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Real-Time Information Content of Macroeconomic Data and Uncertainty: An Application to the Euro Area

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Abstract

Most macroeconomic data is continuously revised as additional information becomes available. We suggest that revisions of data is an important source of uncertainty about the state of the economy. This paper evaluates the quality of major real macroeconomic Euro area variables, published by Eurostat since 2001. The real time data set contains 159 vintages, covering the period of January 1991 until March 2014. The information content or informativeness of revision is measured using three methods: descriptive error statistics, signal-to-noise ratios and entropy measures. Our results document a trend of growing data uncertainty over the past decade for Euro area variables. As a robustness check, we reckon our results using US data and additionally show that uncertainty calculations are robust towards changes in final revision definition. Moreover, Euro area signal-noise-ratios and entropy measures are correlated with popular uncertainty proxies, Euro area news-based EPU and the VSTOXX. Our finding corresponds to the recent literature on increased macroeconomic uncertainty and especially economic policy uncertainty during and after the "Great Recession".

Keywords: forecasting, information content, uncertainty, revisions, revision errors, entropy, signal-to-noise ratio, integrated signal-to-noise ratio, recession, EPU, VSTOXX

JEL classification: C53, C8, D80, E3

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1 Introduction

Business cycle analysis changed the perspective in several dimensions since the seminal paper of Zarnowitz (1985): On the level of data properties, most economists adopted the view of difference stationary time series instead of the trend-stationary paradigm. The new paradigm comes with possible time-variation in the mean, the variance and reduced-form parameters (Ng and Wright, 2013). On the level of macroeconomic analysis, models with tight microfoundations – Real Business Cycle (RBC) or Dynamic Stochastic General Equilibrium (DSGE) models – are at the core of macroeconomic policy analysis and were brought to the data. On the level of stylized business cycle facts, the 1990s brought a very long upswing in the US and several regions of the world, followed by relatively mild recessions. Stock and Watson (2002) assert, that the observable decline in business cycle volatility from the late 1980s to the mid-2000s stems from a lower variance of shocks hitting the economy combined with a higher capacity to absorb shocks mainly due to improved monetary policy. Ng and Wright (2013) argue that the "Great Moderation" ended with the "Great Recession" and some of the stylized business cycle facts are now more in line with the "older" (financial) business cycle theories again, as discussed in Zarnowitz (1985).

The question emerges: how and to what extent the business cycle facts might have changed regarding general uncertainty and data uncertainty. Both are possibly related to each other. The first aspect refers to the role of uncertainty in general: Taleb (2010) motivated a new round in the uncertainty discussion, claiming that we should accept the impossibility of statistical forecasting in the sense of epistemic uncertainty. According to his view and notwithstanding the abilities of the forecaster, propositions and decisions will inevitably be based on incomplete information. Taleb exemplifies the issue with the impossibility to gather sufficient data to calculate probabilities of large-impact events, the so-called *"black swan events"*. These kind of events cannot be forecasted well because known past observations provide the forecaster with a sample too small to quantify the probability of extremely rare events (Terzi, 2010, p.561-563). Davidson (2010) points out that the logic behind Taleb's "black swan events" is merely a new variant of Knight's concept of uncertainty. Most arguments in the so-called uncertainty discussion today refer to what Knight (1921) might have called "quantifiable risks", i.e. measurable volatility shifts in economic data.[1] Bloom (2009); Bloom et al. (2013) and Bloom (2013) address stylized facts on uncertainty and business cycle facts on the microeconomic and the macroeconomic level of economic activity. Baker and Bloom (2013) use exogenous instruments to identify the causality between uncertainty and economic activity. Baker et al. (2014) summarize several empirical proxy variables for the latent (unobservable) variable "economic uncertainty". Those measures are: stock market volatility, cross-sectional dispersion in forecaster beliefs, aggregated individual confidence bounds from surveys of professional forecasters and measures based on content analysis of news from the media as by Baker et al. (2013) or "surprise" index suggested by Scotti (2013). A very recent paper by Jurado et al. (2014) apply statistical decompositions to identify common (macroeconomic) aspects of uncertainty based on factor models.
Another measure widely-used in the literature is by Baker et al. (2013) and can be considered

[1] We will use "uncertainty" and "risk" interchangeably in the course of the paper as we are not discussing truly non-forecastable "black swan events".

as a special case of general macroeconomic uncertainty: economic policy uncertainty index (EPU). The EPU index relies on newspaper coverage of policy-related economic uncertainty, the number and projected revenue effects of federal tax code provisions and disagreement among economic forecasters about policy relevant variables based on the US Survey of Professional Forecasters (SPF) data.
For the Euro area less research is available on uncertainty, while the focus of available papers is on European Central Bank SPF data.[2] On the whole, all the previously mentioned measures detect higher uncertainty during recessions compared to booms, both on macro and micro levels.

The second aspect of uncertainty refers to data uncertainty. Macroeconomic data uncertainty during the "Great Recession" and afterwards, however, has not been analyzed so far. In our paper, we will focus on data uncertainty in terms of the real gross domestic product (GDP) and its component revisions to analyze how the information content might have changed over time. Data uncertainty is an important aspect when it comes to the forecastability of macroeconomic time series. The main driving force of uncertainty here stems from short-horizon revisions of data: Revisions are usually caused by replacing preliminary data with later data, replacing judgemental projections with source data, changing definitions and estimation procedures or by updating the base year in real estimates (Young, 1994, p.63). McNees (1989) argues that there is a certain trade-off between timeliness of data and its reliability. Patterson and Heravi (1991, p.49) showed that there are gains associated with the annual revision process throughout the range of vintages and the results of estimations using particular vintage have to be assessed for their sensitivity with respect to different revisions. Especially in the short-run, revisions may significantly affect the outcome of a model(Croushore, 2011, p.77).

