The effects of Economic Policy Uncertainty on the macroeconomy and the stock market

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A thesis submitted for the degree of

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"This thesis is dedicated to
my parents, Anna and George
and to my sister, Ria."

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The rest of the chapters have been sent to other journals and are under review.

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“The only certainty is that nothing is certain”

Pliny the Elder, Book II, sec. 7, Naturalis Historia

ABSTRACT

The motivation for this thesis was the increased economic uncertainty during the last decade, especially after the global financial crisis and the Eurozone crisis. The aim of the thesis is to examine the Economic Policy Uncertainty (hereafter EPU) index and its spillovers among the Eurozone countries during the period of the turmoil, its implications for Greece, which was severely hurt by the crisis, and the relationship of EPU with the stock market.

More specifically, cornerstone of the present thesis is the construction of the Greek EPU index in an attempt to quantify economic uncertainty for Greece. The EPU index is estimated according to the methodology of Baker, Bloom and Davis (hereafter BBD, 2016) and is based on newspapers coverage frequency. The Greek policy uncertainty index seems to peak during international events before the crisis outburst, like the 9/11 attack and the collapse of the Lehman Brothers, while after the onset of the crisis mainly domestic events trigger increases of economic uncertainty.

The next chapter focuses on the spillovers of the EPU index among the Eurozone countries. By analysing 7 countries and utilising the volatility spillover index and the respective dynamic net spillover indices, the results indicate that uncertainty connectedness among these countries dropped from 50.5% before the crisis, to 30.6% afterwards, and also that during the crisis mostly the periphery countries transmit uncertainty to the other countries, which was not the case before. The same chapter continues with focusing the analysis on the Greek economy, by examining the rolling impulse responses of the GDP, the Economic Sentiment Index, unemployment and the stock market index to shocks on the Greek and the European EPU indices. The analysis shows that the Greek variables are mostly affected by domestic rather than European uncertainty.

Chapters 3 and 4 try to add more to the literature about the relationship of EPU with the stock market, as research so far mostly focuses on its macroeconomic effects. More specifically, chapter 3 attempts to relate the expected US stock market returns to deviations from fundamentals (bubbles) and the EPU index. Using a 2-regime switching model (survival and collapse regimes) and recursively estimating out-of-sample probabilities, the model is found to be able to predict periods of abrupt movements in the US stock market (bubble crashes). An effort is also made to provide a trading rule which will signal to the investor when to exit and reenter the stock market, in order to have the highest gain. The suggested trading rule reinforces the financial usefulness of the model, as it actually offers more profits to the investor than a simple buy-and-hold strategy.

The final chapter of the present thesis examines the contribution of EPU to the persistence of shocks to stock market volatility. An innovative methodology is used, according to which the half-life of a shock in a bivariate VAR model, with the EPU and the stock market volatility as the endogenous variables, is compared to the half-life of a shock in the context of a univariate ARMA model. Daily UK and US data are used and results prove that EPU indeed makes the stock market volatility more persistent, a fact even more intense for the US compared to the UK. An extension of the methodology to the foreign exchange market is also attempted, offering interesting results for some of the currencies under examination.

INTRODUCTION

Economic uncertainty is not a new phenomenon, however research on this field is now more intense than ever. After the outburst of the global financial crisis (Great Recession) and the subsequent Eurozone crisis, the research interest on economic uncertainty has risen. Uncertainty about the economic policies that are followed by the governing authorities of the countries is also rising, as in some cases the implemented policies and their implications have been questioned, especially during crisis.

As uncertainty is a multidimensional and inconceivable concept, there have been several measures that quantify uncertainty, some based on forecast disagreement of macroeconomic time series, others on financial data, and some even on survey data. Recently, the newspaper-based method was introduced by Baker, Bloom and Davis (hereafter BBD, 2016) attracting much research attention.

BBD have introduced the Economic Policy Uncertainty index (hereafter EPU), which is an indicator based on newspapers' coverage frequency. This index proxies uncertainty about who will apply the economic policy, what regulations will be applied by policy makers, and how effective these regulations will be. The construction of the index is based on the number of published articles that include at least one word for each of the three categories: economy (E), policy (P), uncertainty (U).

Cornerstone of the present thesis is the construction of the EPU index for the Greek economy, which was a country severely hurt by the crisis, as there was a lack of data for the country on economic uncertainty. The Greek debt crisis has amplified the need of examining the role of economic policy uncertainty for the Greek economy. Thus the first chapter explains how the Greek EPU index was constructed, based on the BBD methodology. The resulted

Greek EPU time series captures periods of higher or lower volatility of uncertainty as well as high peaks of uncertainty which are usually accompanied by important international or domestic events. Following the construction of the Greek EPU index, the empirical analysis of the next chapter, on the effects of domestic uncertainty on Greek macroeconomic variables, is now possible.

The second chapter consists of a paper that focuses on the spillovers of EPU in the Eurozone and the effects of EPU on the Greek economy. The paper begins by applying the Diebold-Yilmaz spillover index (2009, 2012) to examine the EPU spillovers among seven Eurozone countries for the period 2003 to 2019. Results show a decline in uncertainty spillovers among the Eurozone countries after the Eurozone crisis outburst, as uncertainty connectedness dropped from 50.5% to 30.6%. Moreover, it is concluded that after the crisis uncertainty is driven mostly by domestic factors rather than foreign ones. The dynamic net spillovers are also examined, indicating that core Eurozone countries are mainly exporting uncertainty before the crisis while periphery countries are exporting uncertainty during the crisis. The second half of the paper focuses on Greece, the economy which suffered much during the crisis, and uses rolling Generalised Impulse Response Functions to analyse the effects of EPU on several economic variables. The results reveal that the Greek GDP, unemployment, Economic Sentiment Index (hereafter ESI) and the stock market index were affected more by domestic rather than European uncertainty. The responses are the highest during the crisis. There is also positive interdependence between the Greek and the European EPU index, which however was higher before the crisis.

The third chapter is a paper about abrupt movements in the stock market and how they are related to EPU. In particular, the US stock market is examined for the period 1900 to 2020, through a regime switching model, where the EPU index is considered to be the explanatory variable. The US stock market is found to be most of the time in the low-volatility regime and switching periodically to high-volatility. The paper also aims to investigate the forecasting ability of the model, by using recursively estimated out-of-sample probabilities of a crash. The results support the usefulness of the model in predicting abrupt movements in the US stock market. In addition, the paper proposes a trading rule that uses the estimated model and the associated probability of a crash to advice the investor when to exit and reenter the market. The trading rule seems to be a good tool for the investor, as it offers more profits than a simple buy-and-hold strategy would do, highlighting the financial usefulness of the model.

The last paper of the thesis, presented in chapter 4, examines the contribution of the EPU index to the persistence of shocks to the volatility of the stock market. The empirical research is based on daily data for the UK and the US, and for the period 2001 until 2019. An innovative approach proposed by Malliaropulos et al. (2013) is used, which compares the half-life of a shock in a bivariate VAR model, that includes the EPU index and the stock market volatility, with the half-life of a univariate ARMA model for the stock market volatility. The results reveal that the EPU index indeed contributes to the persistence of volatility in the stock market, but this is more intense in the US, where the contribution is 14.3%, in contrast to the 3.1% in the UK. An extension of the methodology to the foreign exchange market is also made, and the results reveal that EPU contributes to the persistence of some currencies' volatility.

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CHAPTER

ONE

CONSTRUCTION OF THE GREEK EPU INDEX

1.1 Introduction

After the outburst of the global financial crisis in 2008 and the subsequent Eurozone crisis, interest on the multi-dimensional concept of economic uncertainty has risen. Greece was probably the economy affected the most by the crisis as combined with the country's high debt ended up in a prolonged crisis for the country. This ongoing crisis has intensified the economic uncertainty in the country, raising the issue of what the consequences of this uncertainty will be. Thus, a need has been raised to quantify the ambiguous concept of economic uncertainty in Greece.

1.2 Literature review

Over the years, several researchers have tried to find ways of quantifying uncertainty, as it is a concept difficult to define. Different methods to estimate economic uncertainty have been proposed. In general, as Moore (2017) identifies, there are several categories of uncertainty measurements, based on the way uncertainty is quantified, the finance-based, the newspaper-based, and the forecast disagreement ones. The volatility of a series, like of GDP, if proxied by the moving standard deviation of a time series and the forecaster disagreement, is often used as an uncertainty measure. Some researchers use Generalised Autoregressive Conditional Heteroskedasticity (GARCH) models to quantify uncertainty. Specifically, GARCH models are used in order to measure uncertainty for a macroeconomic variable, like GDP growth, inflation, house prices etc, and the conditional variance of these variables is considered as the uncertainty proxy (Grier and Perry, 1998; Fountas, Karanasos and Kim, 2002, 2006; Bredin and Fountas, 2005; Bredin, Elder and Fountas, 2011; Christidou and Fountas, 2018). The CBOE Volatility Index (VIX), which is estimated as the 30-day ahead expected volatility of the stock market and is derived from the S&P500 (SPX) index, is often used as an uncertainty indicator (Bloom, 2009). While the VIX can be considered a financial uncertainty index for the US, the VSTOXX can be considered to be the respective measure for the Eurozone, which is estimated as the 30-day implied volatility of the EURO STOXX 50. However, Bekaert et al. (2013) highlight that VIX is not really capturing economic uncertainty rather than financial uncertainty.

On the other hand, Jurado et al. (2015) are measuring macroeconomic uncertainty based on the unpredictable component of a set of variables. Another approach to measuring uncertainty is based on opinion surveys and the diversity of respondents' replies. Thus, some researchers estimate uncertainty through the dispersion of individuals' or firms' expectations expressed in surveys (Bachmann et al., 2013; Abel et al., 2016; Girardi and Reuter, 2016). Lately, Baker, Bloom and Davis (2016) introduced the Economic Policy Uncertainty index which is an uncertainty indicator based on textual analysis. This index will be further examined in the next section.

1.3 Construction of the EPU index

BBD (2016) introduced the Economic Policy Uncertainty index, in an attempt to contribute to the quantification of uncertainty. Since then, the EPU index has attracted much research interest. BBD at first created the index for the US and the UK, and by now there are available data for 26 countries, all of which are hosted in the policyuncertainty.com official site, as well as in FRED. The countries with available EPU data are Australia, Belgium, Brazil, Canada, Chile, China, Colombia, Croatia, Denmark, France, Germany, Hong Kong, India, Ireland, Italy, Japan, S. Korea, Mexico the Netherlands, Pakistan, Russia, Singapore, Spain, Sweden, the UK, the US. Aim of this thesis was to add Greece to this list.

The EPU index captures both short- and long-term uncertainty about who will apply the economic policy, what policy actions will be taken, what will the results of the policy regulations be etc. It is an indicator based on newspapers coverage frequency. BBD firstly constructed the monthly and daily EPU index for the US, and later they constructed category specific indices[1], monthly indices for other countries, daily US and UK EPU index data, and historical US and UK data (BBD, 2016). For the core case of the monthly US dataset which covers the period since January 1985, they searched the digital archives of ten leading newspapers[2] to get the number of articles per month that contain at least one word of the following three categories: "economy", "uncertainty", and "policy". They then scale this number with the total number of articles published by each newspaper per month, as the volume of published articles may vary among different newspapers as well as through time. After appropriate standardisation procedure, they estimate the EPU index value, by averaging across the ten newspapers.

In order to support the validity of their analysis and the construction of the EPU index BBD proceed to some credibility tests. They conclude that the credibility of the index is remarkable. According to this analysis, the US EPU index spikes during important economic and social events, for example uncertainty seems to have risen during the Gulf Wars in 1991 and 2003, the Russian crisis in 1998, the 9/11 attack in 2001, the collapse of the Lehman Brothers in 2008, the debt ceiling dispute in 2011 etc, however for the case of the US there do not seem to be any noteworthy increases of the EPU index during political events. In recent years the EPU index has attracted much research interest. Research so far has generated important results and has highlighted the international or domestic events that accompany EPU peaks, and the effects of EPU on economic variables.

For the purposes of this thesis and in order to quantify the Greek economic uncertainty, the EPU dataset for Greece was constructed and the data are available in the policyuncertainty.com site and are regularly updated. Following the same methodology, the Greek EPU

[1]These categories are: monetary policy, taxes, fiscal policy and government spending, health care, national security, entitlement programmes, regulation, financial regulation, trading policy, sovereign debt, currency crisis.

[2]USA Today, Miami Herald, Chicago Tribune, Washington Post, Los Angeles Times, Boston Globe, San Francisco Chronicle, Dallas Morning News, New York Times, and Wall Street Journal.

has been constructed since January 1998 by searching one leading daily Greek newspaper[3], for the respective keywords that are presented in Table 1.1. Afterwards, the number of articles that contain the set of words for the index, is scaled to the total number of articles published by the newspaper per month, as the volume of published articles changes over time. Then, a normalisation of the index was also conducted[4] to get the final version of the Greek EPU dateset.

Table 1.1: Key-words for construction of the Greek EPU index

Uncertain OR Uncertainty OR Uncertainties	Αβεβαι*
AND	ΚΑΙ
Economic OR Economy	Οικονομ*
AND	ΚΑΙ
Policy OR Congress OR Deficit OR Federal Reserve OR The Fed OR Legislation OR Regulation OR Regulatory OR The White House	Πολιτικ* Ή Κυβέρνη* Ή 'Ελλειμμ* Ή ΤτΕ Ή ΕΚΤ Ή Νομοθεσ* Ή Μεταρρυθμ* Ή Βουλη*

Notes: An asterisk (*) indicates the term set includes all variants of the word in question.

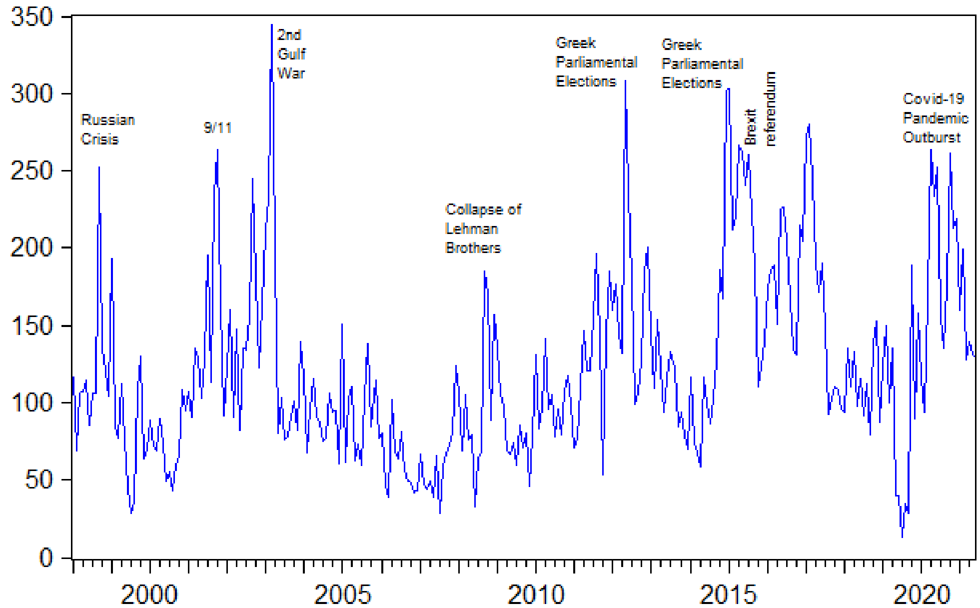
The Greek EPU index series is depicted in Figure 1.1 for the period January 1998 until May 2021[5]. The high volatility of policy uncertainty is highlighted in the figure. Moreover, it is obvious how the Greek uncertainty peaks due to either domestic or international major events. Economic, social, but also political events seem to affect economic uncertainty in Greece, in contrast with the US, where political events did not seem to affect the index that much. Political events in Greece seem to be a major cause of uncertainty, as it will also be explained in Figure 1.2. The Russian crisis, the 9/11 attack in New York, the collapse of the Lehman Brothers and the referendum for the Brexit are only some representative international events during which the Greek EPU index rises. It can be concluded that until the outburst of the Greek debt crisis in early 2010, the Greek EPU index would usually peak during international events, however after 2010 it is mainly domestic events that create and

[3]The newspaper used is "Kathimerini", as it was the only newspaper which can be accessed and provides a handy and useful research machine in order for the query to be searched.

[4]The index is multiplied by $100/mean_{T_1}$, where T_1 is the time period before the beginning of the Greek debt crisis (January 1998-December 2009).

[5]The constructed Greek EPU data can be found in policyuncertainty.com and are regularly updated.

Figure 1.1: The Greek EPU index with international and national events



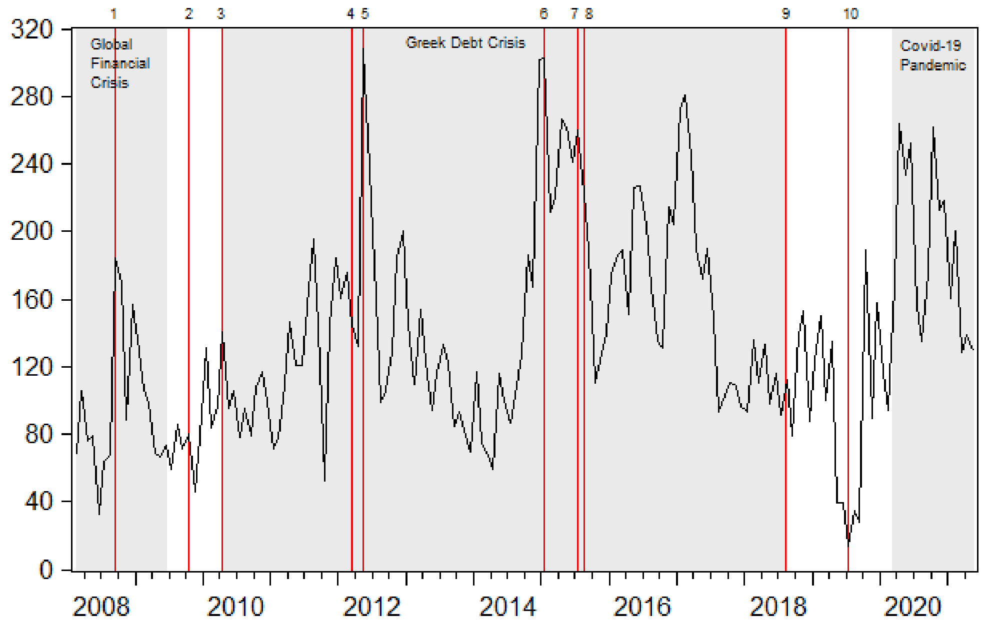
Notes: Sample from January 1998 to May 2021.

intensify uncertainty. EPU seems to have been limited some years after the initial launch of the Euro in the country in early 2002, maintaining relatively lower and less volatile levels until the beginning of the global financial crisis with the collapse of the Lehman Brothers in September 2008, when uncertainty and its volatility started peaking up again, especially after the first memorandum programme in 2010. Examining the mean EPU value and its volatility before and after the onset of the Greek crisis (April 2010) the mean value has increased by 50% (the mean value of the EPU for Greece was 100 for the period January 1998 to December 2009, while it increased to 146 afterwards)[6]. The EPU series also became more volatile after 2010, as its standard deviation increased from 42 to 53.

This can be better observed in Figure 1.2, which depicts the Greek EPU index after 2008. The shaded areas are periods of crisis; the first shaded area is the global financial crisis (September 2008 until June 2009), the second represents the Greek debt crisis (begins with the first memorandum in April 2010 until the end of the third memorandum programme in August 2018), and the third one is the Covid-19 pandemic crisis (March 2020 until the

[6]See Appendix, Table A1

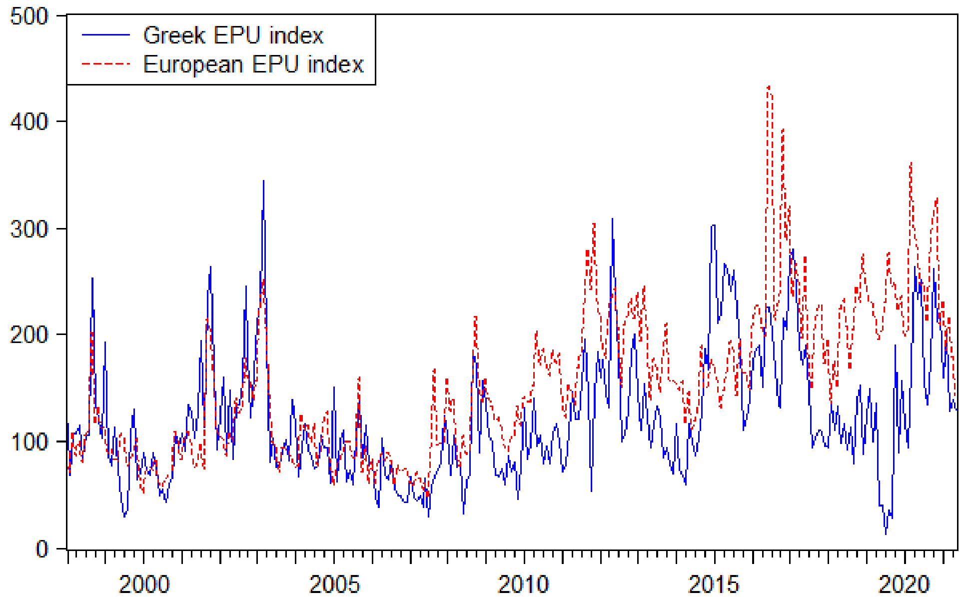
Figure 1.2: The Greek EPU index with national events



Notes: Sample from February 2008 to May 2021.
1. September 2008: collapse of the Lehman Brothers.
2. October 2009: governmental elections
3. April 2010: 1st memorandum
4. May 2012: governmental elections which did not lead to the formation of new government
5. May 2012: governmental elections lead to a coalition government
6. January 2015: governmental elections lead to the first left-party government in the country
7. July 2015: Greek referendum
8. September 2015: governmental elections
9. end of the 3rd and last memorandum programme
10. governmental elections

end of the sample). The red vertical lines are numbered and represent important economic and political events that took place in Greece, like elections and bail-out programmes. Not surprisingly, uncertainty was on the rise after the country entered the prolonged debt crisis (2010-2018) with high volatility (see Table A1 in the Appendix), and high values, especially during periods of political instability; in 2012, a year with two rounds of governmental elections, as the elections of March failed to form a new government, and in 2015, also a year with two governmental elections, a referendum and the initiation of capital controls in Greece. Uncertainty started showing signs of recovery after 2017, to increase again in

Figure 1.3: Greek and European EPU indices



Notes: Sample from January 1998 to May 2021.

2020, due to the outburst of the Covid-19 pandemic, which triggered uncertainty about the stability of the economy globally.

Figure 1.3 combines the Greek and the European[7] EPU indices in the same figure. Until 2009 the two indices move very close together, however after the onset of the Greek crisis in 2010 there are periods when the Greek and the European EPU indices diverge a lot. This corroborates the conclusion mentioned above, that after 2010 most of the peaks of Greek EPU are accompanied by domestic, rather than international events, as it was the case in the previous years[8]. This result is further reenforced in the next chapter, where the volatility spillover effects among the Eurozone countries are examined.

[7]BBD have created a European EPU monthly index, using data from Germany, Italy, the UK, France and Spain. The European EPU data are also available in policyuncertainty.com.

[8]Table A1 in the appendix shows the mean and standard deviation of Greek and European EPU, before and after the crisis.

1.4 Conclusion

The aim of this chapter was to introduce the concept of the EPU index and present the construction the EPU index for the Greek economy. The index was constructed based on the newspapers' coverage frequency methodology of BBD. It is obvious that uncertainty in Greece increases due to major international events, however after the beginning of the Greek debt crisis it is mostly triggered by domestic events, both economic and political ones.

The contribution of this chapter is vital, as the Greek EPU data are hosted and publicly available on the official website of the EPU index, so that more research can be conducted on uncertainty and the Greek economy. In addition, it is now possible to examine the effects of the EPU index on variables of the Greek economy, which is the aim of the next chapter.

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Appendix

A1 Descriptive Statistics

Table A1: Descriptive statistics of the Greek and European EPU indices before and after the crisis

	Mean		Standard Deviation	
	pre-crisis	post-crisis	pre-crisis	post-crisis
Greek EPU	100	146	42	53
European EPU	105	200	32	46

Notes: The pre-crisis refers to the period 1998Q2-2009Q4, while the post-crisis refers to the period 2010Q1-2019Q1

CHAPTER

TWO

ECONOMIC POLICY UNCERTAINTY SPILLOVERS IN EUROPE BEFORE AND AFTER THE EUROZONE CRISIS

Abstract

This paper focuses on economic policy uncertainty spillovers across Europe, before and after the outburst of the Eurozone crisis, using data for seven Eurozone countries for the period 2003–2019. At first, we analyse the spillovers of uncertainty in Europe through the estimation of the Diebold- Yilmaz spillover index. The results indicate that uncertainty connectedness was 50.5% before the crisis, while it dropped to 30.6% afterwards indicating a sharp drop in uncertainty spillovers across the seven Eurozone countries. We also find that the importance of domestic causes in national uncertainty increased during the crisis at the expense of imported factors. Dynamic net spillovers reveal that core Eurozone countries are uncertainty exporters before the crisis, while periphery countries transmit uncertainty to other countries during the crisis. An examination of the country which suffered the most during the crisis, using rolling impulse response analysis, reveals that the Greek macroeconomic indicators (stock market index, GDP, unemployment, and the Economic Sentiment Index) were affected more by domestic, rather than European uncertainty. The highest responses are indicated during the crisis. Overall, there is positive interdependence between Greek and European uncertainty, which diminishes during the crisis.

