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**Unexpectedly low inflation in a small open economy — the
case of Poland**

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INTRODUCTION

After the global financial crisis of 2007-2009 and the subsequent recession, the deepest since 1929, an economic puzzle of unexpectedly low inflation emerged. This baffling phenomenon consisted in inflation evolving ubiquitously in highly developed countries as well as in a number of emerging economies at an exceptionally and unpredictably low level despite rebounding real economic activity, systematically improving labour market conditions and unconventional monetary policy stimulating economy via quantitative easing. One of the symptoms of this conundrum consists in that low inflation prevailed to develop at a lower level than most traditional economic and econometric models describing past macroeconomic regularities between price developments and economic slack would indicate during a protracted period of time.

One of the natural consequences of the occurrence of low inflation was that both inflation forecasts — generated with traditional quantitative models and methods — as well as inflation expectations formulated by market participants and reflecting their belief in the capacity of central banks to successfully stabilize inflation around inflation targets — became systematically biased. Against this background, the credibility of central banks exploiting forward guidance policy — the main purpose of which was to inform economic agents at which level of unemployment and economic growth central bank will eventually start to raise interest rates — quickly eroded. It turned out repeatedly that with very low or even historically low unemployment and a relatively high GDP growth rate with respect to the potential growth rate, inflation in many highly developed countries and a number of emerging economies, including Poland, would evolve well below official inflation targets for a prolonged period of time.

One of the symptoms of how atypical the situation was which central banks started to grapple with alongside low inflation, was that the Federal Reserve and the Bank of Japan introduced official inflation targets at that time not to lower inflation expectations, as it was frequently done in the 1990s, but to raise the level of expected inflation, which turned out to be — also quite unpredictably — severely inefficient. Facing difficulties not only in explaining the price developments on an atypically low level — both on the ground of theoretical as well as empirical approach — but also in accounting for the influence of the central bank on current and expected inflation, major central banks and their economists labelled the occurrence of low inflation a puzzle.

In this particular macroeconomic environment economists faced a daunting challenge. It became essential to explain the reasons for the unexpected behaviour of inflation and to improve forecasting models in order for them to cease to systematically overpredict price developments in the economy. My PhD thesis — submitted as a collection of thematically consistent articles published in scientific journals — concerns both these problems with regard to the small open economy of Poland.

The baffling phenomenon of exceptionally low inflation materialized with a similar intensity in Poland as in highly developed countries. Disentangling the sources of atypical inflation development became essential for the adequacy and effectiveness of future monetary policy conducted by Narodowy Bank Polski. Therefore, the principal aim of my research

was to: (1) identify the sources of protracted and unexpected period of low inflation in an emerging, small open economy during 2012-2016 and (2) develop a new inflation forecasting model that minimizes or even eliminates the systematic overprediction in the short-term horizon.

Due to the fact that the results of my research are mainly of methodological nature and reduce, *among others*, the extent to which short-term inflation forecasts are biased, their significance is universal. Therefore, the conclusions from the conducted studies should prove useful not only for conducting monetary policy in Poland but also in a number of other small open economies.

THE OCCURRENCE OF LOW INFLATION

After 2011 headline inflation in many highly developed and emerging economies first considerably weakened and then evolved at a surprisingly low (and often negative) level. Due to the simultaneous occurrence of these two phenomena in many countries, economic literature started to distinguish between *excessive disinflation* (European Central Bank, 2017) and *low inflation* (Bobeica and Jarocinski, 2019), i.e. a period of unexpectedly low inflation persisting despite the ongoing gradual economic recovery since 2009 and a steady improvement in labour market conditions (Bank for International Settlements, 2017). This situation inherently generated the necessity to identify the causes of unusual inflation developments and urged the improvement of inflation forecasting methods.

The protracted period of exceptionally low inflation is particularly clearly exemplified in the small, open, emerging economy of Poland. Since the beginning of 2012, despite a sound recovery in economic conditions, CPI inflation followed a clear downward trend, declining from 4.1% in the first quarter of 2012 to -1.5% y-o-y in the first quarter of 2015 and remaining negative until the fourth quarter of 2016. Simultaneously, economic growth in Poland weakened only temporarily in the first quarter of 2013 and evolved otherwise at the level exceeding 3% y-o-y. Moreover, the unemployment rate was systematically diminishing and reaching historically lowest levels. The persistence of this phenomenon was manifested in the fact that the inflation forecasts prepared by financial analysts, external institutions as well as Narodowy Bank Polski repeatedly turned out to be overestimated, in particular in the medium term.

RESEARCH OBJECTIVES AND HYPOTHESES

In the publications submitted as my PhD thesis I explain the causes for the occurrence of unexpectedly low inflation period in Poland and develop a new method of forecasting inflation in the short-term. The submitted doctoral dissertation consists of four thematically consistent articles written alone or in co-authorship. All these manuscripts have already been published or are accepted for publication in scientific journals with impact factor and indexed in the *Journal Citation Reports* database.

In the content of the said articles I identify the sources of persistently and unexpectedly low inflation in Poland. I also put special emphasis on the uncertainty related to the

selection of variables entering the econometric model explaining price developments in the economy and the difficulties stemming from the choice of its correct specification. These challenges are particularly important, because the results of analyses — and hence the decisions of monetary authorities — should not be affected by challenges related to the process of modelling economic phenomena in an uncertain environment.

The proposed model approaches consist in formulating recommendations based on the synthesis of results from many competing models. In my research, I estimate a significant number of econometric models with specifications justified on the basis of economic theory, I analyse the complementarity of results obtained on aggregated and disaggregated data, and also average thousands of forecasts from non-linear models generated in a specific manner. Among the rich spectrum of econometric and statistical models used in the course of research for cognitive and forecasting purposes, it is worth distinguishing, *among others*: 1) structural vector autoregression models identified using novel methods (combinations of zero and sign restrictions), 2) models with constant and time-varying parameters estimated using Bayesian methods as well as the generalized method of moments and 3) bagged artificial neural networks with specifications depending on the realization of random variables generated from a given distribution. In the course of the analyses, I also carry out a number of statistical tests to check the relevance of the conclusions.

In my research, I focused on four selected issues related to the onset and development of the period of exceptionally low inflation. The starting point for my research was the analysis of systematically declining inflation in many European countries after 2011 (Halka and Szafranek, 2016). To this end, I used selected quantitative methods — often applied in the context of evaluating the dependence of asset prices on financial markets (Diebold and Yilmaz, 2012) — to measure the so-called inflation spillovers. I analysed this phenomenon — manifesting its nature in the increasing interdependence between price developments — in the national and international dimension. The principal aim of the study was to show that the decline in inflation in different countries does not result solely from the influence of a direct and simultaneous common trend — in this particular instance related to the decline in global commodity prices — but is a more complex phenomenon. The analysis revealed the importance of interdependencies between different components of consumer goods and services within a given consumption basket in a given country, as well as between the same components of inflation in economies characterized by different levels of openness and economic development. This study was a complementary approach to similar analyses presented in the empirical literature (Osorio and Unsal, 2013; Iossifov and Podpiera, 2014). The final goal of measuring the contagion effect connected with the spread of low inflation between countries was to emphasize the growing importance of global factors in shaping inflation on the aggregated (Borio and Filardo, 2007; Ciccarelli and Mojon, 2010a) as well as the disaggregated level (Monacelli and Sala, 2009).

The results of this research — pointing to the growing importance of global conditions shaping domestic inflation — prompted me to enhance the analysis of inflation sensitivity to domestic economic fluctuations, and thus to examine the factors affecting the Phillips curve over time in the Polish economy (Szafranek, 2017). The objective of this study was to determine whether in the period of low inflation the flattening of the Phillips curve

took place, which would result in diminishing inflation sensitivity to the adjustment of domestic real economic activity and rising sensitivity to global demand and supply factors. The analysis was intended to complement the voluminous literature on the subject for highly developed countries (Musso, Stracca, and Dijk, 2009; Kuttner and Robinson, 2010; Abbas and Sgro, 2011; IMF, 2014; Coibion and Gorodnichenko, 2015; Blanchard, Cerutti, and Summers, 2015) with an application for a small, open economy. Due to considerable uncertainty inherently accompanying the estimation process of the hybrid new-Keynesian Phillips curves (Mavroeidis, Plagborg-Møller, and Stock, 2014), in the study I use several competitive econometric methods to estimate equivalent specifications of this equation, all of them well-justified on the basis of economic theory. The conclusions were formulated based on a detailed analysis of a wide cross-section of estimated parameters. The main outcome of the study is that in the period of low inflation the sensitivity of inflation to changes in domestic economic slack significantly declined, which in some circumstances may impede the conduct of monetary policy.

My third research problem concerned disentangling the sources of unexpectedly low inflation by establishing the character and origin of economic shocks affecting price developments (Szafranek and Halka, 2018). It became an important issue, complementing the literature of the subject (Globan, Arčabić, and Sorić, 2016; Halka and Kotłowski, 2017; Bobeica and Jarocinski, 2019; Conti, Neri, and Nobili, 2017) as well as the previous work on the slope of the Phillips curve based on the reduced-form model (Szafranek, 2017), to decompose persistently low inflation into the contributions of demand and supply domestic and foreign shocks with the use of a structural model. One of the tools facilitating answering such research questions was the Bayesian structural vector autoregression model identified with the novel method of combining zero and sign restrictions (Arias, Rubio-Ramírez, and Waggoner, 2018). Thanks to it, I was able to grant the identified shocks economic interpretation by distinguishing between a domestic demand and supply shock, a global (foreign) demand shock, a global oil supply shock, a monetary policy shock and an exchange rate shock. I could also assess their relative strength in affecting price changes in the Polish economy. Moreover, repeating the test on disaggregated data allowed me to check whether the conclusions obtained in the course of the conducted research on the aggregated data are correct and in line with the outcomes obtained for disaggregated price indices. The results indicated that in the period of low inflation, the importance of external shocks increased sharply, with the contribution of the global demand shock to inflation development turning out to be greater than the contribution of the global oil supply shock. Still, the domestic demand shock continued to be important for inflation developments in a small open economy.