The usage of a certain vintage[3] can play an important role in policy decision making and forecasting, since policymakers depend on accurate assessments of the state of the economy.[4] A large string of the "real-time" literature focuses on rationality of revisions and applies tests inspired by Mincer and Zarnowitz (1969) or Nordhaus (1987).[5] But information content or informativeness of data and therefore the revision process depends on the degree of uncertainty at time of estimate release.
Uncertainty, especially uncertainty of economic policy has become the subject of debate during the recent crisis and recession. Therefore we also have to examine data uncertainty in particular. As an example, we can look at the recent history. During the recession between first quarter of 2008 and second quarter of 2009 the magnitude of revisions were significant. The flash estimates mostly underestimated GDP growth. Further revisions after the final[6], especially in the middle of the crisis were positive, indicating underestimation not only of the flash estimate but of the final announcement as well. Eurostat from a historical perspec-

[2] See i.a. Baker et al. (2013); Rich et al. (2012); Marcellino and Musso (2011).
[3] Following the definition by Croushore and Stark (2003, p.605): a vintage captures "...data set corresponding to the information set at a particular date...".
[4] See Swanson and Dijk (2006, p.24), Croushore and Stark (2003, 612-614), Croushore (2006, p.974)
[5] See for rationality tests Ott (1989) using German data and Mankiw and Shapiro (1986); Öller and Barot (2000); Oeller and Hansson (2004); Swanson and Dijk (2006); Clements et al. (2007); Patton and Timmermann (2011); Clements (2012b); Messina et al. (2014) using US data. An excellent overview of revision analysis literature since 1960s can be found in Croushore (2006).
[6] Please refer to the definition of flash and final revisions in the section 2.

tive was too pessimistic about future economic development. But this negative bias is not a unique problem since other statistical offices, for example in the US have the same tendency (Croushore, 2011, p.73).

——————— please insert figure 1 about here ———————

In our paper we add to the literature on increased uncertainty and evaluate the data quality of different vintages of major real macroeconomic variables, such as real gross domestic product, private consumption, government consumption, investment, exports and imports as published by Eurostat. The real time Eurostat revision dynamics is analysed for 159 vintages (or releases), estimates covering the period first quarter of 1991 until the third quarter of 2013, released between January 2001 and March 2014.[7] Previous studies deal mostly with US macroeconomic data, use mostly the Survey of Professional Forecasters (SPF) data and calculated uncertainty is mainly based on probability density of forecasts[8]. For revision analysis only few studies deal with real time based conclusions[9], to the best of our knowledge none so far for the Euro area macroeconomic data[10].

We quantify uncertainty based on data revisions applying different types of methods. The first set of findings is derived from descriptive statistics. Numerous early papers motivate their findings mostly by descriptive error analysis.[11] Following Öller and Teterukovski (2007), we calculate "signal-to-noise" and "integrated signal-to-noise" ratios as well as an entropy measure based on Vasicek (1976). Our results point to increased uncertainty. This contradicts the findings of several previous studies which document the reduction of uncertainty[12] but corresponds to aforementioned recent literature on increasing uncertainty.

The main finding of our analysis can be stated in the following way: uncertainty has been growing continuously over the past decade, though the magnitude of this effect differs across variables. To check the robustness of our results, we reproduce all measures using US data. Uncertainty of revisions has been continuously growing for the US as well, especially during the financial crises. The effects we observe at the end of the sample, both for the Euro area and the US data, can stem from the end-of-the-sample problem or can be interpreted as a sign of a slight reduction in uncertainty since 2013. Moreover, our results are robust to an alternative definition of final estimates. The official Eurostat final estimate is announced 100 days after the end of the quarter, though a prevalent way to determine the final, e.g. in the US and Germany, is eight quarters after the end of the report period. Further, our measures are correlated with the Euro area EPU index and the VSTOXX - EURO STOXX 50 Volatility

[7] The number of vintages included in this study is reduced to 156 because of the beginning-of-sample problem, explained in section 2.

[8] US SPF forecasts were examined by Rich and Tracy (2010); Patton and Timmermann (2011); Clements (2012a) and Rich et al. (2012) used the European Central Bank SPF forecasts to estimate uncertainty.

[9] For example, German real time data was analyzed by Kholodilin and Siliverstovs (2009), US SPF revisions were subject of studies i.a. by Croushore (2010); Patton and Timmermann (2011); Clements (2012b).

[10] Rich et al. (2012) calculated uncertainty based on ECB SPF forecasts, though neither revisions nor real time analysis have been subjects of their interest. Marcellino and Musso (2011) study euro area output gap estimates in real-time context.

[11] See for example Mankiw and Shapiro (1986); Leeuw (1990); Young (1994); Öller and Barot (2000); Marcellino and Musso (2011).

[12] See i.a.Mankiw and Shapiro (1986); Patterson and Heravi (1991); Young (1994); Kholodilin and Siliverstovs (2009)

index. Notwithstanding they are less volatile than the latter indices and capture the continuing increase in data uncertainty during the second recession in the Euro area (since the third quarter 2011).

This paper is organized as follows. Section 2 describes the data set we have been working with as well as computations made for the analysis. Researchers since Mankiw and Shapiro (1986) assumed two characterizations of revisions: the agencies either add news or reduce noise by means of revisions. We show in section 3 that our calculations for the most variables are based on true revision errors rather than forecast errors and are subjects to news rather than noise. In section 4 we introduce the methods used for the analysis. Our findings are presented in section 5 and section 6 presents the robustness check results as well as comparison to the popular uncertainty proxies. The subsequent section 7 summarizes and discusses overall findings.

2 Data

Throughout this paper we measure the information content of revision errors for the major real macroeconomic variables, published by Eurostat.[13] The detailed information about the variables is supplied in appendix A.
Revisions are available from January 3^{rd} 2001 until March 5^{th} 2014. For each quarter the flash estimate of real variables is announced 65 days after the end of the quarter and as more information becomes published, the final estimate is released 100 days after. The detailed release scheme is given in table (1). Additionally to the normal revision scheme described above, benchmark revisions take place about every five years, due to changes in the methodology, changes in the base year or – in the Euro area case – due to changes in regional coverage.

Quarter	flash (+65) release	final (+100) release
first	June	August
second	September	November
third	December	February
fouth	March	May

Table 1: Release Scheme of Eurostat Revisions

The number of vintages per year differs within the sample. At the begining of the sample there have been ten revision per year, while during the last seven years Eurostat revised monthly. Therefore we standardize vintages to twelve months per year. For this purpose we added vintages incorporating all information available at that point of time. This computation has further advantage that it simplifies comparison with the US data, as most US sources revise monthly.[14] The total number of vintages in the sample equals 159.
Another problem concering the begining of our sample is the mismatch between the first vintage published on 3^{rd} January 2001 and the first data point- first quarter 1991. Hence, we

[13] Source:http://sdw.ecb.europa.eu/browseExplanation.do?node=4843526. *Download: April* 29^{th} *2014.* Further information concerning the variables can be found in EUROSTAT (2013).
[14] The Eurostat EU data is updated every month per year, at least for the last decade.

assume that March 2001 estimates of 1991Q1-2000Q3 are final estimates and the revision errors for this vintage equals zero. To avoid statistical problems, the dataset is trimmed here and starts April 2001.