2.1 Introduction

Following the global financial crisis of 2008–2009 and the subsequent Eurozone crisis, uncertainty at the macroeconomic and policy level seems to be on the rise on a global scale. Since the creation of the Economic Policy Uncertainty index by Baker, Bloom, and Davis (2016), research on uncertainty has flourished. The Eurozone, from the end of 2008, when the first bailout program was offered as help to Latvia, until August 2018, when Greece's third and last bailout program ended, is a good example of heightened uncertainty. Due to the strong economic, financial, and trade links among the Eurozone countries, it is anticipated that uncertainty episodes in one country may be easily transmitted to other member states.

The global financial crisis, followed by the Eurozone crisis with high rates of unemployment, high debt levels, and a struggling employment, has heightened uncertainty, as expressed through the media for several years. This increasing uncertainty about the future of each country's economy, the effects of the subsequent economic policies and the regulations applied by governments, some of which were part of memorandum programmes for some European countries, is depicted in the European EPU index. The literature has shown that EPU is negatively correlated with the business cycle and has caused significant negative effects on macroeconomic variables such as GDP, employment, investment etc. (BBD, 2016; Stockhammar & Österholm, 2016; Kaya et al., 2018). Uncertainty has also affected the stock market, as investors in the financial markets closely observe GDP, investment, and other macro variables, that might be negatively impacted by a shock on uncertainty. Combining all this information, the EPU index could further intensify the negative consequences of the crisis.

So far, the biggest part of the literature on uncertainty focuses on the negative effects of an uncertainty shock. However, another important aspect is to examine the spillovers of such a shock to other economies, as the national economy might also be affected by uncertainty shocks in other countries. Despite the recent appearance of the EPU concept in the literature, empirical work on EPU has fast attracted the interest of researchers. However, to date, there has been a small number of papers dealing with uncertainty shock spillovers with the majority focusing on the transmission of US uncertainty shocks (Colombo, 2013;

Armelius et al., 2017; Caggiano et al., 2020). Another part of the literature investigates the effects of US or European uncertainty shocks on the economies of other countries outside the US and Europe (IMF, 2013). Klossner and Sekkel (2014) and Balli et al. (2017) examine the EPU cross-country spillovers in developed countries. The last paper also investigates the determinants of these spillovers and finds that trade links and common language are transmission-enhancing factors.

This paper contributes to the literature on policy uncertainty by highlighting an issue which had until recently been largely neglected by the literature. We concentrate more on the issue of uncertainty spillovers at a Eurozone level, rather than focusing on the effects of uncertainty on the domestic economy. We attempt to contribute to the related literature in two ways. First, we examine the dynamic behaviour of the EPU connectedness and the dynamic net volatility spillovers of uncertainty for seven Eurozone countries in the period that includes the recent Eurozone crisis. Our second aim is to investigate whether it is domestic or European uncertainty shocks that affect Greek macroeconomic variables the most, with an emphasis on the dynamic evolution of these effects before and after the crisis.

We address the first issue by examining EPU transmissions in a Vector Autoregressive (VAR) context, using the Diebold and Yilmaz (2009, 2012) spillover index. Monthly data from March 2003 until June 2019 for seven Eurozone countries are used. Our findings indicate that there is considerable transmission of uncertainty, which however falls significantly after the beginning of the crisis, as the spillover index drops from around 50% to almost 30%. At the same time, the relative importance of domestic uncertainty in all countries increased during the crisis. Findings also show that Greece, Ireland, and Spain are mainly uncertainty importers, whereas the large countries, France and Germany, are mainly uncertainty exporters. The dynamic net spillovers imply that before the crisis the core Eurozone countries (e.g. France and Germany) mainly exported uncertainty shocks, while during the crisis it was mostly the periphery countries (e.g. Greece and Ireland) that transmitted EPU shocks to the rest of the Eurozone.

In quest of the answer to the second question of this research, which is more specific for the Greek economy, we proceed with an impulse response analysis. The analysis is possible following the development of the recently created EPU index for Greece by Fountas et al. (2018). To examine the effects of policy uncertainty shocks, both domestic and European, on Greek economic variables, we use the Greek and the European EPU indices, and the Greek variables of GDP, unemployment, stock market index, and Economic Sentiment Index (hereafter ESI), for the period 1998Q2-2019Q1. Comparing the responses of the Greek economic variables to domestic and European uncertainty shocks, we conclude that the above variables respond to domestic uncertainty shocks for a longer period, compared with European EPU shocks. The results also indicate positive interdependence between domestic and European uncertainty, which however weakens during the crisis, a result in line with our first results concerning the findings of uncertainty spillovers across Europe. Given the considerable instability observed during this period, arising from a volatile economic and political environment, we establish the sensitivity of our results using a rolling impulse response function approach. This dynamic analysis results in similar conclusions to the ones obtained under the traditional full sample approach. An important result is that the largest responses to uncertainty shocks are detected in late 2008/early 2009. For this estimation period, we find that the responses to uncertainty shocks last long, and actually, they gradually keep increasing to reach the highest response 10 quarters after the initial EPU shock.

The rest of the paper is outlined as follows. Section 2 contains a review of the literature on the effects of EPU on macroeconomic variables across various countries and the literature on uncertainty spillovers using the Diebold-Yilmaz spillover index. Section 3 presents the methodology and the empirical analysis on uncertainty spillovers across Europe. Section 4 presents the effects of domestic and European policy uncertainty on Greek macroeconomic variables using rolling impulse response functions and some robustness analysis. Finally, Section 5 concludes the paper.

2.2 Literature review

Recently, applied macroeconomists have attempted to find an appropriate measure that quantifies the multi-dimensional concept of uncertainty. Moore (2017) refers to different categories of uncertainty measurement, the newspaper-based, the finance-based, and the forecaster disagreement measures. The Volatility Index (VIX) is a financial market volatility indicator that is commonly used as an uncertainty measure and is calculated by the implied volatilities on the S&P 500. However, by the nature of its construction, this measurement is not strongly connected to economic activity, as it is mostly related to investors' risk-aversion (Bekaert et al., 2013). Uncertainty proxies that are closely related to economic activity are those of dispersion between forecasters for economic variables (forecaster disagreement measures). In this case, the drawback is that these measures may not indicate uncertainty, but may capture disagreement instead (Moore, 2017). Jurado et al. (2015) proposes a measure of macroeconomic uncertainty that is based on the unpredictable component of a broad set of macroeconomic variables. The conditional variance of a series in a Generalised Autoregressive Conditional Heteroskedasticity (GARCH) model is also considered to be a measure of uncertainty about specific macroeconomic variables, such as output growth or inflation (Bredin et al., 2011; Bredin & Fountas, 2005, 2009; Grier & Perry, 1998; Hamilton, 2010).

The EPU index suggested by BBD (2016) deviates from the previous measures of uncertainty in applied macroeconomics, as it focuses on the uncertainty triggered by economic policy-making. It is a newspaper-based indicator that captures both short- and long-run uncertainty about who will apply the economic policy, what regulations will be applied by policy makers, how effective these regulations will be, and what the consequences of the economic policy will be. BBD have developed EPU series for several major industrial countries, including the US, the UK, France, Germany, Japan, etc. Finally, other researchers, following BBD's approach, created the series for other countries, like Ireland (Zalla, 2017), Chile (Cerda et al., 2018) etc. To the present, the index has been created for more than 25 countries and the number continuously rises. BBD also proceeded with some tests for the credibility and validity of the EPU index. The support of the credibility of the index is remarkable. Much research has been conducted, giving important results on the events that are depicted on an EPU graph, the causal effects between the EPU and macroeconomic or financial variables, and the importance of uncertainty during economic crises.

According to several studies, a large and steep increase in uncertainty has been observed in every country during or after economic crises (BBD, 2016; Cerda et al., 2018). Previous research for other countries indicates that uncertainty shocks negatively affect domestic output, employment, and other macroeconomic variables. More specifically, BBD (2016) use US macro-level data and, following the application of several VAR models and the examination of the impulse responses of macroeconomic variables, they conclude that policy uncertainty shocks are associated with declines in output, investment, and employment. They also perform the same analysis for a panel of 12 different countries and find similar results. Using firm-level data, they find that when uncertainty increases investment falls and stock market price fluctuations increase. Colombo (2013) examines the transmission of US uncertainty shocks to Europe, identifying a high impact on European GDP. Some papers look at the effects of US uncertainty on European uncertainty. Stockhammar and Österholm (2016) and Armelius et al. (2017) find evidence that US uncertainty shocks affect negatively Swedish GDP growth.

For the case of South Korea (Cheng, 2017) there is evidence of negative effects of uncertainty on the domestic economy; however, the important finding is that foreign uncertainty has a greater impact on Korean economy than domestic uncertainty. Zalla (2017) investigates the implications of EPU shocks for the Irish economy and shows evidence of negative effects on industrial production and the stock market. Arbatli et al. (2017) and Sahinoz and Cosar (2018) estimate impulse response functions for Japan and Turkey, respectively, and obtain similar results with other countries. Cerda et al. (2018) run five different VAR models on quarterly data for the economy of Chile and conclude that positive uncertainty innovations lead to deterioration of GDP, investment as well as consumption.

The large literature outlined above focuses on the effects of policy uncertainty on the domestic economy. More recently, some papers examine the transmission of uncertainty shocks to some domestic sectors (e.g. housing) or across a spectrum of domestic uncertainty categories using the Diebold and Yilmaz spillover index. Antonakakis et al. (2016) and Thiem (2018) look at US uncertainty effects on the domestic economy. Antonakakis et al. (2016) test for the existence of spillovers among the EPU, the stock and the housing market in the US. They find evidence for time-varying spillovers which seem to be increasing significantly after the global crisis of 2008. Thiem (2018) examines the connectedness among six different EPU index categories (monetary, fiscal, healthcare, national security, regulatory, and trade policy uncertainty) for the US and finds evidence for high spillovers.

Several studies concentrate on cross-country uncertainty spillovers. Klossner and Sekkel (2014) analyse the EPU spillovers among six developed countries and find that they account for a large share of the dynamics of policy uncertainty with this share rising during the recent financial crisis. Uncertainty may spillover across national borders via various transmission mechanisms. These include trade links, financial links, trade and fiscal imbalances, a common language, and a common border. Balli et al. (2017) estimate cross-country uncertainty spillovers and find out that the main channels through which uncertainty is transmitted from one country to the other are trade and the common language. They also find that the less balanced countries are in financial, fiscal, and trading terms, the higher the possibilities of EPU transmissions. Liow et al. (2018) analyse the EPU spillovers among seven countries (US, UK, Canada, Germany, France, China, and Japan) and estimate the respective spillover index to be almost equal to 50%. However, a distinct EPU spillover channel (where a domestic EPU spike creates uncertainty abroad) has also been identified, even in the presence of a separate trade channel (Caggiano et al., 2020). Caggiano et al. (2020) examine EPU spillovers between the US, Canada, and the UK. They find that US uncertainty spills over to the EPU index in Canada and affects unemployment negatively, thus pointing to an EPU spillover channel. This channel of uncertainty transmission is separate to a possible trade channel. However, trade is not the only channel through which economic policy uncertainty is transmitted abroad, as the paper finds evidence of US uncertainty transmission to the UK, without the UK traditionally having close trading relations with the other side of the Atlantic. Finally, Śmiech et al. (2020) add more to the literature, by investigating the connectedness among three types of uncertainty (consumer, industrial, and financial) across countries. A major finding is that uncertainty transmissions are usually higher among geographically close (which have higher trade and financial links) countries, and Southern European countries are net volatility transmitters during the debt crisis. Moreover, they find that the strength of connection across the EU countries weakens in the post-Eurozone crisis period.

2.3 Uncertainty spillovers in Europe

2.3.1 Model and data

The empirical analysis, as already explained, is divided into two parts. In the first part we estimate the uncertainty spillovers among seven European countries and compare these spillovers in the pre- and post-crisis periods. We consider the beginning of the crisis to be January 2010. We also examine how the dynamic net spillovers of each country evolve through time during the crisis. To do so, we apply a VAR analysis and estimate the Diebold and Yilmaz spillover index (2009, 2012).

Research on spillovers across different countries or different variables within a country is an important part of the empirical economics literature. Diebold and Yilmaz (2009) developed a measure that captures such spillovers, and later, in 2012 expanded their research to further enhance its power. They develop the spillover index using a variance decomposition from a VAR model. This spillover index is actually a measure of connectedness among variables in a multivariate framework; the higher its value is, the more intense the connectedness is. Diebold and Yilmaz (2012) indicated some drawbacks of their initially proposed index (2009). The first one was that the index was dependent on the variables' ordering, as it was based on a Cholesky decomposition of the VAR model. The second limitation was the estimation of an index for the total connectedness, which however was not capturing the direction of the spillover. To overcome these problems, they based the estimation of the spillover index on a generalised VAR framework, to make the index independent of the ordering of the variables. Additionally, they also introduced the directional spillover index.

To derive the index, at first a covariance stationary seven-variable VAR(p) is applied:

$$y_t = \sum_{i=1}^{p} \Phi_i y_{t-1} + \varepsilon_i, \tag{2.1}$$

where $\varepsilon \sim (0, \Sigma)$ is a vector of *iid* disturbances and y is the vector of the EPU indices of the seven Eurozone countries (hereafter Eurozone-7) that will be examined (France, Germany, Greece, Ireland, Italy, Spain, and the Netherlands). The respective moving average (MA) representation is:

$$y_t = \sum_{i=1}^{\infty} A_i \varepsilon_i, \tag{2.2}$$

where A_i is an nxn coefficient matrix and $A_i = \Phi_1 A_{i-1} + ... + \Phi_p A_{i-p}$, A_0 is an nxn identity matrix, and $A_i = 0$ for $i < 0$.

To estimate the variance decompositions, we apply the generalised VAR framework proposed by Koop, Pesaran, Potter and Shin (hereafter KPPS framework) (Koop et al., 1996; Pesaran & Shin, 1998). This framework allows for the shocks to be correlated, but appropriately, using the historically observed distribution of the errors, the result becomes invariant to the ordering. The use of the generalised instead of the orthogonalised shocks means that the row sum of the elements of the variance decomposition is not restricted to be one. Thus, the row sum of the spillover indices will also be different from unity.

Based on the KPPS framework, the z-step-ahead forecast error variance decompositions are estimated:

$$\phi_{ij}^{g}(Z) = \frac{\sigma_{jj}^{-1} \sum_{z=0}^{Z-1} e_i' A_z \Sigma e_j^2}{\sum_{z=0}^{Z-1} e_i' A_z \Sigma A_z' e_j^2}, \tag{2.3}$$

where Σ is the error variance-covariance matrix, σ_{jj} is the standard deviation for the error term for the j^{th} equation, and e_i is the selection vector, where the i^{th} element is 1 and the others 0.

In order to get the spillover index, the variance decomposition is normalised by the row sum.

$$\phi_{ij}^{g}(Z) = \frac{\phi_{ij}^{g}(Z)}{\sum_{j=1}^{N} \phi_{ij}^{g}(Z)}. \tag{2.4}$$

The total spillover index captures the contribution of volatility shocks across all the countries to the total forecast error variance:

$$S^{g}(Z) = \frac{\sum_{\substack{i,j=1 \\ i \neq j}}^{N} \tilde{\phi}_{ij}^{g}(Z)}{\sum_{i,j=1}^{N} \tilde{\phi}_{ij}^{g}(Z)} x100 = \frac{\sum_{\substack{i,j=1 \\ i \neq j}}^{N} \tilde{\phi}_{ij}^{g}(Z)}{N} x100. \tag{2.5}$$

The directional spillover index measures the spillovers received by country i from all the other countries j:

$$S_{i\bullet}^{g}(Z) = \frac{\sum_{\substack{i,j=1 \\ i \neq j}}^{N} \tilde{\phi}_{ij}^{g}(Z)}{\sum_{j=1}^{N} \tilde{\phi}_{ij}^{g}(Z)} x100 = \frac{\sum_{\substack{j=1 \\ i \neq j}}^{N} \tilde{\phi}_{ij}^{g}(Z)}{N} x100, \tag{2.6}$$

and respectively, the directional spillover transmitted from country i to all other countries j:

$$S_{\bullet i}^{g}(Z) = \frac{\sum_{\substack{i,j=1 \\ i \neq j}}^{N} \tilde{\phi}_{ji}^{g}(Z)}{\sum_{j=1}^{N} \tilde{\phi}_{ji}^{g}(Z)} x100 = \frac{\sum_{\substack{j=1 \\ i \neq j}}^{N} \tilde{\phi}_{ji}^{g}(Z)}{N} x100, \tag{2.7}$$

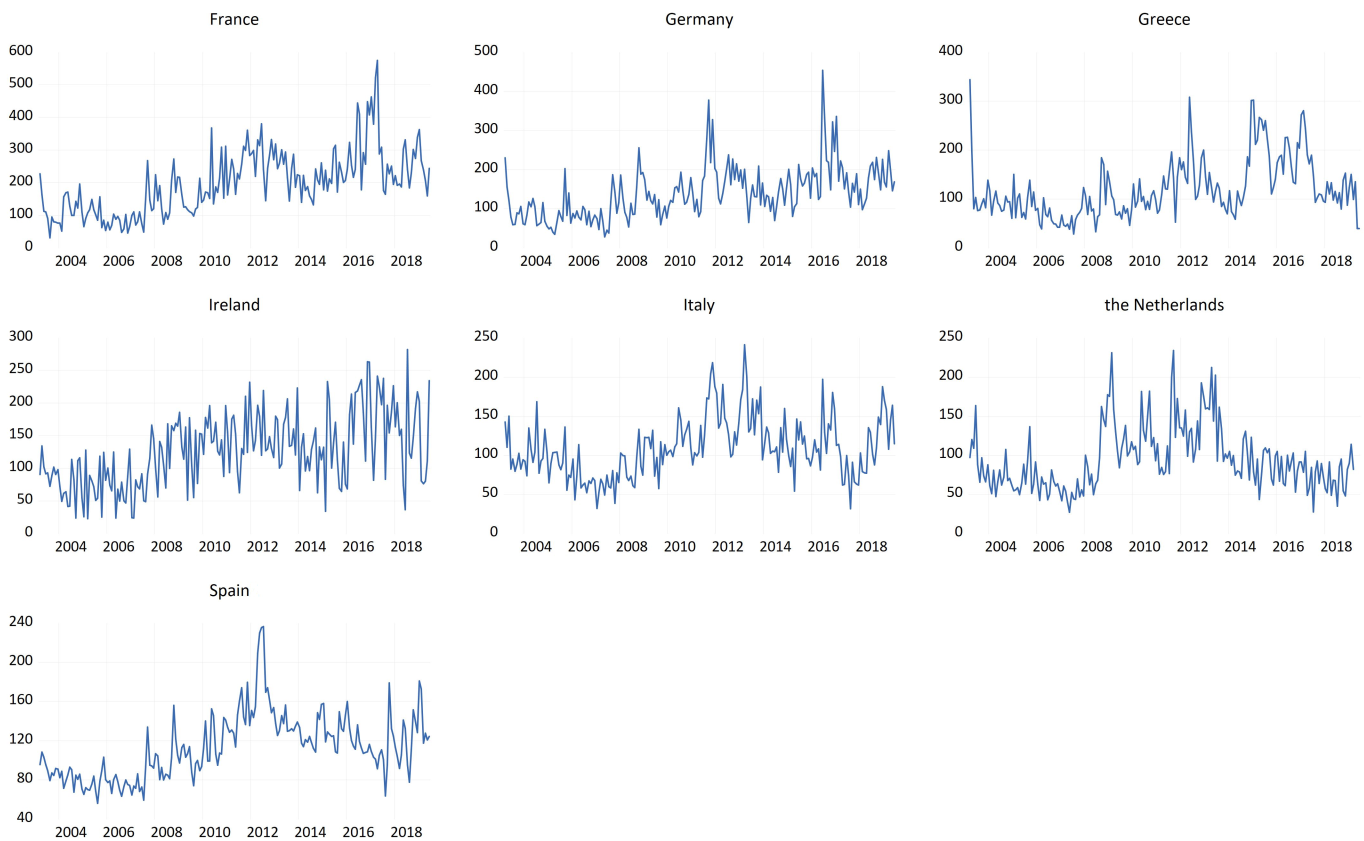
Finally, the net volatility spillover index is:

$$S_{i}^{g}(Z) = S_{\bullet i}^{g}(Z) - S_{i\bullet}^{g}(Z) \tag{2.8}$$

In order to treat the spillover index as time-varying, Diebold and Yilmaz (2012) use a rolling window methodology to estimate the aforementioned indices.

The data for the EPU index of the seven Eurozone countries in our VAR are retrieved from the policyuncertainty.com database. Descriptive statistics are presented in Table B1 in the Appendix. Figure 2.1 plots the monthly EPU index for these countries for the period 2003M03-2019M06. The starting year of the analysis is dictated by data limitations for the Netherlands where EPU data are not available prior to 2003. Figure 2.1 indicates an increase in the mean and the volatility of the policy uncertainty index since the beginning of the global financial crisis.

Figure 2.1: EPU indices for the Eurozone-7 countries



We apply the model for two different periods to estimate the total and directional spillovers: the first begins in January 2003, which is dictated by the availability of EPU data for all the countries in our sample examined, and ends in December 2009, before the beginning of the Eurozone crisis. The second period, dubbed 'post-crisis' period, runs from January 2010 to June 2019. The VMA representation through a generalised framework is used, as proposed by Diebold and Yilmaz (2012, 2014). In this way, the analysis is independent of the ordering of the variables. We also estimated the dynamic total connectedness index and the net spillovers of each country to examine the evolution through time. We set the forecast horizon for the variance decomposition equal to 10 months and the rolling window for the estimation of the spillovers equal to 24 months.

2.3.2 Results

The results of the spillover index for the above seven Eurozone countries are summarised in Table 2.1. Each country-column is divided into two sub-columns: the first is for the period January 2003 to December 2009 (pre-crisis period) and the second for the period January 2010 to June 2019 (crisis period)[1]. The meaning of the off-diagonal entries (directional spillovers) in this table is as follows: the ij^{th} entry ($i \neq j$) measures the estimated contribution to the forecast error variance of policy uncertainty of country i due to innovations in policy uncertainty to country j. The values in the rows report the fraction of the forecast error variance the headline country imports from each of the other countries. For example, 16.1% of the forecast error variance of France is imported from Germany (pre-crisis period). The values in the columns report the fraction of the forecast error variance the headline country exports to each of the other countries. For example, France exports 13.6% of its forecast error variance to Germany. Summing across the rows, we can calculate the fraction of the forecast error variance that is imported from the other countries in total (this is shown in the last column in the table titled 'contribution from others'). This fraction is calculated using Equation 2.6. Summing across the columns, we can calculate the fraction of the forecast error variance that is exported to the other countries in total (this is shown in the row in

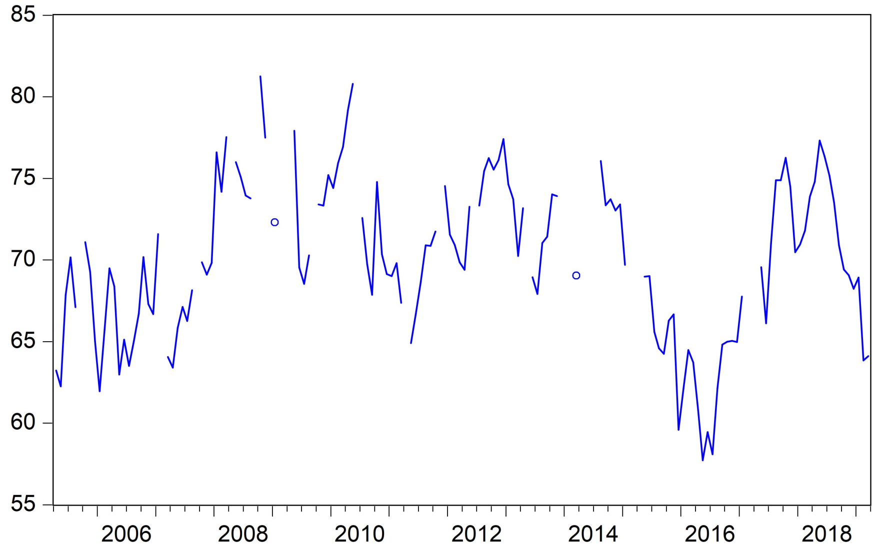
[1]Results for the full sample are provided in Table B3 in the Appendix

the table titled 'contribution to others'). The row entitled 'net contribution' measures the difference between uncertainty exports and imports. The diagonal elements in Table 2.1 measure the own contribution, i.e., the fraction of forecast error variance due to domestic uncertainty shocks. The values in the bottom right corner (50.5% and 30.6% for the pre-crisis and crisis periods, respectively) measure the total connectedness or total spillover index calculated by Equation 2.5. It reflects the average of the non-diagonal entries (below or above the diagonal) in Table 2.1 and it is a measure of the sum of all bilateral uncertainty spillovers in the Eurozone-7. The last row in the table reports the total contribution to the forecast error variance, which includes the contribution to others, plus the own contribution.