The fourth and last research problem I raised was the issue of preparing accurate short-term (i.e. up to twelve months) inflation forecasts during the low inflation period (Szafranek, 2019). Preparing accurate short-term and medium-term inflation forecasts in the environment of increased uncertainty became more challenging than usual and forecasting models traditionally used for forecasting purposes failed extensively (European Central Bank, 2017). This motivated me to conduct additional analyses. In this context, I proposed a new forecasting model, which in its structure combines the use of *i*) rich databases

of macroeconomic indicators describing the national and global economic environment (Baranowski, Leszczyńska, and Szafranski, 2010), *ii*) machine learning methods using bagged artificial neural networks (Breiman, 1996; Zhang, Patuwo, and Hu, 1998) with specifications generated according to a realization of a random variable and *iii*) selected methods of combining forecasts (Timmermann, 2006). In a pseudo real-time forecasting exercise, I checked whether the use of a combination of thousands of strictly non-linear models leads to statistically better predictions than many traditional benchmark models in the period of low inflation. The obtained results enabled me to formulate a recommendation to supplement the forecasting process in central banks with the use of non-linear models to predict inflation. I argued that accurate forecasts of price developments are crucial for determining the monetary policy parameters of the central bank (Kotłowski, 2016), even at the expense of losing direct interpretability of relationships between variables within the model.

In summary, to fulfil the principal objective of the doctoral thesis I set out three intermediate goals:

Goal 1: Analysis of inflation sensitivity in Poland to the price dynamics in the vicinity of the domestic economy:

Research hypothesis 1: Inflation processes in the Polish economy are strongly dependent on the evolution of inflation processes in the external environment.

Goal 2: Determining the sources of unexpectedly low inflation in Poland in 2012-2016:

Research hypothesis 2.A: The influence of domestic economic activity on inflation weakened, leading to the flattening of the Phillips curve.

Research hypothesis 2.B: Although disinflation in Poland resulted primarily from the changes in domestic real activity, the deflation period was predominantly caused by external factors.

Research hypothesis 2.C: Prices of particular goods and services react in a diversified manner to the occurrence of domestic or global demand or supply shocks.

Goal 3: Constructing an inflation forecasting model that takes into account the uncertainty of model specification and the problem of variable selection:

Research hypothesis 3.A: The use of an extensive database and averaging forecasts generated by machine learning methods increases the accuracy of short-term inflation forecasts.

Research hypothesis 3.B: Combining selected linear and non-linear forecasting frameworks leads to more accurate predictions.

SYNTHESIS OF MAIN RESULTS AND CONTRIBUTIONS

In the collection of thematically consistent articles that form my doctoral dissertation, I verified the stated research hypotheses. To the best of the author's knowledge, this is the first work presenting a detailed explanation for inflation development on an unexpectedly low level in a small, open developing economy. The contribution to the international economic literature is as follows.

Firstly, the results of the conducted research indicate that price developments in the Polish economy during the period of low inflation were predominantly shaped by global factors. Analyses carried out using the proposed discrepancy index measuring inflationary pressures in the economy and results of the forecast error variance decomposition from the generalized vector autoregression model (Koop, Pesaran, and Potter, 1996; Pesaran and Shin, 1998; Diebold and Yilmaz, 2012) revealed that the systematic decline in headline inflation was accompanied by the increase in the so-called inflation spillovers. This process intensified both in its domestic dimension — which was indicated by the steadily growing share of components in the consumption basket showing deflationary tendencies — as well as in its international dimension, reflected by the growing dependence of domestic inflation on the price changes in the environment of the Polish economy, primarily in the large economy of the euro area (Halka and Szafranek, 2016). The strong influence of external conditions on the domestic consumer price index was reflected in the flattening of the Phillips curve, manifested by the weakening sensitivity of inflation to the fluctuations of domestic real activity (Szafranek, 2017) and similar to that observed in developed countries (Musso, Stracca, and Dijk, 2009; Kuttner and Robinson, 2010; Abbas and Sgro, 2011; IMF, 2014; Coibion and Gorodnichenko, 2015; Blanchard, Cerutti, and Summers, 2015; Bank for International Settlements, 2017).

In the research conducted with the use of the reduced-form of the stylized hybrid new-Keynesian Phillips curve, it was documented that in the period of low inflation global factors began to play an increasingly important role in shaping not only CPI inflation, but also core inflation (measured as inflation net of food and energy prices as well as the impact of indirect taxation). This confirmed the significance of the influence of indirect factors on the price-setting processes and the occurrence of the contagion effect between individual components of the CPI. Further analysis on the domestic and external sources of inflation based on the structural vector autoregression model (Szafranek and Halka, 2018) highlighted the decisive impact of weakening global demand and plummeting oil prices on price developments in Poland throughout the deflation period, thus corroborating that global demand and supply factors strongly affected inflation in a small, open economy. Simultaneously, the obtained results reflecting the contribution of the global shocks to the observed price changes were consistent with the conclusions provided for other countries for both aggregated data (*inter alia* Ciccarelli and Mojon, 2010a; Mumtaz and Surico, 2012; Aastveit, Bjørnland, and Thorsrud, 2016) as well as disaggregated data (Monacelli and Sala, 2009).

Secondly, despite the significant importance of global factors, the domestic economic slack continued to exert impact on price development in Poland to a certain extent. Although

the Phillips curve flattened considerably — which was accompanied by stronger impact of imported inflation on the domestic inflation as well as underutilization of labour in the Polish economy (Wyszyński, 2016) — the relationship between inflation and domestic cyclical factors remained statistically significant (Szafranek, 2017). Further results obtained with the use of a structural model validated the claim that changes in the level of economic activity contributed primarily to a strong decline in inflation — i.e. excessive disinflation in the Polish economy after 2011 — while in the deflation period lower capacity utilization affected inflation relatively less (Szafranek and Halka, 2018).

Thirdly, the conducted analyses pointed to a broad spectrum of macroeconomic factors temporarily strongly affecting inflation developments, which has important implications for the construction of forecasting models. Throughout the period of low inflation, forecasts from most traditional models — that take into account only key macroeconomic variables — systematically overestimated the level of inflation and became heavily biased (European Central Bank, 2017). This stylized fact was also indicated by counterfactual analyses using hybrid new-Keynesian Phillips curves (Szafranek, 2017). Therefore, the obtained results validated the earlier conclusions from the literature, according to which despite a significant development of econometric tools and the growing number of analyses on inflation determinants, forecasting price dynamics still remains a daunting challenge (Atkeson and Ohanian, 2001; Stock and Watson, 2007; Faust and Wright, 2013). In my conducted research I indicated that the alternative approach to inflation forecasting (Szafranek, 2019), so far used sporadically (Chakraborty and Joseph, 2017), can effectively complement the forecasting toolboxes in central banks. The model I proposed takes into account the significant uncertainty associated with the selection of appropriate explanatory variables, as well as the problem of correct model specification by averaging thousands of randomly generated specifications of non-linear models using selected machine learning methods (Breiman, 1996; Zhang, Patuwo, and Hu, 1998; Timmermann, 2006). The results of the pseudo-real time experiment indicated that this model was characterized by a significantly lower bias and higher forecast quality. Moreover, the obtained results of conducted statistical tests (Giacomini and White, 2006; Hansen, 2005) showed that the accuracy of forecasts from the proposed framework is much higher in the period of low inflation with respect to predictions from considered benchmarks. The analyses also documented the benefits of further averaging short-term inflation forecasts from a range of univariate and multivariate linear and non-linear models.

Fourthly, the conduct of research with the use of both aggregated and disaggregated data, many competitive models, as well as methods of estimation and inference, is motivated in my doctoral dissertation by a significant level of uncertainty which inherently accompanies the modelling and forecasting of inflation (Faust and Wright, 2013; Mavroidis, Plagborg-Møller, and Stock, 2014; Abbas, Bhattacharya, and Sgro, 2016) and proved to be particularly useful in the period of its unexpected and baffling development. In this context, three issues need to be addressed. First, due to the problems with proper variable selection and the choice of estimation methods proposed in the literature, the analysis of the behaviour of the Phillips curve using various measures of economic activity, imported inflation, inflation expectations as well as estimation methods makes it possible to provide more reliable and

robust results, than one selected model can offer. Second, the use of disaggregated data in analyses conducted using the structural vector autoregression model also facilitates a more accurate consideration of reactions of price changes of individual CPI components, complementing and validating the analyses conducted for aggregated data. Third, the analysis carried out on disaggregated price indices enabled us to create monthly price indices that respond to domestic and global demand and supply factors. These measures can be a valuable supplement to the proxies tracking price developments in the domestic and global economy, quickly signalling mounting inflationary and deflationary pressures from various sources. In turn, the approach to inflation forecasting based on the use of an extensive macroeconomic variable database (Baranowski, Leszczyńska, and Szafranski, 2010), machine learning methods (Breiman, 1996; Zhang, Patuwo, and Hu, 1998) and the averaging of tens of thousands of forecasts (Granger and Jeon, 2004; Timmermann, 2006) from individual models made it possible to take into account the significant uncertainty associated with correct selection of variables and the selection of proper specification of a purely non-linear model, and led to a much higher accuracy of forecasts in the period of low inflation.