For our analysis we compute annualized quarterly growth rates proxied by logged differences appropriately rescaled.[15] y is used in liue of a macreoconomic variable.

$$\hat{y} = (\ln y_t - \ln y_{t-1}) * 400 \tag{1}$$

The revision error at time t for the vintage l is defined as:

$$e_t^l = \hat{y}_t^L - \hat{y}_t^l \tag{2}$$

where $\hat{y}_t^l$ is the l^{th} revision for the period t.
The final estimate $\hat{y}_t^L$ in L for each quarter t is defined as officially claimed by Eurostat as "100 days after the end of the quarter". It is held constant for all revision errors for t. Therefore the revision error of quarter t at vintage L equals zero.

To highlight recession periods, we use gray shaded areas on our graphs. The business cycle dating was taken from the Center of Economic Policy Research Business Cycle Dating Committee for the euro area: peak in the first quarter 2008 and trough in the second quarter 2009, as well as the recent peak in the third quarter 2011.[16]

3 Sources of Revisions: News versus Noise

Before we can start with calculation of data uncertainty measures based on revisions, we must be sure that our data is informative and does not contain noise.
Researchers since Mankiw and Shapiro (1986) assumed two characterizations of revisions: the agencies either add news or reduce noise by means of revisions. The revisions are considered optimal forecasts of final values if revision incorporates all available information and the final estimate only eliminates revision error:

$$y_t^L = y_t^l + e_t^l \tag{3}$$

so that $y_t^l \perp e_t^l$ and $e_t^l \perp X_t^l, X_t^l \in \Omega^l$, where X_t^l indicates all known data at vintage l from information set Ω^l.
Alternatively, if the information is not included in the flash estimate than the revisions reduce noise. The difference between the flash estimate and the final equals measurement error u_t^l, which is independent of true value y_t^*, $y_t^* \perp u_t^l$.

$$y_t^l = y_t^* - u_t^l \tag{4}$$

The consequence of these characteristics is in the predictive ability of revisions. If the error is orthogonal to revision than it can not be predicted. Another case occurs when the final value

[15] See Kirchgässner and Wolters (2007, p.7-8)
[16] http://www.cepr.org/content/euro-area-business-cycle-dating-committee

	flash	revflash	final	6 months	12 months	18 months	24 months
Y	2.27	2.28	2.32	2.37	2.44	2.49	2.50
C	1.28	1.13	1.18	1.37	1.45	1.56	1.48
I	4.75	4.98	5.10	5.63	5.59	5.72	5.73
G	1.32	1.13	1.14	1.27	1.47	1.49	1.52
Ex	8.92	8.92	9.01	9.38	8.77	9.16	9.58
Im	8.11	8.11	8.30	8.58	8.13	8.23	8.16

Table 2: Standard Deviation of Revisions

is orthogonal with the error. In this case it is forecastable and correlated with the flash estimate. Moreover, the variance and standard deviation should increase with each revision if it contains new information.(Croushore and Stark (2003, p.609-610), Croushore (2011, p.81-82) and Mankiw and Shapiro (1986, p.22))

To show that our data revisions are driven by news, we check both development of standard deviation and correlation between revisions and errors.
The table 2 below reports standard deviation of revisions for the flash, revised flash and final (+100 days) estimate as well as revisions 6, 12,18 and 24 months after the end of the report quarter. The real GDP and investment exhibit consistent pattern of growing standard deviation from flash estimate to further revisions. Consumption variables seem to include noise, especially in the first estimates. Exports and imports are informative only for the estimates during the first year after the end of the report quarter and become noisy afterwards.
The second test we perform here is whether revisions fulfill the orthogonality condition (3). The previous result is reassured for the GDP and investment: these revisions contain news as we find no correlation between revisions and its errors. Exports and imports show weak correlation, so the orthogonality is fulfilled. The null hypothesis of no correlation can not be rejected for the private and goventment consumption. Hence, the uncertainty we would see in revisions of consumption variables originates unfortunately in Eurostat's measurement errors and noise rather than in news.[17]
By the means of performed tests we proved that our errors for major variables are true revision errors and with every vintage Eurostat eliminates forecast error. As private and government consumption contain noise in revisions, we exclude these variables from the main uncertainty calculations throughout this paper.

4 Methodology

To analyze uncertainty of data revisions we base our findings on three types of methods: descriptive statistics of revision errors, different signal-to-noise-ratios and entropy measures for real macroeconomic variables.

[17] Detailed results are available from the authors on request.

4.1 Descriptive Statistics

The first method we applied to get an idea about the structure and magnitude of revision errors is descriptive statistics. We calculated recursive mean errors (ME), mean squared errors (MSE), mean absolute errors (MAE), root mean squared errors (RMSE), variance and standard deviation of revision errors for each growth rate and each variable.
Each vintage l consists of revision errors of different quarters t[18], though only one quarter can have its final estimate and per defintion zero revision error during the same vintage. All other revison errors are non zero since Eurostat revises each quarter almost at every vintage.

$$ME_l = \frac{1}{T}\Sigma_{t=1}^{T}(\hat{y}_t^L - \hat{y}_t^l) \tag{5}$$

$$MSE_l = \frac{1}{T}\Sigma_{t=1}^{T}(\hat{y}_t^L - \hat{y}_t^l)^2 \tag{6}$$

$$MAE_l = \frac{1}{T}\Sigma_{t=1}^{T} \mid (\hat{y}_t^L - \hat{y}_t^l) \mid \tag{7}$$

$$RMSE_l = \sqrt{\frac{1}{T}\Sigma_{t=1}^{T}(\hat{y}_t^L - \hat{y}_t^l)^2} \tag{8}$$

The focus of analysis is root mean squares errors for vintages of macroeconomic variables.

4.2 Signal-To-Noise and Integrated-Signal-To-Noise Ratios

Another approach to measure the information content of real-time date goes back to "Signal-to-Noise" ratios (SNR). The signal-to-noise ratio is captured by a ratio of variances: The more information comes in, the lower is the variance of revision and the signal content improves compared to the noise level as measured by the variance of the final revision. Of course, SNR approaches one in the limit

$$SNR_l = 1 - \frac{1/T\sum(\hat{y}_t^L - \hat{y}_t^l)^2}{\sigma_L^2} \tag{9}$$

where σ_L^2 denotes the variance of the final revision L.[19] T captures the number of observations - the number of quarters t - for each vintage l.

Öller and Teterukovski (2007) propose an integrated SNR measure, the ISNR, to characterize the overall quality of data. For its computation they consider the mean squared error of signals in vintages l and $l+1$:

$$ISNR_L = \frac{1}{2}\sum_{l=0}^{L-1}(SNR_l + SNR_{l+1})\tau(l, l+1) \tag{10}$$

with $\tau(l, l+1)$ denoting the time interval between the vintages.
Both measures vary in between zero and one: complete ignorance about the final value up to the last revision on the one hand and a situation where the very first forecast (flash estimate) conveys all necessary information on the other hand.