The estimates reported in Table 2.1 lead to the following conclusions. First, the total spillover of uncertainty among the Eurozone countries fell from 50.50% in the pre-crisis period to 30.60%, following the onset of the crisis. The first number implies that a little over one-half of the total variance of the forecast errors for the seven Eurozone countries is explained by the cross-country spillovers of uncertainty shocks. This significant drop in the total uncertainty spillover index is reflected in the fact that the importance of domestic sources of uncertainty (as opposed to uncertainty imports) increased during the crisis period. This is shown by the diagonal elements in the table which increased for all countries from the pre-crisis to the crisis period. In other words, it is clear that, following the onset of the crisis in the Eurozone, each country has been more 'closed' and not affected as much by foreign factors; rather uncertainty is mostly affected by domestic events and shocks.

Second, this increase in the contribution of own uncertainty innovations is more obvious in countries that experienced a more severe debt crisis and, in some cases, followed an economic adjustment programme. For example, the contribution of own innovations increased in Greece from 56.9% to 73.1%, in Ireland from 52.4% to 89.4%, in Italy from 47.5% to 62.5%, and in Spain from 37.6% to 66.4%. Third, core countries of the Eurozone were significant exporters of uncertainty in the pre-crisis periods, notably, France, Germany, and the Netherlands with contributions of uncertainty to others equal to 68.6%, 72.4%, and 69.4%, respectively. Fourth, some countries (e.g., France, Germany, and the Netherlands) even though they were net exporters of uncertainty before the crisis, following the start of the

Figure 2.2: Total connectedness index



Notes: The total spillover plot is derived by the sum of all 'contributions to others' from Table 1, estimated using a 24-months rolling window estimation.

crisis, they became less so, or in some cases became net importers (Germany). On the other hand, some countries were importers of uncertainty during both periods (Greece, Ireland, Spain) or switched from importer to exporter (Italy).

Figure 2.2 plots the time-varying total uncertainty spillover index. As shown in this figure, the uncertainty connectedness index was quite volatile during the study period, as it rose during the crisis (2008–2014), fell afterwards, increased again at the end of 2016, the year of the Brexit referendum, and fell once more after 2018.

To have a clearer picture of the uncertainty transmissions among the Eurozone countries and how they have evolved over time, apart from the total connectedness, we examine the dynamic net spillovers of EPU for the seven countries, presented in Figure 2.3. Figure 2.3 plots the net volatility spillovers of EPU transmitted from each country to the rest of the countries under examination, as estimated by Equation 2.8.

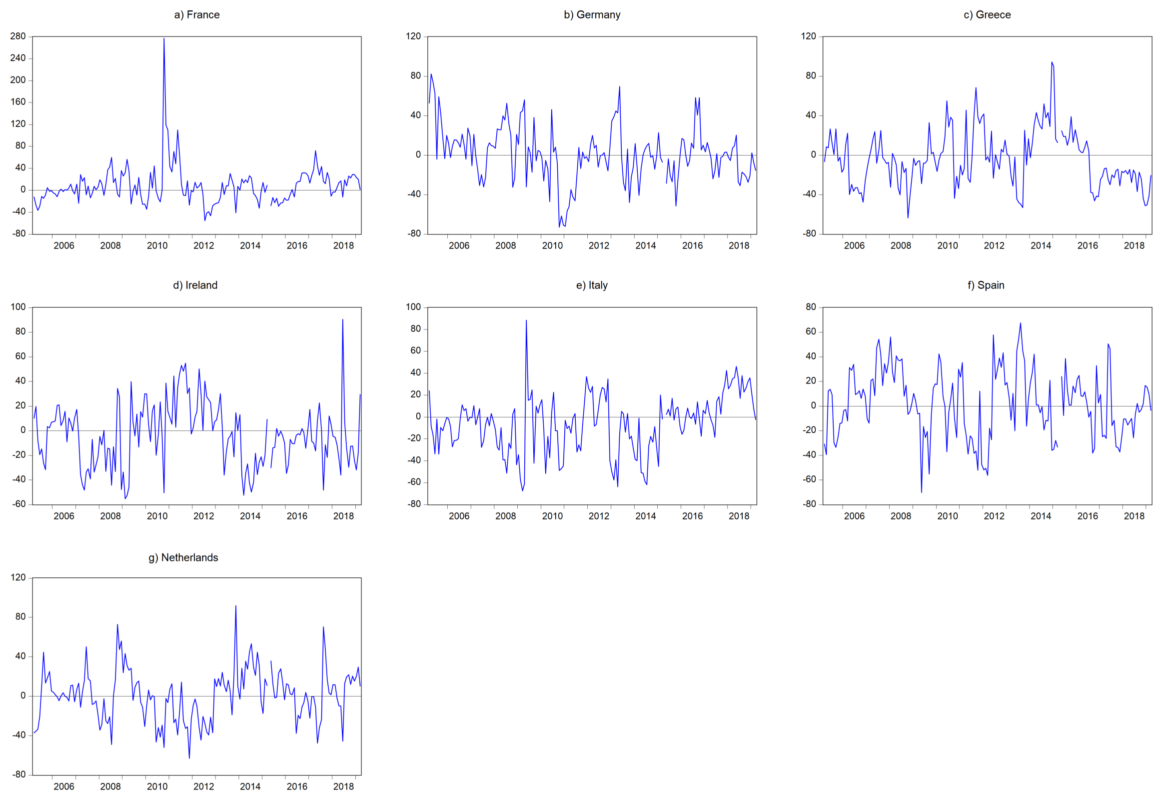
We observe that countries like Germany and the Netherlands, which had been mainly 'exporting' uncertainty in the pre-crisis period, during the crisis have longer periods of negative net spillovers (2009–2012). France, despite the high positive net spillovers in 2010–2011,

Table 2.1: Generalised conditional spillovers among the Eurozone-7 countries

	France		Germany		Greece		Ireland		Italy		Spain		Netherlands		Contribution from others	
France	50.2	58.1	16.1	18.6	6.1	9.6	2.3	0.8	7.7	8	10.3	3.4	7.3	1.5	49.8	41.9
Germany	13.6	16.7	52.3	62	5.4	7	2.6	0.8	0.5	8.2	15.3	3.5	10.2	1.9	47.7	38
Greece	10.9	16.4	8.2	2.4	56.9	73.1	2.5	0.2	6.8	1.9	2.2	5.4	12.5	0.6	43.1	26.9
Ireland	6.7	5.5	10.2	1.7	3.5	0.4	52.4	89.4	5.9	0.2	12.7	1.7	8.6	1.1	47.6	10.6
Italy	11.7	4.4	2	6	11.4	1	5.8	0.3	47.5	62.5	2.5	6.8	19.2	19	52.5	37.5
Spain	15.1	4	22.7	1.1	6.8	3.7	4.3	0.9	1.9	9.8	37.6	66.4	11.6	14.1	62.4	33.6
Netherlands	10.6	1.8	13.3	2.1	8.7	0.7	6.8	1.1	5.9	15.2	5.5	4.5	49.4	74.7	50.6	25.3
Contribution to others	68.6	48.8	72.4	31.9	41.9	22.3	24.4	4	28.7	43.2	48.3	26.2	69.4	38.3	353.8	213.9
Contribution from others	49.8	41.9	47.7	38	43.1	26.9	47.6	10.6	52.5	37.5	62.4	33.6	50.6	25.3	353.8	213.9
Net contribution	18.8	6.9	24.7	-6.1	-1.2	-4.6	-23.2	-6.6	-23.8	5.7	-14.1	-8.4	18.8	13		
Contribution including own	118.7	106.9	124.7	93.9	98.7	95.4	76.9	93.4	76.2	105.8	85.9	91.6	118.8	113	50.5%	30.60%

Notes: For each country, the first column shows the estimate for the period January 2003–December 2009 and the second column includes the estimates for the period January 2010–June 2019. The spillover indices refer to the EPU index of 7 Eurozone countries. A VAR(1) was selected based on the AIC criterion. The variance decomposition to extract the spillover indices was estimated for 10 forecast horizons and a 24-month rolling window. The ij^{th} entry measures the estimated contribution to the forecast error variance of policy uncertainty of country i due to innovations in policy uncertainty to country j. The figures in the rows report the fraction of the forecast error variance the headline country imports from each of the other countries. The figures in the columns report the fraction of the forecast error variance the headline country exports to each of the other countries.

Figure 2.3: Dynamic net volatility spillovers for the Eurozone-7 countries



in the following years it also presents long periods of negative net spillovers, meaning that after 2012 France is a receiver of EPU volatility spillovers from other countries. The high peak in October 2010 for France can be explained by the long-lasting and intense strikes the country was going under, due to the new pension reforms the government was trying to implement.

On the other hand, periphery countries, like Greece and Ireland, which were mainly importing uncertainty shocks before the onset of the crisis, show longer periods of positive net spillovers to the other countries during the crisis. Specifically, Ireland had high EPU volatility transmission to the rest of the countries during 2008–2013 period, which in part coincides with the participation in the bailout programmes. When the bailout program of Ireland ended in December 2013, we observe that the country goes back to its pre-crisis situation, mainly receiving spillovers from other countries. In the same vein, Greece entered the bailout programmes in May 2010. Until then, the net spillovers were negative for long

Table 2.2: Generalised conditional spillovers among the Eurozone-7 plus Russia, Sweden and the UK- robustness

	France		Germany		Greece		Ireland		Italy		Spain		Netherlands		Russia		Sweden		UK		Contribution from others	
France	43.2	42.7	13.4	13.7	4.6	8.4	1.8	0.5	7	6.5	9.3	3.8	5.3	2.8	0.4	0.9	1.3	5	13.7	15.9	56.8	57.3
Germany	11.9	11.7	44.4	43.1	4	5.4	2.6	0.3	0.8	6.3	13.9	3.9	6.1	2.1	0.8	0.3	5	8.2	10.5	17.6	55.6	56.9
Greece	9.5	14.6	7.1	2.5	52.6	63.4	2.2	0.2	6.7	1.5	2.2	4.6	11.2	0.5	2.3	2.2	0.5	6.9	5.8	3.7	47.4	36.6
Ireland	5.5	4.1	7.1	0.9	2.3	0.	46.1	76	5.6	0.6	10.6	1.2	5.3	1.5	0.7	4	3.6	1.3	13.1	10.4	53.9	24
Italy	10.2	4.7	1.4	6.1	9.6	0.9	5.2	0.3	43.2	58.8	2.3	7	18.3	16.4	2.4	0.3	1.2	3.1	6.1	2.4	56.8	41.2
Spain	12.7	5.2	17.5	1.5	5	3.2	3.9	0.7	2	9.8	32.9	59.4	7.6	12.4	0.4	2.3	4	2.8	13.9	2.5	67.1	40.6
Netherlands	8.2	2.5	7.2	3.4	5.4	0.5	6.5	1.4	6.6	14.2	4.6	3.4	36	67.4	3.7	1.3	8.4	1.1	13.4	4.9	64	32.6
Russia	0.7	0.7	2.3	2	2.9	3.3	2	0.6	2	1.2	0.2	4.2	3.9	1.7	82.2	76.3	2.2	9.3	1.6	0.7	17.8	23.7
Sweden	4.3	4.9	3.3	9.4	0.9	6.7	5.7	0.8	1.7	1.4	4	4.7	5.1	0.4	1.5	0.7	64.6	69.6	8.9	1.4	35.4	23.7
UK	15.1	12.6	11.1	15.3	3.3	3.6	7.2	2.6	4.4	1.4	11.2	0.9	6.9	3.4	0.4	0.6	5.8	3.2	34.6	56.3	65.4	30.4
Contribution to others	78.1	61.1	70.4	54.8	38	32.1	37.1	7.4	36.9	43.1	58.5	33.5	69.8	41.2	12.5	12.5	32.1	41.9	87	59.6	520.3	387.2
Contribution from others	56.8	57.3	55.6	56.9	47.4	36.6	53.9	24	56.8	41.2	67.1	40.6	64	32.6	17.8	23.7	35.4	23.7	65.4	30.4	520.3	387.2
Net contribution	21.3	3.8	14.8	-2.1	-9.4	-4.5	-16.8	-16.6	-19.9	1.9	-8.6	-7.1	5.8	8.6	-5.3	-11.2	-3.3	11.5	21.6	15.9		
Contribution including own	121.3	103.8	114.7	97.9	90.6	95.5	83.2	83.3	80.1	101.8	91.4	92.9	105.8	108.6	94.7	88.7	96.7	111.5	121.5	115.9	52%	38.7%

Notes: For each country, the first column shows the estimate for the period January 2003–December 2009 and the second column includes the estimates for the period January 2010–June 2019. The spillover indices refer to the EPU index of Eurozone-7 countries plus Russia, Sweden and the UK. A VAR(1) was selected based on the AIC criterion. The variance decomposition to extract the spillover indices was estimated for 10 forecast horizons and a 24-month rolling window. The ij^{th} entry measures the estimated contribution to the forecast error variance of policy uncertainty of country i due to innovations in policy uncertainty to country j. The figures in the rows report the fraction of the forecast error variance the headline country imports from each of the other countries. The figures in the columns report the fraction of the forecast error variance the headline country exports to each of the other countries.

periods; however, after May 2010 there is high EPU volatility spillover from Greece to other countries, and especially during late 2011 until 2016, with the exception of the first half of 2013, there is a prolonged period of positive and high net spillover for the country. It was the period of high political uncertainty with four governmental elections (two rounds in 2012 and two rounds in 2015), the introduction of capital controls and a referendum in 2015.

2.3.3 Robustness tests

For the validation of the previous results, we run some robustness tests. At first, we use different samples, according to the different point in time when the crisis began or ended for different countries. More specifically, we choose the break date and the end of the sample according to the beginning and the end dates of the bailout programme in three countries (Greece, Ireland, and Latvia). Moreover, we change the forecast horizon used in the variance decomposition to 12 and 24 months as well as the rolling window to 12 months. We also repeated the estimations by excluding one country at a time. The results from the robustness tests corroborate the conclusion that during the crisis the importance of domestic uncertainty is in all countries higher than in the pre-crisis period. Additionally, the percentage of total uncertainty spillover among the countries in the robustness tests, in both periods under examination, remains qualitatively and quantitatively similar to the initial analysis See Appendix, Table B5.

Finally, as part of the robustness testing procedure, we added three more European countries, which are not members of the Eurozone, i.e., Russia, Sweden, and the UK. Table 2.2 provides all the estimated spillover indices (total, directional, net)[2]ot. We can see that the total connectedness falls from 52% before the crisis to 38.7%, a result in line with the analysis of the seven Eurozone countries. Also, regarding the diagonal elements, apart from France, Germany and Russia, in all other cases they imply an increase of the importance of domestic uncertainty after the beginning of the crisis.

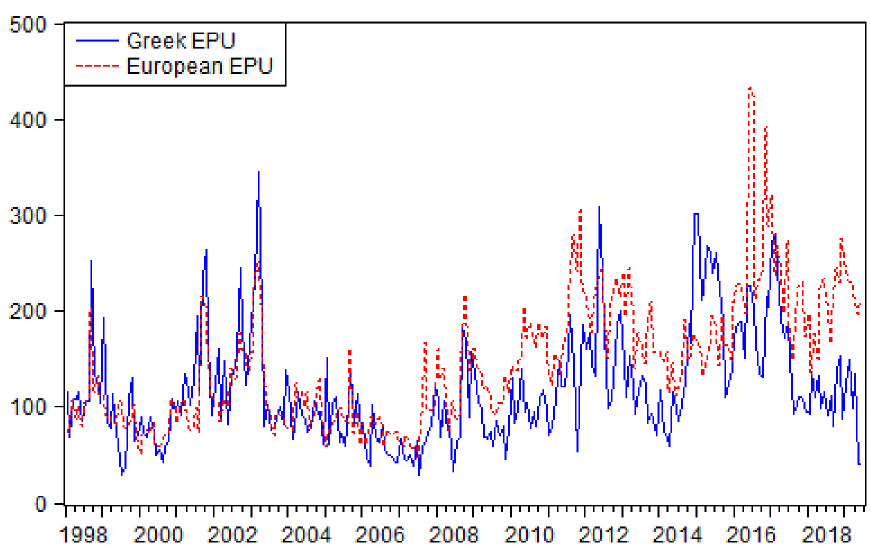
[2]Results for the full sample are provided in the Table B4 in the Appendix

2.4 Uncertainty and the Greek economy

2.4.1 Data and methods

Given the increasing uncertainty surrounding the Greek economy following the economic crisis, we attempt to measure the effects of uncertainty on key Greek macroeconomic variables. Chapter 1 presented the construction of the Greek EPU index from January 1998 to January 2018. Figure 2.4 illustrates the Greek and European EPU indices in monthly frequency for the period January 1998 to June 2019. For the case of the Greek index some of its movements are accompanied by important economic, social and political events, both domestic and international. A first look at the graph might not give us the picture of increased uncertainty during the crisis, both for the European and especially for the Greek EPU, as there were months with high uncertainty even before the beginning of the crisis. However, simple descriptive statistics help us establish the deterioration in terms of uncertainty, as the mean value as well as the standard deviation (volatility) increase significantly after 2010, both for Greece and Europe in general[3].

Figure 2.4: The Greek and European economic policy uncertainty indices



Notes: Monthly data for the two EPU indices, for the period January 1998-June 2019.

[3]See Appendix Table B2 for the mean values and standard deviation of Greek and European EPU indices.

More specifically, the mean of the Greek uncertainty index increased by 50% and the mean of the European EPU index almost doubled. As shown in Figure 2.4, until the beginning of the crisis, Greek and European uncertainty move very closely to each other, even though Greek uncertainty seems to be more volatile. After the onset of the crisis the picture changes a bit and the two EPU indices seem to follow different paths. This observation comes to add to the results of the spillover index that the uncertainty spillovers in the Eurozone fall after the beginning of the crisis. We observe periods of high uncertainty in Europe like in 2010 and 2016, when the Greek EPU is not as high as it would have been expected regarding the European turmoil in those years. In addition, in 2015, a year full of important events for the Greek economy that triggered a rise in domestic uncertainty, the European uncertainty index does not reach high levels. Thus, to account for the likely importance of EU membership in shaping the effects of uncertainty on the Greek economy, we examine the effects of shocks on both the Greek and the European EPU indices[4] on Greek macroeconomic variables. We also wish to examine if these effects differ before and after the beginning of the crisis. In this respect, we first analyse the effects for the full sample, and then, as a robustness test, we employ a rolling impulse response function analysis.

To measure the impact of uncertainty on the Greek economy, we follow the previous literature and estimate VAR models and the impulse responses of Greek macroeconomic variables to uncertainty shocks. The VAR in standard form is given by the following equation:

$$y_t = A_0 + A_1 y_{t-1} + \ldots + A_p y_{p-1} + \beta t + e_t, \tag{2.9}$$

where y_t is an $n \times 1$ vector of the six endogenous variables, Greek EPU index, European EPU index, Greek real GDP, Greek ESI, unemployment and stock market index, A_is are $n \times n$ coefficient matrices, e_t is an $n \times 1$ vector of error terms, p is the lag length, and t is a linear time trend. We choose real GDP as an important proxy for real economic activity,

[4]BBD (2016) constructed a European EPU index, as a mean of the EPU indices of France, Germany, Italy, Spain, and the UK.

a similar choice with Armelius et al. (2017) and Cheng (2017). The unemployment rate is a crucial variable to consider given the high value observed during the peak of the crisis reaching the extraordinary level of 28%. In the literature, some studies use the employment variable, but the unemployment variable has also been used (Caggiano et al., 2020). The stock market index is included as a proxy for conditions in the financial markets (see also, BBD, 2016; Zalla, 2017). The European EPU is included due to Greece's Eurozone membership and the anticipated transmission of uncertainty among countries sharing a common currency. Other studies use a foreign EPU index that relates to an important trading partner or a large country. For example, Caggiano et al. (2020) use the US EPU when the domestic country is Canada, and Cheng (2017) also uses the US EPU in a VAR for the South Korean economy. Finally, the ESI is a composite index that captures the sentiment of various sectors of the supply-side of the economy (industrial, services) and consumers and is expected to be influenced by uncertainty.

To investigate the effects of uncertainty on macroeconomic variables, we calculate Generalised Impulse Response Functions (hereafter GIRFs). We choose GIRFs instead of simple IRFs because, as shown by Pesaran and Shin (1998), GIRFs are constructed using an orthogonal set of innovations that does not depend on the ordering of the variables that are included in the VAR model. We estimate a VAR model on quarterly data for the full period 1998Q2-2019Q1. The sample period is dictated by the avail- able data for the Greek harmonised unemployment. The variables Greek real GDP (millions of chained 2010 Euros) and Greek (harmonised) unemployment are seasonally adjusted, and the stock price index is the FTSE-ATHEX-Large-Cap. The EPU indices were retrieved from the policyuncertainty.com (the official site of the EPU index), the ESI from the European Commission, real GDP from FRED, harmonised unemployment from OECD, and finally the stock market index from investing.com. All variables are in log levels. Descriptive statistics are presented in the Appendix. As it is customary in the literature, we run a VAR in levels, and not in first differences, following previous similar research (BBD, 2016; Colombo, 2013) in order not to lose important long-run information of the variables (Sims et al., 1990). Furthermore, due to the shortness of our sample, we do not consider the possibility of cointegration.

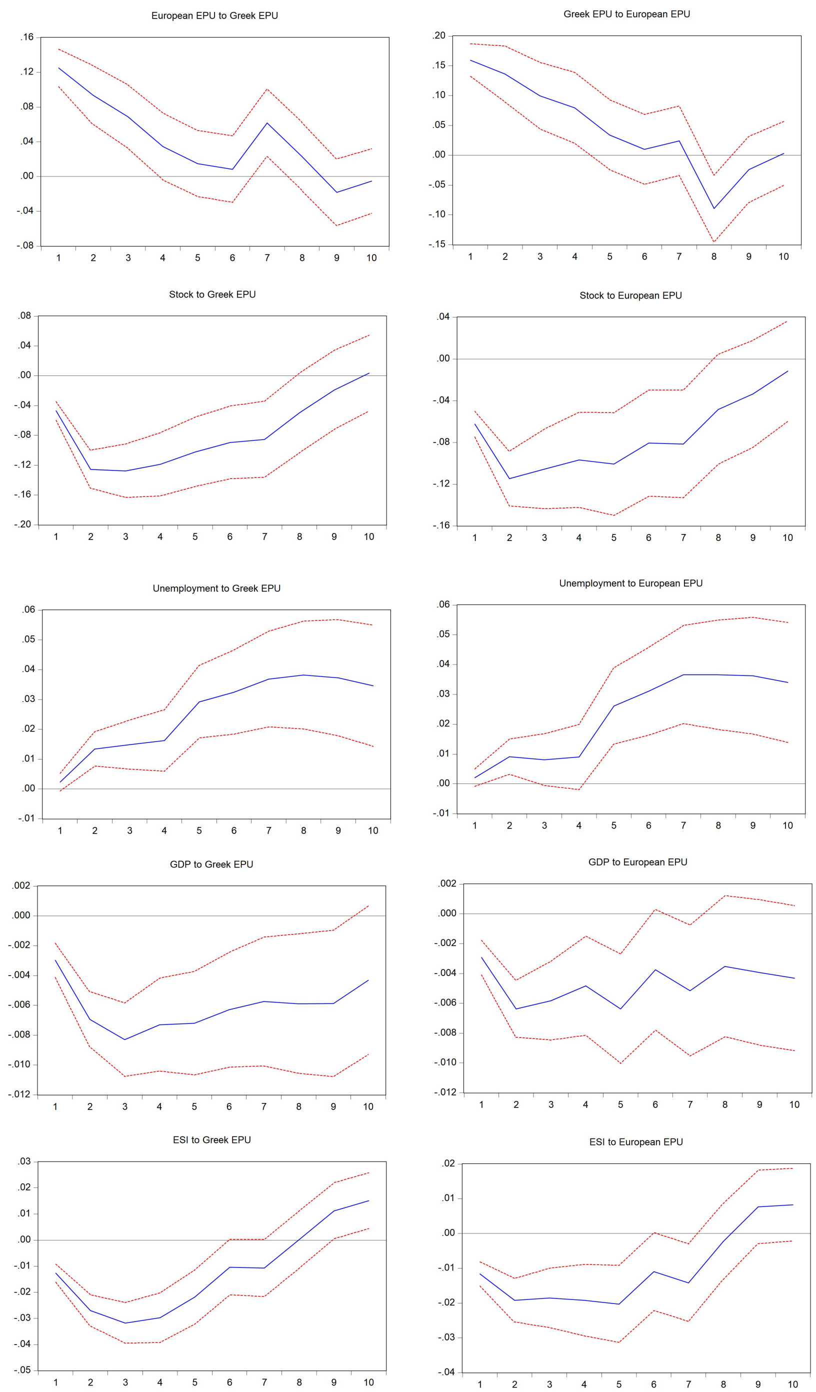
2.4.2 Results and discussion

The starting point of our empirical analysis is a VAR model for the full sample (1998Q2-2019Q1). Based on the LR test, six lags were chosen; this lag length is sufficient to ensure serially uncorrelated errors. The generalised impulse responses for up to 10 quarters for the full sample are depicted in Figure 2.5. The graphs on the left column portray the responses of the variables to Greek uncertainty shocks, and the graphs on the right column show the corresponding responses to European EPU innovations. The median response is reported, as well as 67% confidence interval bands based on asymptotic standard errors. We find that stock prices respond negatively to shocks on the Greek as well as the European EPU index, with the highest response in second and third quarter after the shock, and later the response gradually falls. The impulse responses of unemployment to Greek uncertainty shocks are statistically significant almost through the 10 quarters and the responses to European uncertainty are statistically significant, except for the 3rd and fourth quarter after the shock. They are positive and increasing until eight quarters after the shock, and then start falling. Real GDP responds negatively to both shocks and its response to Greek uncertainty shocks is a bit higher and longer in duration than to European uncertainty shocks. Finally, ESI responds negatively to both Greek and European uncertainty shocks, and the response lasts for about six quarters, while the response to Greek EPU is a bit larger than the response to European EPU innovations.