Determining the reasons for the persistently low inflation in a small, open economy was crucial for conducting an adequate macroeconomic policy, in particular by monetary authorities. Studying the mechanism and importance of external conditions in shaping price development in Poland, inflation spillovers between economies, the persistence of low inflation and its determinants, as well as the development of modern methods of forecasting price changes is important for conducting and communicating monetary policy and the results of these analyses contain valuable information that monetary authorities may apply while reaching policy decisions (Blinder, Ehrmann, Fratzscher, Haan, and Jansen, 2008; Orphanides and Wieland, 2008; Kotłowski, 2016). Simultaneously, the presented evidence indicates that passive monetary policy throughout the low inflation period in Poland was justified and the impact of interest rates on inflation remained neutral (Szafranek and Halka, 2018), although the flattening of the Phillips curve posed a non-negligible risk that the economic cost of stabilizing inflation would rise (Szafranek, 2017). Finally, the strictly non-linear forecasting model proposed by Szafranek (2019) can be included in the range of models used to create short-term inflation forecasts that play an important role in the decision-making process with regard to determining the future shape of monetary policy. However, the inclusion of a purely non-linear model comes at a price of losing direct interpretability of the relationships between variables within the model, a considerably high hurdle for practitioners interested in the analysis of causal relationships.

In the collection of publications I analyse four interconnected issues aimed at explaining the causes for unexpectedly low inflation and providing implications resulting from its occurrence for forecasting purposes. The proposed order of the discussion:

1. inflation spillovers,
2. flattening of the Phillips curve,
3. sources of low inflation,
4. forecasting in low inflation environment

resembles the succession of the considered research problems, discussed in more detail in

section *Research objectives and hypotheses*. In the remaining part of this summary of the doctoral dissertation, I present how these issues were treated in the submitted publications.

INFLATION SPILLOVERS

The collection of thematically consistent publications begins with the article entitled *Whose Inflation Is It Anyway? Inflation Spillovers Between The Euro Area and Small Open Economies*, which was published in *Eastern European Economics* (Halka and Szafranek, 2016).

The starting point for this article is the observation that headline and core inflation began to decline steadily since the beginning of 2012 across economies. This process intensified further as mounting deflationary pressures emerged coinciding with a gradual — albeit anaemic at first — economic recovery. The simultaneous occurrence of a rare combination of disinflation and an increase in economic activity motivated me and my co-author to perform an in-depth analysis of this phenomenon from a domestic and international point of view.

The theory of economics predicts that an increase in aggregate output is typically accompanied by rising prices. Naturally, prices may also fall as a result of a supply shock connected with declining commodity prices, among others. To this end, in the economic literature the influence of external factors on inflation is usually determined by analysing the Phillips curve, which takes into account the foreign output gap, the impact of supply factors (Borio and Filardo, 2007) or the impact of unobservable factors (Ciccarelli and Mojon, 2010a). Hakkio (2009) formulates the hypothesis that the commonality of inflation in different countries reflects the commonality of the factors that cause it. It should also be taken into account that inflation in small, open economies may be influenced by the inflation developments in the geographic proximity of their large trading partners (Iossifov and Podpiera, 2014; Osorio and Unsal, 2013; Auer and Sauré, 2013).

Looking through the prism of the statistical decomposition of CPI inflation, among factors conducive to lowering inflation after 2011, economists usually mentioned declining energy and food prices. In a study carried out together with my co-author, we analyse the simultaneous spreading (the so-called spillovers) of inflation on an international scale (in different countries at the same time). We also examine the relative changes in the particular components of the harmonised index of consumer prices (henceforth HICP) when affected by deflation. The aim of the analysis is to show that, contrary to the general belief at that time, the slowdown in price changes during excessive disinflation was not solely due to direct effects caused by a common factor — a strong drop in commodity prices — but is a more complex phenomenon, in the case of which indirect effects and their spreading — spillovers or even contagion — are important. For this purpose, we use a disaggregated price indices of consumer goods and services to determine the extent of the contagion of low inflation between the various components of the consumption basket. For this purpose, we create the discrepancy index measuring inflationary pressures reflecting the development of price pressure in the economy. Moreover, in order to quantify the inflation spillover between economies, we use a generalized vector autoregression model and a methodology

for calculating spillover effects developed by Diebold and Yilmaz (2012) based on the KPPS decomposition (Koop, Pesaran, and Potter, 1996; Pesaran and Shin, 1998).

The results of the conducted research indicate that the discrepancy index measuring inflationary pressures signalled a decline in inflation in the analysed economies since the beginning of 2012. The ubiquity of low inflation in selected countries motivated further analysis of the contagion effect of low inflation between small, open economies and the large, developed economy of the euro area. Analysing inflation spillovers between economies in the full sample, we recorded the largest spillover effects for HICP inflation and the weakest for HICP core inflation (measured here as inflation net of energy and unprocessed food prices). This conclusion is consistent with economic intuition, as HICP inflation is more broadly shaped by factors common to various economies — including global output gap or commodity prices (Ciccarelli and Mojon, 2010b) — while core inflation should be more affected by domestic factors (which was later documented by Szafranek and Halka, 2018). In turn, the spillover effects of goods and services inflation turned out to be similar and moderate.

Obtaining more detailed results of the described tendencies over time and emphasising the role of international spillovers was possible thanks to the analysis performed in the rolling window of estimation. The spillovers of HICP inflation and HICP core inflation were stable after the outbreak of the global financial crisis, showing only a slightly growing trend in the period of low inflation — the penetration of price impulses between economies was moderate. However, since the beginning of 2012, the spillovers of non-energy industrial goods and services inflation grew steadily, which indicated the increasing impact of globalization on prices of these components. A thorough analysis of the directions of mutual influence of inflation in various countries, enabled by the use of the generalized VAR model and structural decomposition of KPPS, emphasized the strong dependence of inflation in small, open economies, including in Poland, on inflation in the large, developed economy of the euro area. The conclusions warranted in the paper proved to be in line with those of other studies that analysed similar relationships regarding the interaction of price impulses spilling over between economies with different characteristics but remaining in geographical vicinity (Iossifov and Podpiera, 2014; Osorio and Unsal, 2013).

From the monetary policy point of view, the study contains two important findings. First of all, inflation in Poland was increasingly influenced by inflation in the large developed economy of the euro area. This means that the price-setting mechanism in the Polish economy is becoming more and more dependent on regional and global factors. Additional analysis of disaggregated data indicate simultaneously an increasing dependence of service inflation in Poland on services price dynamics in the euro area, which can be interpreted as a progressive process of their globalization. Secondly, the study proposed a methodology for calculating a simple measure which proxies the intensity of inflationary pressure in the economy based on disaggregated data. Importantly, the presented index is not subject to revision and it is of monthly frequency. This seems to be an interesting and simple alternative to more complex measures of economic activity reflecting the level of price pressure — e.g. the output gap, which typically is unobserved, of lower frequency and subject to revision. The introduced index enables monetary authorities to monitor inflationary

pressures in the economy on an ongoing basis.

FLATTENING OF THE PHILLIPS CURVE

The conclusion of the first publication emphasising the role of external developments in shaping domestic inflation (Halka and Szafranek, 2016) motivated me to check whether the inflation sensitivity to adjustments in the real economic activity in Poland diminished in the period of low inflation.

In order to achieve this objective, in the second article I analysed the stability of the relationship between inflation and domestic real economic activity by examining the flattening of the Phillips curve in a small open economy in the period of low inflation. To this end, I used the data for Poland. The article entitled *Flattening of the New Keynesian Phillips curve: Evidence for an emerging, small open economy* was published in *Economic Modelling* (Szafranek, 2017).

Empirical studies discussing the changing sensitivity of inflation to domestic economic slack are conducted predominantly for highly developed economies. Their results indicate that the Phillips curve is flattening (Musso, Stracca, and Dijk, 2009; Kuttner and Robinson, 2010; Abbas and Sgro, 2011; Blanchard, Cerutti, and Summers, 2015) as a consequence of rising nominal rigidities (Baranowski and Kuchta, 2015), asymmetric wage rigidities (Daly and Hobijn, 2014), the increased importance of the global product, capital and labour market and of the global value chains (Auer, Borio, and Filardo, 2017) as well as the increasing credibility of central banks — institutions effectively stabilizing inflation by firmly anchoring inflation expectations (Bernanke, 2007). However, empirical analysis on this subject for small, open emerging economies remains relatively scarce. In the published article I investigate the issue of the flattening Phillips curve in a small, open economy.

The landmark specification of the Phillips curve (Phillips, 1958; Samuelson and Solow, 1960) is subject to a heated discussion in the economic literature. In a comprehensive review, Mavroeidis, Plagborg-Møller, and Stock (2014) as well as Abbas, Bhattacharya, and Sgro (2016) indicate that there are many equivalent and economically reasonable specifications for the equation between price or wage developments and the level of economic activity. However, selecting appropriate measures and estimation methods remains a contentious issue. As part of the neoclassical synthesis (Goodfriend and King, 1997), a commonly used hybrid new-Keynesian Phillips curve is proposed to describe the relationship between inflation in the economy and firms' marginal costs, inflation expectations of economic agents and the persistence of inflation (Gali and Gertler, 1999). From the empirical point of view, expanding the theoretical specification of the Phillips curve by adding proxies reflecting the influence of foreign factors inducing cost-push inflation (Gordon, 1990) and playing an important role in the transmission of inflation and deflation shocks between economies (Borio and Filardo, 2007; Ciccarelli and Mojon, 2010a; Auer, Borio, and Filardo, 2017), as well as estimating the reduced-form parameters (Nason and Smith, 2008) can provide a more complete picture of the process of price formation in the studied economy. The evaluation of Phillips curve parameters provides also important insight for the monetary policy conduct by allowing the researcher to determine the extent to which inflation

responds to adjustments in cyclical factors, economic agents' expectations, the influence of external environment and its own inertia.