[18] T captures the number of observations - the number of quarters t - for each vintage l.
[19] Öller and Teterukovski (2007, p.207), Kholodilin and Siliverstovs (2009, p.3)

4.3 Entropy

The third method to evaluates information content of revisions in terms of entropy reduction, i.e. the reduction in uncertainty as new vintages of data are published. The usage of this measure in economics measure goes back to Theil (1966, 1967) and Theil and Scholes (1967). The concept however originates in thermodynamics and statistical mechanics, and is closely related to the concept of information in communication theory and mathematical statistics (Patterson and Heravi, 1991, p.36).

The traditional entropy approach establishes H as a continuous distribution function F with a density function $f(x)$, defined in terms of normal distribution:

$$H(f) = -\int_{-\infty}^{+\infty} f(x)\log(f(x))dx \tag{11}$$

The means of the successive distributions, conditioned on the different stages in the forecasting process are assumed to be constant (Theil, 1967; Patterson and Heravi, 1991). According to (Patterson and Heravi, 1991, p.36), the normal distribution is the one with the largest entropy, where the entropy is a linear function of the logarithm of the variance. A positive difference between the entropies of distributions conditioned on the different stages in the forecasting process implies a reduction of uncertainty attributable to the revision process (Patterson and Heravi, 1991, p.36). The decrease in entropy is usually referred to as "information gain" in the literature. The information gains are independent of time and represent the average vintage information gain across years and variables (Öller and Teterukovski, 2007, p.210).
Vasicek (1976) proposed an entropy measure, for which he dropped the restrictive normality assumption. Patterson and Heravi (1991, p.39) point out that a normal distribution assumption in general only holds if the variables are pooled and restated the concept of Vasicek (1976):

$$H_{MT} = T^{-1}\sum_{t=1}^{T}\ln(\frac{T}{2M}\left[e^l_{(t+M)} - e^l_{(t-M)}\right]) \tag{12}$$

where $e^l_{(t)}$ is the ordered error such that $e^l_{(1)} \leqslant e^l_{(2)} \leqslant \cdots \leqslant e^l_{(T)}$ and M is a positive integer smaller than $T/2$, where T captures the number of observations in a vintage l. (Vasicek (1976, p.54-55), Patterson and Heravi (1991, p.39)).[20]

For the computation of the entropy measure we use the definition in equation (12). Hence, the entropy is the difference between ordered revision errors within a vintage. Our extention to the foregone entropy estimate is that we calculate an optimal value for M for each vintage separately, depending the number of observations T within the vintage l. Following Vasicek (1976, p.58), we decide upon M according to the table (3)

[20]The notation of the original papers is changed to be consistent within this paper.

T	$T < 50$	$50 < T < 70$	$T > 70$
M	3	4	5

Table 3: Optimal Values for M

5 Results

This section presents the results of revision analysis. As we previously detected noise in revisions of private and government consumption, we exclude these variables from the main discussion.[21]. Along the way, we find additional support for the claim that data uncertainty rose in the past decade, notwithstanding the applied measure.

The measures of descriptive statistics capture primarily the magnitude of revisions. The results here are based on the root mean squared revision errors for all sample vintages. Hereby we are not making conclusions about data uncertainty explicitely, but rather concentrate on the intuition: if a variable exhibits high revision errors, than its flash estimate and probably even the final estimate does not capture enough information to match present economic situation.
We find that revision errors grow during the estimation period. The magnitude of revision errors diffes between macroeconomic variables. GDP is less revised comparing with investment, exports and imports. The errors of the latter variables follow an upward trend.
Still, if we assume that the higher root mean squared error of revisions, the higher the uncertainty, this measure supports increasing uncertainty during the ”Great Recession” agrument.

——————— please insert figure 2 about here ———————

The focus of data uncertainty analysis is on the ”real” uncertainty measures such as signal-to-noise ratios and entropy.
The entropy measure (12) is calculated as a distribution function of ordered revision errors and can be interpreted straighforward: the higher the entropy, the higher is the uncertainty in the data. All examined macroeconomic variables exhibit higher entropy and hence uncertainty levels within the last decade. The revision errors of exports, imports and investment are relatively high. Therefore the entropy measure for these aggregates is at the level higher as well, comparing with GDP.

——————— please insert figure 4 about here ———————

Concerning signal-to-noise ratios we detect a clear downward trend. According to the definition of SNRs: the higher the ratio, the lower the uncertainty. Hence, uncertainty based on both SNR and ISNR has been rising throughout the vintages for all investigated variables.

——————— please insert figure 3 about here ———————

[21] The results of uncertainty measures calculations for these variables can be found on figure 8.

Moreover, there are two structural breaks in signal-to-noise ratios and entropy measures: level shifts during the ”Great Recession” and the recent recession. Other fluctuations of measures can be explained by different economic and political events, e.g. changes in the regional coverage of the Euro area, ”black Monday”, ”bloody Friday”.
All applied methods detect that the uncertainty of the real GDP is lower than of its aggregates. This finding is probably due to the aggregation effect. The calculation of the real GDP includes two types of aggregation: firstly aggregation of the components and secondly aggregation throughout the Euro area countries.
The highest and consistent within different measures uncertainty is verified for investment.

On the whole the aforementioned upward uncertainty trend is detected for uncertainty in revisions. Our results are in line with new macroeconomic uncertainty literature. However, this finding contradicts to the old revision studies, such as Kholodilin and Siliverstovs (2009) or Öller and Teterukovski (2007) because of two main reasons. Firstly, the real data they used for uncertainty calculations ends during the Great Moderations, the period of low uncertainty levels in most countries. Secondly, these papers ignore the possible noisiness of revisions since they did not test for this issue explicitly. In the next section we test whether our results are robust if we apply this methodology to the US data and robust to the alternative definition of final estimate. Further we compare SNR and entropy to the recently popular measures of uncertainty based on news and stock market volatility.

6 Robustness Checks and Comparison with VSTOXX and Euro area EPU indices

6.1 Robustness to data definitions

To demonstrate the robustness of our measures we additionally apply our concept to the US data published by the Eurostat and the Federal Reserve Bank of Philadelphia (FED).[22] Both sources provide monthly revisions of quarterly estimates since August 1998. To be consistent with previous calculations we assume the same definition of final revision.

Starting with descriptive statistics we see that the root mean squared errors of the US revisions has been constantly growing, actually during the crisis at a higher level than the Euro area errors. Therefore the result of signal-to-noise ratios is not surprising: the data uncertainty of US Eurostat and FED real GDP growth rate is higher than of the Eurostat Euro area aggregate. Moreover, the entropy measures of the US and Euro area real GDP seem to converge during the recent recession, notably Fed data based estimates are closer to the Euro area measure.

