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Tsvetomir Tsvetkov[1]
Sonya Georgieva[2]

INFLATION, INFLATION INSTABILITY AND NOMINAL UNCERTAINTY IN THE BULGARIAN ECONOMY[3]

The main goal of the paper is to assess the relationship between inflation, inflation instability and nominal uncertainty in the Bulgarian economy in January 2000 – May 2022. Employing the ARCH model, GARCH-M model, EGARCH model and Granger Causality Test we find a two-way causal relationship between inflation and inflation instability. Initially, inflation provokes inflation instability, and inflation instability provokes inflation consequently. Nominal uncertainty is measured by wavelet analysis, which establishes the presence of nominal uncertainty in the Bulgarian economy. Therefore, at certain lags, the inflation instability is transformed into nominal uncertainty. The empirical evidence raises the question of the effectiveness of the Currency Board Arrangements in Bulgaria.
Keywords: inflation; inflation instability; nominal uncertainty
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Introduction

The monetary shocks in the Bulgarian economy in 1997 led to the introduction of currency board arrangements, the main objective of which was to achieve price stability. This has meant a stable inflation process and the prevention of inflationary instability and nominal uncertainty. Inflationary instability and nominal uncertainty should not be induced under a currency board, as traditional monetary policy cannot be pursued. Therefore, the study of the relationship between inflation, inflation instability and nominal uncertainty in the Bulgarian economy under the currency board arrangements is an important and topical macroeconomic issue. Particularly, the importance of inflation instability and nominal uncertainty raises since the inflation in the global, European and Bulgarian economy has started to increase at a very

[1] *Tsvetomir Tsvetkov, PhD, Chief Assistant Professor, Sofia University "St. Kliment Ohridski", Faculty of Philosophy, ORCID: 0000-0002-4657-9519; e-mail: c.cvetkov@phls.uni-sofia.bg.*
[2] *Sonya Georgieva, PhD, Chief Assistant Professor in Economic Research Institute at the Bulgarian Academy of Sciences, e-mail: s.georgieva@iki.bas.bg.*
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fast pace at the end of 2021. The importance of this issue increases, especially for the Bulgarian economy, as in late 2021 and early 2022, the monthly inflation rate in Bulgaria was among the highest in the EU.

The main objective of the paper is to assess the relationship between inflation, inflation instability and nominal uncertainty in the Bulgarian economy. The relationship between inflation and inflation instability is assessed using a four-stage model that includes ARCH methodology, GARCH-M model, EGARCH model and Granger causality test. Thus, the four-stage model constructed using these technical tools provides one of the most reliable estimates of the direction and strength of the relationship between inflation and inflation instability over time. The relationship between inflation instability and nominal uncertainty is estimated by wavelet analysis. The conditional estimation of nominal uncertainty is done by a synthesis of the fractal approach and a priori structuring. A certain abstraction is introduced to represent nominal uncertainty as a hidden signal from the standard deviation noise of inflation, and hence the relationship between inflation, inflation instability and nominal uncertainty.

The basic view is that the relationship between inflation and inflation instability in the Bulgarian economy is bidirectional, i.e. in one lag inflation leads to inflation instability, and in another lag inflation instability leads to inflation. The very fact that such a bidirectional causality is found leads to the conclusion that nominal uncertainty is also reproduced as a consequence of inflationary instability.

Section one critically outlines the main theoretical and empirical approaches to measuring the relationship between inflation and inflation instability. The theoretical concept of the nominal uncertainty measurement approach is also presented.

In the second section, econometric methods for estimating the relationship between inflation, inflation instability and nominal uncertainty are reviewed and discussed, as well as the specifics of the used data and methods for assessing the adequacy of the econometric models employed.

The third section discusses and analyses the empirical results of the estimations of the relationship between inflation, inflation instability and nominal uncertainty.

Literature Review

The relationship between inflation and inflation instability is first considered by J. Tobin (1965), who found that price volatility affects asset returns. Therefore, the amplitude and the speed of the transition of prices from an inflation trajectory to a deflation trajectory and vice versa create inflation instability. Thus, Tobin manages to bring out the invisible relationship between inflation and inflation instability. A. Okun (1971) adopts Tobin's view that inflation leads to inflation instability. However, based on the understanding that inflation cannot increase over a long period in a stable trajectory, he postulates that in the long run prices always show volatility, which leads to inflation instability. The difference in Tobin's and Okun's views lies in the fact that Okun manages to point out that regardless of the amplitude, inflation increases permanently, and this increase is associated with inflation instability measured by standard deviation. On the other hand, according to Tobin, inflation instability manifests in cases where the inflation change is abrupt.

The relationship between inflation and inflation instability is also found in M. Friedman (1977), who theoretically reasons the relationship between inflation and inflation variability, manifested in the presence of an average increase in inflation values. The new contribution of Friedman to the theory of inflation instability is the notion that the current values of inflation instability are determined by past values of inflation volatility. This is how Friedman's view builds on the theoretical views of Tobin and Okun. Friedman points out also that the inflation increase is, in many cases, due to monetary policy. Therefore, the monetary policy, if conducted ineffectively, also provokes inflation instability.

Okun's view that the standard deviation of inflation means inflation instability leads E. Foster (1978) to formulate inflation instability as a variable inflation rate expressed as price instability. Therefore, according to Foster, the faster the volatility increases as inflation rises, the greater the inflation instability is reproduced. In fact, with this logic, Foster does not further develop Okun's theoretical views, but stands on his theoretical positions. Even Foster adopts from Okun the variable by which inflation instability is measured, namely the standard deviation.

The views of Friedman and Tobin are found in the theoretical position of L. Ball (1992), who, with his statement that inflation instability occurs both in an inflation process and in a deflation process, starts from Tobin's position and further develops it. Ball also adopts Friedman's view that the conduct of monetary policy can lead to inflation and inflation instability when the monetary policy is subordinated to political rather than economic goals. Expanding on Friedman's view, Ball argues that the lack of predictability in the conduct of future monetary policy leads to future inflation instability.

J. Tobin (1965), A. Okun (1971), M. Friedman (1977), E. Foster (1978) and L. Ball (1992) consider the inflation instability metaphysically and fail to understand its essence, and therefore fail to show the elements the inflation instability creates. They do not understand that inflation instability is divided into measurable inflation instability and unmeasurable inflation instability. Measurable inflation instability takes the form of risk that can change the expectations and decisions of the economic agents. Unmeasurable inflation instability contains an unpredictable random element that can be defined as nominal uncertainty. According to Okun, measurable inflation instability can be measured as the standard deviation of the inflation growth rate. This idea is applied by Foster, who concludes that the results show a good approximation of the proximal expression of inflation instability. Okun's approach, through which he expresses the instability that arises from inflation, is adopted by many authors, like D. Logue and R. Sweeney (1981), who attempt to practically assess inflation instability. They derive the instability from the average inflation rate relative to the standard deviation of the rate of inflation. On the other hand, however, Logue and Sweeney criticise Okun by pointing out that his approach covers only the current inflation instability, not the future one. In fact, the critical view of Logue and Sweeney is sound, but on the other hand, practical forecasting of future inflation instability is difficult to realise, because the probability of the statistical adequacy of possible forecast values of the future inflation instability will very likely be some mathematical approximation rather than accurate forecast number. Another critical point revealed in Okun's methodology is the definite static nature of the method, which does not cover well the change of inflation instability over time. The static Okun's approach arises as a consequence of its technical application, which is based on the method of overlapping moving averages. G. Katsimbris (1985) attempts to solve this problem with the technical application of Okun's approach by replacing the overlapping moving averages with moving average proxy variables that express inflation and its variance. Despite this technical change, Katsimbris fails to measure future inflation instability because he fails to distinguish future inflation instability from possible predictable changes in the inflation dynamics (Jansen, 1989). According to Jansen, it is precisely the failure to cover the parameters of inflation variation over time that is the main problem with the methodology of Katsimbris. For this reason, Jansen adopts the Katsimbris methodology, but he employs an ARCH model. Thus, he manages to assess the parameters of the consequences of the mean variance on inflation and economic growth.