In general, these results highlight the importance of uncertainty originating in both Greece and core European countries in shaping movements in Greek macroeconomic variables. The signs of the responses are as anticipated in all cases. In other words, in response to positive uncertainty shocks, the stock index, real GDP, and the ESI fall, and unemployment rises. Another interesting result concerns the interdependence between European and Greek uncertainty. As anticipated, we observe that the response of the Greek EPU to a shock on the European EPU index is positive and qualitatively similar with the response of the European EPU to shocks on the Greek EPU. Quantitatively though, it seems that the effect of European uncertainty on Greek uncertainty is larger for the full sample.

For robustness, the model is run for two sub-samples, 1998Q2-2010Q1 and 2010Q2-

Figure 2.5: Generalised impulse responses for the full sample



Notes: Generalised impulse responses to one SD innovations (±1 SE) in the Greek and European EPU indices. Sample: 1998Q2-2019Q1.

2019Q1 and the results are presented in the Appendix. To test the robustness of the results, we additionally run the GIRFs for these sub-samples by replacing the European uncertainty index with the global EPU index[5]. The results, shown in the Appendix, provide again similar to the initial model of our analysis, thus re-enforcing the robustness of the initial model. The only exception is the duration of the response of Global EPU to Greek EPU shocks, which is smaller compared with the European response to Greek uncertainty shocks. This divergence makes sense, as the European countries and their uncertainty are expected to be affected more from Greek uncertainty shocks, compared with the rest of the countries of the world.

As mentioned previously, a rolling VAR model estimation has been applied as a next step. In other words, rolling impulse responses are estimated to capture the dynamic evolution of the responses and thus examine how changes evolve before, during, and after the Greek debt crisis. The sample extends from the first quarter of 2004 until the first quarter of 2019, and we use a window of 24 quarters[6], that is 6 years. The size of the window has been selected based on the sample size. However, robustness tests have been conducted for window sizes of 22 quarters and 28 quarters. The general pattern of the rolling GIRFs in these cases is similar to the 24-quarter window estimations presented in this paper, apart from some minor differences in non-statistically significant estimations. The smoothness of the estimations also changes, but this is expected as the larger the size of the window in a rolling estimation, the smoother the estimations are (Zivot & Wang, 2006). The GIRFs have been estimated for up to 10 quarters after the shock. Figures 2.6 includes the responses of the variables to Greek uncertainty shocks, while Figures 2.7 portray the responses of the variables to European uncertainty shocks, so that we can make a comparison between the responses to domestic and European EPU shocks[7]. The median responses are reported in the graphs, and the 67% confidence interval bands are estimated, but not depicted for reasons of simplicity and clarity of the 3D figures.

A comparison of Figures 2.6 with those on the left column of Figure 2.5 indicates

[5] The global EPU index is constructed by BBD (2016) as a GDP-weighted average of the uncertainty indices of 21 countries (see policyuncertainty.com).

[6] A rolling estimation for a window size less than 21 quarters does not run, due to a lack of degrees of freedom.

[7] Respective tables for the statistical significance of the rolling GIRFs can be found in the Appendix, Tables B6 and B7

that the pattern of the responses to Greek EPU shocks changes over time for all examined variables. In particular, the responses diverge especially in late 2008-early 2009 from the rest of the examined period. The responses also become smoother during the most recent years, when the crisis period is excluded from the sample of the window.

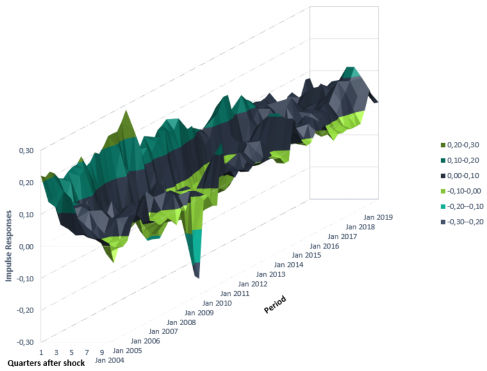
Figure 2.6a shows that the responses of European uncertainty to Greek uncertainty were higher in the first years of the sample and were getting smoother toward the most recent years. Until the beginning of the Greek debt crisis, there were high responses in the first quarter after the shock, which would diminish after some quarters, while in last quarter of 2008 and first of 2009 we identify the highest response, and also a very sharp fall 8–10 quarters after the shock, which however are not statistically significant. The responses are statistically significant only for two to four quarters after the shock until 2016 and later the statistically significant duration of the responses is longer, lasts even eight to nine quarters, though lower in value.

Comparing the above response to its reverse, meaning the response of the Greek EPU impulse responses to a European uncertainty shock shown on Figure 2.7b, we detect higher values throughout the whole examined period. Responses are higher and statistically significant in the first two quarters after the European EPU shock, and fall afterwards. However, the values of the responses are much higher, reach almost 0.7, while the reverse responses reached only 0.3. But in this case the responses are statistically significant only for two to three quarters after the shock throughout the whole period, thus the duration of the shock is not higher during the recent years. We also observe that in last quarter of 2008 and first of 2009, there is a sharp increase of the response after six quarters from the shock, instead of a sharp fall; however, again it is not statistically significant, as in the reverse response. This comparison is in line with the results of the full sample estimation, corroborating the finding that Greek EPU responses to European EPU shocks are higher than the reverse responses, and do not fall even in recent years.

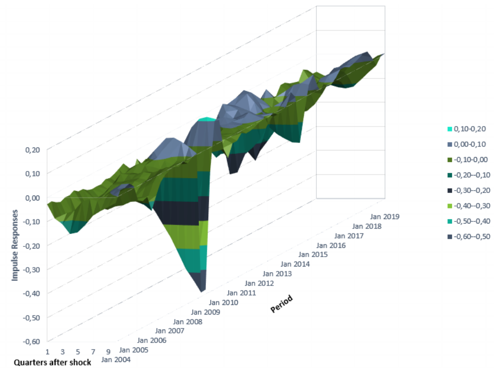
The stock index impulse responses shown in Figure 2.6a are negative. The highest responses are detected around two to three quarters after the shock, with the exception of late 2008 and early 2009, when the response is low the first quarter after the shock but increases

Figure 2.6: Rolling generalised impulse responses to Greek EPU shocks

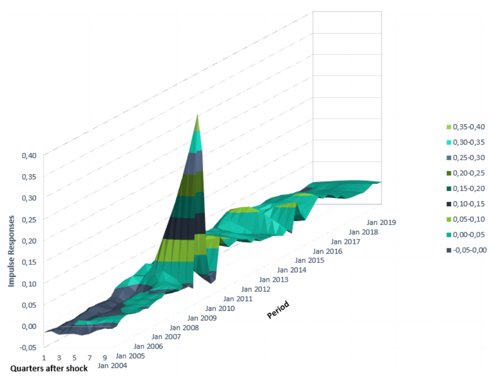
(a) European EPU to Greek EPU shocks



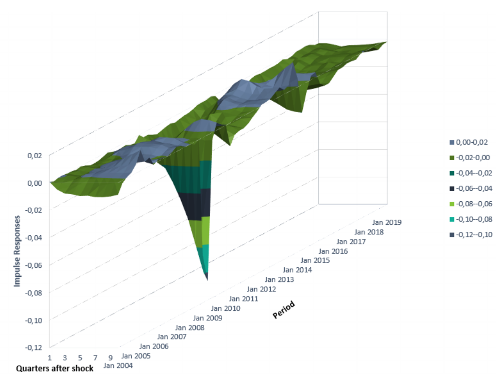
(b) Stock index to Greek EPU shocks



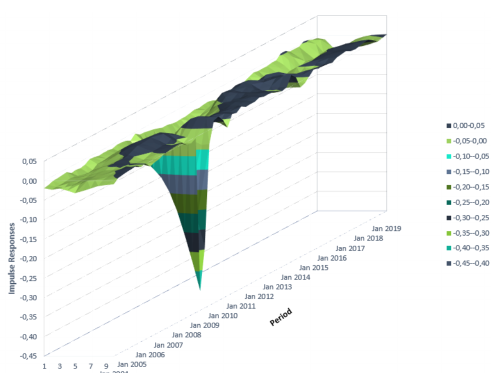
(c) Unemployment to Greek EPU shocks



(d) GDP to Greek EPU shocks



(e) ESI to Greek EPU shocks



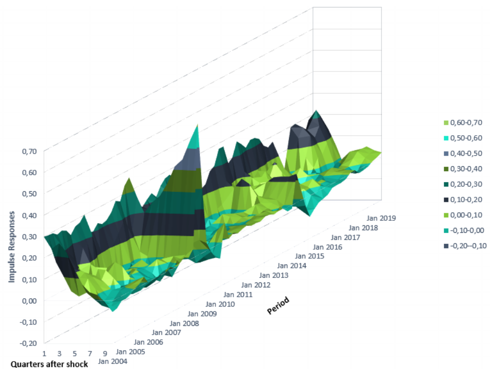
and reaches its highest value in absolute terms 10 quarters after the shock. Interestingly, in the first quarter of 2009 the responses are statistically significant even nine quarters after the initial shock. This might be a sign of how much the Greek stock market was negatively affected by the collapse of the Lehman Brothers in October 2008 and the onset of the global financial crisis. In general, the responses of the stock market index to domestic uncertainty shocks were lower before the crisis, while there are high responses in absolute value during the crisis and, in particular, in 2012 to 2014, but this period the duration of the statistically significant response is much shorter (only three quarters). The values of the rolling responses of the Greek stock market index to European uncertainty shocks, depicted in Figure 2.7b, are very similar to the responses to domestic uncertainty shocks; however, the duration is shorter.

Responses of unemployment to Greek uncertainty shocks are depicted in Figure 2.6c. They are very smooth before the crisis but in late 2008 and early 2009, there is again a sharp increase. During the years of the crisis, until 2017, there are relatively high responses which grow higher some quarters after the shock, while in the last 2 years the responses of unemployment are smoother. The interesting finding which again corroborates the results of the full sample GIRFs is that the responses of unemployment start smoother and gradually increase and they reach high values about eight quarters after the uncertainty shock. It is also noteworthy that the statistically significant responses last very long during most part of the examined period, as also found in the full-sample analysis. The responses of unemployment to European uncertainty shocks are very similar, as portrayed in Figure 2.7c, however shorter in duration than the responses to Greek EPU shocks.

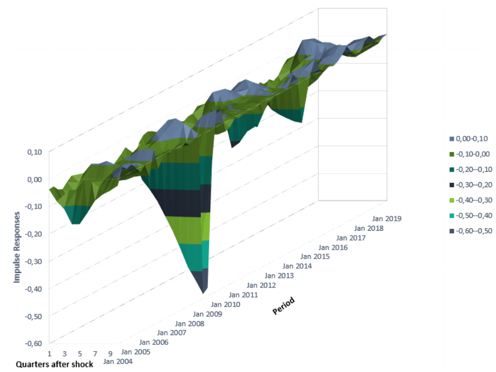
GDP responses (Figure 2.6d) follow a pattern very similar to the stock market index. We observe negative responses to domestic uncertainty shocks across all rolling IRFs. It is important to note that an uncertainty shock in the first quarter of 2009 leads to a sharp increase in absolute value in the response after 10 periods, and then comes back to the normal pattern. In the recent post-2016 period, the responses are milder, probably due to excluding the values of the crisis from the sample. Most of the time responses are statistically significant for about three quarters after the shock, but after 2015 the duration of the response is much longer, about eight quarters. The responses of GDP to European uncertainty innovations shown in Figure 2.7d are very similar throughout the years, with the exception of duration,

Figure 2.7: Rolling generalised impulse responses to European EPU shocks

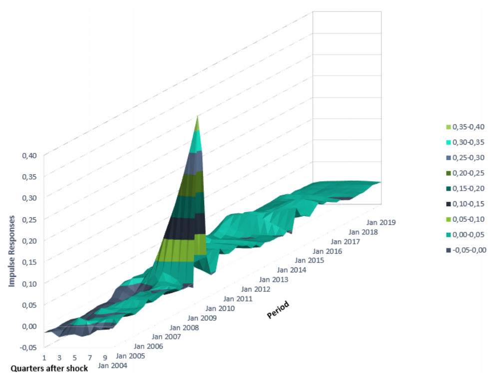
(a) Greek EPU to European EPU shocks



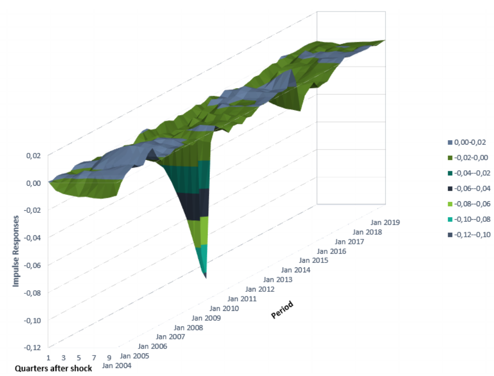
(b) Stock index to European EPU shocks



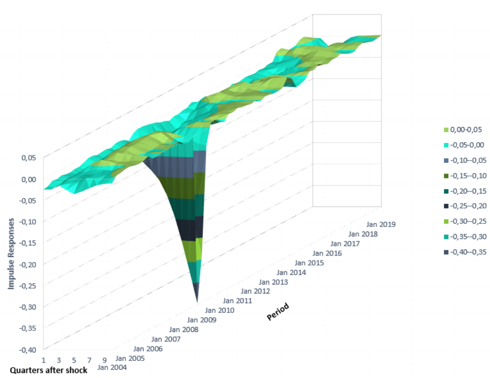
(c) Unemployment to European EPU shocks



(d) GDP to European EPU shocks



(e) ESI to European EPU shocks



as they are statistically significant for fewer quarters after the shock, a finding again in line with the full sample estimation.

Finally, Figures 2.6e and 2.7e show the rolling impulse responses of Greek ESI to domestic and European uncertainty shocks, respectively. The two figures show a very similar pattern. The responses are very smooth and negative throughout the whole examined period, apart from late 2008 and early 2009, when again there is a sharp increase in absolute value. The highest response is around two to three quarters after the shock and then it smoothens gradually. The responses are statistically significant for almost up to five quarters after the shock, which is in line with the full sample findings. In summary, the reported results indicate that the adverse effects of uncertainty shocks on economic variables have the expected sign and are largest in absolute magnitude when shocks occur in late 2008/ early 2009, a time associated with the recent financial crisis.

2.5 Conclusions

The main subject of this study is the examination of uncertainty spillovers in Europe during the period 2003–2019. We estimate the Diebold-Yilmaz spillover indices (total, directional and net) for several European countries in order to measure total uncertainty spillovers as well as spillovers between country pairs. We obtain the following results. First, there is evidence of considerable transmission of EPU among Eurozone countries. Second, comparing the value of the total spillover index before the crisis and since the start of the crisis, we conclude that the transmission of uncertainty between countries fell following the start of the recent crisis. The finding that own uncertainty contribution increases in all economies after 2010 means that the crisis led to countries becoming more 'closed' and mostly affected by domestic events and turbulence. Third, the directional spillover indices reveal that the countries with larger and stronger economies are mainly uncertainty exporters, while those with weaker economies tend to be uncertainty importers. To examine the evolution of these spillovers over time, we estimated the dynamic net volatility spillovers for each country. The findings indicate that before the onset of the crisis, the core countries of the Eurozone, like France and Germany, were the ones transmitting uncertainty shocks to the other Eurozone countries. However, the crisis changed this norm, making periphery countries, like Ireland and Greece, EPU shock exporters during the years of the crisis.

In order to further investigate the magnitude of uncertainty spillovers and the time variation of these spillovers before and during the recent crisis, we examine the case of Greece, the country that suffered the most severe crisis. We compare the impulse responses of Greek macroeconomic variables to both domestic and European EPU shocks using data for the full sample as well as rolling estimations. The results indicate the negative reaction of GDP, stock market index, and the ESI and the positive reaction of unemployment to uncertainty shocks. It is also obvious that the highest responses are detected in the beginning of the crisis.

The value of the responses to domestic and European uncertainty shocks is very similar; however, the duration of the response of the economic variables to Greek EPU shocks is longer than the response to European EPU shocks, indicating that the Greek economic variables are affected for a longer term by domestic uncertainty rather than foreign. This result is perhaps anticipated as the Greek EPU index is, especially during the crisis, affected mostly by domestic political and economic events. There is also positive interdependence between Greek and European policy uncertainty, but the results indicate that Greek EPU responses to European EPU shocks are higher than the reverse responses. This finding is in line with the evidence from the spillover analysis that Greece is mainly importing uncertainty from the Eurozone countries, rather than exporting.

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Appendix

B1 Data Statistics

Table B1: Descriptive statistics of the EPU indices for the Eurozone-7 countries

	France	**Germany**	**Greece**	**Ireland**	**Italy**	**Spain**	**Netherlands**
Mean	196.23	139.66	119.78	126.58	109.11	113.07	94.148
Maximum	574.63	454.00	344.23	282.12	241.03	236.58	233.73
Minimum	30.62	28.43	28.63	22.96	31.70	56.27	27.21
SD	97.27	66.21	60.28	56.79	38.076	33.05	40.03

Table B2: Descriptive statistics of the Greek economic variables

	Greek EPU	**European EPU**	**GDP**	**Stock Market Index**	**Unemployment**	**ESI Index**
Mean	119.96	145.68	51832.83	11253.71	734511.90	98.72
Maximum	51.73	60.55	6080.22	8389.27	325676.70	10.95
Minimum	44.47	60.33	44207.00	1517.48	378000.00	77.97
SD	265.75	307.63	63346.00	28831.10	1343000.00	119.97

B2 Spillovers robustness tests

Table B3: Generalised conditional spillovers for the Eurozone-7 countries - full sample

	France	Germany	Greece	Ireland	Italy	Spain	Netherlands	Contribution from others
France	45.9	16	7.7	4.8	8.6	14.1	2.9	
Germany	24	40.4	7.5	4.4	4.9	14.5	4.4	
Greece	22.5	7.8	49.2	3.5	4.4	11.2	1.4	
Ireland	19.8	10.1	2.2	50.3	3.3	11.1	3.2	
Italy	13.8	6.8	4.2	3	46	11.3	15	
Spain	20.7	9.5	5.6	4.2	7.8	41.9	10.4	
Netherlands	6.8	8.7	2.1	2.4	10.4	11.1	58.6	
Contribution to others	107.5	58.9	29.3	22.1	39.4	73.2	37.3	367.7
Contribution from others	54.1	59.6	50.8	49.7	54	58.1	41.4	367.7
Net contribution	53.4	-0.7	-21.5	-27.6	-14.6	15.1	-4.1	
Contribution including own	153.4	99.2	78.5	72.4	85.4	115.1	95.9	52.5%

Notes: The sample used is from January 2003 until June 2019. The spillover indices refer to the EPU index of Eurozone-7 countries. A VAR(1) was selected based on the AIC criterion. The variance decomposition to extract the spillover indices was estimated for 10 forecast horizons and a 24-month rolling window. The ij^{th} entry measures the estimated contribution to the forecast error variance of policy uncertainty of country i due to innovations in policy uncertainty to country j. The figures in the rows report the fraction of the forecast error variance the headline country imports from each of the other countries. The figures in the columns report the fraction of the forecast error variance the headline country exports to each of the other countries.

Table B4: Generalised conditional spillovers for the Eurozone-7 countries plus Sweden, Russia and the UK

	France	Germany	Greece	Ireland	Italy	Spain	Netherlands	Russia	Sweden	UK	Contribution from others
France	31.8	11.9	6.5	2.2	5.7	11	2.7	2.1	5.6	20.6	
Germany	14.6	31.6	5.7	2	3.6	11.3	3.1	1.2	8.1	18.9	
Greece	16.4	6.5	43.1	1.6	3.7	8.4	1.3	1.7	4.9	12.4	
Ireland	9.6	6	2.3	46.7	2.7	7.3	2.4	0.9	3.1	18.9	
Italy	11.3	5.1	4.5	2.1	40.6	9.7	14.8	0.6	4.3	7	
Spain	14.8	7.7	5.5	1.9	6.6	36.2	8.5	1.9	5.8	11.1	
Netherlands	5	5.3	2.9	3.3	10.3	8.2	53.9	0.8	5.1	4.3	
Russia	6.4	5.5	4.8	1.6	1.5	5.7	0.5	56.5	7.6	10.1	
Sweden	10.2	7.3	4.7	2.3	2.8	10.9	1.3	1.8	44.5	14.3	
UK	17	11.6	5	4.6	2.6	9.7	0.8	2.4	7.7	38.7	
Contribution to others	106.4	66.9	41.9	21.4	39.5	82.1	35.4	13.4	52.2	117.4	576.5
Contribution from others	68.2	68.4	56.9	53.3	59.4	63.8	46.1	43.5	55.5	61.3	576.5
Net contribution	38.2	-1.5	-15	-31.9	-19.9	18.3	-10.7	-30.1	-3.3	56.1	
Contribution including own	138.2	98.4	85	68.1	80.1	118.4	89.3	69.9	96.7	156	57.6%

Notes: The sample used is from January 2003 until June 2019. The spillover indices refer to the EPU index of 7 Eurozone countries. A VAR(1) was selected based on the AIC criterion. The variance decomposition to extract the spillover indices was estimated for 10 forecast horizons and a 24-month rolling window. The ij^{th} entry measures the estimated contribution to the forecast error variance of policy uncertainty of country i due to innovations in policy uncertainty to country j. The figures in the rows report the fraction of the forecast error variance the headline country imports from each of the other countries. The figures in the columns report the fraction of the forecast error variance the headline country exports to each of the other countries.

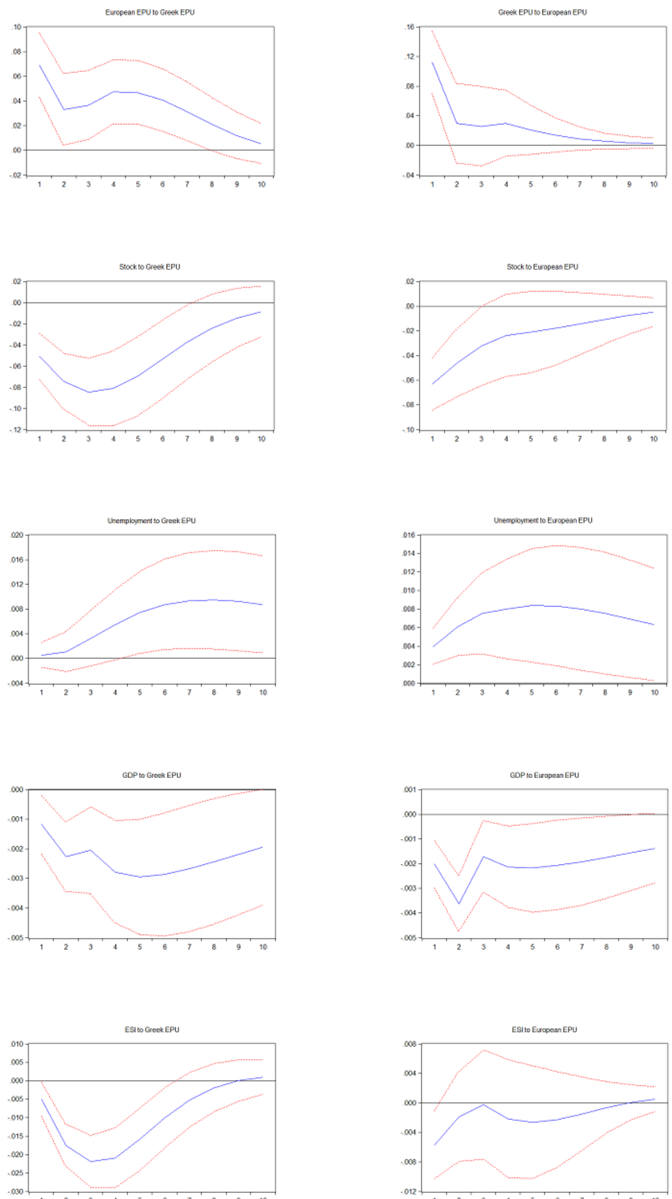
Table B5: Total spillovers of robustness tests with different forecast horizon, rolling window and country excluded

Country excluded	Period	Forecast Horizon	Rolling Windows	Total Spillover (%)
-	1st	12	12	50.6
-	1st	24	12	50.6
-	2nd	12	12	30.6
-	2nd	24	12	30.6
-	1st	12	24	50.6
-	2nd	24	24	30.6
France	1st	10	24	44
Germany	1st	10	24	45.2
Greece	1st	10	24	48.6
Ireland	1st	10	24	48.3
Italy	1st	10	24	47.5
Spain	1st	10	24	42.5
Netherlands	1st	10	24	43.5
France	2nd	10	24	22
Germany	2nd	10	24	24.8
Greece	2nd	10	24	28.5
Ireland	2nd	10	24	33.2
Italy	2nd	10	24	24.6
Spain	2nd	10	24	26.9
Netherlands	2nd	10	24	25.9

Notes: As 1st period we define the period January 2003 to December 2019, while 2nd is the period January 2010 to June 2019. The main estimation of the paper is for 10 forecast horizons and a rolling window equal to 20.