——————— please insert figure 5 about here ———————

[22] See appendix A for details.

Finally, we show that our measures are robust towards alternative definition of final estimates. Eurostat announces the final estimate 100 days after the end of the quarter. In line with the US revision announcement policy we introduce revised final estimate as if it was announced eight quarters after the end of the report period. In terms of monthly revision structure the announcement is equivalent to $(t + 24)$ vintage. Figure (6) and (7) below give a comparison of revision errors calculation based on revised final definition. It can be clearly seen that the detected uncertainty trend is robust. The magnitude of uncertainty changes for the revision errors calculations with the revised final estimate only marginally. This finding indicates that the introduction of an official revised final would not significantly reduce the uncertainty and increase the accuracy of Eurostat data for all macroeconomic variables.[23]

——————— please insert figure 6 about here ———————

——————— please insert figure 7 about here ———————

6.2 Comparison with EPU and VSTOXX

Further we compare our measures to other recently proposed uncertainty proxies, such as Euro area EPU news-based index and the VSTOXX, Euro area stock market volatility index.

Our first benchmark is the Economic Policy News Index. The Euro area news- based EPU index captures at equal shares the frequency of references to policy-related economic uncertainty in leading newspapers.[24] The European EPU encompasses Germany, Spain, France, Italy and the UK. To make the index comparable with our Euro area estimates, we adjusted the index only for the Euro area countries and exclude the UK, using Baker-Bloom individual country data[25] and Eurostat individual country real GDP shares of total real Euro area GDP.
For our analysis we examine whether there is any correlation between the EPU index and our uncertainty measures for each variable. Mean squared errors and entropy are positively correlated with the index, while for signal-to-noise ratios we detect a negative relation to the EPU index. The negative correlation is explained by the definition of ratios. Declining SNR and ISNR underline rising uncertainty, and vise versa.

——————— please insert table 5 about here ———————

Another traditional measure of uncertainty is stock market volatility. The EURO STOXX 50 volatility index (VSTOXX)[26] captures variance across all options of a given time to expiry. The options contract on the EURO STOXX 50 in one of the products of Eurex with the highest trading volume. VSTOXX is calculated on the basis of eight expiry months with a maximum time to expiry of two years. Though the VSTOXX index follows the same trends, it is hardly correlated

[23] Additionally we checked further definition of final: 36 months respectively three years after the end of report quarter. Though levels of uncertainty measures are lower than before, the consistent pattern of growing uncertainty is confirmed in this case as well.
[24] See for further details Baker et al. (2013, p.9-10) The computation of the EPU index for the US and the European countries differs due to the idiosyncratic role of tax in the US policy.
[25] The media data includes two newspapers per country.
[26] http://www.stoxx.com/index.html. Download on 27.05.2014.

with our measures.
Further interesting finding: we detect disagreement between both proxies and our measures, for instance entropy of the real GDP revisions, during the recent recession period. On one hand, the Euro area EPU and VSTOXX exhibit reduction of uncertainty since 2012. On the other hand, the entropy seems to increase from the third quarter 2011 onwards, following the business cycle. The possible reason is the computation of the EPU index: it is computed only based on information from two newspapers published in four Euro area countries. Therefore it probably does not capture enough information about macroeconomic uncertainty or the public concern about uncertainty became lower.

——————— please insert table 10 about here ———————

Our analysis shows that data uncertainty estimates applied within this paper are both robust towards changes in final revision definition and implementation to another country - the US - data and are related to popular uncertainty proxies.

7 Conclusion

Prior work has documented increased uncertainty in terms of different uncertainty proxies[27]; Baker et al. (2013), for instance, applied the news-based economic policy uncertainty index, another popular proxies are stock market volatility index or Scotti's "surprise" index. However, most of uncertainty measurements are made based on US data, especially on the US SPF forecast probability distribution. For the Euro area there is less research concerning uncertainty, the focus of available papers is again on SPF data. In this study we analyzed how the information content for the Euro area has changed over time using Eurostat real time data and focused on data uncertainty in terms of real gross domestic product (GDP) and its component revisions. Data uncertainty is an important aspect when it comes to the forecastability of macroeconomic time series.

Our study measured uncertainty applying three methods: descriptive statistics, signal-to-noise ratios and entropy. We found that data uncertainty of macroeconomic variables in the Euro area has become higher within the last decade. This finding extends Bloom (2013) stylized fact on uncertainty based on the US data, who postulated that during the recession uncertainty is much higher than within the stability and prosperity period. We can luckily transfer this stylized fact to the revisions. Uncertainty has been continuously growing with the last decade. The increase is even dramatic during the recession for all Euro area macroeconomic variables, comparing with reference uncertainty proxies, which indicates relief of uncertainty.

Most notably, the uncertainty increase of the real GDP is weaker than for its aggregates, probably because of the double aggregation effect. In addition, investment tends to be highly uncertain. According to signal-to-noise ratios, private and government consumption exhibited high uncertianty level and contradicted entropy measure. Unfortunately revisions of these

[27] See i.e. Bloom (2009); Bloom et al. (2013); Bloom (2013); Baker et al. (2014); Scotti (2013); Jurado et al. (2014).

variables are correlated with errors and therefore contain noise instead of new information. Revisions of all other variables fulfill orthogonality condition, validating uncertainty calculations.

Our results provide evidence on increased data uncertainty in the Euro area. However, we do not discuss the reasons for this development. Future work should therefore include follow-up work designed to analyse the sources of uncertainty in real-time data.

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A Data Download Information

In the recent version of the paper the Eurostat data was updated on April 29^{th} 2014 and Federal Reserve Bank of Philadelphia real time US data on August 22^{nd} 2014[28].

