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# **Uncertainty and Measurement in Macroeconomics**

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**Declaration:**

Hereby I declare that this doctoral thesis, my original investigation and achievement, submitted for the doctoral degree at Tallinn University of Technology has not been submitted elsewhere for a doctoral or equivalent academic degree.

Natalia Levenko

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signature

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# **Ebakindlus ja mõõtmine makroökonomikas**

NATALIA LEVENKO





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## List of Publications

The list of the author's publications, on the basis of which the thesis has been prepared:

- I Levenko, N., Oja, K., & Staehr, K. (2019). Total factor productivity growth in Central and Eastern Europe before, during and after the global financial crisis. *Post-Communist Economies*, Vol. 31, No. 2, 137–160. DOI: [doi.org/10.1080/14631377.2018.1460713](https://doi.org/10.1080/14631377.2018.1460713). (ETIS 1.1)
- II Levenko, N. (2020). Perceived uncertainty as a key driver of household saving. *International Review of Economics & Finance*, Vol. 65, 126–145. DOI: [doi.org/10.1016/j.iref.2019.10.005](https://doi.org/10.1016/j.iref.2019.10.005). (ETIS 1.1)
- III Levenko, N. (2020). Rounding bias in forecast uncertainty. *Research in Economics*, forthcoming. DOI: [doi.org/10.1016/j.rie.2020.08.001](https://doi.org/10.1016/j.rie.2020.08.001). (ETIS 1.1)

## **Author's Contribution to the Publications**

Contribution to the publications in the thesis is:

- I The author of the thesis had a leading role in writing the paper and acted as the corresponding author in the publishing process.
- II The author of the thesis is the sole author of the paper.
- III The author of the thesis is the sole author of the paper.

## Introduction

The thesis contains three studies on applied macroeconomics that cover a range of topics on growth accounting, household saving, and measuring forecast uncertainty. The motivation for them came from different observations. Publication I was motivated by the sluggish recovery after the global financial crisis, while Publications II and III got their inspiration from the quite vague economic prospects and the massive wave of uncertainty that accompanied the financial crisis and the recession after the crisis.

An overarching theme for the three studies can be broadly defined as analysis of economic uncertainty with a special focus on data quality and data measurement. This holds for all three papers, including Publication I, on total factor productivity (TFP), which is unobservable and fairly uncertain, as that paper puts a lot of effort into constructing informative underlying series. The main attention of the publications in the thesis is on measurement and economic uncertainty, and they take a closer look at what was happening during the global financial crisis and in the post-crisis recession, seeking to shed light on the dynamics of economic growth.

Long-term economic growth and short-term economic fluctuations are two phenomena that are very different but are closely linked together (Martin & Rogers, 2000). Business cycles can theoretically affect long-term growth both positively and negatively, and the empirical evidence on this interaction is mixed. (Aghion & Saint-Paul, 1998; Malley & Muscatelli, 1999). Martin & Rogers (2000) find that increased fluctuations affect long-term growth negatively in a large sample of OECD and European countries, though this relation does not hold for developing countries. Given this, growth accounting, which is the focus of Publication I, could be crucial for understanding the different patterns of economic cycles across economies and could be of particular importance for the economies of Central and Eastern Europe (CEE) that have volatile growth; see Arratibel et al. (2007).

Short-run fluctuations in output around its long-term trend can be explained using the mechanics of capital flows or investment formation, while an explanation for the negative effect of short-run volatility on long-run growth may be rooted in uncertainty (Staehr, 2015; Ramey & Ramey, 1995). Dimelis & Dimopoulou (2002) argue however that a starting point for understanding the cyclical nature of economic growth could be capital accumulation and TFP growth. This might also be useful for assessing the sustainability of growth. Analysis of this kind is performed in Publication I.

The high levels of economic uncertainty seen during the global financial crisis invigorated the literature on the role of uncertainty in the cyclical fluctuations of economic growth. Ilut & Schneider (2014) point out that variations in ambiguity, or Knightian uncertainty, are a major source of business cycle fluctuations. This source of output volatility is examined in Publication II in the context of household saving. Bloom et al. (2018) point out that one of the key questions with uncertainty and business cycles is the direction of causality. They find that uncertainty grows endogenously during recessions, and as it is high, it amplifies the negative effects of downturns. The same conclusions on a bidirectional relationship between output and uncertainty are reached in Straub & Ulbricht (2015), Van Nieuwerburgh and Veldkamp (2006), and Kozlowski et al. (2020a) to name but a few.