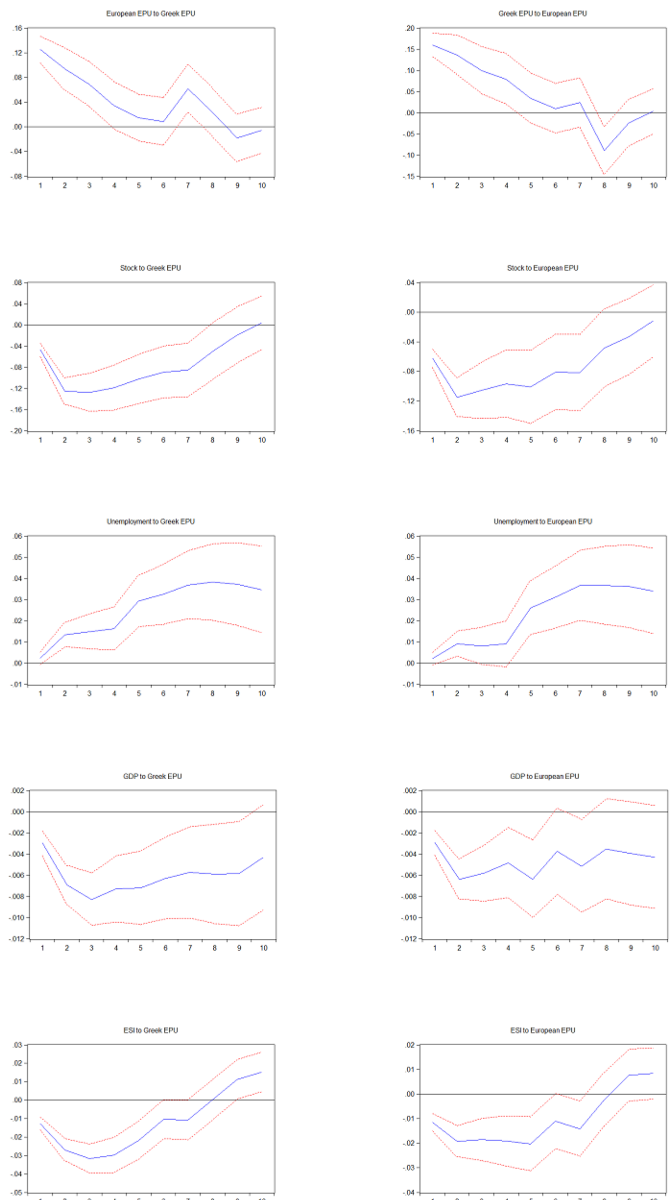
B3 Greek GIRFs robustness tests

Figure B1: Generalised impulse responses for the pre-crisis period



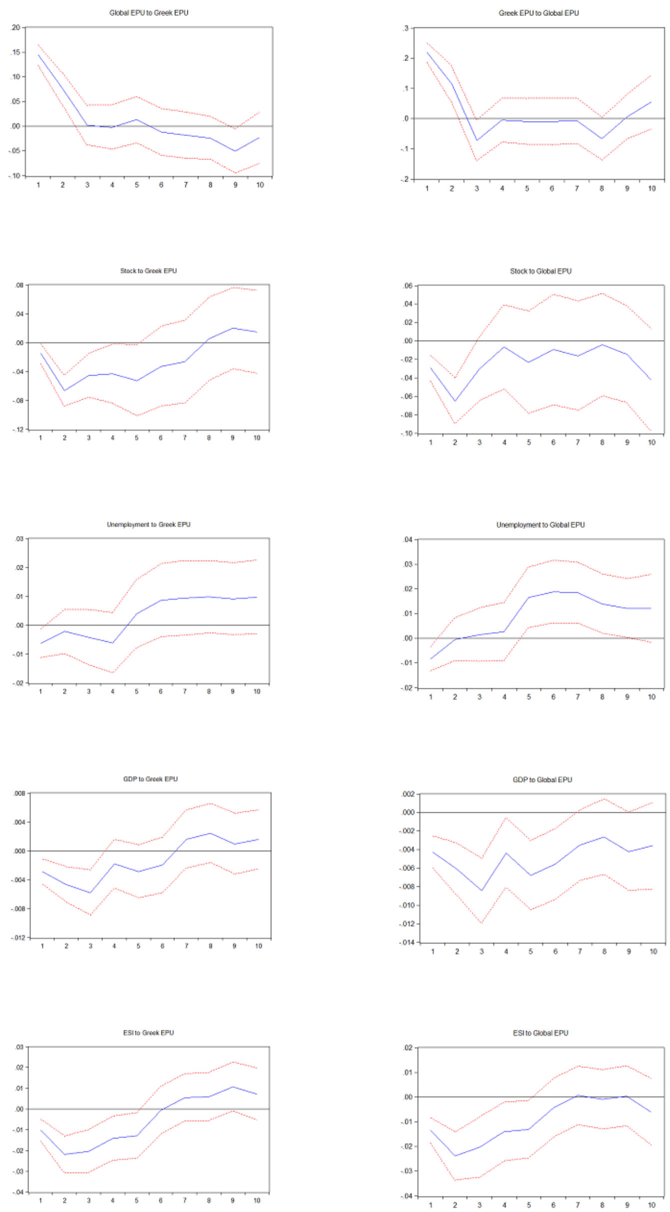
Notes: Generalised impulse responses to one SD innovations (±1 SE) in the Greek and European EPU indices. Sample: 1998Q2-2010Q1.

Figure B2: Generalised impulse responses for the post-crisis period



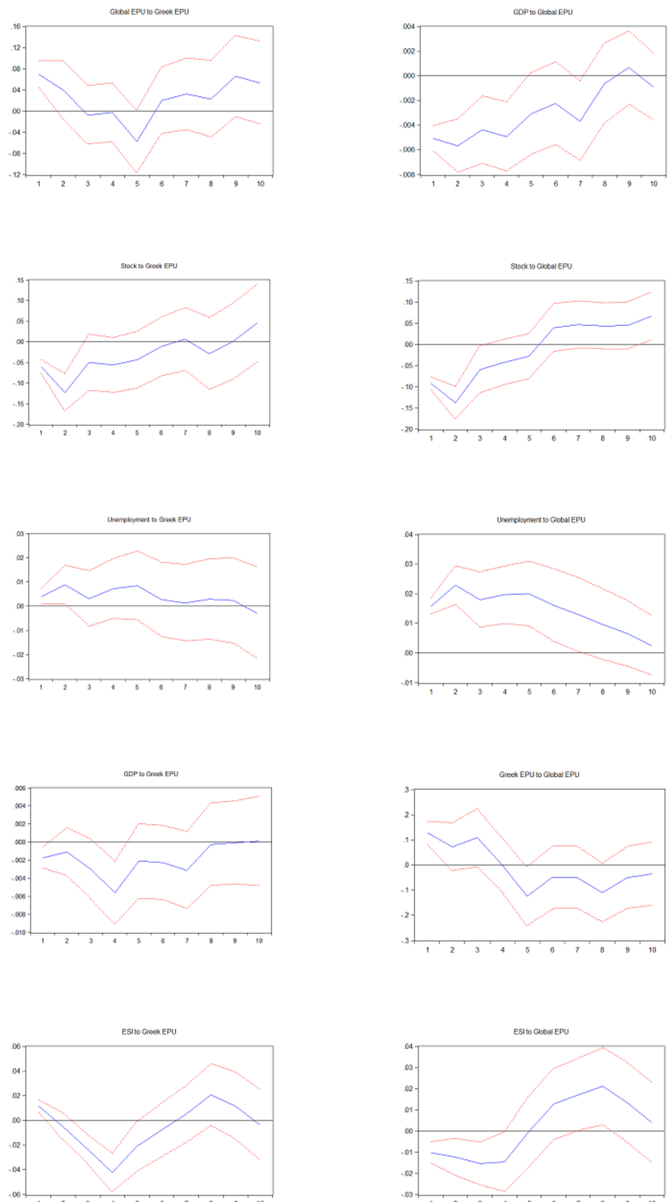
Notes: Generalised impulse responses to one SD innovations (±1 SE) in the Greek and European EPU indices. Sample: 2010Q2-2019Q1.

Figure B3: Generalised impulse responses for the pre-crisis period with Global EPU instead of European EPU



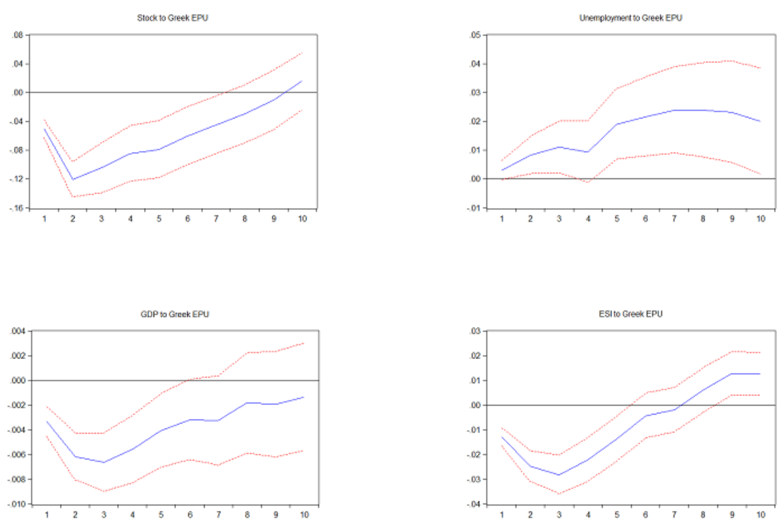
Notes: Generalised impulse responses to one SD innovations (±1 SE) in the Greek and European EPU indices. Sample: 1998Q2-2010Q1.

Figure B4: Generalised impulse responses for the post-crisis period with Global EPU instead of European EPU



Notes: Generalised impulse responses to one SD innovations (±1 SE) in the Greek and European EPU indices. Sample: 2010Q2-2019Q1.

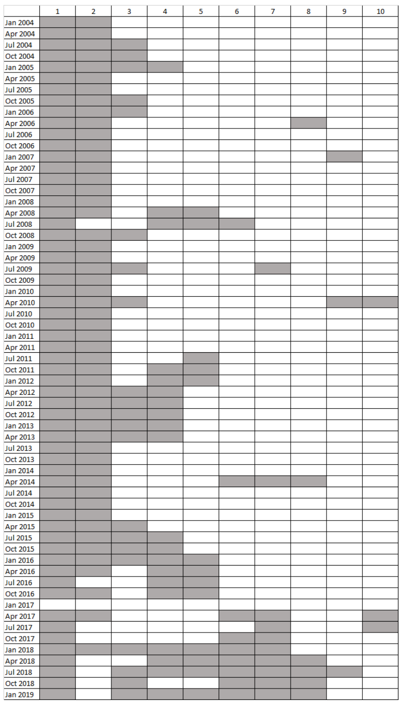
Figure B5: Generalised impulse responses for the full sample without the European EPU index



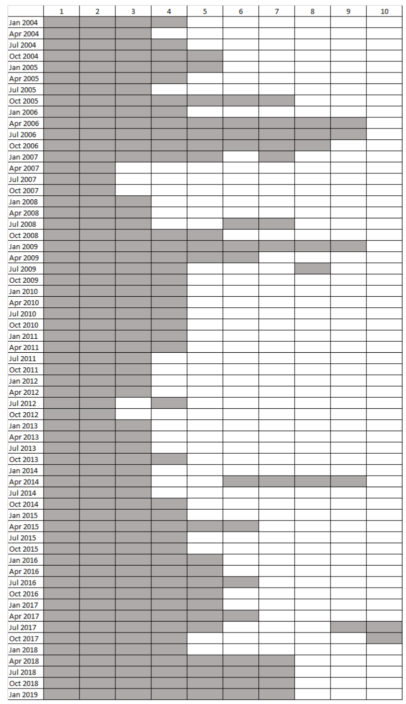
Notes: Generalised impulse responses to one SD innovations (±1 SE) in the Greek and European EPU indices. Sample: 1998Q2-2019Q1.

Figure B6: Statistical significance of rolling GIRFs

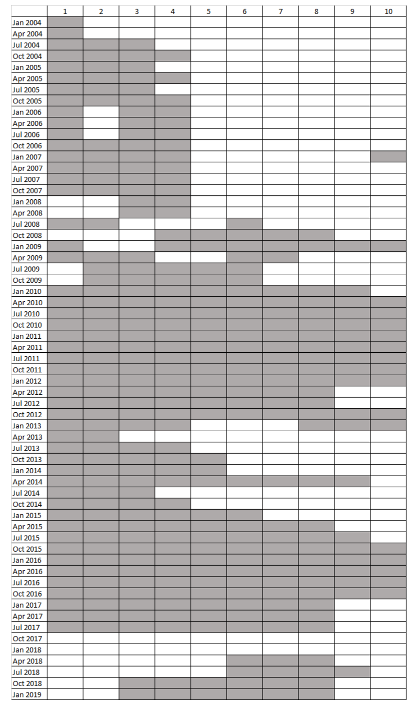
(a) European EPU to Greek EPU shocks



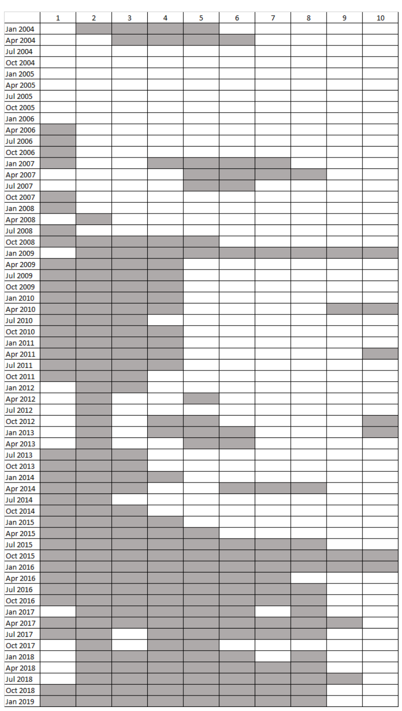
(b) Stock index to Greek EPU shocks



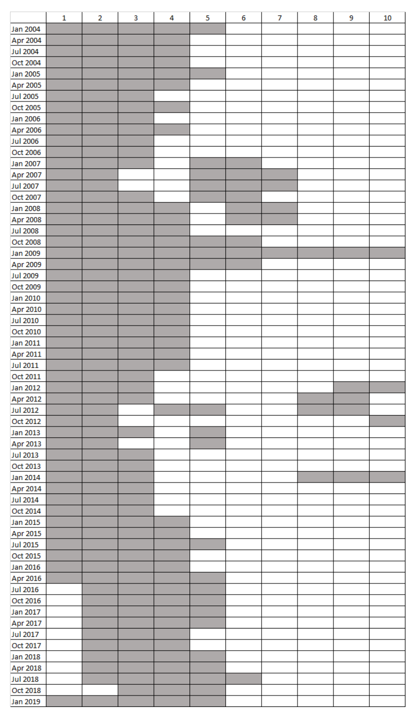
(c) Unemployment to Greek EPU shocks



(d) GDP to Greek EPU shocks



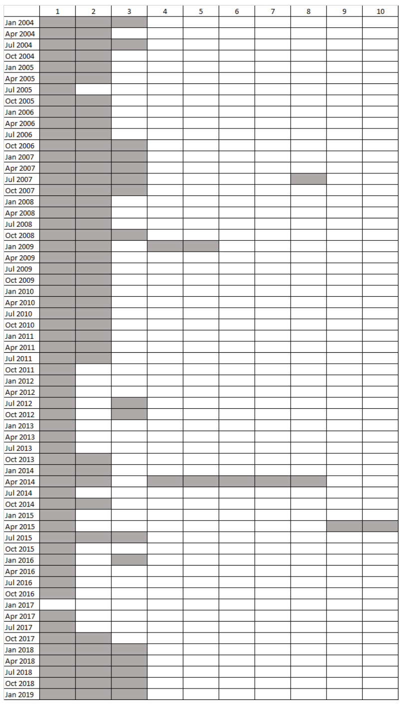
(e) ESI to Greek EPU shocks



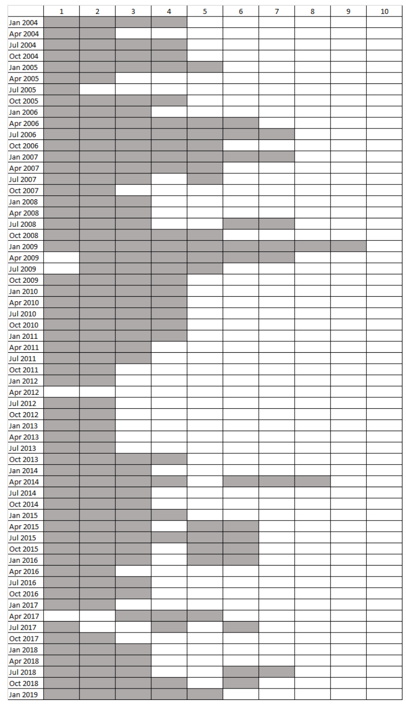
Notes: Coloured cells imply statistical significance of the response, while the blank ones imply the response is not statistically significant.

Figure B7: Statistical significance of rolling GIRFs

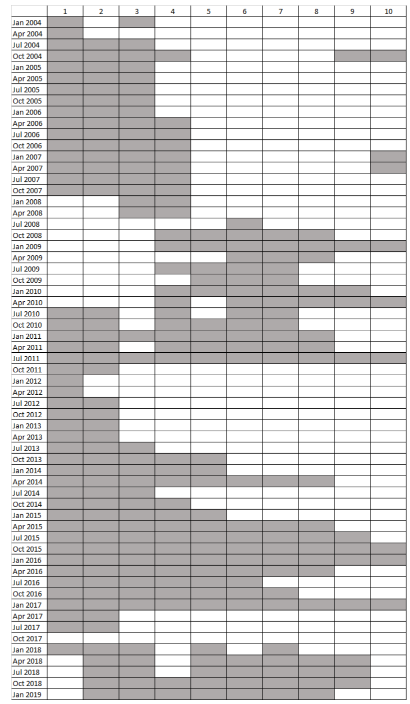
(a) Greek EPU to European EPU shocks



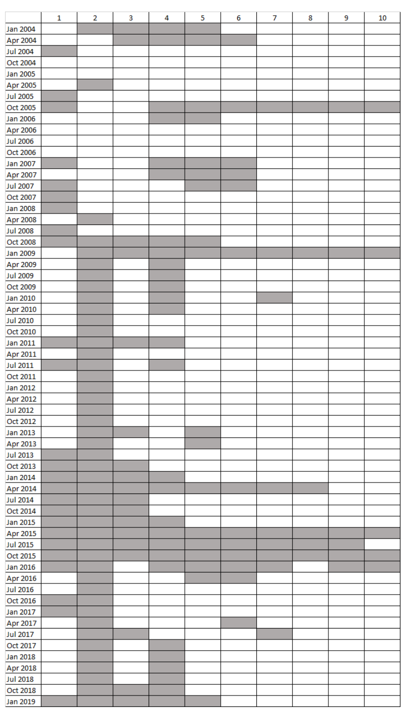
(b) Stock index to European EPU shocks



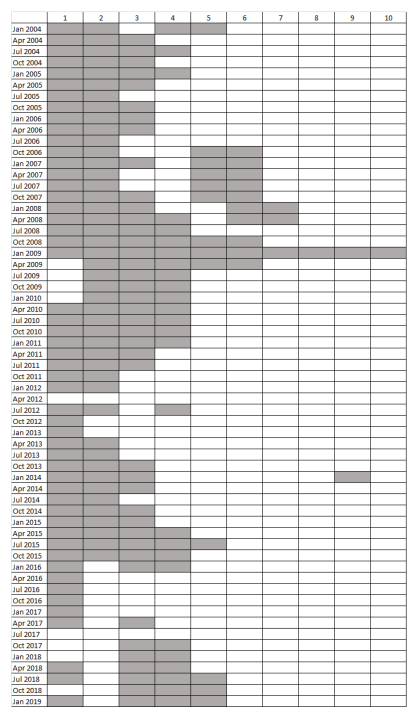
(c) Unemployment to European EPU shocks



(d) GDP to European EPU shocks



(e) ESI to European EPU shocks



Notes: Coloured cells imply statistical significance of the response, while the blank ones imply the response is not statistically significant.

CHAPTER

THREE

ECONOMIC POLICY UNCERTAINTY AS AN INDICATOR OF ABRUPT MOVEMENTS IN THE US STOCK MARKET

Abstract

A two-state regime switching model is developed in an attempt to relate expected US stock market returns to deviations from fundamentals and to Economic Policy Uncertainty (EPU). The analysis is based on monthly data that cover the period from January 1900 to March 2020 and the EPU index is used as an explanatory variable. The findings suggest that the US stock market spends most of the time in a low-volatility regime, periodically switching to a high-volatility regime during times of financial instability. In an attempt to examine the forecasting ability of the model, out-of-sample probabilities of a crash are estimated recursively. The results provide evidence that our model is able to depict periods of abrupt movements in the US stock market. Finally, the estimated model and the associated probability of a crash is used to develop and evaluate a proposed trading strategy, in order to analyse the financial usefulness of the model. This trading rule outperforms the simple buy-and-hold strategy and this superiority is statistically significant.

3.1 Introduction

The global financial crisis of 2008 and the Eurozone economic crisis have brought about increased interest on economic uncertainty. The Economic Policy Uncertainty index (hereafter EPU), introduced by Baker, Bloom and Davis (hereafter BBD, 2016), has been the subject of a significant part of the literature recently. The EPU index was introduced as a measurement that quantifies uncertainty about the economic policies. It is a newspaper-based indicator that captures both short- and long-run uncertainty about who will apply the economic policy, what economic regulations will be made, what will the results of these policy actions be etc. It is constructed by searching the digital archives of large newspapers for the number of published articles that refer to economic policy uncertainty. More specifically, the EPU index measures the proportion of articles that include at least one word from each of the following 3 categories: Economy, Policy, Uncertainty.

So far, most of the research on EPU focuses on its relationship with various macroeconomic variables, such as output and unemployment, while only a few studies examine its effect on the stock market. Among them, most studies focus on the effects of EPU on stock market volatility. In this study, we investigate the ability of EPU to capture the dynamics in the stock market returns and predict stock market crashes. To the best of our knowledge, Arouri et al. (2016) is the only study in the literature that applies a regime switching model to examine the effect of EPU on stock market returns. However, there are significant differences between the aforementioned study and our analysis. More specifically, we contribute to the literature since, contrary to Arouri et al. (2016), our specification (i) includes deviations from fundamentals (we call them "bubbles"), (ii) allows EPU to enter both the mean and the probability equation and (iii) helps us develop a trading strategy. In this way, we test the ability of EPU to act as an early warning indicator for abrupt movements in the stock market. Thus, our model allows us to calculate the probability of a stock market crash as a function of both the bubble size and EPU and develop a trading strategy that takes this information into account.

We use monthly data from 1900 to 2020 for the US stock market and the US EPU index, and apply a two-state regime switching model, where we identify the *survival* and the *collapse* regimes. The in-sample analysis shows that the EPU coefficient is statistically significant, both in the return equation and the probability equation. We then proceed with the out-of-sample analysis to examine the forecasting ability of the model. The model seems to predict some of the bubble crashes, but not all of them. Finally, we propose a trading rule, which informs the investor when to exit the market and when to reenter the market based on estimated probabilities of a stock market crash. This trading rule seems to offer higher return to the investor compared to a buy-and-hold strategy for the period under scrutiny.

The rest of the paper proceeds as follows. Section 3.2 provides a literature review, Section 3.3 presents the empirical analysis that includes the description of the data, the bubble measures and the methodology we use, the in-sample and the out-of-sample findings and a trading rule that we introduce. Several robustness tests are presented in Section 3.4. Finally, Section 3.5 concludes the paper.

3.2 Literature Review

Since the innovative work by Hamilton (1989), the regime switching models became very popular in modelling economic and financial variables and many studies follow this approach in an attempt to describe the dynamics in international stock markets. For example, van Norden and Schaller (1993) and Schaller and van Norden (1997) build on the work of Blanchard and Watson (1982) and use regime switching models to identify the relationship between stock market returns and bubbles, or deviations from fundamentals as they aptly call them. They assume two states: the state in which the bubble survives and the state in which the bubble collapses. Their specification also allows for partial bubble collapses. In their approach, van Norden and Schaller (1993) allow the probability of being in each state to be a function of the bubble, and more specifically they assume that the probability falls as the size of the bubble grows. Their findings show that bubbles help in indicating regime switches in the US stock market. Later, in 1997, they extend their approach by introducing a multivariate specification in their regime switching model. They show that by adding macroeconomic variables to the specification of their model, strong evidence of predictability of stock market returns is found. Another contribution of Schaller and van Norden (1997) to the literature is that they allow the probability of transitions between the two states to depend on macroeconomic variables.