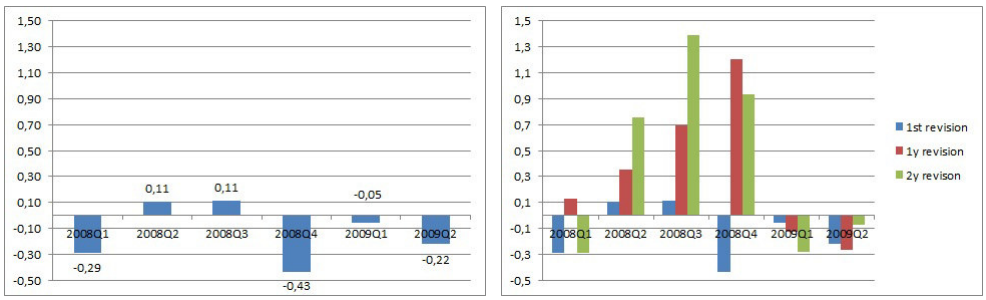
Eurostat name	Short name	
Euro area (moving concept in the Real Time database context) Gross domestic product at market price Chain linked volumes - Euro	Gross Domestic Product	Y
Euro area (moving concept in the Real Time database context) Final Consumption of Households and NPISH's (private consumption)[29] Chain linked volumes - Euro	Consumption	C
Euro area (moving concept in the Real Time database context) Gross Fixed Capital Formation Chain linked volumes - Euro	Investment	I
Euro area (moving concept in the Real Time database context) Final Consumption of General Government Chain linked volumes - Euro	Government Consumption	G
Euro area (moving concept in the Real Time database context) Exports of Goods and Services Chain linked volumes - Euro	Exports	Ex
Euro area (moving concept in the Real Time database context) Imports of Goods and Services Chain linked volumes - Euro	Imports	Im
United States (moving concept in the Real Time database context) Gross domestic product at market price Chain linked volumes - US dollar Eurostat	US GDP	YUS
Federal Reserve Bank of Philadelphia Name		
Real GNP/GDP (ROUTPUT) Billions of real dollars, seasonally adjusted	US FED GDP	YUSFED

Table 4: Download Information

[28] http://www.philadelphiafed.org/research-and-data/real-time-center/real-time-data/data-files/ROUTPUT

	LN_EA_EPU	LN_VSTOXX
LN_EA_EPU	1.00	0.62
LN_VSTOXX	0.62	1.00
RMSE_Y	0.54	0.01
RMSE_C	0.40	-0.02
RMSE_I	0.27	-0.20
RMSE_G	0.19	-0.12
RMSE_EX	0.18	-0.24
RMSE_IM	0.48	-0.10
AVERAGE	**0.34**	**-0.11**
SNR_Y	-0.55	0.00
SNR_C	-0.43	0.01
SNR_I	-0.32	0.18
SNR_G	-0.22	0.12
SNR_EX	-0.22	0.24
SNR_IM	-0.53	0.08
AVERAGE	**-0.38**	**0.11**
ENT_Y	0.54	0.04
ENT_C	0.42	-0.11
ENT_I	0.34	-0.17
ENT_G	0.36	-0.13
ENT_EX	0.33	-0.16
ENT_IM	0.37	-0.15
AVERAGE	**0.39**	**-0.11**

Table 5: Correlation between the Euro area EPU news based index, VSTOXX and different uncertainty measures



(a) Revision of the flash estimate

(b) Comparison of different revisions

Figure 1: Revison size during the recession: euro area real GDP growth rates

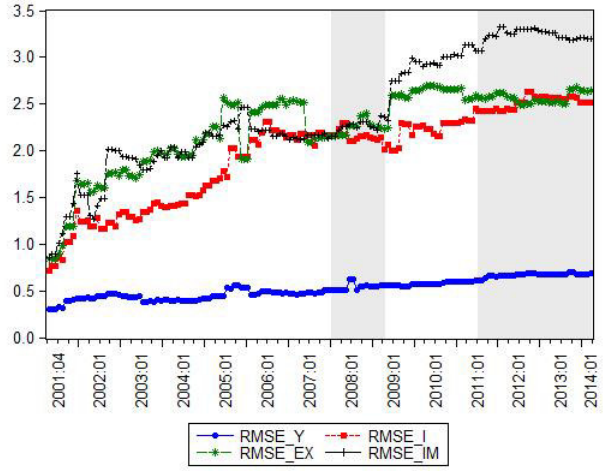
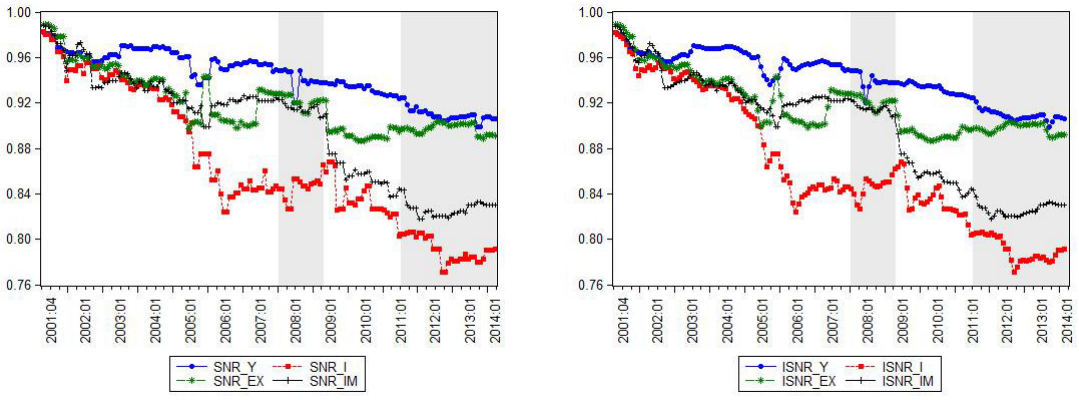


Figure 2: Root Mean Squared Errors for the Euro area aggregates
Note:The gray shaded area underlines recession



(a) SNR

(b) ISNR

Figure 3: Signal-to-Noise Rations for the Euro area aggregates
Note:The gray shaded area underlines recession

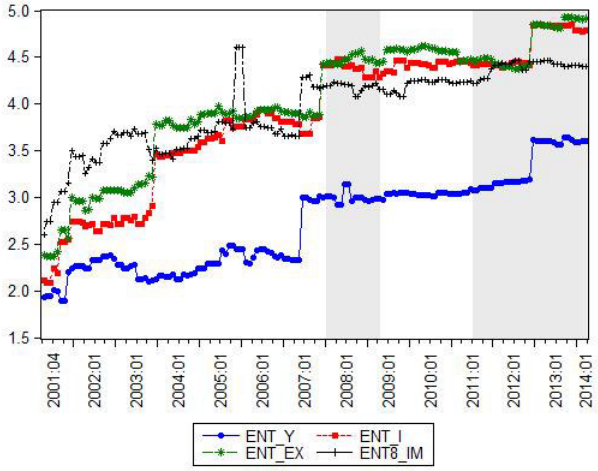
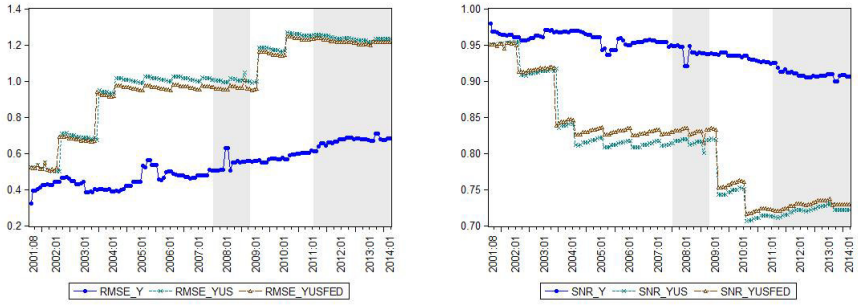
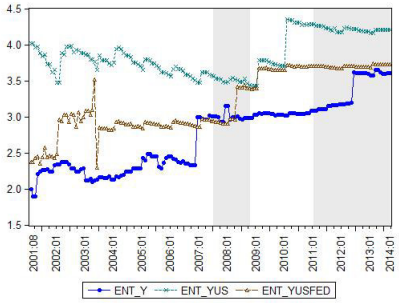