Among the channels through which uncertainty may affect the real economy are precautionary saving by households, a wait-and-see stance towards investment at firms, a higher cost of borrowing, distortions in financial markets, and increased capital



costs that lead to lower capital accumulation; see Fernández-Villaverde et al. (2015), Basu and Bundick (2017), Bloom et al. (2007), Stokey (2016), Bernanke (1993), and Kozłowski et al. (2020a). These channels may not only amplify a recession but may also slow the recovery after the crisis and so affect the economy for a long time (Bloom et al. 2018).

The persistent dynamics of a large shock to the economy may be explained by productivity loss and accelerated capital obsolescence. This may happen because changes in the habits, tastes and behaviour of agents persist after the shock has faded away. Kozłowski et al. (2020b) label this mechanism the belief-scarring effect as it reflects a persistent change in beliefs about the probability of an extreme, negative shock to the economy; see also Nordhaus et al. (1974) and Barro (2006).

In the short run, the effects of a crisis are a decline in output accompanied by decreasing consumption and investment, but in the longer run the consequences might be more painful, including problems in the labour market resulting in lower employment and subsequent drops in income and consumption (Gali 2020). Further worsening of market conditions might be partly caused by increased economic uncertainty, as this has a substantial impact on the confidence that households and firms feel about their consumption and investment plans. The impact of uncertainty is twofold, as it amplifies recessions and might slow a recovery (Barrero & Bloom 2020). This is what was observed in 2010-2014 when the European economy was recovering at a very slow pace from the recession induced by the financial crisis, and a similar effect might be expected as a consequence of the current Covid-19 pandemic.

In addition to its direct effects on the economy, the global financial crisis also provoked drastic changes in the global economic environment. The main features of the new economic conditions are a slowdown in productivity; interest rates that are close to zero and so leave less space for monetary policy; and a flattening of the Phillips curve, and in consequence of all this an increasing need for new frameworks for monetary policy and a greater role for fiscal policy (Gali & Gambetti 2019). Moreover, the recession had a large impact on labour market conditions, worsening not only the current state of the market but also the future perspectives perceived by market participants. Given the changed economic and social environment, it is important to have updated empirical evidence on these topics of productivity, household saving, and forecast uncertainty. The thesis contributes towards this objective.

A key issue with economic uncertainty is measuring it, given that uncertainty itself is not directly observable, and that it is often challenging to find a proper proxy for it. Numerous uncertainty variables are used in the economic literature and there is no single recognised definition of macroeconomic uncertainty. Knight (1921) distinguished between risk and uncertainty as two different types of randomness, with uncertainty defined as the unpredictability of an event. However, this concept is not generally followed in the literature and the most commonly used proxies are various measures of volatility.

One categorisation of types of uncertainty is made by considering the different approaches to measurement. Ex-post measures of uncertainty are all the measures that use past data such as volatility indices, the variance of macroeconomic indicators, and conditional variance estimated with ARCH-type models (Bloom 2014). Ex-ante measures use information on expectations about future projections and are typically based on survey data. Text mining and machine learning techniques have more recently been added to the arsenal of methods used to produce indicators of uncertainty in

addition to the conventional measures of uncertainty noted above; see Priyaranjan & Pratap (2020) for an overview. Publication III focuses on the dynamics of a survey-based measure of uncertainty. The main scope of Publication III is to ascertain how far this indicator depends on exogenous factors that are not related to the actual level of uncertainty perceived by economic agents.

The issues discussed above of the decline in productivity and the dynamics and decomposition of economic growth, the deterioration of labour market conditions and the role of expectations in determining the behaviour of households, and the challenges of measuring and aggregating expectations are considered in this thesis. The three publications of the thesis focus on the developments and cyclical fluctuations of European economies. Europe is of particular interest to this study as it is one of the largest economic areas in the world and it is studied less than the US economy. The samples in the publications are, however, different. Publication I studies the fast growing CEE countries, Publication II considers a larger sample of the countries in the European Union (EU), and Publication III looks at the euro area as a whole.

The thesis contributes to three different areas of applied macroeconomics. Publication I decomposes economic growth in the sample of CEE countries into the contributions of labour, capital, utilisation of capital, and TFP. Decomposing growth helps to give a better idea of how important total factor productivity was and is for economic growth before and after the global financial crisis. The first step of the analysis is to compute a new series of physical capital as the existing data were found to be of poor quality. An important innovation is that the capital series are adjusted for capital utilisation. Another novelty of the paper is that it splits the sample into subsamples to reflect business cycles in the region, and analyses the developments of TFP over different stages of the business cycle.

Publication II examines precautionary saving, one of the channels through which uncertainty is transmitted to economic activity, with special attention paid to the financial crisis and the post-crisis period. The main innovation of the study is two proxies for labour income uncertainty. One proxy is based on the actual changes in the labour market conditions, and the other uses expectational data. The buffer-stock saving model is tested on a large up-to-date sample of European countries. As expectations are found to be one of the main determinants of the saving behaviour of households, it can be modified by changing the expectations that agents have for future developments in the labour market. These findings might have policy implications that could be particularly important during recessions when the labour market is depressed.