Considering the vast uncertainty of the Phillips curve specification demonstrated in the literature (Mavroidis, Plagborg-Møller, and Stock, 2014), in the first step I estimate the parameters of many stylized hybrid new Keynesian Phillips curves for a small, open economy. For this purpose, I make use of fixed parameter models estimated by the use of generalized method of moments (henceforth GMM) estimators (Hansen, 1982; Hansen, Heaton, and Yaron, 1996) as well as time-varying parameter with stochastic volatility models estimated in a Bayesian manner (Carter and Kohn, 1994; Primiceri, 2005). In the second step, I compare the distributions of parameters obtained for the two considered real-time samples and two different measures of inflation (the research is conducted for harmonized measures of consumer prices: HICP inflation and HICP inflation net of the impact of food, energy, alcohol and tobacco prices, the two inflation measures being adjusted for the impact of indirect taxation). I also conduct counterfactual analyses in the period of low inflation in order to determine whether conditional forecasts from estimated Phillips curves reflect effectively the inflation processes occurring in the Polish economy in the period of low inflation.

The results of my research indicate that the Phillips curve in the small, open economy of Poland in the period of low inflation flattened. Simultaneously, the importance of external factors in shaping inflation increased as did indirect effects related to the impact of external macroeconomic conditions. However, it should be emphasized that the macroeconomic relationship between price dynamics in the economy and domestic cyclical factors remained statistically significant. This indicated that the period of excessive disinflation was at least partly due to the temporary weakening of domestic economic activity, though inflation in Poland — core inflation in particular — began to fall under a stronger influence of imported inflation and external factors (which was also indicated by the rising inflation spillovers between countries). Detailed analyses highlighted that one of the reasons for the weakening of the studied dependence was the underutilization of labour (Wyszyński, 2016). However, the counterfactual analysis documented that at least *ex post* some of the models reflect inflation accurately in the period of its steady decline, although in most cases conditional estimates consistently overestimated the level of inflation in the analysed period. The obtained results indicate that the forecasts from traditional models proved to be heavily biased during the period of low inflation, which motivated me to conduct further research on the use of the machine learning approach to forecasting inflation in the period of its unexpected developments.

The drop in the sensitivity of inflation to the adjustment of the domestic economic situation may raise concerns for the central bank. On the one hand, the flattening of the Phillips curve means that only significant fluctuations in domestic economic activity may lead to a slowdown or acceleration of inflation. As a result, the economic cost of stabilizing inflation around the inflation target may turn out to be significant. On the other hand, low sensitivity of inflation to changes in domestic economic slack may facilitate central bank's policy to keep inflation close to its target.

SOURCES OF LOW INFLATION

The outcome of the conducted research on the Phillips curve in Poland (Szafranek, 2017), indicating its flattening, justified the necessity to establish the character and origin of economic shocks contributing to the unexpectedly low level of domestic inflation. Analysing the sources of low inflation with the means of structural vector autoregression model became an important addition to the previous analysis of the reduced-form parameters of the Phillips curve.

The article discussing the results of these analyses, entitled *Determinants of low inflation in an emerging, small open economy through the lens of aggregated and disaggregated approach*, was co-authored and is accepted for publication in *Emerging Markets Finance and Trade* (Szafranek and Halka, 2018).

As I pointed out earlier, the persistence of exceptionally low inflation, despite the gradual economic recovery and steadily improving labour market conditions, was an ubiquitous phenomenon unexpected by economists, central banks and external institutions in 2012-2016, (European Central Bank, 2017; Bank for International Settlements, 2017). In the economic literature attempts have been made to explain the reasons for the persistently low price growth in the US economy, the euro area, as well as other developed economies (among others Coibion and Gorodnichenko, 2015; Christiano, Eichenbaum, and Trabandt, 2015; Friedrich, 2016; International Monetary Fund, 2016; Conti, Neri, and Nobili, 2017; Bobeica and Jarocinski, 2019). In the article of my co-authorship (Szafranek and Halka, 2018), I conduct a complementary study on available analyses, identifying the reasons for this phenomenon in the small, open Polish economy.

Analysis of the sources of low inflation aimed at establishing the character and origin of the shocks shaping inflation in the economy is an important extension of the research on the relative impact of domestic and foreign conditions influencing inflation with the use of stylized new Keynesian Phillips curves. In the study we make use of a structural vector autoregression model identified using a combination of zero and sign restrictions (Arias, Rubio-Ramírez, and Waggoner, 2018). The chosen direction of research as well as the selection of the particular research method is justified for several reasons. The use of such framework enables us to determine the significance of the impact of domestic and global factors on price developments. Moreover, thanks to the adopted specific model approach, it is possible to decompose the impact of shocks on demand (caused by a change in the domestic or global economic situation, the effects of which are usually spread over time and often lead to changes in monetary policy) and supply (usually resulting from technological changes, the changing availability of commodities or, for example, transient weather factors). The proposed model approach makes it also possible to consider indirect effects connected with the occurrence of economic shocks, a clear advantage with respect to simple statistical decompositions.

We analyse factors influencing inflation in a small, open economy using both aggregated and disaggregated data. The study is concerned mainly with the period of low inflation, throughout which we distinguish the period of excessive disinflation (2012Q1-2014Q2) and persistent deflation (2014Q3-2016Q4). In the manuscript we undertake a polemic with

previously published scientific articles on inflation determinants, proposing an alternative econometric approach. In particular, in comparison to earlier works using two-stage methods and VAR models identified on the basis of zero restrictions (Globan, Arčabić, and Sorić, 2016; Halka and Kotłowski, 2017) in our framework we rely on the Bayesian vector autoregression model à la (Sims and Zha, 1998) and identification based on a combination of zero and sign restrictions (Rubio-Ramírez, Waggoner, and Zha, 2010; Arias, Rubio-Ramírez, and Waggoner, 2018) which is insensitive to the order of variables in the model. The identification scheme adopted by us is inspired by the works by Corsetti, Dedola, and Leduc (2014) and Bobeica and Jarocinski (2019), although in the course of the analyses we introduced minor changes due to the characteristics of the Polish economy and the manner in which monetary policy is conducted by Narodowy Bank Polski. The proposed approach enables us to identify disturbances in the model with economic interpretation of demand and supply shocks, including domestic and foreign shocks. We repeat the analysis conducted for headline and core inflation for individual components of inflation, using disaggregation according to the Classification of Individual Consumption by Purpose (COICOP) at the three-digit level. On the basis of such disaggregated analyses, we classify those goods and services which are sensitive to identified shocks and subsequently use this assignment to calculate theoretical inflation measures which are responsive to adjustments in global and domestic supply and demand shocks.

The obtained results are compared with the analyses carried out for the selected highly developed economies (Conti, Neri, and Nobili, 2017; Bobeica and Jarocinski, 2019). In a broader discussion on inflation determinants, we define their demand and supply as well as domestic and global sources, complementing the current economic literature (Ciccarelli and Mojon, 2010a; Petrović, Mladenović, and Nojković, 2011; Mumtaz and Surico, 2012; Ferroni and Mojon, 2016) with conclusions for a developing economy. We also analyse the consistency and robustness of our results, confronting them with the outcomes of analyses on aggregated and disaggregated data (Monacelli and Sala, 2009).

The results of the conducted research reveal that in the period of excessive disinflation the main factor contributing to the decline in headline inflation was the slowdown in domestic economic activity. Therefore, the outcomes confirm the importance of domestic cyclical factors in shaping inflation, although the role of global factors — foreign demand shocks and oil supply shocks — in shaping inflation in a small, open economy can be occasionally dominant. This conclusion is consistent with the results of previous studies (Szafranek, 2017) indicating that to some extent domestic real economic activity influences price growth in the Polish economy (in other words, the Phillips curve is not entirely flat). In turn, the subsequent prolonged period of deflation was caused primarily by the convolution of global demand and supply shocks. As counterfactual analyses indicate, deflation in Poland was a phenomenon imported from the global economy. This was previously indicated by the increase in the importance of global inflation, the spillovers of low inflation between countries (Halka and Szafranek, 2016) and the importance of the external environment in shaping price developments in a small open economy (Szafranek, 2017). Throughout the period of unexpectedly low inflation, global shocks explain over 50% of deviations in CPI inflation and core inflation from their long-term averages.

The main conclusions obtained in the study are also consistent with the analyses carried out in relation to other countries (Ciccarelli and Mojon, 2010a; Aastveit, Bjørnland, and Thorsrud, 2016; Ferroni and Mojon, 2016). In addition, the analysis for the disaggregated data confirms the results obtained for aggregated data. At the same time, as in the case of results for other countries obtained in studies for disaggregated data (Monacelli and Sala, 2009), also in the case of our analyses we notice a significant heterogeneity of the response of inflation components to the impact of various shocks. In addition, using the models for disaggregated data, one can observe a significant impact of globalization on prices of selected goods and services in accordance with the hypotheses presented in the analysis of inflation spillovers (Halka and Szafranek, 2016). In the last step, we indicate the additional value resulting from the indexes of prices sensitive and resilient to changes in domestic and global economic conditions calculated on the basis of disaggregated data. On their basis we draw conclusions regarding the extent of the price pressure in the Polish economy resulting from the impact of domestic and global factors.