Figure 4: Entropy measures for the Euro area aggregates
Note:The gray shaded area underlines recession

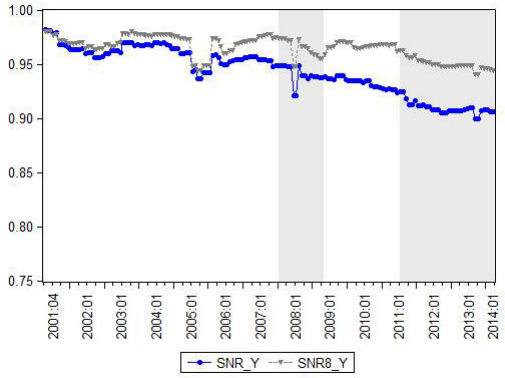


(a) Root Mean Squared Errors (b) SNR

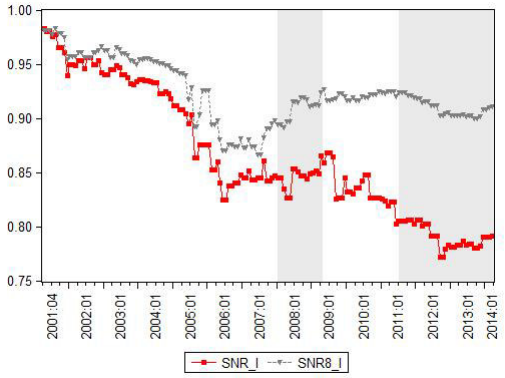


(c) Entropy

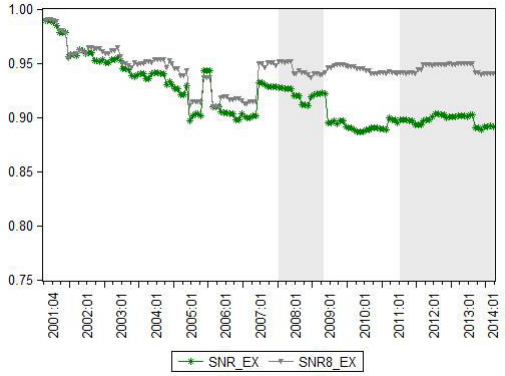
Figure 5: Comparison between the Euro area and the US real GDP uncertainty estimates
Note:The gray shaded area underlines recession



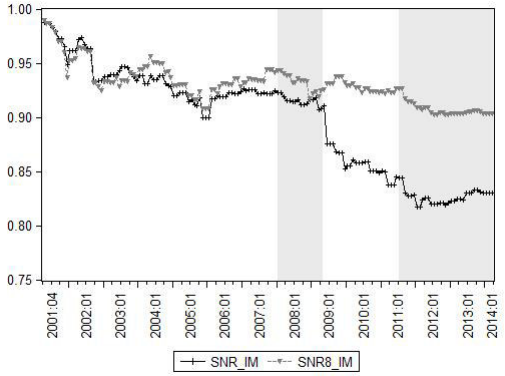
(a) Euro area real GDP



(b) Euro area Investment

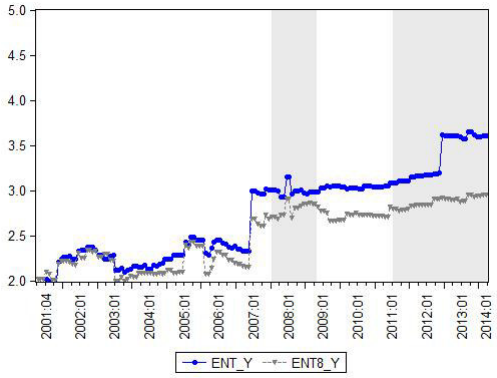


(c) Euro area Exports

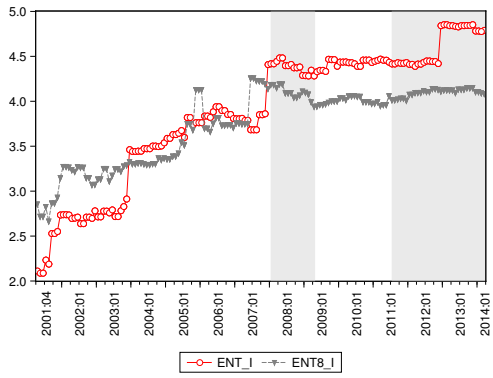


(d) Euro area Imports

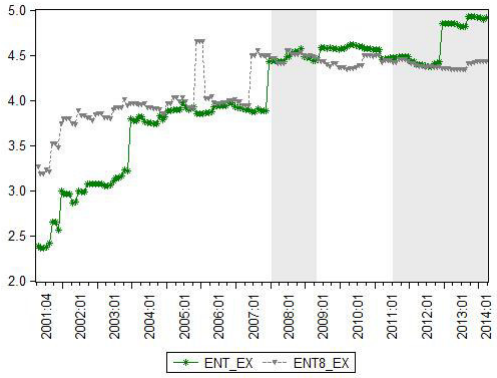
Figure 6: SNRs: Eurostat final estimate definition versus revised final ($t + 8$)
Note:The gray shaded area underlines recession