Some weaknesses are found in the methodologies of A. Okun (1971), E. Foster (1978), D. Logue, R. Sweeney (1981). They fail to cover the great probability of inflation instability and also they failed to provide an empirical assessment of the nominal uncertainty. Okun, Foster, Logue, Sweeney and Katsimbris do not reflect the change in the inflation instability over time. The problem of assessing the inflation instability with a greater probability approximation to the real inflation instability is addressed by D. Jansen (1989). Through the application of the ARCH model, he manages to assess the inflation instability as a conditional inflation variance over time. However, Jansen makes no attempt to calculate the nominal uncertainty at all.

Samut (2014) assesses the two-way effects between inflation instability and the different components of the price level through the ARCH model and then applies Granger causality tests and Impulse response analysis. The ARCH methodology, though allowing the conditional variance to depend on its historical values, i.e. covers the inflation instability over time, does not provide accurate parameters if the rate of change of the inflation instability is faster than the model predicts. Also, if the parameters are too much, the assessment procedure becomes difficult and gives an inaccurate direction for the development of the ARCH coefficients. This does not lead to the rejection of the application of ARCH. On the contrary, its use is recommended, but in combination with the GARCH methodology. That is why authors such as Grier and Perry (2000) state that in order to assess the inflation instability with a higher probability of approximation, the time-varying residual variance that captures the essential characteristics of the instability should be assessed. This is possible with the application of the GARCH methodology.

Karahan (2012) applies a similar approach when he studies the relationship between inflation and instability in Turkey. The author expresses the instability quantitatively by the conditional variance of the inflation mean. The relationship between inflation and instability is studied with a general ARMA-GARCH model, which means that instability takes the form of conditional volatility. In fact, Karahan empirically proves the conclusion of Ball (1992) that an increase in inflation leads to an increase in instability (Karahan, 2012, p. 227). Sharaf (2015) also assesses the instability as a conditional variance calculated through the GARCH-M model. He comes to the conclusion that under inflation shocks, instability increases and the increase is on a sustainable trend. Authors like Fountas and Karanasos (2007) assess the instability by the conditional variance of inflation. This means that the residual information from the inflation process should be covered, so the autoregressive conditional heteroskedasticity to be calculated. The procedure for calculating the autoregressive conditional heteroskedasticity is implemented through the GARCH model.

Fountas and Karanasos raise the important question of determining the type of instability. According to them, instability can be anything but nominal, i.e. to result from inflation, it can also be real, i.e. the instability to arise from real factors. The study of Viorica, Jemna, Pintilescu and Asandului (2014) is interesting. They measure the inflation instability with four models, which are the ARCH model, GARCH model, EGARCH model and PARCH model. The instability is again considered a conditional variance. The authors analyse the relationship between inflation and instability in the case of Bulgaria, Poland, Croatia, Czech Republic, Romania, Hungary, Slovenia, Malta, Latvia, Slovakia, Lithuania, Romania. Apergis (2005) also explores the relationship between inflation and instability, by covering the instability through the GARCH model. The conclusion of the author is that the rate of inflation in the short run creates instability. According to Apergis, shocks that create instability do not lead to large negative effects, i.e. the duration and the degree of the instability are not in threatening proportions to the economic growth and pass quickly. Similar to Apergis (2005), N. Ananzeh (2015) also studies inflation instability through the GARCH model.

Mandeya and Ho (2021) consider the inflation instability as a percentage change in the standard deviation of inflation. Considering this approach to express the inflation instability, the authors take a step back in the possibility to accurately determine the inflation instability, since they measure the instability when the inflation process has already occurred. Mandeya and Ho study the impact of inflation instability on the economic growth of South Africa through assessment of autoregressive distributed lag. They conclude that instability affects economic growth in the short run, while inflation affects economic growth both in the short run and long run. Another important conclusion that Mandeya and Ho draw is that the implementation of inflation targeting leads to ignoring the instability as a factor that negatively affects economic growth.

Golob (1994) studies the dynamics of instability and inflation and concludes that an increase in inflation leads to an increase in instability. That is why, an inflation-targeting policy should be implemented to manage the inflation process and to lead to price stability. Otherwise, the rising instability as a consequence of the rising inflation will have a negative impact on both the nominal and the real economic variables. Terzioğlu (2017) goes even further by arguing that inflation instability confuses and unbalances the distribution function of the price system, which has an adverse effect on the allocation of resources. It becomes clear that inflation instability actually leads to information asymmetry, which in turn leads to false price signals, which lead to irrationality in the allocation of resources. The described process leads to the spillover of instability into uncertainty.

Berger, Grabert and Kempa (2017) study the global macroeconomic instability. The authors use a dynamic factor model, through which they derive the instability as stochastic volatility of the conditional variations of the variables included in the model. The main conclusion of Berger, Grabert and Kempa is that instability negatively affects the economic growth.

In the discussed literature, the instability is measured by conditional variance. According to Jurado, Ludvigson and Ng (2015), deriving the conditional variance from stock exchange index returns or returns of the different stocks does not provide accurate information about the effect of the instability. The authors claims that the instability cannot be accurately measured by the proxy variables because there is heterogeneity in the conditional variance that arises from the cross-section that characterises the variance in returns of all financial assets in the stock market (Jurado et al., 2015). Jurado, Ludvigson and Ng separate the instability from the conditional volatility. That is why they remove the predictable component in the calculation of the conditional volatility, which means that the constant average is removed because it is, in fact, the predictable component. According to the authors, another important element in the study of instability is that the instability requires an aggregate consideration of the variation. Therefore, according to Jurado, Ludvigson and Ng, deriving the unpredictable aggregate element of the aggregate conditional variance is a more accurate assessment of the instability. In the sense of Jurado, Ludvigson and Ng, instability is actually described as the conditional variability of the unpredictable element in the future value of the considered series (Jurado et al., 2015, pp. 1178-1179).

Authors such as Fountas and Karanasos, Karahan, Golob, Berger, Grabert, Kempa, Jurado, Ludvigson and Ng, as well as the other mentioned researchers, do not cover the exogenous variations of the instability. That is why, Piffer and Podstawski (2018) conduct a study that focuses on the exogenous variations of the instability. Piffer and Podstawski technically parameterise the effects of the exogenous variations of the instability with the SVAR model that is applied one time with recursive technology and a second time with proxy specialisation. According to them, the SVAR technology provides a broader and deeper explanation of the exogenous variations of the instability, because the variances of the real variables are better specified. Piffer and Podstawski study real instability, not inflation instability, because ARCH and GARCH methodologies are more suitable for the study of inflation instability. In the study of instability Bloom (2009) applies the VAR methodology. Redl (2017) assume that the instability is the conditional expectation in the time of the squared error of the forecast, which means that the instability is considered variable in the conditions of a stochastic process. That is why he applies the FAVAR model. The study of Bobasu, Geis, Quaglietti and Ricci (2021) synthesises the approaches of Piffer and Podstawski and Jurado, Ludvigson and Ng, as well as Bloom and Redl, and further develop them by constructing a model that assesses the effect of the global macroeconomic instability in the euro area. The author’s conclusion is that global macroeconomic instability has a negative impact on the economy of the euro area. Nenovsky, N. et al. (2000) quantitatively measure, by means of a VAR model, the behaviour of inflation under Currency Board Arrangements and come to the conclusion that the rise in the prices of traded goods and real wages are the main inflation factors.