From the monetary policy point of view, the main advantage of the discussed analyses resides within the quantification of the impact of demand and supply shocks on inflation in Poland. It should be pointed out that the monetary policy parameters are not usually adjusted under the influence of supply shocks, although in the case of very strong indirect effects and a non-negligible risk of second-round effects, the central bank may feel compelled to combat inflationary or deflationary pressures (Slawiński, 2011; Holtenöller and Mallick, 2016). The conducted research proved that deflation in Poland had predominantly global causes, while the influence of domestic demand factors was strongest in the period of disinflation. As a result, it can be stated that Narodowy Bank Polski was justified in conducting a passive monetary policy in the face of a positive global supply shock and a negative global demand shock.

FORECASTING IN LOW INFLATION ENVIRONMENT

The onset of a period of persistent, unexpectedly low inflation had serious implications for the accuracy of forecasts. Apart from explaining its causes, an important issue was to prepare credible inflation forecasts in the environment of high uncertainty since the predictions generated from traditional approaches became severely biased (Szafranek, 2017; European Central Bank, 2017).

The last publication in the collection of thematically consistent articles is devoted to forecasting exceptionally low inflation. The manuscript is entitled *Bagged neural networks for forecasting Polish (low) inflation*. I am the sole author of this article which was accepted for publication in *International Journal of Forecasting* (Szafranek, 2019).

In the article, I undertake the research problem of providing accurate inflation forecasts, which are — by their very nature — crucial for conducting effective monetary policy by the central bank. Due to the fact that the transmission mechanisms of monetary policy take time to induce macroeconomic effects, decisions regarding changes in interest rates must be made in advance. However, this means that accurate and reliable inflation forecasts need to be prepared (Orphanides and Wieland, 2008; Kotłowski, 2016), with one of their crucial

features consisting in effective communication with economic agents (Blinder, Ehrmann, Fratzscher, Haan, and Jansen, 2008; Sławiński, 2011).

The constantly emerging challenges for monetary policy, such as the period of exceptionally low inflation, are an important factor stimulating the development of inflation forecasting models. Traditional approaches used to forecast price changes commonly use large macroeconomic data sets (Stock and Watson, 1999; Forni, Hallin, Lippi, and Reichlin, 2003) or disaggregated data (Duarte and Rua, 2007; Tallman and Zaman, 2017), Phillips curve models (Koop and Korobilis, 2012; Dotsey, Fujita, and Stark, 2017), vector autoregression models (Berg and Henzel, 2015; Belmonte, Koop, and Korobilis, 2014; Stelmasiak and Szafranski, 2016), structural models (Rünstler and Valderrama, 2010; Edge and Gurkaynak, 2010) and judgemental forecasts (Faust and Wright, 2013). However, despite the development of many advanced econometric methods, forecasting inflation remains a very demanding test for most models and obtaining statistically better forecasts than from both simple and complex naive methods is often impossible (Atkeson and Ohanian, 2001; Stock and Watson, 2007).

In the period of exceptionally low inflation, the traditionally used methods of inflation forecasting failed (European Central Bank, 2017). The results of analyses obtained for the small, open economy of Poland also indicated that the forecasts generated on the basis of the Phillips curve model were characterized by a consistent bias (Szafranek, 2017). This observation motivated me to investigate the quality of inflation forecasts obtained from combining thousands of forecasts from specific artificial neural networks (Zhang, Patuwo, and Hu, 1998; Ahmed, Atiya, Gayar, and El-Shishiny, 2010), scarcely used so far in central banks (Chakraborty and Joseph, 2017) due to the limited possibility of their interpretation. The economic literature indicates, however, that forecasts generated by artificial neural networks may be competitive when stacked against those obtained from traditional linear models (Moshiri and Cameron, 2000; Chen, Racine, and Swanson, 2001; Nakamura, 2005; Binner, Bissoondecal, Elger, Gazely, and Mullineux, 2005; Crone, Hibon, and Nikolopoulos, 2011) especially in the period of structural changes (McAdam and McNelis, 2005), and in particular after taking into careful consideration their specific properties at the modelling stage (Nakamura, 2005; Ahmed, Atiya, Gayar, and El-Shishiny, 2010).

Due to the significant uncertainty accompanying the modelling of inflation (starting from the selection of explanatory variables, through the choice of the proper model and ending with the selection of its optimal specification), in my pseudo real-time forecasting experiment I use extensive databases of macroeconomic indicators for Poland (Baranowski, Leszczyńska, and Szafranski, 2010) to forecast price developments in the period of low inflation using a combination of generated artificial neural networks. Due to the considerable uncertainty regarding the specification of the artificial neural network (Zhang, Patuwo, and Hu, 1998), in my framework its structure depends on the realization of a random variable with a given distribution, and the final inflation forecast is a result of the estimation of tens of thousands of individual models (Granger and Jeon, 2004) and of averaging their forecasts using several methods of forecast combination (Stock and Watson, 2004; Timmermann, 2006). Due to the risk of model overfitting, I use a specific algorithm (bagging) to divide the observation set (Breiman, 1996) into the generated pseudo-learning, validation and

test sets. Empirical studies indicate that the use of these methods leads to a reduction in the variance of unstable decision rules and a general improvement in the quality of forecasts (Inoue and Kilian, 2008; Rapach and Strauss, 2010; Khwaja, Naccm, Anpalagan, Venetsanopoulos, and Venkatesh, 2015; Bergmeir, Hyndman, and Benítez, 2016). I compare the forecasts from the proposed model with predictions from nine popularly used models for forecasting inflation, using standard statistics of forecast accuracy, measures aggregating information on the distribution of forecasts (Gneiting and Raftery, 2007) and statistical tests of significance to determine the relative accuracy of inflation predictions (Giacomini and White, 2006; Hansen, 2005).

The results of the analyses carried out indicate that in the period of exceptionally low inflation, the proposed model predicts inflation in the Polish economy more accurately. In particular, the model pins down the slowly changing local inflation mean more precisely, while remaining less biased. Forecasts from the model are statistically more accurate than some of the benchmark models studied at different analysed horizons. In the article, I point out that the key to achieving high accuracy forecasts is proper data processing and the use of methods aimed at the reduction of variance of chosen estimators. Moreover, further increase in the accuracy of these forecasts is possible by averaging forecasts generated from linear and non-linear models with different assumptions about the functional form of the model, which makes it possible to obtain statistically significant differences in selected forecast horizons against rigorous benchmarks proposed in the economic literature (Atkeson and Ohanian, 2001; Stock and Watson, 2007).

The article emphasizes the trade-off between higher accuracy of the proposed model and lack of its direct interpretability. On the one hand, it poses a considerable hurdle for the entities conducting monetary policy interested in determining the reasons for the observed phenomena as well as forecasts. On the other hand, the analysis of the relatively long period of exceptionally low inflation reveals that the inclusion of accurate forecasts from non-linear models may lead to overall higher accuracy of inflation forecasts, which are an important element of the decision-making process for determining the shape of monetary policy (Kotłowski, 2016).

CONCLUDING REMARKS

In the collection of thematically consistent articles discussed above, I have achieved the following research objectives:

1. I have identified the sources of the low inflation period in a small, open economy, by analysing the impact of domestic and foreign factors on price dynamics. The conclusions from the research have a cognitive nature, are consistent and complement each other. I have also constructed a forecasting model, which is characterized by higher accuracy than some traditional models used to predict inflation and which takes into account the uncertainty of inflation modelling in the period of its unusual changes.
2. An exceptionally low price growth in Poland was accompanied by the growing importance of inflation spillovers. This means that domestic inflation is becoming

more and more dependent on the evolution of price growth abroad. In disaggregated terms, this phenomenon mainly involves the prices of non-energy industrial goods and services, and is characterized by the growing influence of globalization on price-setting processes, especially in these inflation components. Therefore, one should conclude that inflation in a small, open economy is strongly dependent on price-setting mechanisms in large economies which constitute their important trading partners. The increase in the significance of foreign factors on domestic inflation may limit the effectiveness of domestic monetary policy.

3. In the period of unexpectedly low inflation and a subsequent period of persistent deflation, the Phillips curve in Poland flattened — inflation sensitivity to changes in domestic real economic activity diminished. Simultaneously, a statistically significant increase in the impact of foreign factors on price developments in Poland can be observed, while the impact of indirect effects of changes in the economic environment turned out to be stronger than the impact of direct effects. This conclusion confirms the growing importance of external factors in shaping the price-setting process in Poland, which predominantly involves the components of core inflation.
4. Despite the changes in the parameters of the estimated Phillips curve in the period of low inflation, this equation can still adequately describe the prices growth. This indicates its suitability for modelling inflation in Poland. On the other hand, a clear decline in the sensitivity of inflation to changes in the domestic economic slack may raise concerns of the central bank, as the impact of domestic monetary policy on inflation decreases — especially when inflation deviates significantly from the official inflation target for a prolonged period of time. Nevertheless, in the case when the inflation rate oscillates around the inflation target, the flat Phillips curve potentially facilitates the conduct of monetary policy by the central bank.
5. Despite the observed flattening of the Phillips curve, there is still a statistically significant relationship between aggregated price dynamics and domestic cyclical factors in Poland. This is corroborated by the results obtained from the structural vector autoregression model which indicates that domestic cyclical factors were an important source for the unusual decline in inflation labelled in the economic literature as a period of excessive disinflation. On the other hand, the impact of global demand and supply shocks was exceptionally strong in Poland during the deflation period, which was validated by several counterfactual analyses. In disaggregated terms, prices of goods and services react in a diversified way to the occurrence of domestic and foreign demand and supply shocks.
6. The occurrence of the period of exceptionally low inflation was a demanding test for econometric models used for inflation forecasting. In my research, I show that forecasts from a non-linear model that averages predictions from thousands of individual models in the period of low inflation forecasts inflation more accurately than some of the currently used methods. The results of my analyses also indicate that averaging forecasts from linear and non-linear models with different assumptions results in a further increase in the accuracy of forecasts.

