appendix 4. Factor analysis

In order to give weights to the components described in Section 2.1., the author performs factor analysis. Factor analysis is chosen because it allows choosing weights statistically, according to the significance of the variables. Following a simple identification methodology, provided by Mazziotta & Pareto (2013), the indicator is considered to be substitutable, because a deficit in one component should be compensated by a surplus in another one. The type of aggregation to be chosen is complex, so more objectivity is guaranteed. Accordingly, the most suitable objective method of giving weights is multivariate analysis, either principal component analysis or factor analysis (FA). In that paper, FA is used. The second step is to normalize the components of the indicator because initial scalings are different. The normalization method used is simple min-max transformation, which allows to rescale the data in the range 0-1. The formula is as follows:

The first step in FA is to determine the common factors that variables share. The factors are extracted with the principal component analysis. The eigenvalues of the factors are provided in Table 7.

Table 7. Descriptive statistics of disagreement

	Eigenvalues		
Component	total	% of variance	cumulative %
1	1,525	38,135	38,135
2	1,310	32,761	70,896
3	0,734	18,346	89,242
4	0,430	10,758	100,000

Source: the author's calculations from econometric software SPSS

According to Kaiser rule (Kaiser, 1991), factor should be chosen if its eigenvalue is greater than one. Also, a common practice is that relevant factors individually contribute to the explanation of the overall variance of more than 10% and cumulatively contribute more than 60% (Nicoletti *et al*. 1999). Table 7 shows that such factors are the first two with eigenvalues 1,525 and 1,310. The second step is to rotate the factors to minimize the number of indicators that have a high loading on the same factor. The most common rotation method is varimax rotation (Joint Research Centre-European Commission, 2008), which is used in that case. The factor loadings after the rotation are provided in Table 8.

Table 7. The matrix of factor loadings (varimax rotated)

	Factor loadings	
Variable	factor 1	factor 2
Disagreement	0,294	0,752
CondVariance	0,821	-0,309
VSTOXX	0,826	0,317
EPU	-0,284	0,742

Source: the author's calculations from econometric software SPSS

According to the factor loadings in Table 7, there are 2 different dimensions, which contribute to the initial assumption that macroeconomic uncertainty consists of both *ex-ante* (factor 1) and *ex-post* (factor 2) components.

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