Apart from ARCH methodology, GARCH methodology and VAR methodology and their methodological variants, authors such as Shelton Masimba, Tafadzwa Mandeya and Sin-Yu Ho (2021) apply ARDL methodology to study inflation and inflation instability and their effect on the GDP of South Africa. Despite the large set of econometric instruments applied in the assessment of inflation instability, the best methods are ARCH methodology and GARCH methodology, which allow the inflation instability can be covered most precisely. The variations of GARCH methodology like EGARCH and GARCH models-M model with a high probability provide credible assessments of the inflation instability. The reason is that ARCH methodology and GARCH methodology best capture the conditional variance, which effectively expresses inflation instability.

Cukierman and Meltzer (1986) derive the instability from the relationship between the response that the economic agents reproduce as a result of the political dynamics. According to Cukierman and Meltzer, instability is a consequence of the uncertainty of political decisions. According to Grier and Perry (2000), the definition of instability derived by Cukierman and Meltzer is characterised as an unpredictable component. Also, Grier and Perry distinguish the variability from the instability because the variability can be predictable while the instability is unpredictable. Therefore, for them, the instability borders on uncertainty.

Cukierman and Meltzer as well as Grier and Perry provide guidance on how the uncertainty can be defined, namely as an unpredictable random event in the setting of a stochastic process. This unpredictable random event is a component of inflation instability and of instability in general, regardless of its dimensions and areas of manifestations.

According to Wiliett ((1951),1901), the instability contains risk. A risk is a random event that has a probability of happening, and when the risk is "hardened", then the given probability will necessarily happen sometime. The fact that the risk will ever happen is a measurable instability, and exactly when it will happen is an unmeasurable instability or uncertainty. That is why, according to Knight (1964), Willett distinguishes between instability and risk, but fails to understand that the uncertainty cannot be quantified through the mathematical parameterisation of the probability of loss. It becomes clear that the instability is a phenomenon that, in the sense of Knight (1964), contains both a risk factor and an element of uncertainty, i.e., uncertainty is a complex composite phenomenon. The element of uncertainty manifests as a random element in the process of developing the instability. This perspective leads Knight to the understanding that uncertainty as a random element of instability cannot be fully expressed through the mathematical theory of probabilities, which parametrises the chance of developing one or another event. In fact, Knight separates the risk from the uncertainty and from the instability, because the instability contains both risk and uncertainty. Uncertainty arises from the free action and ability of a person to make decisions that cannot be covered by the mathematical apparatus. Knight states that the Monte Carlo method is incapable of predicting uncertainty (Knight, 1964, p. 221). The view developed by Knight and Willett that uncertainty arises from human imperfection in making decisions about the future, is also adopted by Mises (1998). He claims that uncertainty appears in the future as a consequence of human action, i.e. the human action is seen as an imperfection of the cognitive and information capacity available to the person. Therefore, the human choice, which is transformed into a future action and future uncertainty, is inextricably linked, according to Mises. The mathematical instruments cannot calculate correctly the probability of whether an event will occur because, as Mises (1998, p. 107) argues, the probability does not always have a frequency characteristic. This means that the probability cannot always be assumed to take the form of a constant event. Mises writes: *"It is a serious mistake to believe that the calculus of probability provides the gambler with any information which could remove or lessen the risk of gambling."* (Mises, 1998, p. 108).

The conclusion from the mentioned quote is that mathematics and even physics, which further develops the mathematical instruments, cannot predict and measure the uncertainty, because in uncertainty there is a synthesis between the unknown and the chance in the future time.

The analysed views of Wiliett, Knight and Mises have their logic which is difficult to be disputed, because the uncertainty in its factual dimensions cannot be assessed accurately. Also, there is no generally accepted definition of uncertainty in economic theory. Therefore, assuming that uncertainty is an unknown random process in the future whose frequency and magnitude cannot be determined, the views of Wiliett, Knight, and Mises that even the physics cannot study future uncertainty are inevitably confirmed. However, in this paper, a part of the goal set is to study the nominal uncertainty. That is why, in order to achieve the goal, a fractal approach and a priori structuring of the uncertainty will be applied (Gradinorov, 2019). A part of the nominal uncertainty will be studied, which will allow extracting information that falls within a strong information interval and will inform the whole process of the nominal uncertainty. The fractal approach is synthesised with a priori nominal uncertainty, which means that certain information criteria will be isolated so to allow elements of the random, unpredictable process expressing the nominal uncertainty to be covered.

Uncertainty can be described by Heisenberg's mathematical equation (Soloviev, Saptsin, 2011):

$$\Delta x \times \Delta v \geq \frac{\hbar}{2m_0} \tag{1}$$

where:

Δx and Δv are squared deviations from the mean;

$\hbar$ – Planck's constant;

m_0 – particle in a mass.

Equation (1) expresses the root mean square deviations of the allocation (location) of *x* and the impulse speed *v* corresponding to a particle of the total mass at rest m_0. So, equation (1) illustrates that the product of the location and speed of the impulse forms a particle of the mass of the uncertainty and carries information that indicates the purity and the scale of the uncertainty at a given time. Placing the Heisenberg equation (1) within the framework of the fractal approach and a priori structuring of the uncertainty, and assuming that *x* is the scale and *v* is the frequency and that their interaction is cut in time and space when nominal uncertainty occurs, with certain conventionality a part of this nominal uncertainty can be measured, and the probability of estimating the part of the nominal uncertainty may be significant. It is important to say that when measuring the part of the nominal uncertainty, the already realised values of nominal uncertainty but not the future values of nominal uncertainty are covered.

In order to describe the nominal uncertainty under a given economic system, we made some assumptions in equation (1). It is assumed that a stochastic process is observed, which moves along a given trajectory and is manifested by a dummy variable that registers a certain scale and a certain purity in a certain time period. The scale registers the value of the root mean square deviations, and the frequency registers how many times in the time period and at what rate the root mean square deviations are registered. The dummy variable that illustrates the stochastic process and its manifestations over time, which include the interaction between the scale and the frequency of manifestation of the square deviations, manifested by chaotic volatility and returns, can be expressed by the following formula (Soloviev, Saptsin, 2011):

$$\Delta x_i \times \Delta v_i \sim \frac{h}{m_i} \tag{2}$$

Equation (2) on its left side illustrates the nominal uncertainty, and on its right side illustrates the time and its characteristics over the considered stochastic process.