In further research I intend to extend the analyses, whose results I presented in my previous publications. In my currently conducted research I focus on explaining the phenomenon of inflation synchronization in developed and developing countries. The principal aim is to measure the impact of synchronization of business cycles and monetary policies between economies as well as the volatility of oil prices and exchange rates on inflation synchronization. Therefore, in this strand of research I aim to fill an important niche in the literature on the sources of synchronization of inflation on the international scale. I expect the research results to broaden our knowledge about global, regional, national and idiosyncratic sources of inflation to a certain extent. I also hope that analyses conducted for a large number of economies will help to identify the causes of specific inflation developments in individual countries, which is important for the course of monetary policy pursued by central banks.

An interesting direction of research is the analysis of the impact of digital technological progress on inflation. Currently, various studies concerning this relationship have sprung up. My approach based on extending the hybrid new-Keynesian Phillips curve by a proxy reflecting the impact of modern digital technologies seems interesting and may provide additional conclusions on pricing processes.



Karol Szafraniec

BIBLIOGRAPHY OF ARTICLES CONSTITUTING
A THEMATICALLY CONSISTENT COLLECTION

Articles published and accepted for publication in scientific journals with impact factor:

1. Halka A., K. Szafranek, 2016, Whose inflation is it anyway? Inflation spillovers between the euro area and small open economies, *Eastern European Economics*, vol. 54(2): 109-132.

My contribution to this article is estimated at 50%. It consists in proposing using the Diebold and Yilmaz (2012) methodology to measure inflation spillovers, performing literature search, programming and estimating the models and interpreting as well as discussing the results in the manuscript. I am the corresponding author for this publication.

2. Szafranek K., 2017, Flattening of the New Keynesian Phillips curve: Evidence for an emerging, small open economy, *Economic Modelling*, vol. 63(C): 334-348.
3. Szafranek K., A. Halka, Determinants of low inflation in an emerging, small open economy through the lens of aggregated and disaggregated approach, *Emerging Markets Finance and Trade*, in press.

My contribution to this article is estimated at 75%. It consists in proposing using the novel approach to SVAR models identification based on the combination on zero and sign restrictions (Arias et al., 2018), performing literature search, programming and estimating the models on aggregate and disaggregate data as well as interpreting and discussing the results in the manuscript. I am the corresponding author for this publication.

4. Szafranek K., Bagged neural networks for forecasting Polish (low) inflation, *International Journal of Forecasting*, accepted for publication.

REFERENCES

- AASTVEIT, K. A., H. C. BJØRNLAND, AND L. A. THORSRUD (2016): "The World Is Not Enough! Small Open Economies and Regional Dependence," *The Scandinavian Journal of Economics*, 118(1), 168–195.
- ABBAS, S. K., P. S. BHATTACHARYA, AND P. SGRO (2016): "The New Keynesian Phillips Curve: An Update on Recent Empirical Advances," *International Review of Economics & Finance*, 43, 378–403.
- ABBAS, S. K., AND P. M. SGRO (2011): "New Keynesian Phillips Curve and Inflation Dynamics in Australia," *Economic Modelling*, 28(4), 2022–2033.
- AHMED, N. K., A. F. ATIYA, N. E. GAYAR, AND H. EL-SHISHINY (2010): "An Empirical Comparison of Machine Learning Models for Time Series Forecasting," *Econometric Reviews*, 29(5-6), 594–621.
- ARIAS, J. E., J. F. RUBIO-RAMÍREZ, AND D. F. WAGGONER (2018): "Inference Based on Structural Vector Autoregressions Identified With Sign and Zero Restrictions: Theory and Applications," *Econometrica*, 86(2), 685–720.
- ATKESON, A., AND L. E. OHANIAN (2001): "Are Phillips curves useful for forecasting inflation?," *Quarterly Review*, (Win), 2–11.
- AUER, R. A., C. BORIO, AND A. FILARDO (2017): "The Globalisation of Inflation: The Growing Importance of Global Value Chains," CESifo Working Paper Series 6387, CESifo Group Munich.
- AUER, R. A., AND P. SAURÉ (2013): "The Globalisation of Inflation: a View from the Cross Section," in *Globalisation and inflation dynamics in Asia and the Pacific*, ed. by BIS, vol. 70 of *BIS Papers chapters*, pp. 113–118, Bank for International Settlements.
- BANK FOR INTERNATIONAL SETTLEMENTS (2017): "87th Annual Report," Discussion paper, Bank for International Settlements.
- BARANOWSKI, P., AND Z. KUCHTA (2015): "Changes in Nominal Rigidities in Poland – a Regime Switching DSGE Perspective," Lodz Economics Working Papers 6/2015, University of Lodz.
- BARANOWSKI, P., A. LESZCZYŃSKA, AND G. SZAFRAŃSKI (2010): "Krótkookresowe prognozowanie inflacji z użyciem modeli czynnikowych [Short-term inflation forecasting using factor models]," *Bank i Kredyt*, 41(4), 23–44.
- BELMONTE, M. A., G. KOOP, AND D. KOROBILIS (2014): "Hierarchical Shrinkage in Time-Varying Parameter Models," *Journal of Forecasting*, 33(1), 80–94.
- BERG, T. O., AND S. R. HENZEL (2015): "Point and density forecasts for the euro area using Bayesian VARs," *International Journal of Forecasting*, 31(4), 1067–1095.
- BERGMEIR, C., R. J. HYNDMAN, AND J. M. BENÍTEZ (2016): "Bagging exponential smoothing methods using STL decomposition and Box–Cox transformation," *International Journal of Forecasting*, 32(2), 303–312.
- BERNANKE, B. S. (2007): "Inflation expectations and inflation forecasting," Discussion paper.
- BINNER, J. M., R. K. BISSOONDEEAL, T. ELGER, A. M. GAZELY, AND A. W. MULLINEUX (2005): "A comparison of linear forecasting models and neural networks: an application to Euro inflation and Euro Divisia," *Applied Economics*, 37(6), 665–680.
- BLANCHARD, O., E. CERUTTI, AND L. SUMMERS (2015): "Inflation and Activity – Two Explorations and their Monetary Policy Implications," NBER Working Papers 21726, National Bureau of Economic Research, Inc.
- BLINDER, A. S., M. EHRMANN, M. FRATZSCHER, J. D. HAAN, AND D.-J. JANSEN (2008): "Central Bank Communication and Monetary Policy: A Survey of Theory and Evidence," *Journal of Economic Literature*, 46(4), 910–945.

- BOBEICA, E., AND M. JAROCINSKI (2019): "Missing disinflation and missing inflation: a VAR perspective," *International Journal of Central Banking*, p. forthcoming.
- BORIO, C. E. V., AND A. FILARDO (2007): "Globalisation and Inflation: New Cross-Country Evidence on the Global Determinants of Domestic Inflation." BIS Working Papers 227, Bank for International Settlements.
- BREIMAN, L. (1996): "Bagging Predictors," *Machine Learning*, 24(2), 123–140.
- CARTER, C. K., AND R. KOHN (1994): "On Gibbs Sampling for State Space Models," *Biometrika*, 81(3), 541–553.
- CHAKRABORTY, C., AND A. JOSEPH (2017): "Machine learning at central banks," Discussion paper, Bank of England, Staff Working Paper, forthcoming.
- CHEN, X., J. RACINE, AND N. R. SWANSON (2001): "Semiparametric ARX neural-network models with an application to forecasting inflation," *IEEE Transactions on neural networks*, 12(4), 674–683.
- CHRISTIANO, L. J., M. EICHENBAUM, AND M. TRABANDT (2015): "Understanding the Great Recession," *American Economic Journal: Macroeconomics*, 7(1), 110–67.
- CICCARELLI, M., AND B. MOJON (2010a): "Global Inflation," *The Review of Economics and Statistics*, 92(3), 524–535.
- CICCARELLI, M., AND B. MOJON (2010b): "Global Inflation," *The Review of Economics and Statistics*, 92(3), 524–535.
- COIBION, O., AND Y. GORODNICHENKO (2015): "Is the Phillips Curve Alive and Well after All? Inflation Expectations and the Missing Disinflation," *American Economic Journal: Macroeconomics*, 7(1), 197–232.
- CONTI, A. M., S. NERI, AND A. NOBILI (2017): "Low inflation and monetary policy in the euro area," Working Paper Series 2005, European Central Bank.
- CORSETTI, G., L. DEDOLA, AND S. LEDUC (2014): "The International Dimension Of Productivity And Demand Shocks In The Us Economy," *Journal of the European Economic Association*, 12(1), 153–176.
- CRONE, S. F., M. HIBON, AND K. NIKOLOPOULOS (2011): "Advances in forecasting with neural networks? Empirical evidence from the NN3 competition on time series prediction," *International Journal of Forecasting*, 27(3), 635–660, Special Section 1: Forecasting with Artificial Neural Networks and Computational Intelligence, Special Section 2: Tourism Forecasting.
- DALY, M. C., AND B. HOBLIN (2014): "Downward Nominal Wage Rigidities Bend the Phillips Curve," *Journal of Money, Credit and Banking*, 46(S2), 51–93.
- DIEBOLD, F. X., AND K. YILMAZ (2012): "Better to Give than to Receive: Predictive Directional Measurement of Volatility Spillovers," *International Journal of Forecasting*, pp. 57–66.
- DOTSEY, M., S. FUJITA, AND T. STARK (2017): "Do Phillips Curves Conditionally Help to Forecast Inflation?," Working Papers 17-26, Federal Reserve Bank of Philadelphia.
- DUARTE, C., AND A. RUA (2007): "Forecasting inflation through a bottom-up approach: How bottom is bottom?," *Economic Modelling*, 24(6), 941–953.
- EDGE, R. M., AND R. S. GURKAYNAK (2010): "How Useful Are Estimated DSGE Model Forecasts for Central Bankers?," *Brookings Papers on Economic Activity*, 41(2 (Fall)), 209–259.
- EUROPEAN CENTRAL BANK (2017): "Low Inflation in the Euro Area: Causes and Consequences," Occasional Paper Series 181, European Central Bank.