A few years later, Brooks and Katsaris (2005) extend the regime switching specification of van Norden and Schaller (1993) and Schaller and van Norden (1997) by introducing a third state in their model. During the dormant state, as they call the third state of their specification, the bubble continues to grow steadily at the fundamental rate of return. In the context of the three-state regime switching framework, they find evidence that deviations from fundamentals have explanatory power over the stock market returns. They also create trading rules in an attempt to enhance the financial usefulness of their model.

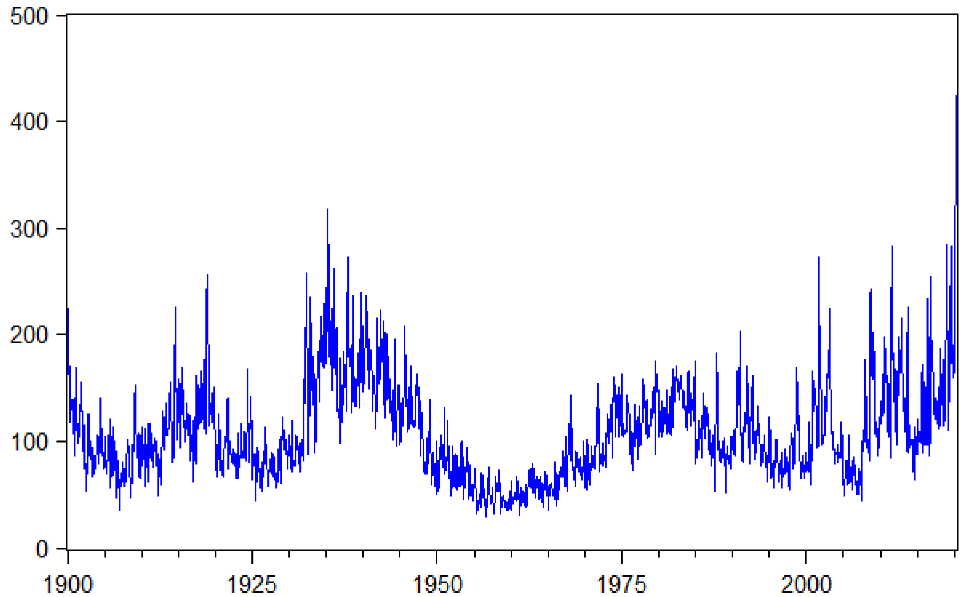
Many studies estimate regime switching models to investigate the dynamics in other markets, such as the commodities and the foreign exchange markets. Roche (2001) provides evidence of bubbles in house prices in Dublin by means of a regime switching model. On the other hand, Shi and Arora (2012) and Panopoulou and Pantelidis (2015b) focus on the oil market using both two- and three-state regime switching models. Their findings reveal that regime switching models are able to capture the dynamics in the oil market and they also have better oil price predictability than the Random Walk model. Other studies use regime switching models to examine the exchange rate markets. For example, van Norden (1996) applies a regime switching model of stochastic bubbles for the exchange rate of the US Dollar, the Canadian Dollar, the Japanese Yen and the German mark. Regime switching models are later used as a test for exchange rate bubbles also by Panopoulou and Pantelidis (2015a), who apply both two- and three-regime switching models using various variables as early warning indicators. They find that the regime switching models outperform the Random Walk model.

The introduction of the EPU index by BBD (2016) attracted the interest of many researchers. However, most studies focus on the effect of EPU on macroeconomic variables. BBD (2016) and Antonakakis et al. (2016), using VAR models, find that investment, output and employment respond negatively to EPU changes. Evidence for Sweden supports that the GDP is negatively affected by the EPU index (Armelius et al., 2017). Zalla (2017) examines the impact of EPU on the macroeconomic variables of Ireland. Cerda et al. (2018), Sahinoz and Cosar (2018), and Ghirelli et al. (2019) show how investment, consumption and GDP respond with a fall to increases of the Chilean, Turkish and Spanish EPU indices, respectively.

So far, only a few papers have investigated the relationship between the EPU index and the stock market. One of the first papers in this strand of the literature is by Karnizova and Li (2014) who use both in-sample and out-of-sample analysis to examine the forecasting ability of EPU. They find that adding the EPU index to a model that includes other financial variables as well, improves the forecasting accuracy for recessions. Antonakakis et al. (2013) provide evidence that EPU increases result in a fall of stock market returns. On the other hand, Liu and Zhang (2015) aim at examining the predictive ability of the EPU index for the realised volatility of the stock market. The in-sample results show a positive effect of EPU on stock market volatility and the out-of-sample analysis concludes that EPU helps in predicting the realised volatility of the stock market. More recently, He et al. (2020) examine the asymmetric volatility spillovers between EPU and the S&P500 index and they find evidence that the volatility of the stock market is a net recipient of EPU spillovers. Moreover, Luo and Zhang (2020) find that an increase on EPU has a significant positive effect on the aggregated stock price crash risk.

Finally, our study is related to Arouri et al. (2016), since both studies use regime switching models to examine the effect of EPU on stock market returns. More in detail, Arouri et al. (2016) use a three-state regime switching model and, based on data that cover a long period (1900-2018), they conclude that the EPU-stock market relationship is not linear, since it differs among different states. Moreover, their findings suggest that the impact of EPU on the stock market is stronger and more persistent in the high volatility regime. However, their specification does not include the EPU index in the equation that determines the probability of transitions among states. Contrary to Arouri et al. (2016), our study allows EPU to enter the probability equation and to serve as an early warning indicator for abrupt movements in the stock market. In this way, we are able to estimate the probability of a crash in the stock market as a function of EPU and develop a trading strategy that takes into account this information. Finally, another important difference between our paper and Arouri et al. (2016) is that, contrary to them, we include deviations from fundamentals in our specification.

Figure 3.1: Economic Policy Uncertainty index, January 1900 - March 2020, US



3.3 Empirical analysis

3.3.1 Data

Our dataset consists of monthly US data and covers a period of more than a century, from January 1900 to March 2020. The data for the US EPU index are retrieved from Baker, Bloom and Davis (2016)[1]. The path of the US EPU index is shown in Figure 3.1 and it can be seen that the EPU mean value and volatility increased during the Great Depression (1930) and during the global financial crisis (2008). For the estimation of the bubble measure we need the S&P500 composite index, the dividend and the Consumer Price Index (hereafter CPI) as a proxy of the general price level. These three variables are retrieved from Shiller (2000)[2] and used to estimate the bubble size as explained in Section 3.3.2.

[1]Data are available at the website *http://www.policyuncertainty.com/*. For the US there are two different measurements of the EPU index; the baseline overall index and the news-based policy uncertainty index. The first measurement is only estimated for the US, while the second one is available for various countries. We, therefore, choose to use the news-based policy uncertainty index.

[2]Data are available at the following website: *http://www.econ.yale.edu/∼ shiller/data.htm*.

3.3.2 Methodology

Deviations from fundamentals ("bubbles")

Shiller (2000) highlights the importance of understanding whether an increase in the stock market is actually a deviation from the fundamental values of the market, thus a speculative bubble, that will eventually at some point collapse. The query of whether and how asset bubbles can be detected has been the focus of many economists for many years. Early research on this field of stock market bubbles was conducted by Blanchard (1979), Flood and Garber (1980), and Blanchard and Watson (1982). The term "bubble" is also explained as rational deviations from the fundamental value. Fundamentals are only one part of the price of the stock market. There is also another part, that might be influenced by extraneous factors. So, rational deviations from the fundamental price might exist and this exact deviation from fundamentals is the so called "rational bubble". Gürkaynak (2008) presents an analytic and critical review of the ways that bubbles can be identified. Much literature has focused on the field of stock market bubbles, like Diba and Grossman (1988), Hamilton and Whiteman (1985), Evans (1991), Froot and Obstfeld (1991), and Enders and Granger (1998).

The literature proposes several ways of estimating bubbles. We choose to estimate two different bubble measures, in order to be able to test for robustness. The first way is with a constant dividend growth rate. We begin with the following arbitrage condition:

$$E_t(P_{t+1}) = (1+r)(P_t + D_t), \tag{3.1}$$

where P_t is the stock market price, r is the constant rate of return and D_t is the dividend. To estimate the value of the bubble, we first need to have the value of the fundamental price, which, according to Lucas (1978), is:

$$P_t^* = \rho D_t, \tag{3.2}$$

where $\rho = \frac{1+r}{exp(\alpha+\frac{\sigma^2}{2})-1}$.

The bubble equals the deviation of actual prices from the fundamental price, thus is estimated as:

$$b_t^A = \frac{P_t - P_t^*}{P_t} = 1 - \rho\frac{D_t}{P_t}, \tag{3.3}$$

and ρ is the mean of the price-dividend ratio.

The second bubble measure assumes that the dividend growth rate is not constant but varies over time. Following the present-value model presented by Campbell and Shiller (1987), we assume that the present value of the stock prices is a linear function of the discounted value of the dividends:

$$P_t = E_t \sum_{i=0}^{\infty} \left(\frac{1+r}{r}\right)^i D_{t+i}. \tag{3.4}$$

Campbell and Shiller (1987) also use the term *spread*, defined as:

$$S_t = P_t^* - \frac{1+r}{r}, \tag{3.5}$$

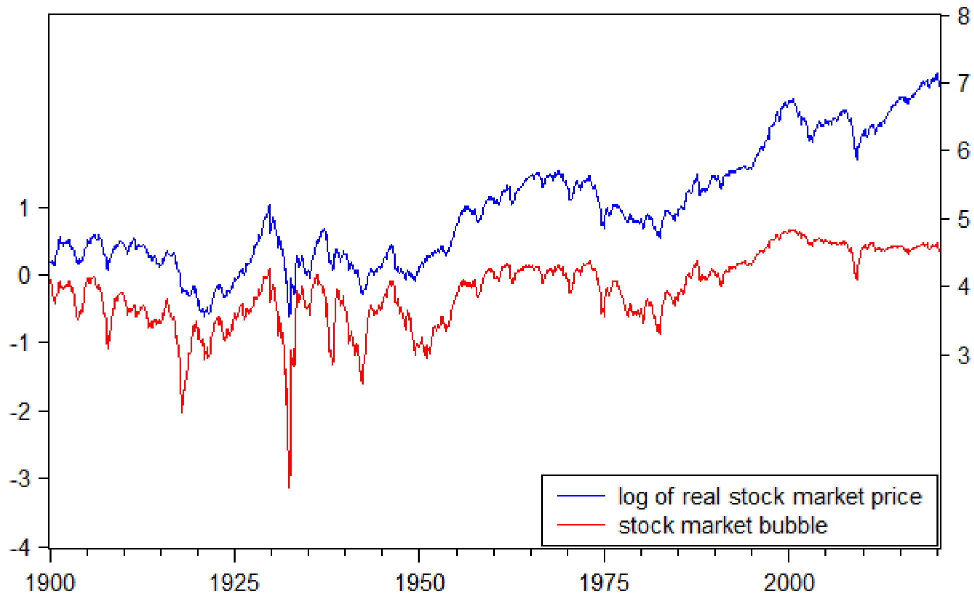
which can be written in the form of a linear function of the dividends (D_t):

$$S_t = \frac{1+r}{r} \sum_{i=0}^{\infty} \left(\frac{1+r}{r}\right)^i E_t(\Delta D_{t+i}). \tag{3.6}$$

They note that for the case of stocks, this spread represents "the difference between the stock prices and a multiple of dividends". The spread is estimated by applying a Vector Autoregressive (VAR) model and then we get the second bubble measure as follows:

$$b_t^B = 1 - \frac{S_t + \frac{1+r}{r}D_{t-1}}{P_t} = \frac{P_t - [S_t + \frac{1+r}{r}D_{t-1}]}{P_t}, \tag{3.7}$$

Figure 3.2: Stock market bubble and stock market prices, US



where $r = \frac{\bar{D}-1}{\bar{P}}$, $\bar{D}$ is the mean value of the dividend, and $\bar{P}$ is the mean value of the price. We repeat our empirical analysis using both bubble measures. For brevity, we present the findings only for the first bubble measure, while results for the second one are quantitatively and qualitatively similar.

Figure 3.2 plots the first bubble measure for the US stock market, as estimated by equation (3.3), together with the real stock market price level in logarithms. It is obvious that the path of the bubble is similar to the path of the stock market price level. When the bubble moves away from the zero value, the stock market deviates much from it's fundamental value and as it can be seen by the figure this usually happens when the real stock market price falls sharply. High deviations from fundamentals are observed (i) in 1931-32 during the Great Depression, (ii) in 1938, a year with a stock market crash, triggered by the economic recession that was caused by the Great Depression and the high uncertainty about the effectiveness of Roosvelt's New Deal policy, (iii) in 1982 when a bear market was experienced due to a prolonged stagflation, and (iv) in 2008, when the Lehman Brothers collapsed and the global financial crisis began. Another observation worth noting is that the deviations from fundamentals were much sharper until the 1950s, and, especially since 1990, the volatility of the bubble measure is much smoother than in the previous years, with only a sharp fall in 2008.

Regime switching model

Following van Norden and Schaller (1993), we use a two-state regime switching model that allows the bubble to move between two different states: *(i)* the *survival* (S) state, in which the bubble continues to survive, and *(ii)* the *collapse* one (C), in which the bubble crashes. The linear two-state regime switching model and the associated probabilities we use are described by the following equations:

$$R^s_{t+1} = b_{s0} + b_{s1}B_t + b_{s2}epu_t + e^s_{t+1}, \tag{3.8}$$

$$R^c_{t+1} = b_{c0} + b_{c1}B_t + e^c_{t+1}, \tag{3.9}$$

$$Pr(W_{t+1} = s) = n_t = \Phi(b_{n0} + b_{n1}|B_t| + b_{n2}epu_t), \tag{3.10}$$

$$Pr(W_{t+1} = c) = 1 - n_t, \tag{3.11}$$

where R_i is the expected excess return for regime i, B_t is the bubble size, epu_t the Economic Policy Uncertainty index, $e^i_{t+1} \sim N(0, \sigma^2_i)$ and Φ is the standard normal cumulative density function. The expected excess return in regime S is a function of both the bubble size and the EPU index, while the expected return in regime C is only a function of the bubble size. $Pr(W_{t+1} = s)$ is the probability of being in the S regime and it is assumed to be a function of the absolute value of the bubble and EPU, while $Pr(W_{t+1} = c)$ is the probability of being in regime C.

The model is estimated by maximising the likelihood function:

$$l(r_{t+1} \mid \xi) = \prod_t \left[\frac{n_t \phi\left(\frac{b_{s0}+b_{s1}B_t+b_{s2}epu_t-R^s_{t+1}}{\sigma_s}\right)}{\sigma_s} + \frac{(1-n_t)\phi\left(\frac{b_{c0}+b_{c1}B_t-R^c_{t+1}}{\sigma_s}\right)}{\sigma_c} \right], \tag{3.12}$$

where ϕ is the standard normal probability density function (*pdf*) and σ_i is the standard deviation of $e_{i,t+1}$.

As presented above, the *ex ante* probability of R_{t+1} being in regime S is n_t and in regime C is $1 - n_t$. The *ex post* probabilities can be derived by the following equations:

$$p_t^{x,s} = \frac{\frac{n_t}{\sigma_s}\phi\left(\frac{e^s_{t+1}}{\sigma_s}\right)}{\frac{n_t\phi\left(\frac{R^s_{t+1}-b_{s0}-b_{s1}B_t-b_{s2}epu_t}{\sigma_s}\right)}{\sigma_s} + \frac{(1-n_t)\phi\left(\frac{R^c_{t+1}-b_{c0}-b_{c1}B_t}{\sigma_c}\right)}{\sigma_c}}, \tag{3.13}$$

$$p_t^{x,c} = \frac{(1-\frac{n_c}{)}\sigma_c\phi\left(\frac{e^c_{t+1}}{\sigma_c}\right)}{\frac{n_t\phi\left(\frac{R^s_{t+1}-b_{s0}-b_{s1}B_t-b_{s2}epu_t}{\sigma_s}\right)}{\sigma_s} + \frac{(1-n_t)\phi\left(\frac{R^c_{t+1}-b_{c0}-b_{c1}B_t}{\sigma_c}\right)}{\sigma_c}}. \tag{3.14}$$

The probabilities of unusually low returns can also be calculated. As an unusual movement of the returns, we consider the case of changes by more than two standard deviations below the mean return. Thus, the conditional probability of a crash is given by:

$$Pr(r_{t+1} < k) = n_t\Phi\left(\frac{k - b_{s0} - b_{s1}B_t - b_{s2}epu_t}{\sigma_s}\right) + (1 - n_t)\Phi\left(\frac{k - b_{c0} - b_{c1}B_t}{\sigma_c}\right), \tag{3.15}$$

where the critical value is $k = mean(R_t) - 2\sigma_{R_t}$.

3.3.3 In-sample results

In this section, we provide the results of the two-state regime switching model presented above for the first bubble measure (equations 3.8, 3.9, 3.10, 3.11). Table 3.1 presents the coefficient estimates and their standard errors. Almost all coefficients are statistically significant at the 1% level, and only b_{s0} and b_{s1} are not statistically significant. The constant, b_{c0}, in the collapse regime is significant and negative (-0.045258), as it was expected from the theory and the literature. This means that in regime C the expected excess return is almost -4.5% per month. When it comes to the slope coefficients, theory implies no sign restrictions. Moreover, the slope coefficient in the collapse regime is negative, meaning that in the

Table 3.1: Model coefficients for the first bubble measure

	Coefficient	Std. Error
b_{s0}	0.001256	0.002404
b_{s1}	0.000457	0.001950
b_{s2}	7.23E-05**	2.17E -05
b_{c0}	-0.045258**	0.015540
b_{c1}	-0.022060**	0.010484
σ_s	0.029099**	0.000782
σ_c	0.089747**	0.004801
b_{n0}	2.275214**	0.235244
b_{n1}	-0.745436**	0.206305
b_{n2}	-0.005580**	0.001519

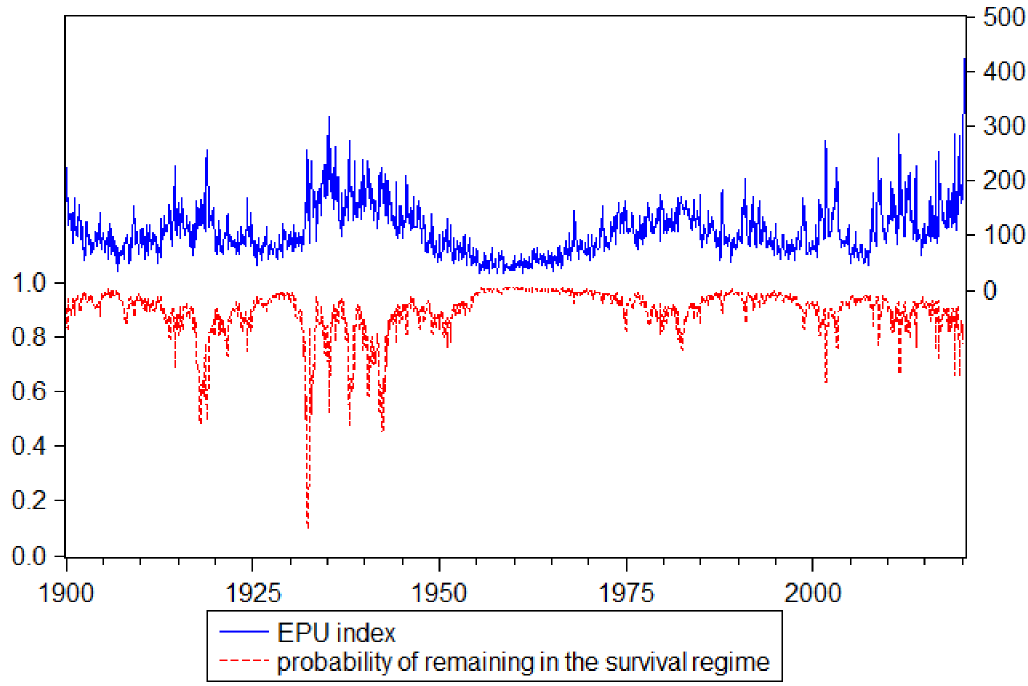
Notes: The coefficients marked with ** are significant at 1% level. Sample January 1900 to March 2020. 1443 observations.

collapse regime expected returns fall when the bubble size increases, as expected. The slope coefficient of EPU in the survival regime is positive, implying that when EPU increases the expected return for the next period will increase. This makes sense, as increased uncertainty implies increased risk, which would require higher returns for the investors.

The estimated constant coefficient for the probability of being in the survival regime is 2.275214 and by calculating the probability $\Phi(b_{n0})$ we get that, on average, if the bubble size and EPU were zero, the probability of being in the survival regime would be about 98.86%. The coefficients of both the bubble size and the EPU index are negative, which connotes that when the bubble size or/and the EPU index increase, the probability of switching to the collapse regime increases as well. The standard deviation of the error term in the collapse regime (0.089747) is higher than the standard deviation in the survival regime (0.029099). This is reasonable since volatility increases sharply during a stock market crash.

The red dotted line in Figure 3.3 captures the probability of being in regime S. The probability is, in general, very high and close to unity, as expected, but there are also significant drops implying that at these points in time, there was a high probability for a regime change, that means high probability for the bubble to collapse. Some sharp declines in the probability of being in regime S are observed during periods of abrupt market moves, such as the declines in (i) 1932 (Great Depression), (ii) 1942 (2nd World War bear market), (iii)

Figure 3.3: EPU and the probability of being in the survival regime



1982 (bear market due to long-lasting stagflation), (iv) 2000 (dot-com bubble crash), (v) 2008 (Lehman Brothers and global financial crisis) and (vi) 2011 (Black Monday of August 8th). The same graph also pictures the path of the EPU index, indicating that uncertainty and the probability of being in the survival regime move coordinately in different directions throughout the sample.

The probability of being in any of the two regimes has so far been estimated based on the full-sample. However, in order to examine the predictive ability of our model, we should re-estimate all probabilities in an recursive way using only the information that is available to the investor. This is what we do in Section 3.3.4.

In an attempt to evaluate the ability of our model to identify the regimes, we calculate the Regime Classification Measure (RCM) proposed by Ang and Bekaert (2002). They suggest that if an estimated model does a good job in identifying regimes, the estimated probabilities of being in each regime should be close to either 1 or 0 throughout the estimation sample. RCM can vary from 0 to 100 and for a two-state regime model it is calculated as follows:

$$RCM = 400 * \frac{1}{T} \sum_{t=1}^{T} p_t(1 - p_t). \tag{3.16}$$

The lower the value of RCM, the better the regime classification of the estimated model, since an RCM equal to 0 implies a regime switching model that identifies regimes perfectly. In our case, RCM is equal to 35 suggesting a good, but not a perfect, regime classification.

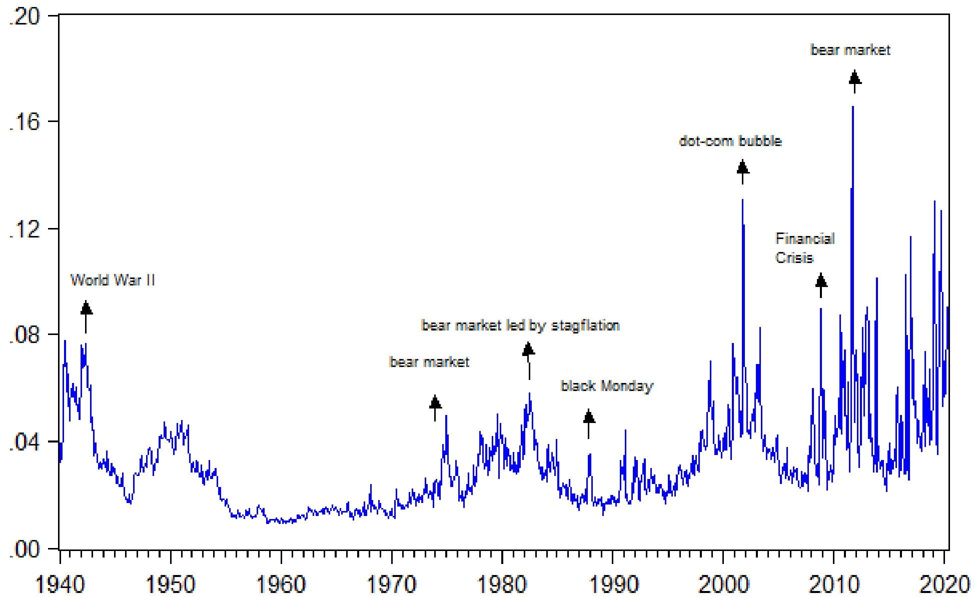
3.3.4 Out-of-sample results

So far, we have examined the in-sample power of the model to capture the dynamics of the stock market returns. Since all the aforementioned analysis is based on full-sample estimates, we cannot say much about the actual forecasting ability of the model. In this section, we present a set of out-of-sample results in an attempt to evaluate the forecasting ability of our model.

We start by recursively estimating our model and the corresponding probabilities of a crash as described in equation (3.15) (Brooks & Katsaris, 2005). More in detail, we use the first 40 years of our sample (January 1900 to December 1939) to estimate our model and the probability of a crash and we repeat the estimation adding one observation at a time until we reach March 2020. In this way, we obtain a recursive estimation of the model and the associated probabilities of a crash.