The uncertainty described by equations (1) and (2) shows that the assessment of the nominal uncertainty can be realised if the parameters scale, frequency and time are simultaneously taken into account. This can be realised by applying the physico-economic instruments of the wavelet analysis. It is wavelet analysis that manages to simultaneously cover scale, frequency and time (Rua, 2012), i.e. it is possible to assess simultaneously, and with great accuracy, the frequency and the time of manifestation of the hidden signal which is the nominal uncertainty. Wavelet analysis allows flexible and adequate resolution of the frequencies and the time of occurrence of the signal (Rua, 2012). In wavelet analysis, the duration of time is tuned to purity, and each point contains all frequencies for the time window it falls into (Rua, 2012). This allows to extract the hidden random signals that express particles of the nominal uncertainty during the given time period. Nix and McNevin (2020) study sectoral uncertainty with wavelet analysis. They come to the empirical conclusions that uncertainty in the monetary, energy and manufacturing sectors is characterised by greater frequency and time. Also, the authors manage to capture the transfer of uncertainty from one sector to another. It becomes clear that wavelet analysis succeeds in capturing the hidden signals of uncertainty. Uncertainty, particularly nominal uncertainty, has the characteristics of a hidden signal that cannot be captured by conventional econometric methods. The wavelet methodology, however, manages to capture part of the uncertainty and extract the necessary information about the dynamics of the uncertainty.

The empirical studies examining the relationship between inflation and inflation instability in Bulgaria are carried out by D. Viorica et al. (2014) and M. Khan et al. (2013). D. Viorica et al. (2014) draw the empirical conclusion that in Bulgaria the relationship between inflation and inflation instability is two-way and according to M. Khan et al. (2013) inflation leads to greater inflation instability in the Bulgarian economy.

The theoretical analysis leads to the following theoretical models explaining the relationship between inflation and its volatility. The first concept is based on the view of Friedman (1977), adopted by L. Ball (1992). The second concept is that of A. Purgerami, K. Maskus (1987) who argue that inflation does not lead to inflationary instability. The third concept is developed by A. Kukerman, A. X. Meltzer (1986), who argue that inflationary instability leads to inflation. The fourth concept is developed by A. C. Holland (1995), who argues that inflation instability leads to inflation decrease. The derived concepts view inflation as a specific risk that is generated by various factors.

According to Petranov, S. et al. (2020), a specific risk arises from the dynamics of prices of necessities, which leads to an increase in the prices of all other goods and services. Another view of Viorica, D. et al. (2014) is that, in some cases, inflation volatility leads to higher inflation. Raleva argues that inflationary instability is determined by wages, administrative prices (Raleva, 2013), exchange rate depreciation and oil prices (Raleva, 2012). According to Zatinov (2017), inflationary uncertainty on household spending is determined by increasing tax payments. The author argues that the largest inflationary increase is registered in food (Zlatinov, 2017). Garvalova (1998) points out that consumer price increases are predominantly driven by inflation expectations and speculative shocks.

The critical review of the theoretical and empirical literature leads to the following conclusions: an increase in inflation leads to an increase in inflation instability, as well as to the view that ceteris paribus, an increase in inflation instability leads to conditions of nominal uncertainty. Technical parameters can be derived to assess inflation instability and nominal uncertainty. The most suitable for assessing the inflation instability are the ARCH and GARCH models and the wavelet instruments – for the nominal uncertainty.

Methodology and Specifics of the Study

The period under review is January 2000 – May 2022 on a monthly basis. The data source is the National Statistical Institute (NSI). The variable used to express the inflation in the Bulgarian economy is the annual, monthly difference of the Logarithm of the Consumer Price Index (LCPI). This approach is applied by Khan, Kebewar and Nenovsky (2013).

The study of the relationship between inflation and inflation instability and, accordingly, the effect of the dynamics of inflation instability, is realised through an extended one-dimensional four-step approach, which includes the ARCH model, GARCH-M model, EGARCH model and Granger causality test. The chosen empirical instruments are also applied by Engle (1982), Jansen (1989), Grier and Perry (2000), Apergis (2005), Karahan (2012), Khan, Kebewar and Nenovsky (2013), Samut (2014), Viorica, Jemna, Pintilescu and Asandului (2014), N. Ananzeh (2015), and Sharaf (2015). Inflation instability in the Bulgarian economy is studied simultaneously with several empirical instruments that complement each other and compensate for their technical weaknesses. The nominal uncertainty is estimated using a one-dimensional wavelet methodology.

Stationarity is assessed using Dickey-Fuller Test (Dickey, Fuller, 1979), Phillips-Perron Test (Phillips, Perron, 1988), and the Breakpoint Test. Then ARCH LM test is applied (Hong, Shehadeh, 1999).

ARCH model is described by the following equations (Engle, 1982, p. 988):

$$\gamma_t = \varepsilon_t h_t^{1/2} \tag{3}$$

$$h_t = \alpha_0 + \alpha_1 \gamma_{t-1}^2 \qquad (4)$$

$$\gamma_t | \psi_{t-1} \sim N(0, h_t) \qquad (5)$$

where:

γ_t is variance;

ε – white noise;

h – variable variance;

t – the time;

ψ_{t-1} – information in a previous period.

GARCH-M (p, q) model is described by the following equation (Hill et al., 2011, p. 528):

$$h_t = \delta + \alpha_1 e_{t-1}^2 + \beta_1 h_{t-1} \qquad (6)$$

The exponential GARCH model is described by Nelson (1991, pp. 350-351) with the following mathematical expression:

$$\ln(\delta_t^2) = \alpha_t \sum_{k-1}^{\infty} \beta_k g(z_{t-k}) \qquad (7)$$

Wavelet technology is described by the following mathematical expressions (Ramsey, 2002, p. 5):

$$s_{j,k} = \int f(t) \Phi_{j,k}, \qquad (8)$$

where:

$s_{j,k}$ is scaling coefficients;

Φ *(t)* – low-frequency filter.

$$d_{j,k} = 2\int f(t) \psi_{j,k}, j = 1, \ldots J, \qquad (9)$$

where:

$d_{j,k}$ is a difference coefficient;

ψ (t) – high-frequency filter.

The waves “father” (equation 8) and “mother” (equation 9) are complementary and thus cover all the necessary information for the studied process.

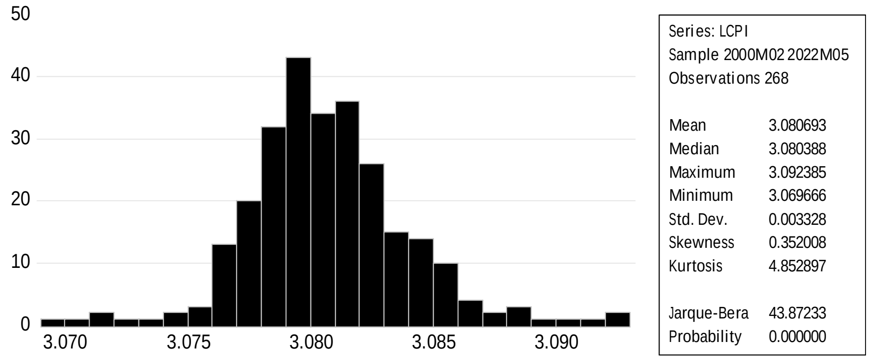
Empirical Results

The time series expressing inflation (LCPI) in the Bulgarian economy is asymmetrically distributed over time.