- FAUST, J., AND J. H. WRIGHT (2013): "Chapter 1 - Forecasting Inflation," in *Handbook of Economic Forecasting*, ed. by G. Elliott, and A. Timmermann, vol. 2, Part A of *Handbook of Economic Forecasting*, pp. 2–56. Elsevier.
- FERRONI, F., AND B. MOJON (2016): "Domestic and global inflation," Discussion paper, Banque de France, University of Surrey and Ecole Polytechnique, mimeo.
- FORNI, M., M. HALLIN, M. LIPPI, AND L. REICHLIN (2003): "Do financial variables help forecasting inflation and real activity in the euro area?," *Journal of Monetary Economics*, 50(6), 1243–1255.
- FRIEDRICH, C. (2016): "Global inflation dynamics in the post-crisis period: What explains the puzzles?," *Economics Letters*, 142(C), 31–34.
- GALI, J., AND M. GERTLER (1999): "Inflation Dynamics: A Structural Econometric Analysis," *Journal of Monetary Economics*, 44(2), 195–222.
- GIACOMINI, R., AND H. WHITE (2006): "Tests of Conditional Predictive Ability," *Econometrica*, 74(6), 1545–1578.
- GLOBAN, T., V. ARČABIĆ, AND P. SORIĆ (2016): "Inflation in New EU Member States: A Domestically or Externally Driven Phenomenon?," *Emerging Markets Finance and Trade*, 52(1), 154–168.
- GNEITING, T., AND A. E. RAFTERY (2007): "Strictly Proper Scoring Rules, Prediction, and Estimation," *Journal of the American Statistical Association*, 102(477), 359–378.
- GOODFRIEND, M., AND R. KING (1997): "The New Neoclassical Synthesis and the Role of Monetary Policy," in *NBER Macroeconomics Annual 1997, Volume 12*. NBER Chapters, pp. 231–296. National Bureau of Economic Research, Inc.
- GORDON, R. J. (1990): "The Phillips Curve Now and Then," NBER Working Papers 3393, National Bureau of Economic Research, Inc.
- GRANGER, C. W., AND Y. JEON (2004): "Thick modeling," *Economic Modelling*, 21(2), 323–343.
- HALKA, A., AND J. KOTLOWSKI (2017): "Global or Domestic? Which Shocks Drive Inflation in European Small Open Economies?," *Emerging Markets Finance and Trade*, 53(8), 1812–1835.
- HALKA, A., AND K. SZAFRANEK (2016): "Whose Inflation Is It Anyway? Inflation Spillovers Between the Euro Area and Small Open Economies," *Eastern European Economics*, 54(2), 109–132.
- HAKKIO, C. S. (2009): "Global Inflation Dynamics," *Research Working Paper, Federal Reserve Bank of Kansas City*. (RWP 09-01).
- HANSEN, L. (1982): "Large Sample Properties of Generalized Method of Moments Estimators," *Econometrica*, 50(4), 1029–54.
- HANSEN, L. P., J. HEATON, AND A. YARON (1996): "Finite-Sample Properties of Some Alternative GMM Estimators," *Journal of Business & Economic Statistics*, 14(3), 262–280.
- HANSEN, P. R. (2005): "A Test for Superior Predictive Ability," *Journal of Business & Economic Statistics*, 23(4), 365–380.
- HOLTEMÖLLER, O., AND S. MALLICK (2016): "Global Food Prices and Monetary Policy in an Emerging Market Economy: The Case of India," *Journal of Asian Economics*, 46, 56–70.
- IMF (2014): "The Dog That Didn't Bark: Has Inflation Been Muzzled or Was It Just Sleeping?," in *World Economic Outlook Recovery Strengthens, Remains Uneven*, chap. 3. International Monetary Fund.
- INOUE, A., AND L. KILIAN (2008): "How Useful Is Bagging in Forecasting Economic Time Series? A Case Study of U.S. Consumer Price Inflation," *Journal of the American Statistical Association*, 103(482), 511–522.

- INTERNATIONAL MONETARY FUND (2016): "Global disinflation in an era of constrained monetary policy," in *World Economic Outlook – Subdued demand - symptoms and remedies*, chap. 3, pp. 121–170. International Monetary Fund.
- IOSSIFOV, P., AND J. PODPIERA (2014): "Are Non-Euro Area EU Countries Importing Low Inflation from the Euro Area?," IMF Working Papers 14/191, International Monetary Fund.
- KHWAJA, A., M. NAEEM, A. ANPALAGAN, A. VENETSANOPOULOS, AND B. VENKATESH (2015): "Improved short-term load forecasting using bagged neural networks," *Electric Power Systems Research*, 125, 109–115.
- KOOP, G., AND D. KOROBILIS (2012): "Forecasting inflation using dynamic model averaging*," *International Economic Review*, 53(3), 867–886.
- KOOP, G., M. H. PESARAN, AND S. M. POTTER (1996): "Impulse Response Analysis in Nonlinear Multivariate Models," *Journal of Econometrics*, 74(1), 119–147.
- KOTŁOWSKI, J. (2016): "Polityka pieniężna zorientowana na przyszłość. Wybrane aspekty analityczne," *Szkola Główna Handlowa w Warszawie - Oficyna Wydawnicza, Warszawa*.
- KUTTNER, K., AND T. ROBINSON (2010): "Understanding the Flattening Phillips Curve," *The North American Journal of Economics and Finance*, 21(2), 110–125.
- MAVROEIDIS, S., M. PLAGBORG-MØLLER, AND J. H. STOCK (2014): "Empirical Evidence on Inflation Expectations in the New Keynesian Phillips Curve," *Journal of Economic Literature*, 52(1), 124–88.
- MCADAM, P., AND P. MCNELIS (2005): "Forecasting inflation with thick models and neural networks," *Economic Modelling*, 22(5), 848–867.
- MONACELLI, T., AND L. SALA (2009): "The International Dimension of Inflation: Evidence from Disaggregated Consumer Price Data," *Journal of Money, Credit and Banking*, 41, 101–120.
- MOSHIRI, S., AND N. CAMERON (2000): "Neural network versus econometric models in forecasting inflation," *Journal of Forecasting*, 19(3), 201–217.
- MUMTAZ, H., AND P. SURICO (2012): "Evolving International Inflation Dynamics: World and Country-Specific Factors," *Journal of the European Economic Association*, 10(4), 716–734.
- MUSSO, A., L. STRACCA, AND V. D. DIJK (2009): "Instability and Nonlinearity in the Euro-Area Phillips Curve," *International Journal of Central Banking*, 5(2), 181–212.
- NAKAMURA, E. (2005): "Inflation forecasting using a neural network," *Economics Letters*, 86(3), 373–378.
- NASON, J. M., AND G. W. SMITH (2008): "The New Keynesian Phillips Curve: Lessons from Single-Equation Econometric Estimation," *Economic Quarterly*, (Fall), 361–395.
- ORPHANIDES, A., AND V. W. WIELAND (2008): "Economic projections and rules of thumb for monetary policy," *Review*, (Jul), 307–324.
- OSORIO, C., AND D. F. UNSAL (2013): "Inflation Dynamics in Asia: Causes, Changes, and Spillovers from China," *Journal of Asian Economics*, 24(C), 26–40.
- PESARAN, H. H., AND Y. SHIN (1998): "Generalized Impulse Response Analysis in Linear Multivariate Models," *Economics Letters*, 58(1), 17–29.
- PETROVIĆ, P., Z. MLADENOVIĆ, AND A. NOJKOVIĆ (2011): "Inflation Triggers in Transition Economies: Their Evolution and Specific Features," *Emerging Markets Finance and Trade*, 47(5), 101–124.
- PHILLIPS, A. W. (1958): "The Relation between Unemployment and the Rate of Change of Money Wage Rates in the United Kingdom, 1861-1957," *Economica*, 25(100), 283–299.