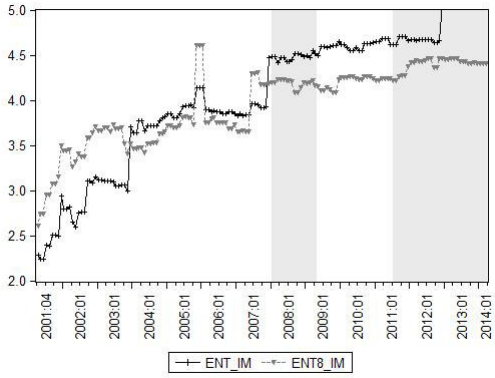
(a) Euro area real GDP



(b) Euro area Investment

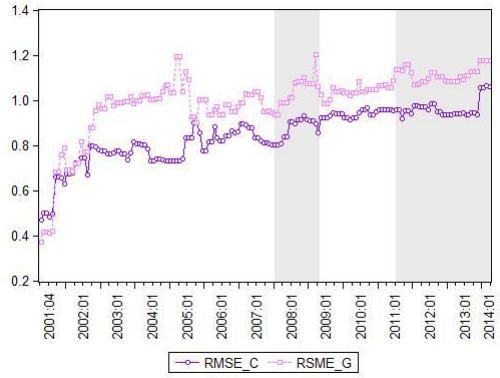


(c) Euro area Exports

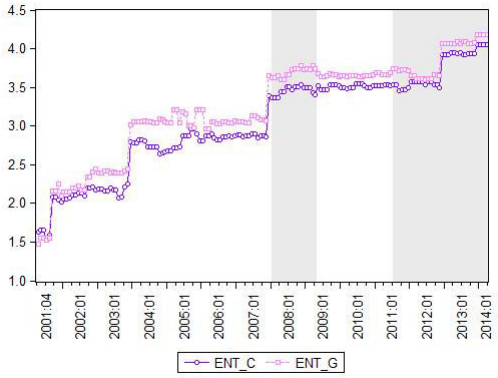


(d) Euro area Imports

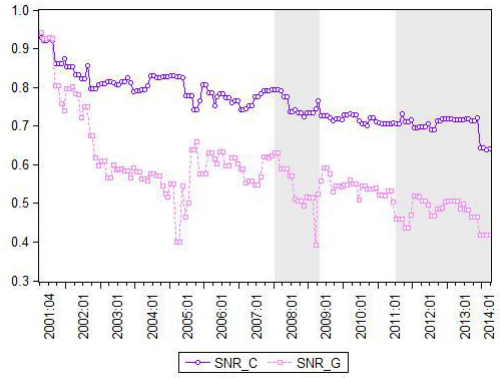
Figure 7: Entropy: Eurostat final estimate definition versus revised final ($t + 8$)
Note:The gray shaded area underlines recession



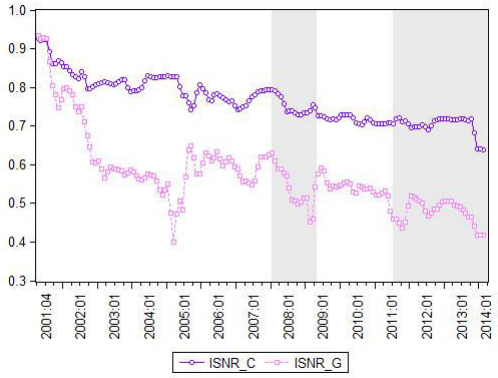
(a) RMSE



(b) Entropy

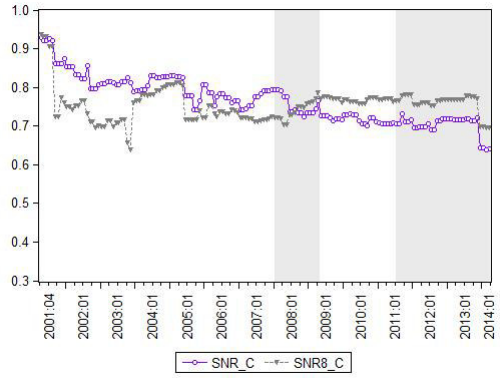


(c) SNR

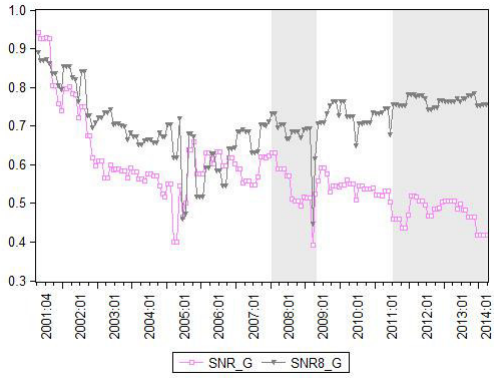


(d) ISNR

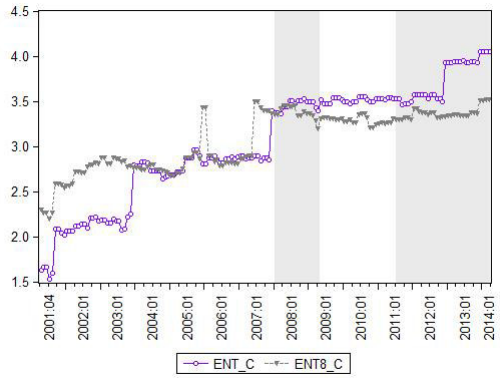
Figure 8: Uncertainty Measures for the Euro area Private and Government Consumption
Note:The gray shaded area underlines recession



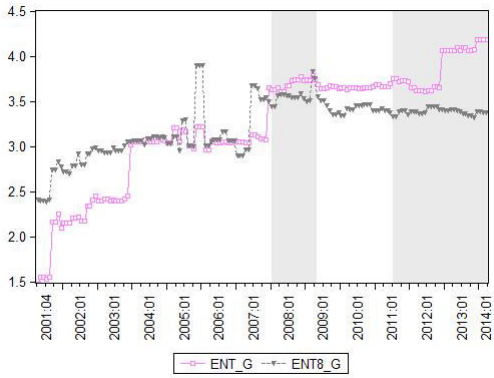
(a) SNR Consumption



(b) SNR Government Consumption



(c) Entropy Consumption



(d) Entropy Government Consumption

Figure 9: Singnal-to-Noise Ratios and Entropy: Eurostat final estimate definition versus revised final ($t + 8$)

Note:The gray shaded area underlines recession

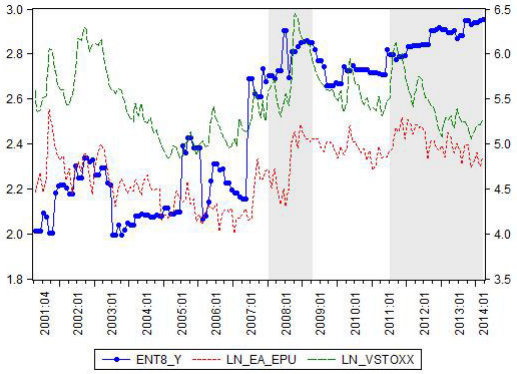


Figure 10: Entropy, Euro area news-based Economic Policy Index(EA_ EPU) and EURO STOXX 50 volatility index (VSTOXX)

Note:The gray shaded area underlines recession