The values of the median and the mean are duplicated (Figure 1). This means that the center of distribution assumes predominantly high monthly values of inflation in Bulgaria, which is a sign of the existence of inflation instability that arises from the inflation process in Bulgaria. Inflation takes both low and high values, which means that the inflation transition from low to high values creates great volatility – a sign of inflation instability. This logic is supported by the standard deviation, which manifests through positive asymmetry. The standard deviation is represented by a long right-sided solid tail, which expresses the increasing inflation uncertainty from inflation in the period tending to 2021-2022. The value of the asymmetric indicator, as well as the excess value show that the distribution of the signs in the inflation series is not normal. The frequency distribution is characterised by peaks that are registered by the excess and a right tail, which confirms the presence of asymmetry in the frequency distribution. These two characteristics are indicators of an uneven frequency distribution of the inflation process, which is also confirmed by Jarque-Bera test.

Figure 1

Frequency distribution of inflation for the period 2000/01-2022/05



Source: authors' calculations; LCPI-inflation.

The ACF function of the time series, including inflation, registers a fluctuating character that decays and increases its information signals. The PACF function also demonstrates a similar trajectory of manifestation (Table 1). The two functions, demonstrating a variable trend of their dynamics in the different lags, predominantly register decreasing dynamic coefficients, which leads to the conclusion that the stochastic inflation process in the Bulgarian economy is characterised by stationarity, but also by ARCH effects. This conclusion fully corresponds to the possibility of inflation instability, as a consequence of the volatility and the increasing inflation value in the Bulgarian economy.

Table 1

ACF and PACF functions

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
.|*** |	.|*** |	1	0.433	0.433	50.912	0.000
.|** |	.|. |	2	0.229	0.051	65.178	0.000
.|* |	.|. |	3	0.158	0.051	71.985	0.000
.|. |	*|. |	4	-0.051	-0.180	72.710	0.000
.|. |	.|. |	5	-0.064	0.002	73.837	0.000
.|. |	.|. |	6	-0.037	0.016	74.216	0.000
*|. |	.|. |	7	-0.080	-0.042	75.974	0.000
.|. |	.|. |	8	-0.041	0.004	76.450	0.000
.|* |	.|* |	9	0.101	0.150	79.291	0.000
.|* |	.|. |	10	0.103	0.031	82.294	0.000
.|* |	.|* |	11	0.149	0.074	88.560	0.000
.|** |	.|** |	12	0.351	0.278	123.46	0.000

Source: authors' calculations.

The three tests confirm that the inflation series has characteristics of a long-term average value (Table 2). The variations of the different signs do not change over time. This leads to a stochastic process that, despite the random shocks it reproduces, does not lead to a disturbance in the variations of the inflation signs in the long run.

Table 2

Tests for Stationarity and Structural Fracture

	Augmented Dickey-Fuller Test on LCPI	Phillips-Perron Test on LCPI	Unit Root with Break Test on LCPI
t-Statistic	-10.23604	-10.19850	-10.85813
P-value	0.0000	0.0000	< 0.01

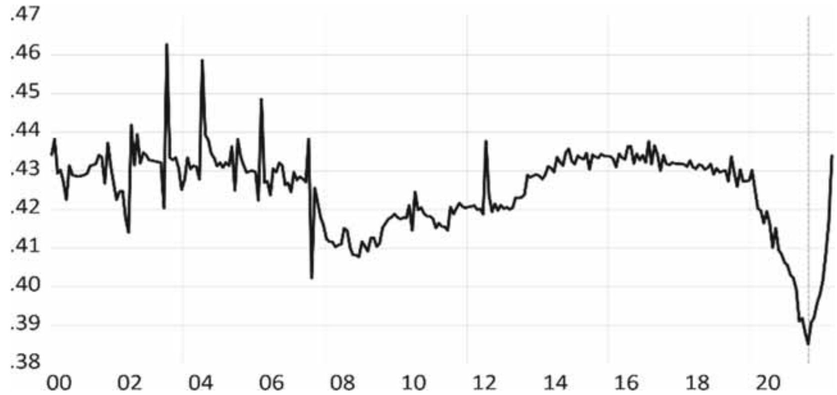
Source: authors' calculations; LCPI-inflation.

The stationary process is characterised by an asymmetry that realises significant volatility. That volatility forms clusters of manifestation in the different lag windows. The described process fully corresponds to the characteristics of inflation instability, which is a consequence of the significant dynamics of the volatility of inflation in the Bulgarian economy. The dynamics of the stationary process are predominantly characterised by variations that lead in most lag values to a fracture in the stationary process, which, however, returns to its average value. In the period January 2020 – May 2022, there is a large fracture in the stationary process, which turns into a break (Figure 2). It is this structural break expressing high inflation volatility that indicates inflation instability. This means that the ARCH effects should be analysed and will provide the necessary information on whether there is a possibility of inflation instability as a consequence of inflation dynamics.

The presence of information in the residuals is confirmed by the test for ARCH effects (Table 3), which means that there are lagged squares that reproduce trends of structural fractions in the stationary stochastic process of the inflation dynamics. Therefore, this supports the view that the inflation dynamics in the Bulgarian economy create inflation instability. The inflation shock may have been reproduced both in the previous period and in several lags later than the previous period, and nevertheless, the uncertainty could be manifested in the current period. This logic is argued by TR^2statistic and P-value (Table 3). The derived ARCH effects (Table 3) give reasons to apply an ARCH model, which can be ARCH(1), as well as the GARCH methodology, which manages to assess and capture inflation instability much more finely.

Figure 2

Moments of fracture of the stationary process



Source: authors' calculations.

Table 3

ARCH_LM Test on LCPI

Lag	TR^2statistic	P-value
1	10.58296	0.0011
2	14.63422	0.0007
3	14.67592	0.0021
4	21.16844	0.0003
5	22.84652	0.0004
6	25.70835	0.0003
7	28.03037	0.0002

Source: authors' calculations; LCPI-inflation.

The estimated ARCH(1) model specificities have close values of Akaike info criterion and Schwarz criterion, but the z-Statistic weights of the coefficients differ, and yet the trends in all three models are identical. The three specifications of the ARCH(1) methodology confirm that inflation in the previous period leads to an inflation increase in the current period (Table 4). Therefore, the inflation process is self-reproducing as the inflation expectations, created in the previous period, form the inflation in the current period. A part of the effect of the inflation shock takes the form of a hidden signal, which is characterised as unknown in terms of the effects it creates in the Bulgarian economy during the period under review. Inflation provokes inflation instability, which increases because the sign of the conditional variance is positive. The conclusion here is that during the studied period, inflation instability increased. The volatility of inflation over time creates conditions for the risk of inflation instability. The inflation expectations in the previous period affect future inflation and future inflation instability. Another important conclusion is that inflation instability is reproduced as a consequence of its past value in the previous period.

Table 4

ARCH(1) model

	Dependent Variable: LCPI		Variance Equation		Values	
Method	C	LCPI(-1)	C	RESID(-1)^2	Akaike info criterion	Schwarz criterion
Normal distribution	1.610894 (7.329244)	0.477115 (6.685776)	6.84E-06 (11.22907)	0.244237 (2.272756)	-8.805521	-8.812161
Student's t	1.689668 (8.909506)	0.451496 (7.333165)	6.24E-06 (5.719081)	0.371691 (1.947968)	-8.879338	-8.812161
Generalised error distribution	1.743030 (124.9614)	0.434166 (95.91639)	6.55E-06 (6.917218)	0.281323 (1.696967)	-8.850379	8.783202

Source: authors' calculations; (z-Statistic); LCPI-inflation.