Figure 3.4 depicts the estimated probabilities of a crash. The graph clearly shows that sharp increases of the probability of a crash coincide with abrupt crashes of the stock market. For instance, the peak of the recursively estimated probability of a crash in September 2011 captures the severe, but short-lived, crash in the stock market that period. Other peaks of the probability of a crash capture the dot-com bubble crash, the 2008 global financial crisis, the bear market during the 2nd World War etc. However, not all peaks of the probability of a crash are followed by actual stock market falls. Another interesting point is that after 2000 the probability of a crash is much more volatile compared to the previous years.

Figure 3.4: Recursive probability of a crash

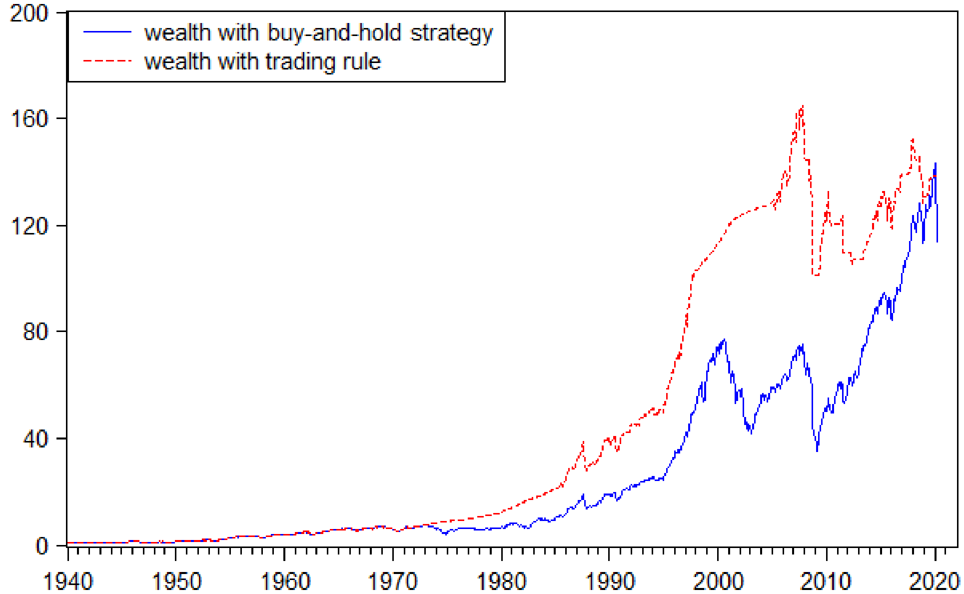


3.3.5 Trading rule

We now try to develop a trading rule in an attempt to enhance the financial usefulness of our model. We apply the trading rule to a period that covers about 80 years, that is, from January 1940 to March 2020. We consider two investors who decide to invest 1 US dollar each in January 1940. However, the two investors follow different trading strategies. The first investor follows a simple buy-and-hold strategy, meaning that she enters the market in January 1940 and stays in the market until March 2020. On the other hand, the second investor chooses to use our model to decide when to enter and when to exit the market on a monthly basis.

The trading rule we apply is similar to the one proposed by Brooks and Katsaris (2005). Specifically, we assume that when the probability of a crash is higher than the upper 90^{th} percentile of its 20-year historical value, the investor exits the market, investing her money to a risk-free asset and gaining the risk-free rate. This position is maintained until the probability of a crash falls below its 20-year historical median value. The median is used to avoid the decision being affected by extraordinary large values of the probability of a crash.

Figure 3.5: Wealth with and without trading rule

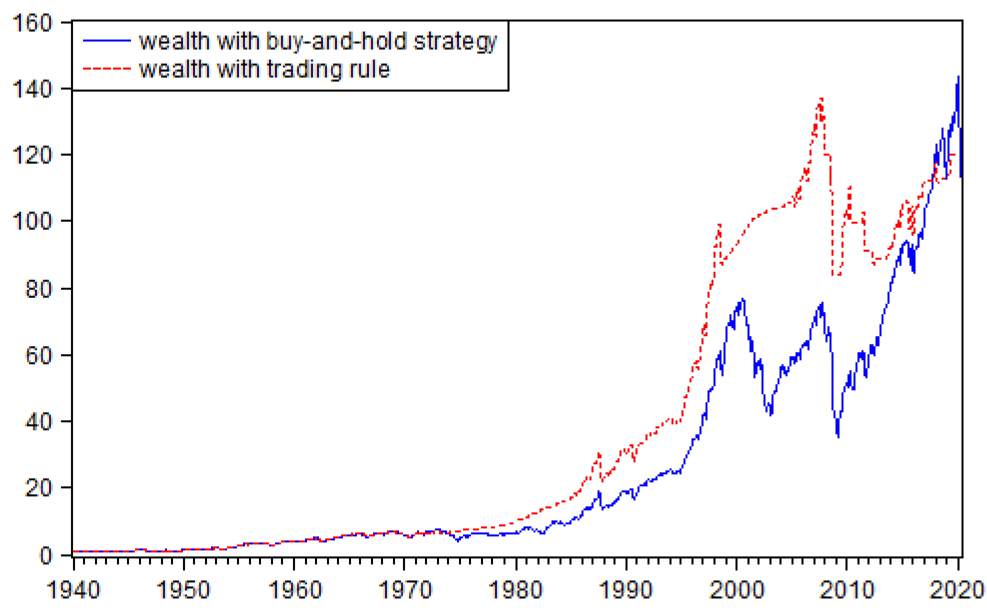


In all cases, the median and the 90^{th} percentile of the probability of a crash are calculated using a fixed-size window of the latest 240 months (20 years). When the investor is out of the market, she earns the risk-free rate. We consider the 3-month treasury bill rate as the risk-free rate. We also assume that the transaction cost every time the investor exits or enters the stock market is equal to 0.1% of the value of the trade.

In order to have a clear picture of whether the estimated wealth for the trading rule is statistically significant or not, we apply a test for the significance of the estimation by running a simulation of 10,000 trading paths, which randomly generate dummy series of 1s and 0s, indicating when the investor is in or out of the market, respectively. The length of the dummy series is equal to 963 periods which is equal to the number of months in the January 1940 to March 2020 period. We also set the randomly selected exits and enters in the market equal to 28 ($14x2$), equal to the total exits and enters of the actual trading strategy. We then compare the returns of the actual trading rule with the simulated ones and if the wealth of our actual trading strategy is higher than the 90%, 95% or 99% of the simulated ones, we establish the corresponding significance level.

According to Figure 3.5, until the early 1970s both our trading strategy and the buy-and-hold approach generate equal wealth. However after the mid 70s the investor seems to benefit from the trading rule, as the wealth starts exceeding the one from the buy-and-hold strategy. Especially after 2000 the difference becomes larger and continues like that for a long period. Only for 3 months, that is December 2019 to February 2020, the wealth of the investor who follows the simple buy-and-hold strategy exceeds the wealth from our trading rule. And then, in March 2020 the buy-and-hold strategy wealth drops sharply, probably as a result of the coronavirus pandemic, while the wealth of the investor that follows our trading rule is not affected since she is already out of the market. In a nutshell, the trading strategy that uses the regime switching model outperforms the simple buy-and-hold strategy for the whole period under scrutiny with a short exception that covers the December 2019 to February 2020 period. It is interesting to mention that our trading strategy leads the investor to exit the market 14 times and stays out of the market almost 32% of the whole period (1940-2020). Finally, our actual trading strategy produces higher end-of-period wealth compared to more than 95% of the simulated strategies.

Figure 3.6: Wealth with and without trading rule for the model with the second bubble measure



3.4 Robustness tests

We now perform a series of robustness tests in order to examine the sensitivity of our findings to various factors/changes. First, we check the robustness of our results to the bubble measure. For this reason, we repeat the whole analysis using the second bubble measure described in Section 3.1 by equations (3.4) to (3.7). The results are quantitatively and qualitatively similar. For example, the estimated coefficients of the regime switching model are presented in Table 3.2 and all estimates are similar to the ones in Table 3.1. Additionally, we apply the same trading rule based on the model that uses the second bubble measure and the results are depicted in Figure 3.6. It is obvious that the trading strategy generates a similar path compared to the model with the first bubble measure, with a minor deviation during the last years of the sample (after 2018) where the wealth of the trading rule is slightly lower than the one of the initial model, outperforming however the buy-and-hold strategy. Thus, the results support the robustness of our analysis to the definition of the bubble measure.

To further test the robustness of our findings, we use different percentiles for the trading strategy. Specifically, instead of using the 90^{th} percentile, we now use the 85^{th} and the 95^{th} percentile to test the robustness of the results. The results of these robustness tests are depicted in the Appendix. Using the 85^{th} percentile, the trading rule generates a relatively lower end-of-period wealth, and the generated wealth falls below the wealth of the buy-and-hold strategy after 2018. When we use the 95^{th} percentile the compounded wealth of the trading strategy is always higher than that of the buy-and-hold strategy.

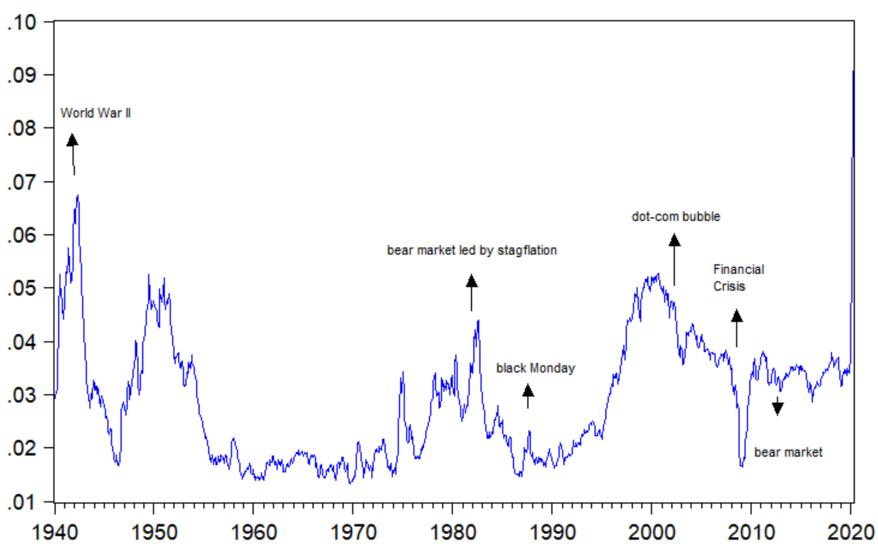
As an additional robustness test, we apply the same trading rule using a different window size for the calculation of the upper 90^{th} percentile and the median. The results are reported in the Appendix of the chapter. The initial size of the rolling window was 20 years, and we now use a window of either 15 years or 25 years. When it comes to the 15-year window, our trading strategy is beaten by the buy-and-hold strategy after the second half of 2016. The results for the 25-year window are even worse, as our strategy is outperformed after 1997. Thus, the effectiveness of the trading strategy seems sensitive to the selected length of the rolling window. A window size of 20 years is the one that leads to the most

Table 3.2: Model coefficients for the second bubble measure

	Coefficient	Std. Error
b_{s0}	0.001203	0.002459
b_{s1}	-0.000241	0.001986
b_{s2}	7.21E-05**	2.18E -05
b_{c0}	-0.049010**	0.016678
b_{c1}	-0.025183**	0.011746
σ_s	0.028879**	0.000788
σ_c	0.088143**	0.004512
b_{n0}	2.328535**	0.245586
b_{n1}	-0.748638**	0.202205
b_{n2}	-0.005905**	0.001507

Notes: The coefficients marked with ** are significant at 1% level. Sample January 1900 to March 2020. 1443 observations.

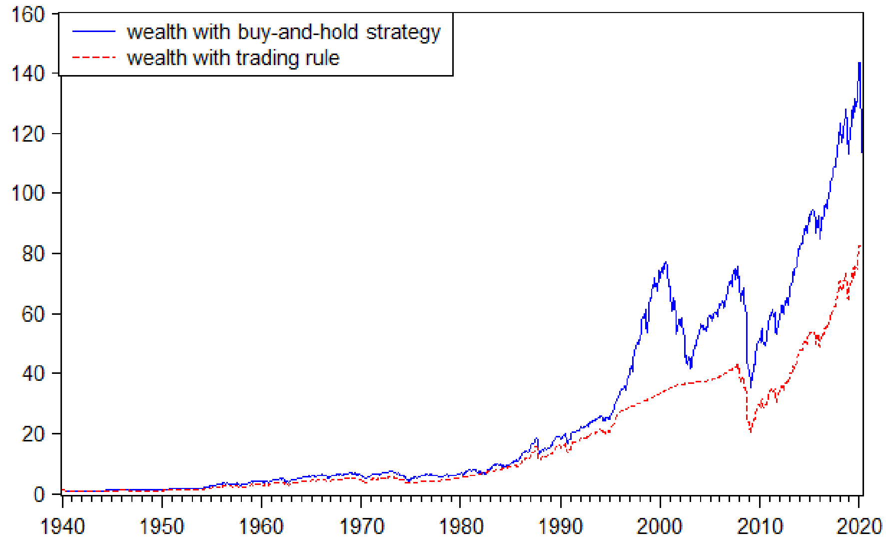
Figure 3.7: Recursive probability of a crash in the model without the EPU index



effective trading strategy.

A final test for the robustness of the model and the trading rule is to re-estimate the regime switching model without including the EPU index, so that we test whether the inclusion of EPU contributes to a better ability of the model to describe the stock market dynamics. We observe in Figure 3.7 that the recursively estimated probability of a crash does not capture very well all the actual crashes of the stock market, especially the most recent

Figure 3.8: Wealth with and without trading rule the model without EPU index



ones, thus connoting the importance of the use of EPU as an early warning indicator in our model. Moreover, when we apply the trading rule using the model without the EPU index we get the results presented in Figure 3.8. Apparently, in this case the wealth generated by the trading rule is much lower compared to the buy-and-hold strategy for the whole sample. This is a clear and strong indication that EPU significantly improves the behaviour of our model.

3.5 Conclusion

In this paper we have examined the ability of the EPU index to describe the dynamics of the US stock market returns and to serve as an early warning indicator for abrupt stock market movements. We use a two-state regime switching model that relates excess stock market returns to the size of deviations from stock market fundamentals (”bubbles”) and EPU. EPU enters both the conditional mean equation and the probability equation. We use monthly data for the US for a long period that covers more than a century; January 1900 to March 2020. We also develop a trading strategy based on our estimated model.

The results of the in-sample analysis prove that the EPU coefficients both in the conditional mean equation and the probability equation are statistically significant. The in-sample probability of being in the survival regime is, in general, very high with some drops at some points in time implying a high probability of switching to the collapse regime. Some of these sharp declines are observed during periods of abrupt stock market moves (the Great Depression of 1932, the second World War in 1942, the dot-com bubble crash in 2000 etc.). Moreover, the results prove that the economic policy uncertainty index and the probability of being in the survival regime move coordinately in different directions.

To test the forecasting ability of our model, we, then, conduct an out-of-sample analysis and the results show the estimated model has some predictive power for bubble crashes. Moreover, the recursive probability of a crash seems to be much more volatile after 2000 compared to the previous years.

To further enhance the usefulness of our model, we also propose a trading rule that indicates to investors when to exit and when to enter the stock market. According to this trading rule, the investor exits the market when the probability of a crash exceeds the $90^t h$ percentile of its 20-year historical value, and will enter the market again when this probability falls below its 20-year historical median. The results prove that the investor who follows the proposed trading rule has higher return compared to an investor who follows a simple buy-and-hold strategy.

An interesting suggestion for future research would be to examine whether the EPU index can serve as an early warning indicator for stock market bubble crashes in other countries as well. Moreover, it would be interesting to investigate other categorical policy uncertainty indices for the US in a similar framework.

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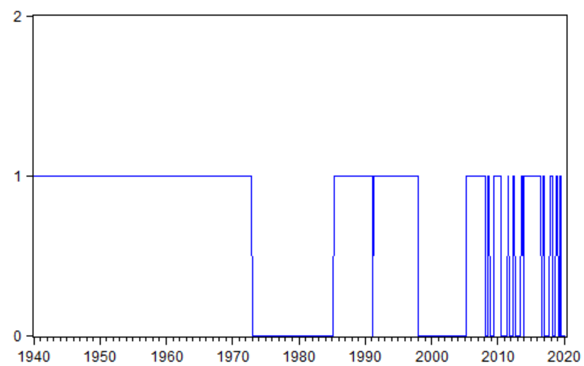
Appendix

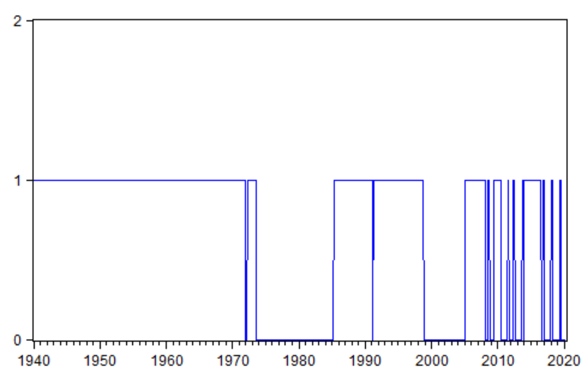
C1 Robustness tests graphs and tables

Figure C1: Periods when the investor who follows the trading rule is in the stock market for the model with the first bubble measure



Notes: The dummy takes value 1 when the investor is in the market and value 0 when the investor is out of the market.

Figure C2: Periods when the investor who follows the trading rule is in the stock market for the model with the second bubble measure



Notes: The dummy takes value 1 when the investor is in the market and value 0 when the investor is out of the market.

Figure C3: Wealth with and without trading rule - 85th percentile

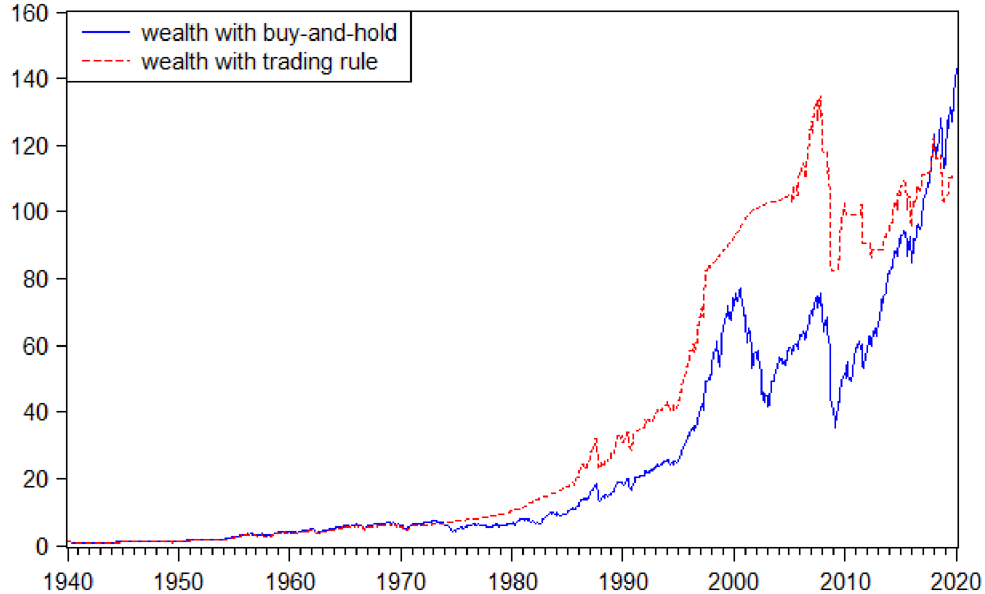


Figure C4: Wealth with and without trading rule - 95th percentile

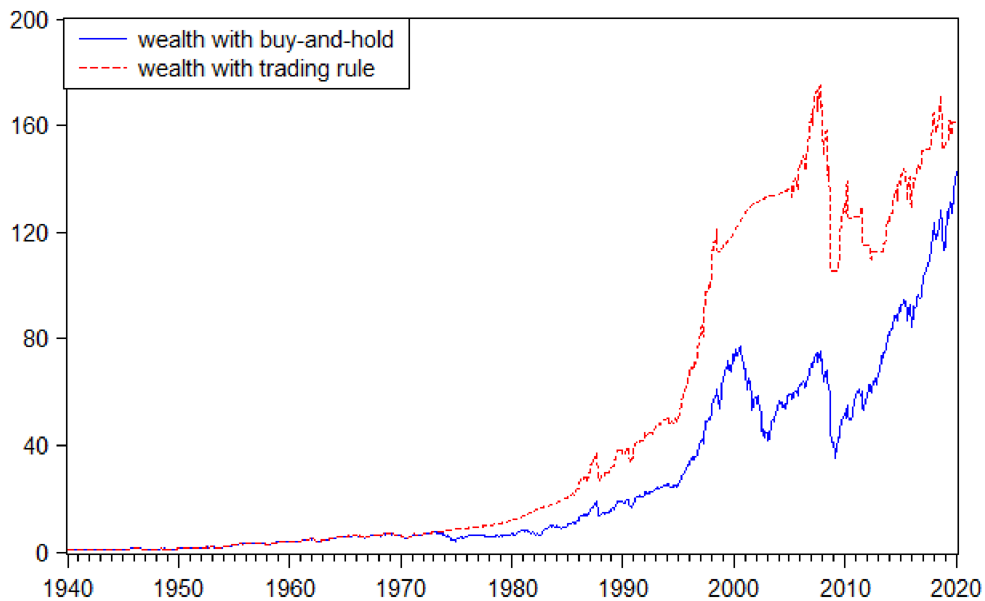


Figure C5: Wealth with and without trading rule - 15-year window for 90th percentile and median estimation

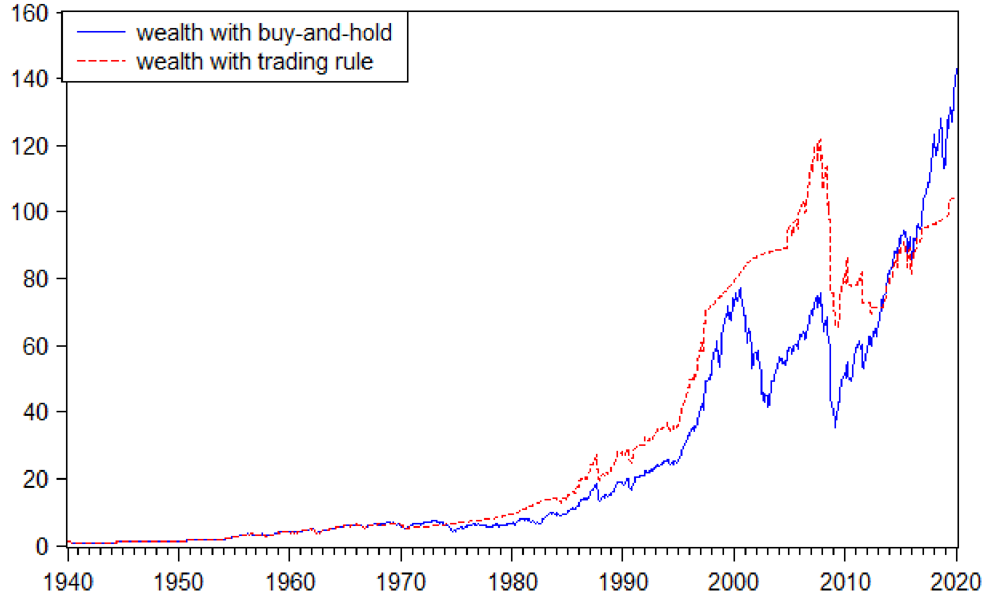
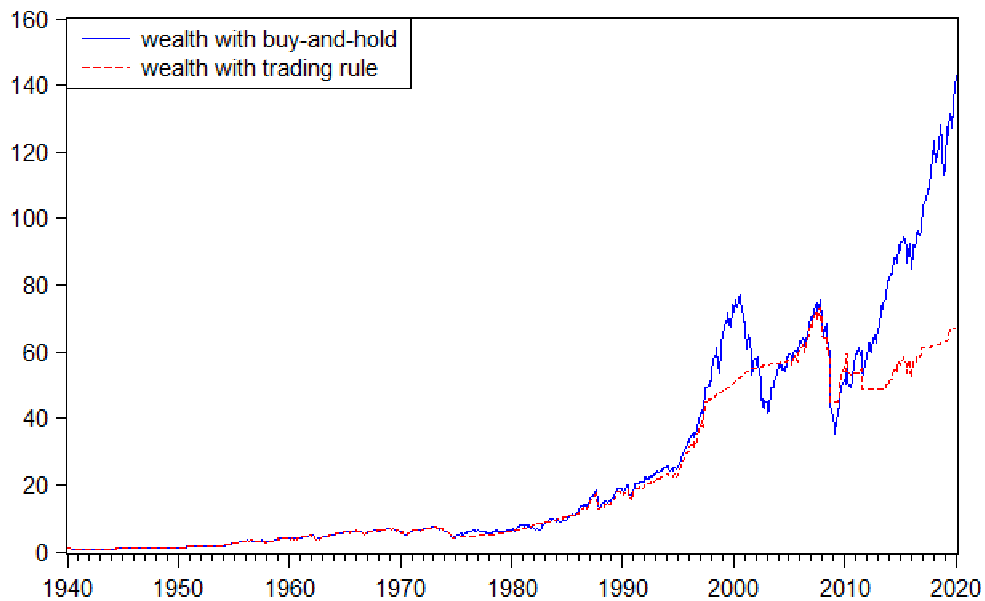


Figure C6: Wealth with and without trading rule - 25-year window window for 90th percentile and median estimation



CHAPTER

FOUR

THE CONTRIBUTION OF ECONOMIC POLICY UNCERTAINTY TO THE PERSISTENCE OF SHOCKS TO STOCK MARKET VOLATILITY

Abstract

This paper examines the contribution of Economic Policy Uncertainty (EPU) to the persistence of shocks to stock market volatility. The study applies an innovative approach that compares the half-life of a shock in the context of a bivariate VAR model that includes the volatility of stock returns and EPU, with the half-life of the equivalent univariate $ARMA$ model for the stock return volatility. Based on daily data for the UK and the US, the empirical results corroborate that EPU contributes to the persistence of shocks to stock market volatility for both countries. This contribution is higher for the US, where 14.3% of the persistence of shocks to stock market volatility can be attributed to the EPU index.