Publication III contributes to the literature on economic measurements by examining a widely-used proxy of forecast uncertainty and showing that the indicator considered is a function of the modelling preferences of forecasters and for that reason should be treated with caution. As uncertainty cannot be measured directly, it is of crucial importance to ensure that the proxies used in economic modelling are adequate for the purpose.

One of the key contributions of the thesis is its focus on the quality and interpretation of data. Each publication in the thesis pays close attention to finding suitable proxies for the variables being modelled and to transforming the data appropriately; moreover, Publication III is dedicated entirely to assessing the quality of a widely-used proxy for uncertainty.

The three publications use a variety of empirical methods. In Publication I, a growth accounting approach is used, while simulation exercises are conducted to obtain the

distributions of possible outcomes with different parametrisation. Publication II uses the system GMM estimator in the baseline estimations and difference GMM for the robustness check. GMM estimators make it possible to account for the possible endogeneity of uncertainty in the saving behaviour of households and to address a possible Nickell bias (Wooldridge 2010, chs. 5 and 8, Nickell 1981). Publication III uses principal component analysis to reduce the dimensionality of the data, and smooth transition estimations to analyse the relationships between the variables of interest. Simulations are used to show the effect on density forecasts when rounding is used.

The thesis is organised as follows. Section 1 gives an overview of Publication I and discusses the economic fluctuations in the CEE countries, and growth accounting decomposition. Section 2 gives an overview of Publication II, focusing on measures of labour income uncertainty and the saving behaviour of households. Section 3 discusses the main points of Publication III, including the measurement of uncertainty, issues with the quality of uncertainty indicators, and the modelling preferences of forecasters. Finally, Section 4 concludes by outlining the contributions of the thesis and discussing potential avenues for future research. Appendices I-III contain the three publications.

# 1 Business cycles and economic growth

Publication I, “Total factor productivity growth in Central and Eastern Europe before, during and after the global financial crisis”, decomposes economic growth into the contributions of factors of production, and looks at the dynamics of the decomposition over the different stages of business cycles. It breaks down the growth rate of GDP in the sample of eleven CEE countries, using a growth accounting approach to gain insights into the dynamics of economic growth across the business cycle in these countries.

Growth accounting was introduced by Solow (1957) and is typically used to shed light on different patterns of economic growth. Empirical evidence of this kind might be useful for policymaking, particularly during recessions and recoveries, when the growth rates may be far from steady. Decomposing economic growth might also be instructive for assessing the sustainability of growth.

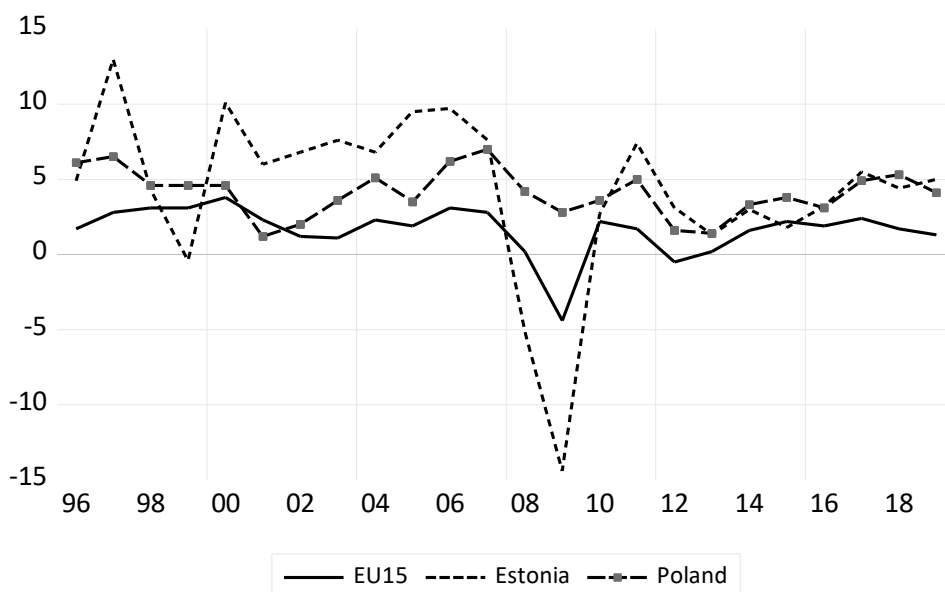


Figure 1. Output growth in Estonia, Poland and the EU15, %  
Sources: Eurostat [table code: nama\_10\_gdp]

The countries in the sample were growing rapidly on average from the middle of the 1990s to 2007, and they then experienced deep recessions during the global financial crisis and sluggish economic recovery in 2010-2014. There is however some heterogeneity in the sample, in how the global financial crisis affected the CEE economies for example. While the Baltic states experienced an average aggregate decline of about 20%, Poland had positive rates of output growth even during the time of the crisis (see Figure 1).