The three models have nearly equal explanatory power. Inflation increases as a consequence of its past values. Inflation instability is presented as standard deviation and as conditional variance, and in both cases, inflation instability increases in all three models. It is important to note that inflation instability, measured as the conditional variance, is characterised by higher coefficients when measured by the standard deviation. The positive coefficients of the standard deviation and the conditional variance lead to the conclusion that inflation instability in the Bulgarian economy is a factor that manifests itself quite often. An argument for this conclusion is that the standard deviation manages to capture the signal of inflation instability. The degree and frequency of manifestation of inflation instability determine the increase of inflation. Also, an increase in inflation volatility leads to an increase in inflation instability. This view is theoretically postulated by Friedman (1977) and Ball (1992). Golob (1994) and Karahan (2012) obtain similar empirical results. Another empirical result is that the inflation instability is expressed better than the conditional variance (Table 5). The latter conclusion is found in Jansen (1989) and Karahan (2012).

Table 5

GARCH- M (1,1) model

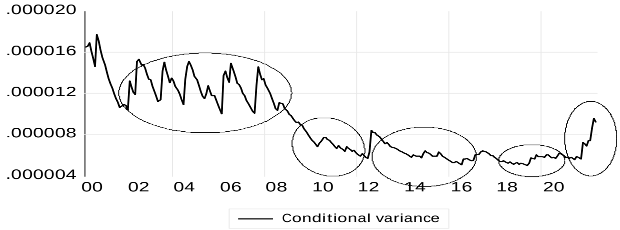
Dependent Variable: LCPI				Variance Equation			Values	
Method	@SQRT(GARCH)	C	LCPI(-1)	C	RESID(1)^2	GARCH(1)	Akaike info criterion	Schwarz criterion
Student's distribution	0.788349 (1.930705)	1.792975 (10.93203)	0.417205 (7.829615)	1.94E-07 (1.190511)	0.036611 (1.495050)	0.939185 (29.46111)	-8.86989	-8.77584
Normal distribution	0.653175 (1.945710)	1.792953 (10.72755)	0.417389 (7.688966)	9.67E-08 (1.485019)	0.028901 (1.772773)	0.955645 (53.41031)	-8.84486	-8.76425
Generalised error distribution	0.757299 (2.054985)	1.788762 (99.60269)	0.418616 (71.63366)	1.41E-07 (1.187686)	0.034650 (1.525442)	0.945598 (34.87059)	-8.86539	-8.77134

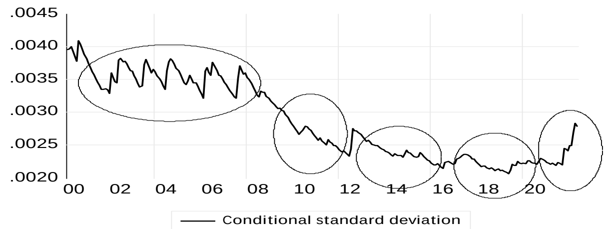
Source: authors' calculations; (z-Statistic); LCPI-inflation.

The change in inflation instability is characterised by periods of volatility and periods of relative stability. Therefore, the dynamics of the inflation instability change over time, and this change is grouped into certain cluster formations. The dynamics of inflation instability is characterised by an uneven distribution over time (Figure 3). The inflation instability in the period 2000-2007 shows high volatility, and in the period 2009-2010, the volatility of the inflation instability decreases. In the following years, a period of relative constancy in the dynamics of the volatility of inflation instability is observed, while a large increase in inflation instability is registered at the end of 2021 and until the middle of 2022.

Figure 3

Dynamics of instability estimated with GARCH-M model





Source: authors' calculations.

The relationship between inflation and inflation instability is most fully revealed through the application of the EGARCH model (Table 6). The self-replicating process of inflation increase leads to an increase of inflation instability. The initial inflation shock originates in past lag values but manifests in the current lag by generating inflation instability. Once the inflation shock generates inflation instability, the inflation instability starts to increase. The transformation of inflation shock into inflation instability takes some time. The generation of inflation instability from the inflation shock leads to inflation instability that does not fade as the inflation shock fades. The fading of the inflation instability is realised later than the fading of the inflation shock. It becomes clear that the inflation increase in the current period leads to an increase of inflation instability in the next lag, because the transformation of the inflation shock into inflation instability takes a certain time. The inflation instability starts to fade not only later than inflation fades, but when the inflation fading is considered to be significant. The dynamics of inflation instability are determined by the "feeling" that economic agents take the inflation effect into account as regards their consumption and cost of living. In the first moment, economic agents feel "significantly" the inflation pressure and this predetermines great instability in the following periods. The actions and decisions of the economic agents are determined by the expectations of an inflation increase, which creates instability that will not immediately fade with the inflation fading. The reason is that the behaviour of the economic agents will be characterised as cautious and they will act cautiously. This will create instability in the system, and after a certain period of time, when economic agents change their expectations, the inflation fading will start to correspond with the fading of the inflation instability, i.e. the inflation instability will start to decrease.

Table 6

EGARCH(6,5)

A	1.742793*
LCPI(-1)	0.434190*
C	-1.550894
ARCH(1)	0.551036*
ARCH(2)	0.080306
ARCH(3)	0.289827
ARCH(4)	-0.560483*
ARCH(5)	0.053503
GARCH(1)	0.070021
GARCH(2)	-0.510517*
GARCH(3)	0.551922*
GARCH(4)	0.434999*
GARCH(5)	0.323022
GARCH(6)	0.020325
Y(1)	-0.229544***
Y(2)	-0.071029
Y(3)	0.130460
Y(4)	0.133533
Y(5)	0.267355*

* statistically significant at 1%; ** statistically significant at 5%; *** statistically significant at 10% LCPI-inflation

Source: authors' calculations.

The value of the inflation shock in the previous period does not permanently lead to an increase in the value of inflation in the current period (Table 6). The autoregression coefficients illustrate several trends in the change of the inflation values. The first trend they register is that the past inflation rates do not lead to a significant change in the inflation in the current period. This trend shows that there are exogenous factors that determine inflation, which is inherent to the Bulgarian economy, since it functions under Currency Board Arrangements. This creates conditions for inflation to be imported. The imported inflation is not determined by the past values of the domestic inflation, but it determines the values of the domestic inflation in the current period. The second trend is characterised by a rupture of the relationship between the historical and the current variation of the inflation dynamics. The rupture of the past with the current variation of the inflation dynamics coincides with the outbreak of the Great Recession that caused a prolonged period characterised by deflation shocks in the Bulgarian economy and creeping inflation. The last trend that stands out is a significant positive influence of the historical variation of the inflation dynamics on the current variation of the inflation dynamics. This period coincides with the post-COVID economic recovery of the Bulgarian economy and the subsequent rise in global and domestic inflation. The reasons for the impact of the historical prices on the current prices is the increase in the money supply as an instrument to combat the COVID economic turbulence, as well as the increase in the global prices of fuel and energy and, of course, the increase in the prices of the production materials.