4.1 Introduction

Previous literature documents the high persistence in the conditional variance of stock market returns (Chou, 1988; Lee et al., 2001; Bentes, 2014). Early research of Chou (1988) highlights the highly persistent shocks to the US stock return volatility, from 1962 until 1985, using GARCH models. Similar findings are supported by Lee et al. (2001) for the Chinese stock market, indicating through GARCH and EGARCH models that stock market volatility is highly persistent and predictable. Bentes (2014) also finds long memory in the conditional variance of the daily returns of the G7's stock markets, especially for the relatively smaller ones, attributing this finding to the lower liquidity of the smaller markets, which makes them more prone to correlated fluctuations. Koutmos et al. (1994) come to a similar conclusion, noting that the smaller the capitalisation of the market, the higher the volatility persistence.

Recently, the Economic Policy Uncertainty index (hereafter EPU), an indicator introduced by Baker, Bloom and Davis (hereafter BBD, 2016), has gained a lot of research interest. Most of the related literature focuses on the effects of EPU on macroeconomic variables, and in particular, the negative effects of an EPU increase on growth, inflation, investment, and employment (Colombo, 2013; Antonakakis et al., 2016; Baker et al., 2016; Armelious et al., 2017; Zalla, 2017). Part of the literature also examines the effects of EPU on the stock market. Antonakakis et al. (2013) find that an EPU increase results in a fall of stock returns for the US stock market. Despite the norm that stock prices are affected by economic policy reforms, the analysis by Chang et al. (2015) suggests that there are cross-country differences in the reaction of the stock market to policy decisions and changes. Liu and Zhang (2015) provide evidence that EPU has predictive power over stock market volatility, as higher EPU leads to higher stock market volatility. Finally, Arouri et al. (2016) also find evidence that higher EPU reduces stock returns in the US, and using regime switching models they indicate that this is more intense during periods of high volatility

In this paper, we investigate the contribution of EPU to the persistence of stock market volatility. To the best of our knowledge, no other study focuses on this issue. We apply an innovative approach proposed by Malliaropulos et al. (2013) that compares the half-life of a shock in a bivariate VAR model that includes the volatility of stock returns and EPU, with the half-life of the equivalent univariate $ARMA$ model for the stock market volatility. We use daily data for the UK and the US and our findings corroborate that the EPU index contributes to the persistence of shocks to stock market volatility for both countries.

The paper proceeds as follows. Section 4.2 presents the empirical analysis, specifically the data description in section 4.2.1, the methodology and results in 4.2.2, and the robustness tests in 4.2.3, while section 4.3 concludes the paper.

4.2 Empirical Analysis

4.2.1 Data

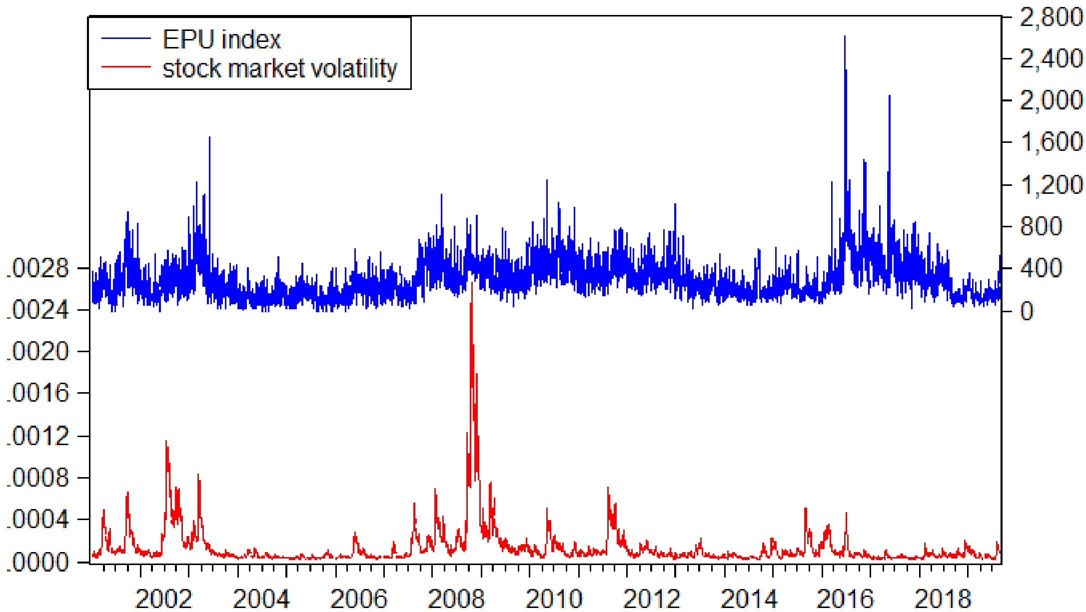
In this study we use daily data for the UK and the US, for the period January 2001 to September 2019. The selection of the countries is based on the availability of daily EPU index data and the selection of the sample is dictated by the availability of daily data for the UK EPU index. The EPU index is an indicator estimated based on newspapers coverage frequency of keyword-sets that are related to economics, policy and uncertainty, and data are retrieved from the official website of the EPU index [1]. We use the FTSE100 and S&P500 indices for the UK and the US stock markets, respectively. The stock market volatilities are derived from estimated $ARMA-GARCH$ models for the stock returns. Figures 4.1 and 4.2 show the EPU index and the stock market volatility for the UK and the US, respectively. For both countries, increases in the EPU index are often accompanied by peaks in the stock market volatility, but this seems to be more pronounced for the US. Specifically, at the beginning of the global financial crisis in 2008 an increase in both EPU and stock market volatility are obvious, while this is not the case for the UK at that point.

4.2.2 Methodology and Results

Linear transformations of VAR processes constitute the basis for the methodology we apply in this study. The methodology, introduced by Malliaropulos et al. (2013), aims at determining the contribution of a (set of) variable(s) to the persistence of shocks to the

[1] https://www.policyuncertainty.com/

Figure 4.1: Stock market volatility and the EPU index for the UK



Notes: Stock market volatility is labelled on the left axis and EPU on the right axis.

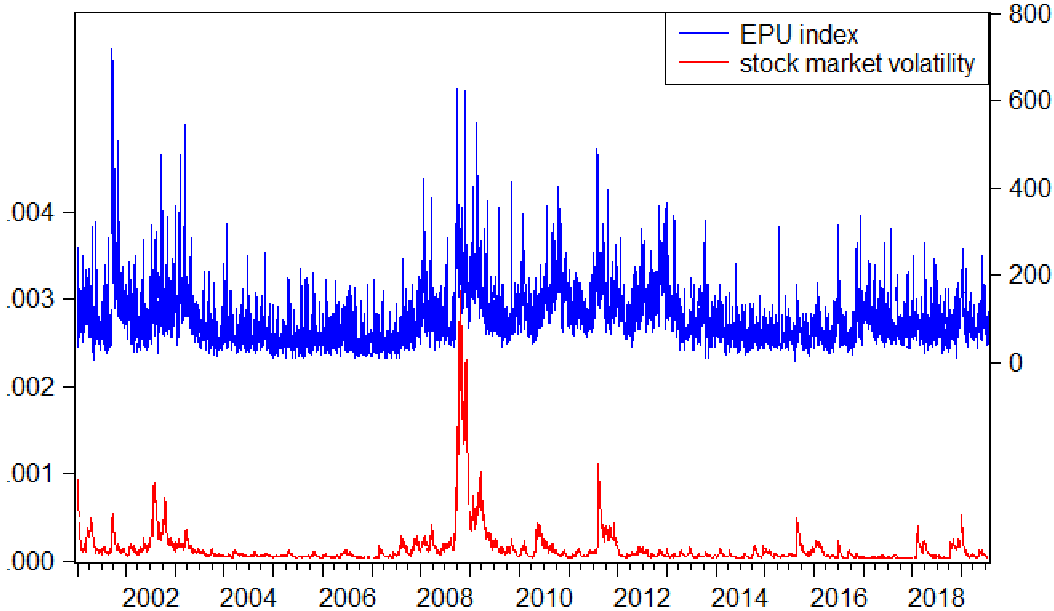
variable of interest. In our case, we focus on the contribution of EPU, y_{2t}, to the persistence of shocks to stock market volatility, y_{1t}. Assume that $Y_t = (y_{1t}, y_{2t})'$ follows a bivariate $VAR(p)$ process, that is:

$$Y_t = \begin{bmatrix} c_1 \\ c_2 \end{bmatrix} + \sum_{k=1}^{p} \begin{bmatrix} \alpha_{11,k} & \alpha_{12,k} \\ \alpha_{21,k} & \alpha_{22,k} \end{bmatrix} Y_{t-k} + \begin{bmatrix} u_{1t} \\ u_{2t} \end{bmatrix},$$

where $U_t = (u_{1t}, u_{2t})'$ is a white noise[2]. Then, given that a $VARMA$ process constitutes a class that is closed to linear transformations[3], y_{1t} has an equivalent univariate $ARMA(2p, p)$

[2]It is possible that the equivalent $ARMA$ model of y_{1t} is of a lower order. In other words, some of the $\varphi_i' s$ and $\theta_i' s$ can be zero.
[3]A linear trasformation of a finite-order $VARMA$ process is always a finite-order $VARMA$ process.

Figure 4.2: Stock market volatility and the EPU index for the US



Notes: Stock market volatility is labelled on the left axis and EPU on the right axis.

representation (Lütkepohl, 1993)[4]:

$$y_{1t} = \varphi_0 + \sum_{k=1}^{2p} \varphi_k y_{1t-k} + \varepsilon_t + \sum_{k=1}^{p} \theta_k \varepsilon_{t-k},$$

where ε_t is a white noise[5]. The equivalence suggests that there is no specification error in one's decision to model y_{1t} using any of the two specifications. In the context of the $VAR(p)$ model, the IRF of a shock on u_{1t} captures the effect of all factors that affect the variable of interest, y_{1t}, other than y_{2t}. On the other hand, ε_t is a combination of u_{1t} and u_{2t}, thus, the IRF of a shock on ε_t includes the effect of, among all other factors, y_{2t} on y_{1t}. The difference between the univariate IRF (IRF_u), and the bivariate IRF (IRF_b), reveals the contribution of y_{2t} to the persistence of shocks to y_{1t}. Following Malliaropulos et al. (2013) we measure the persistence of shocks by means of half-life that represents the number of periods needed

[4]In general, Lütkepohl (1993) provides uppper bounds for the $VARMA$ orders of linearly transformed $VARMA$ models.

[5]It is possible that the equivalent $ARMA$ model of y_{1t} is of a lower order. In other words, some of the $\varphi_i's$ and $\theta_i's$ can be zero.

for the effect of a shock to fall below half its initial value.

From an empirical point of view, the calculation of the contribution of EPU to the persistence of shocks to stock market volatility consists of the following steps:

- First, we estimate an $ARMA(k, l) - GARCH(1, 1)$ model for the stock market return and derive the conditional variance, denoted as y_{1t}.

- Afterwards, we estimate a bivariate $VAR(p)$ model that includes y_{1t} and y_{2t} (that is EPU) and calculate the half-life of a shock to y_{1t}, denoted as HL_b.

- We then estimate a univariate $ARMA(q, r)$ model for y_{1t} and calculate the half-life of a shock on y_{1t}, denoted as HL_u.

- Finally, the contribution of EPU to the persistence of shocks to stock market volatility is given by the formula: $\frac{HL_u - HL_b}{HL_u}$.

In all cases, the lag order is selected by means of the Akaike Information Criterion[6].

Table 4.1 reports the estimated half-lives for the bivariate and univariate models, together with the calculated contribution of EPU to the persistence of shocks to stock market volatility. For both countries under scrutiny, the half-life of the VAR model is lower than that of the equivalent $ARMA$ model indicating that EPU contributes to the persistence of shocks to stock market volatility. More specifically, for the UK the HL_u is 32 while the HL_b is 31, and this difference between the half-lives is attributed to the EPU index. Hence, we conclude that the contribution of EPU on the UK stock market volatility is 3.1%. In the same way, for the US the half-life is 42 and 36 for the ARMA and VAR models respectively, thus revealing a 14.3% contribution of EPU to the persistence of shocks on the US stock market volatility. The effect is substantially lower for the UK, while it is more pronounced for the US. This finding is in accordance with what we observe in Figure 1, where it is obvious that the EPU index and the stock market volatility move more closely together in the US, compared to the UK.

[6]The upper bounds for the $ARMA$ model are determined by the selected order of the VAR model, based on the upper bounds of the equivalent univariate representation provided by Lütkepohl (1993). The maximum lag order for the VAR model is set to be 10.

Table 4.1: Half-lives and EPU's contribution to stock market volatility persistence

	HL_u	HL_b	**Contribution of EPU (%)**
UK	32	31	3.1
US	42	36	14.3

4.2.3 Robustness Tests

We now conduct a variety of robustness tests; the results are reported in Table 4.2. At first, we change the frequency and employ the same methodology on weekly data. The figures of the EPU and the stock market volatility on weekly data are included in the Appendix, and the conclusions driven are similar to the ones for the daily data. The results corroborate the robustness of the findings, as the contribution of EPU to the persistence of stock market volatility is 8.3% for the UK and 11.1% for the US.

The robustness of the findings is further supported when we replace the US EPU index with the US Equity Market Uncertainty index, constructed by BBD. Using the same sample period, results are quantitatively and qualitatively similar, as the contribution of the Equity Market Uncertainty index to the persistence of stock market volatility shocks is 11.9%.

Finally, applying the same methodology for the US for a longer sample, using daily data since 1986, we do find evidence of EPU contribution to the persistence of stock market volatility, but lower in this case. On the other hand, if we use weekly data for the extended sample period, the effect of EPU is much stronger reaching 25%.

Table 4.2: Half-lives and EPU's contribution to stock market volatility persistence - robustness

	HL_u	HL_b	**Contribution of EPU (%)**
UK weekly	12	11	8.3
US weekly	9	8	11.1
US daily Equity Market Uncertainty index	42	37	11.9
US daily for the extended sample (since 1986)	17	16	5.88
US weekly for the extended sample (since 1986)	8	6	25

4.3 Conclusion

In this paper, we have investigated the contribution of EPU to the persistence of shocks to stock market volatility in the UK and the US. By means of an innovative methodology, that compares the half-lives of a VAR model for the stock market volatility and the EPU, and of an ARMA model for the volatility of stock returns, we manage to quantify the effect of EPU to the persistence of stock market volatility. Our findings seem robust to various robustness tests; different data frequency, sample and uncertainty indicator; and suggest that the contribution of EPU to the persistence of stock market volatility is higher for the US.

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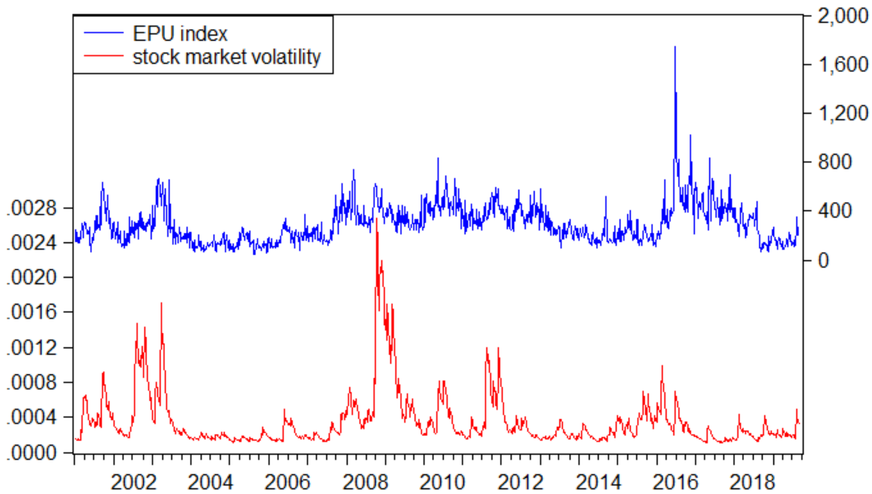
Appendix

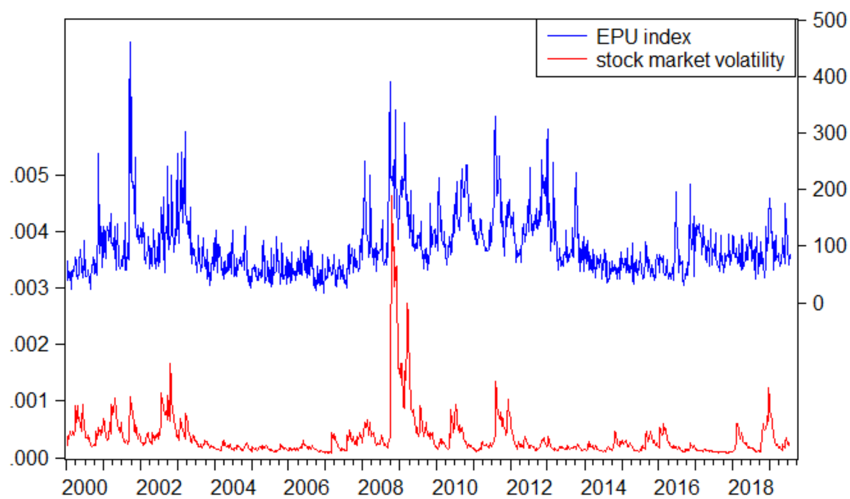
D1 Figures on weekly data for robustness

Figure D1: Stock market volatility and the EPU index for the UK - weekly data



Notes: Stock market volatility is labelled on the left axis and EPU on the right axis.

Figure D2: Stock market volatility and the EPU index for the US - weekly data



Notes: Stock market volatility is labelled on the left axis and EPU on the right axis.

D2 An application to the foreign exchange market

A further extension of the application of the Malliaropulos et al. (2013) methodology is presented in this Appendix, this time for the foreign exchange (hereafter forex) market. As it has been mentioned in the main part of this chapter, most of the literature on the EPU index focuses on its implications to macroeconomic variables and the stock market. However, it would be interesting to examine the relationship of EPU with the exchange rates.

The existing literature about economic uncertainty and the forex market is limited. Balcilar et al. (2016) examine the impact of EPU on the exchange rate return and volatility for 16 currencies. They find that for 7 out of the 16 currencies the EPU differentials have an impact on the variance of the exchange rates, but not on the returns. A research that focuses specifically on the Chinese economy proves that causality is more significant in the tail quantile intervals highlighting the high EPU rates in China that are accompanied by high exchange rate fluctuations (Yin et al., 2017). Nilavongse et al. (2020) corroborate that shocks on economic uncertainty cause exchange rate fluctuations. In addition, Chen et al. (2020) examine the impact of the EPU index on exchange rates for several countries (China, Europe, Japan, Hong-Kong and the US) and find different impacts of EPU on the exchange rate for each case.

Aiming to add more to the literature on the relationship between EPU and the exchange rate volatility, we apply the methodology of Malliaropulos et al. (2013) to examine the contribution of the EPU index to the persistence of a shock to the exchange rate volatility. The exchange rates of 14 currencies are examined (Australian Dollar, Brazilian Real, Canadian Dollar, Chilean Peso, Chinese Yuan, Colombian Peso, Indian Rupee, Japanese Yen, Mexican Peso, Pakistani Rupee, Russian Ruble, Singaporean Dollar, Swedish Krona, and British Pound). The sample of the analysis covers the period January 2003 until December 2020. We begin by estimating the bivariate VAR(p) model for the exchange rate volatility and the EPU index and estimate the half-life of a shock on the volatility of the exchange rate (HL_b). The next step includes the univariate ARMA(q,r) model for the exchange rate volatility through which we derive the half-life of a shock on the exchange rate volatility (HL_u). Comparing the half lives of the two models we get the contribution of EPU to the persistence of a shock

Table D1: Half-lives and EPU's contribution to exchange rate volatility persistence

	HL_u	HL_b	**Contribution of EPU (%)**
Australian Dollar	2	2	0
Brazilian Real	1	1	0
Canadian Dollar	9	8	11.1
Chilean Peso	2	1	50
Chinese Yuan	7	5	28.6
Colombian Peso	10	11	0
Indian Rupee	19	8	57.9
Japanese Yen	1	1	0
Mexican Peso	2	2	0
Pakistani Rupee	4	2	25
Russian Ruble	2	2	0
Singaporean Dollar	4	3	25
Swedish Korona	3	3	0
British Pound	3	3	0

on the exchange rate volatility. The results shown on Table D1 prove that for 6 out of the 14 currencies examined the EPU index contributes to the persistence of a shock on exchange rate volatility. In India, we find the highest contribution of the EPU index, as it explains the 57.9% of the forex market volatility persistence. Next is the Chilean Peso with half of the persistence of its exchange rate volatility being attributed to economic policy uncertainty. The contribution of EPU to the persistence of the Chinese Yuan's volatility is more than 28%, 25% is the contribution of the Pakistani EPU index to the persistence of Pakistani Rupee volatility, same for the Singapore Dollar, while the contribution of EPU to persistence of the volatility of the Canadian Dollar is about 11%.

It can be observed that for the Asian currencies EPU seems to play a more important role to the persistence of the exchange rate volatility, as the Japanese Yen is the only Asian currency examined whose volatility persistence does not seem to be affected by the EPU index. In a nutshell, the methodology of Malliaropulos et al. (2013) provides a good insight not only for the stock market but also for the foreign exchange market as well. Thus, investors could benefit by observing the EPU index and its fluctuations to better plan their investments in currencies. Policy makers can benefit as well, as they can use EPU as a tool to choose the appropriate policy actions to safeguard the currency.

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CONCLUSION

The aim of the present thesis was to fill some gaps in the relatively new field of economic policy uncertainty. Cornerstone of the thesis was the construction of the EPU index for Greece, as presented in the first chapter. The index was constructed based on the newspapers coverage frequency methodology of BBD. The results depict that economic uncertainty in Greece rises during international events, like the Russian crisis, the 9/11 attack, the collapse of the Lehman Brothers, the Brexit referendum etc. However, after the Greek debt crisis outburst, mostly domestic economic or political events seem to affect Greek uncertainty (elections, Greek referendum, memorandum programmes etc.). The most important contribution of this thesis is that hereafter the Greek EPU index will be available for further research to examine how it can be utilised as a tool to decide about the monetary policy applied. This index was utilised in the second chapter of the present thesis.

The second chapter begins by analysing the EPU spillovers among the Eurozone countries and continues with the analysis of the impulse responses of Greek macroeconomic and stock market variables to both domestic and European EPU. The results indicate a considerable transmission of EPU shocks among the Eurozone countries, which however falls after the outburst of the crisis, as the total spillover index fell from 50.5% to 30.6% after 2010. The analysis suggests that after the crisis the EPU index of the Eurozone countries is mostly affected by domestic events. In addition to that, the results also show that during the period of economic stability the core Eurozone countries (like Germany and France) were transmitting uncertainty to the other countries, while after the beginning of the crisis, things changed and the periphery countries (like Greece and Ireland) are the ones exporting economic uncertainty. This can probably be explained as the periphery countries are the ones affected the most by the crisis. Regarding the second half of the chapter, the impulse response analysis that focuses on the Greek economy indicates that the Greek GDP, stock market index and the ESI have negative responses to EPU shocks, while unemployment responds positively as expected. The most intense and long in duration responses are indicated at the beginning of the crisis. In addition, the comparison of the impulse responses to Greek and to European EPU shocks reveals that Greek macroeconomic variables and the stock market are affected more and for a longer duration by domestic rather than European uncertainty.

The next two chapters contribute to the literature on the relationship of EPU and the stock market. Chapter three specifically, examines the role of EPU as an early warning indicator for stock market crashes, through a regime switching model, where EPU enters both the conditional mean and the probability equations. The results support the importance of EPU in the model. The out-of-sample analysis proves the predictive power of the model over bubble crashes. At the end of this chapter, a trading rule is developed and the tests reveal that if an investor followed that rule, she would gain more profits compared to a simple buy-and-hold strategy. Thus, this trading rule can be utilised by investors to improve their trading strategy.

The last chapter of the present thesis examines whether EPU contributes to the persistence of a shock to stock market volatility. The countries examined are the UK and the US and results of the empirical analysis prove that EPU indeed contributes to stock market volatility persistence; the calculated contribution is 3% and 14.3% for the UK nad the US, respectively. The robustness of the findings is also verified by a series of robustness tests.

In a nutshell, the present thesis has contributed to the literature on economic policy uncertainty in several ways, such as (i) by creating the EPU index for Greece, so that further research for the country is now possible, (ii) by finding important results on EPU spillovers among countries, and (iii) by filling some gaps on the relationship of EPU and the stock market. The thesis offers findings which can be used either by policy makers, by investors and obviously by other researchers for further investigation of the hotly-debated issue of economic uncertainty.