- PRIMICERI, G. E. (2005): "Time Varying Structural Vector Autoregressions and Monetary Policy," *The Review of Economic Studies*, 72(3), 821–852.
- RAPACH, D. E., AND J. K. STRAUSS (2010): "Bagging or Combining (or Both)? An Analysis Based on Forecasting U.S. Employment Growth," *Econometric Reviews*, 29(5-6), 511–533.
- RUBIO-RAMÍREZ, J. F., D. F. WAGGONER, AND T. ZHA (2010): "Structural Vector Autoregressions: Theory of Identification and Algorithms for Inference," *Review of Economic Studies*, 77(2), 665–696.
- RUMLER, F., AND M. T. VALDERRAMA (2010): "Comparing the New Keynesian Phillips Curve with time series models to forecast inflation," *The North American Journal of Economics and Finance*, 21(2), 126–144. Special Issue: 50 Years of the Phillips Curve.
- SAMUELSON, P. A., AND R. M. SOLOW (1960): "Analytical Aspects of Anti-Inflation Policy," *The American Economic Review*, 50(2), 177–194.
- SIMS, C. A., AND T. ZHA (1998): "Bayesian Methods for Dynamic Multivariate Models," *International Economic Review*, 39(4), 949–968.
- SLAWIŃSKI, A. (2011): "Polityka pieniężna," *Wydawnictwo CH Beck, Warszawa*.
- STELMASIAK, D., AND G. SZAFRAŃSKI (2016): "Forecasting the Polish Inflation Using Bayesian VAR Models with Seasonality," *Central European Journal of Economic Modelling and Econometrics*, 8(1), 21–42.
- STOCK, J. H., AND M. W. WATSON (1999): "Forecasting inflation," *Journal of Monetary Economics*, 41(2), 293–335.
- STOCK, J. H., AND M. W. WATSON (2004): "Combination forecasts of output growth in a seven-country data set," *Journal of Forecasting*, 23(6), 405–430.
- (2007): "Why Has U.S. Inflation Become Harder to Forecast?," *Journal of Money, Credit and Banking*, 39, 3–33.
- SZAFRANEK, K. (2017): "Flattening of the New Keynesian Phillips curve: Evidence for an emerging, small open economy," *Economic Modelling*, 63, 334–348.
- (2019): "Bagged neural networks for forecasting Polish (low) inflation," *International Journal of Forecasting*, p. accepted for publication.
- SZAFRANEK, K., AND A. HALKA (2018): "Determinants of low inflation in an emerging, small open economy through the lens of aggregated and disaggregated approach," *Emerging Markets Finance and Trade*, p. in press.
- TALLMAN, E. W., AND S. ZAMAN (2017): "Forecasting inflation: Phillips curve effects on services price measures," *International Journal of Forecasting*, 33(2), 442–457.
- TIMMERMANN, A. (2006): "Chapter 4 Forecast Combinations," vol. 1 of *Handbook of Economic Forecasting*, pp. 135–196. Elsevier.
- WYSZYŃSKI, R. (2016): "Zjawisko niepełnego wykorzystania zasobu pracy – czym jest i co mówi o rynku pracy w Polsce [The Phenomenon of Underemployment - What Is It and What Does It Reveal about the Polish Labour Market]," *Bank i Kredyt*, 47(3), 267–284.
- ZHANG, G., B. E. PATUWO, AND M. Y. HU (1998): "Forecasting with artificial neural networks: The state of the art," *International Journal of Forecasting*, 14(1), 35–62.

APPENDIX: RESEARCH AND ACADEMIC ACTIVITY

EDUCATION

1. M.A. in Economics, Warsaw School of Economics, 2012-2014
Major: Quantitative Methods in Economics and Information Systems
Specialty: Econometrics
Thesis title: Financjalizacja rynków surowcowych. Wnioski z modelu rVARX DCC GARCH (Financialization of commodity markets. Conclusions from the rVARX DCC GARCH model)
Advisor: dr hab. Jacek Kotłowski, prof. SGH
2. B.A. in Economics, Warsaw School of Economics, 2009-2012
Major: Quantitative Methods in Economics and Information Systems
Specialty: Methods of Decision Analysis
Thesis title: Efektywność strategii inwestycyjnych (The effectiveness of investment strategies)
Advisor: prof. dr hab. Tomasz Szapiro

PUBLICATIONS IN SCIENTIFIC JOURNALS

1. Halka A., K. Szafranek, 2016, Whose inflation is it anyway? Inflation spillovers between the euro area and small open economies, *Eastern European Economics*, vol. 54(2): 109-132
2. Szafranek K., 2017, Flattening of the New Keynesian Phillips curve: Evidence for an emerging, small open economy, *Economic Modelling*, vol. 63(C): 334-348
3. Szafranek K., A. Halka, Determinants of low inflation in an emerging, small open economy through the lens of aggregated and disaggregated approach, *Emerging Markets Finance and Trade*, in press.
4. Szafranek K., Bagged neural networks for forecasting Polish (low) inflation, *International Journal of Forecasting*, accepted for publication.
5. Szafranek K., Determinanty zmiennej w czasie korelacji pomiędzy cenami ropy naftowej a kursem walutowym dolara amerykańskiego (Determinants of time-varying correlation between oil prices and the dollar exchange rate), *Bank i Kredyt*, in press.

INTERNATIONAL CONFERENCES AND WORKSHOPS

1. Econometric Research in Finance Workshop, Warsaw, Poland, September 14, 2018: *The nexus between oil prices and the US dollar.*
2. 7th NBP Summer Workshop, Warsaw, Poland, June 11-15, 2018: *The nexus between oil prices and the US dollar.*

3. 37th International Symposium on Forecasting, Cairns, Australia, 25-28 June, 2017: *Bagged artificial neural networks in forecasting inflation: An extensive comparison with current modelling frameworks.*
4. 9th International Conference Economic Challenges in Enlarged Europe, Tallinn, Estonia, June 11-13, 2017: *Determinants of low inflation in emerging, small open economy: Comparison of aggregated and disaggregated approaches*, joint work with Aleksandra Halka.
5. 3rd International Workshop on Financial Markets and Nonlinear Dynamics, Paris, France, June 1-2, 2017: *Bagged artificial neural networks in forecasting inflation.*
6. 2017 Conference of the Scottish Economic Society, Perth, Scotland, April 24-26, 2017: *Determinants of low inflation in emerging, small open economy: Comparison of aggregated and disaggregated approaches*, joint work with Aleksandra Halka.
7. Ecomod2016 International Conference on Economic Modelling, Lisbon, Portugal, 6-8 July, 2016: *Disinflation Period in Poland. A Hybrid New Keynesian Phillips Curve Perspective.*
8. 9th International Conference on Computational and Financial Econometrics, London, Great Britain, December 12-14, 2015: *On neural networks in forecasting inflation.*
9. NBP Workshop on Forecasting, Warsaw, Poland, October 28-29, 2015: *Neural networks in forecasting inflation. A magician's trick?*
10. Ecomod2015 International Conference on Economic Modelling, Boston, USA, 15-17 July, 2015: *Financialization of the Commodity Markets. Conclusions from the restricted VARX ADDC MVT GARCH.*
11. 7th International Conference Economic Challenges in Enlarged Europe, Tallinn, Estonia, June 14-16, 2015: *Whose Inflation Is It Anyway? The Inflation Spillovers Between the Euro Area and Small Open Economies*, joint work with Aleksandra Halka.
12. ECB Low Inflation Task Force Meeting, Frankfurt, Germany, March 5-6, 2015: *Whose Inflation Is It Anyway? The Inflation Spillovers Between the Euro Area and Small Open Economies*, joint work with Aleksandra Halka.
13. 8th International Conference on Computational and Financial Econometrics, Pisa, Italy, December 6-8, 2014: *Financialization of the Commodity Markets. Conclusions from the restricted VARX ADDC MVT GARCH.*

OTHER WORKSHOPS, CONFERENCES AND SEMINARS

1. INE PAN economic seminar, Warsaw, Poland, October 18, 2018: *Pokryzysowe zagadki inflacji (Inflation puzzles after the great financial crisis)*

2. Econometric modelling seminar SENAMEK, Warsaw, Poland, November 22, 2017: *Bagged artificial neural networks in forecasting (low) inflation: An extensive comparison with current modelling frameworks.*

TEACHING EXPERIENCE

1. Econometrics (Fall 2014/2015, 2015/2016, 2016/2017, 2017/2018, 2018/2019, Spring 2016/2017, in polish)
2. Financial Markets (Spring 2015/2016, in polish)

AWARDS, GRANTS AND DISTINCTIONS

1. Rector's scholarship for exceptional postgraduate students
2. Rector's scholarship for exceptional master and bachelor students
3. International Institute of Forecasters grant for all participation expenses in *37th International Symposium on Forecasting*
4. Research grant no. KAE/BMN16/16/16 from Warsaw School of Economics
5. Research grant no. 2017/27/N/HS4/00409 from the National Science Center

OTHER PUBLICATIONS AND INTERVIEWS

1. *Wpływ digitalizacji na inflację w Polsce (The impact of digitalization on inflation)*
on-line publication: www.obserwatorfinansowy.pl, October 10, 2018
2. *Polacy coraz częściej kupują on-line (Poles shop on-line more frequently)*
on-line publication: www.obserwatorfinansowy.pl, October 10, 2018
3. *Internet zwiększa konkurencję i ogranicza możliwość wzrostu cen (The Internet increases competition and hampers price growth)*
on-line interview: www.obserwatorfinansowy.pl, October 8, 2018
4. *Przyczyny niskiej inflacji w Polsce (Sources of low inflation in Poland)*
on-line publication: www.obserwatorfinansowy.pl, July 30, 2018
5. *Zmienne losy ceny ropy naftowej i kursu dolara (The changing relationship between oil prices and the US dollar)*
on-line publication: www.obserwatorfinansowy.pl, April 24, 2018
6. *Po kryzysie inflacja nie przychodzi o czasie (The missing inflation after the great financial crisis)*
on-line publication: www.obserwatorfinansowy.pl, October 18, 2016