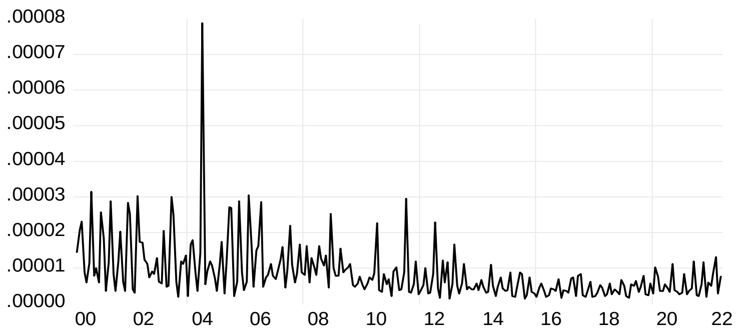
In lag 1, when rising, the inflation leads to a significant increase in the inflation in the current period. This self-replicating rise in inflation leads to an increase in inflation instability. Inflation instability is characterised by high volatility, which goes from positive to negative values. The volatility of the instability is difficult to be predicted in the Bulgarian economy, because it is characterised by sharp and sudden changes in both the direction of movement and the magnitude of the manifestation of the instability (Table 6). These empirical arguments support the view that the Currency Board Arrangements and the impossibility of conducting monetary policy in a traditional manner create unpredictability of the ongoing inflation instability in Bulgaria.

The volatility of the inflation instability in some lags depends on the historical volatility, while in other lags, it does not depend on the historical volatility, introducing an element of stochasticity. The random element increases the risk of volatility of the inflation instability and introduces certain uncertainty in the dynamics of inflation instability due to inflation in the Bulgarian economy. The fact that inflation instability in Bulgaria is highly volatile (Figure 4) and that at the same time, in some lag values it does not depend on its historical values, means that there is a random element that leads to the risk of nominal uncertainty.

The volatility of the inflation instability leads to lower incomes of the economic agents, an increase in the prices of goods and services, export of capital from Bulgaria and a decrease in investments, which causes a deterioration of the business environment. Therefore, inflation instability leads to the reproduction of several risks that correspond to each other and that is precisely why unpredictability is created in the Bulgarian economy.

Figure 4

Inflation instability in Bulgaria



Source: authors' calculations.

The analysis of the relationship between inflation and inflation instability using the ARCH model, GARCH_M model and EGARCH model leads to the empirical arguments that when the inflation increases, inflation instability is also determined, i.e. inflation dynamics leads to inflationary instability. This view corresponds to the theoretical positions of Friedman (1977) and Ball (1992). On the other hand, the empirical results also provide arguments that inflation instability leads to an inflation increase which contradicts the Friedman-Ball model. The assessment of the causal relationships clearly confirms the empirical conclusions presented (Table 7). The two empirical conclusions do not contradict each other, on the contrary, they even complement each other. This is because, initially, the inflation shock is the factor that reproduces inflation instability. Then inflation instability leads to the generation of inflation.

Table 7

Causal relationship between inflation and inflation instability

Null Hypothesis	P-value	Lag
UN does not Granger Cause LCPI LCPI does not Granger Cause UN	0.9574 0.0004	1
UN does not Granger Cause LCPI LCPI does not Granger Cause UN	0.8647 5.E-10	3
UN does not Granger Cause LCPI LCPI does not Granger Cause UN	0.0591 2.E-14	6

Source: authors' calculations; UN-inflation instability; LCPI-inflation.

In fact, the current study confirms and further develops the Friedman-Ball model, because in a small open economy under Currency Board Arrangements, the processes of inflation and inflation instability in their interaction reproduce each other (Table 7).

The empirical analysis provides grounds for claiming that nominal uncertainty is manifested in the dynamics of the volatility of inflation instability. Nominal uncertainty is a process that remains as a hidden signal in the noise of inflation instability. In the range of the highest frequencies covered by the "mother" waves, 39 wave coefficients are registered, which contain information characterised by unknown values (see Appendix). These unknown values are information that is part of the noise of the inflation instability, but this information is not extracted. Therefore, in this information of unknown content lies the nominal unpredictability or the nominal uncertainty. The strongest frequency, which is covered by the first scale, contains the most coefficients that are outside the standard deviation limit, which means that to the low-frequency ranges, more and more wave coefficients will be added, which will illustrate the presence of hidden information that will take the form of an information signal.

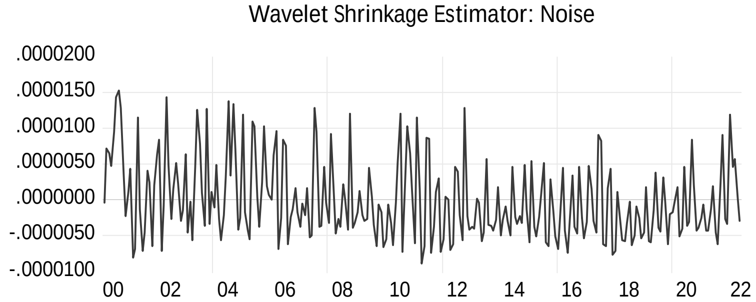
In the medium frequency ranges, the wavelet coefficients increase(with 95 wavelet coefficients being registered in scale 16) and the majority of them remain outside the noise, which illustrates the information that represents nominal uncertainty. Moreover, in the medium frequency range, there is a sign of shaping the transition of noise into a signal that is characterised by volatility. In fact, in the low-frequency spectrum, a signal with unknown information is already clearly outlined, which is expressed by 267 wave coefficients with unknown values. Therefore, an unknown wave signal is identified in the low-frequency spectrum, which is a carrier of unpredictability for the economy and expresses nominal uncertainty. Therefore, this signal can be considered as a consequence of inflation instability, which, containing an unpredictable element, at some point grows into nominal uncertainty. This process of converting the noise, expressing the inflation uncertainty into a signal and also expressing the inflation uncertainty, is actually a transformation of the inflation instability into nominal uncertainty.

Nominal uncertainty (Figure 6B) is clearly visible when inflation instability is muffled (Figure 6A). The signal expressing the nominal uncertainty is different from the noise, expressing the inflation instability. The nominal uncertainty and its signal registrations are indicated by rectangles when a nominal uncertainty is registered, but it does not lead to large negative feedback effects. The nominal uncertainty is indicated by an ellipse (circle) when it leads to larger negative shock effects. The nominal uncertainty is depicted by an ellipse in the trajectory of a rectangle when the nominal uncertainty leads to negative shocks whose end cannot be determined exactly and there is also a presence of overlapping risks or crisis events with an unknown end and of different nature, as well as a gradation of crises,

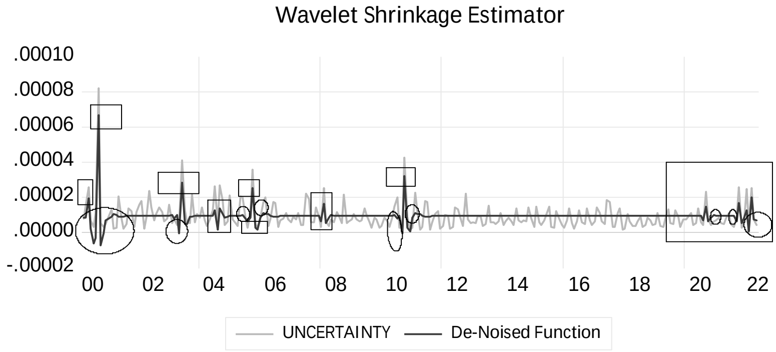
Figure 6

Revealing the signal expressing the nominal uncertainty

6.A. Inflation instability



6.B. Nominal uncertainty



Source: authors' calculations.

In 2000, 2003, 2005-2006, 2007 and 2010-2012, nominal uncertainty was registered in the Bulgarian economy, which is a consequence of the inflation instability, and in turn, is a consequence of higher inflation. The causes of inflation, and respectively inflation instability and nominal uncertainty, are the increase in the prices of basic goods, external inflation, the ECB policy of money printing and the Currency Board Arrangements, which, when foreign exchange reserves increase, lead to an increase in the money supply.

In January 2020 – May 2022, there was an overlap of crises that led to nominal uncertainty. The reasons for the gradation of inflation into inflation instability and the gradation of inflation instability into nominal uncertainty are the increase in government expenditures as a measure to combat COVID-19, the liberalisation of the electricity market, the lack of diversification in the energy sector, the external inflation and the rising fuels prices on the international markets caused by the war in Ukraine, which generates a large inflation shock and creates a large nominal uncertainty. It becomes clear that several risk factors, determining the nominal uncertainty accumulate and overflow. Therefore, the nominal uncertainty is determined by inflation instability and inflation. The lags, in which nominal uncertainty is determined, are characterised either by galloping inflation or by a sharp change in the trajectory of inflation, which is characterised by high volatility. This leads to turbulent inflation instability, which in turn is characterised by very high volatility and also causes nominal uncertainty.

The nominal uncertainty in the high-frequency range registers the largest coefficient, which constitutes a little more than half of the value of the aggregate nominal uncertainty in the period under review and leads to a moderate accumulation of nominal uncertainty. Again, in the high-frequency spectrum, the scale of the nominal uncertainty coefficient decreases. This decrease explains a small fraction of the value of the total nominal uncertainty, but has a significant effect on the accumulation of nominal uncertainty in the current period. Such a trend persists until the end of the high-frequency spectrum. The nominal uncertainty has the largest value in the high-frequency range, then the value decreases and increases again, but does not reach the scale of the initial value. In the low-frequency spectrum, the nominal uncertainty does not have a significant impact on the economic system. Therefore, it can be concluded that in the short and medium run, nominal uncertainty has a significant impact on the economic system (Table 8).

Table 8

Decomposition of the hidden signal

Scale	Variance	Rel. Proport.	Cum. Proport.	Lower	Upper
W1	3.26e-11	0.5874	0.5874	2.59e-11	4.22e-11
W2	1.88e-11	0.3387	0.9261	1.37e-11	2.75e-11
W3	2.11e-12	0.0380	0.9641	1.33e-12	3.67e-12
W4	1.31e-12	0.0236	0.9877	6.88e-13	3.19e-12
W5	6.83e-13	0.0123	1.0000	2.54e-13	2.97e-12

Source: authors' calculations.

The nominal uncertainty is a consequence of the excessively increasing inflation instability. An interesting fact is that under Currency Board Arrangements in Bulgaria, there are processes like inflation instability and nominal uncertainty. This fact contradicts the concept of the currency boards, which should not allow processes like inflation instability and nominal uncertainty.

Conclusion

The empirical study shows that inflation in Bulgaria leads to inflationary instability. It is also empirically shown that inflation instability leads to inflation. The results are similar to the studies of Viorica, Jemna, Pintilescu and Asandului (2014), who argue that there is a bidirectional causality between inflation and inflation instability in Bulgaria. The results obtained from the present study, especially regarding the finding that inflation leads to inflation instability, overlap with the results of Khan, Kebewar and Nenovsky (2013). Examining the case of Bulgaria, the authors conclude that the theoretical proposition of

Friedman (1977) and Ball (1992) that inflation increases inflation instability is valid for Bulgaria.

An important result of the study is that inflation instability leads to nominal uncertainty. The novel contribution of this study is that it provides empirical evidence on the existence of nominal uncertainty in the Bulgarian economy. It is empirically demonstrated that inflation instability creates nominal uncertainty. Thus, the question arises – why inflationary instability and nominal uncertainty are realised under a currency board arrangements, given that these processes contradict the main objective of introducing currency board, namely the achievement of price stability? On the other hand, it is not possible to achieve price stability in the presence of inflation instability and nominal uncertainty. It is obvious that the currency board should not allow the inflationary process to lead to inflationary instability and nominal uncertainty. However, empirical results show that inflation instability and nominal uncertainty are reproduced in the Bulgarian economy, which calls into question the effectiveness of the currency board itself. Therefore, the impact of the currency board in Bulgaria on the inflation process can be characterised as ineffective.

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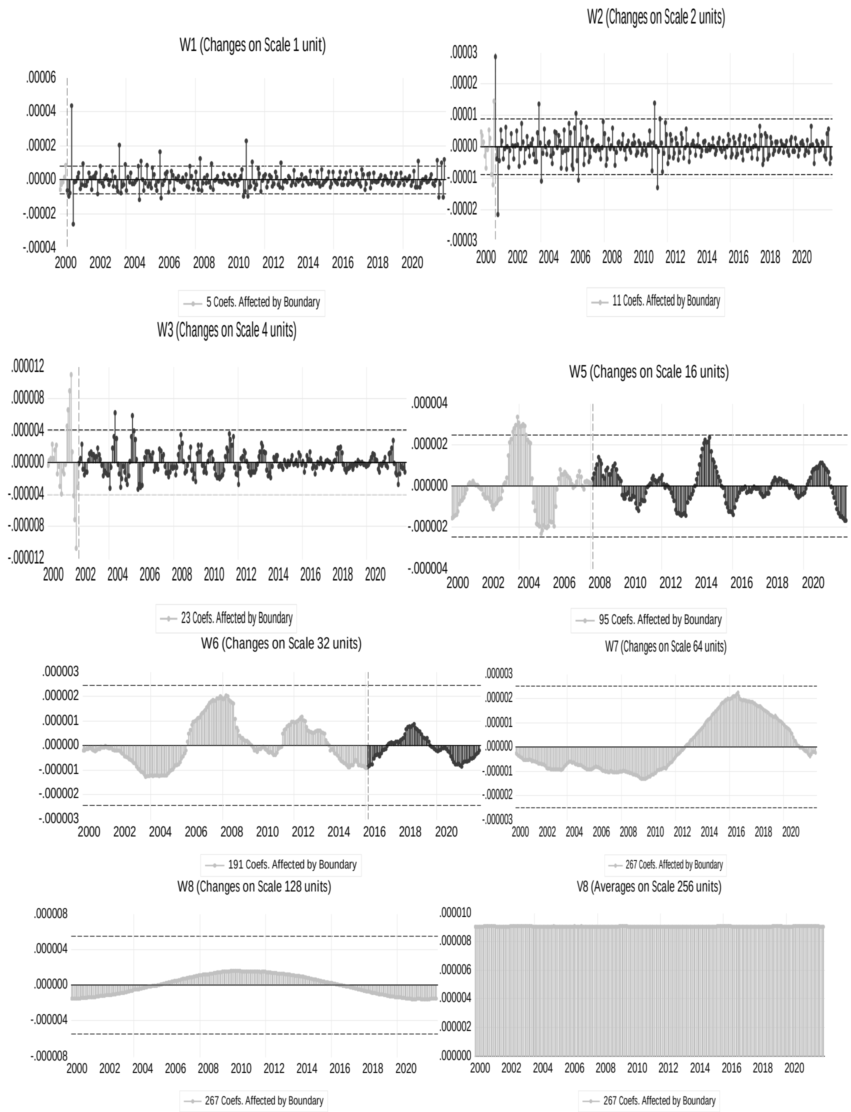
APPENDIX

Discrete wavelet transformation of inflation instability



Source: authors' calculations.