The growth accounting exercise can give insights into the drivers of the divergences between the countries in the sample and the slowdown in economic growth during the years after the crisis. Growth decomposition might also be of interest in the light of the Covid-19 crisis, given the general slowdown in the economy and the expected reduction in total factor productivity (Dimelis & Dimopoulou, 2002; Elenev et al., 2020; Dietrich et al., 2020).

Growth in TFP, which is the focus of Publication I, is generally interpreted as technical or institutional change or as a change in production technology and as a measure of productivity (Solow, 1957; Dimelis & Dimopoulou, 2002; Baier et al., 2006). Externalities like changes in the sectoral composition of production and in the quality of government or management might also be reflected in the changes in TFP (Easterly & Levine, 2002; Fischer, 1993). However, this paper does not seek to explain the factors behind TFP growth. The aim is merely to characterise the dynamics of TFP growth and to link it to the trends in the business cycle in the sample period.

Before running the growth accounting exercise, the paper takes a few steps to identify and overcome the caveats in the underlying data. The first is to compute new series for physical capital using the perpetual inventory method, as the data available from the Eurostat and AMECO databases cannot be considered satisfactory for a number of reasons. First of all, it should be noted that the capital stock data provided in these databases differ not only in levels but also in dynamics. While AMECO calculates the capital series, Eurostat gets them from the national accounts. In both cases, the perpetual inventory method is used, though the approaches to calculating the initial capital are different.

AMECO uses a mechanistic approach of equating the capital-to-output ratio in 1995, the initial year in the sample, to two for all the CEE countries except Czechia, where the capital-to-output ratio is set to three. In the national accounts, which provide the data made available in Eurostat, the initial capital stock is calculated in many different ways. Czechia, Hungary Estonia, Slovenia and Lithuania use data from surveys, census data, or expert estimates; company records and administrative data are used in Poland, Romania and Croatia; while Latvia and Slovakia use the cumulative flows of investment approach to calculate initial capital. In some sense, the national accounts could be expected to provide more accurate estimates of capital stock than the AMECO approximation, but the use of different methods to estimate the initial capital make the series less comparable, and some of these methods, like cumulative flows of investment, are of questionable quality. Besides, the time series provided in Eurostat are much shorter than those of AMECO and for some countries the data are missing.

When calculating the capital series, we assume the depreciation rate to be constant across countries and over time, the underlying assumption being that the sectoral composition of the sample countries is largely similar and that it does not change much during the period examined. Keeping the depreciation rate constant follows from the literature, but for a robustness check, we use different depreciation rates in the main specification of the model and in the simulation exercise.

Second, the paper takes the utilisation of capital into account, as Solow (1957) pointed out that capital in use rather than capital in place is what is important when decomposing output growth. We use capacity utilisation in manufacturing as a proxy of economy-wide capital utilisation, with the assumption that capital is utilised in other sectors of the economy at the same rate as in manufacturing. This is a simplification but not an oversimplification. Our argument in favour of this proxy is that capacity utilisation in manufacturing captures cyclical components quite well. In the paragraph above, questions were raised about the quality of the official data on the physical capital available in the Eurostat and AMECO databases. This does not mean, however, that all the data in these databases are considered to be of low quality. In addition, the data on the capital stock come directly from the national accounts and face a measurement and comparability problem, while the data on capacity utilisation are

quarterly survey-based data from a survey that is conducted by the Directorate General for Economic and Financial Affairs of the European Commission. Solow (1957) uses the unemployment rate to adjust the capital series for utilisation, arguing that capital is generally used at the same rate as labour. The paper exploits the same approach in a robustness check.

The main idea behind adjusting capital for its uneven utilisation over cycles is to remove all or at least some of the cyclicity from the final TFP series. This can also be done by employing a more precise measure of labour and considering employment as hours worked instead of as the number of employees. This is also done in the paper but only as a robustness check since the data on working hours are not available for a number of countries.

Finally, the paper decomposes output growth and provides annual and average TFP growth figures for the CEE countries in the sample. The analysis shows that before the global financial crisis, Slovenia, Hungary and Slovakia were the countries where TFP growth contributed most to growth in output, while capital accumulation was more important in the Baltic states, Poland and Czechia.

The contributions of TFP growth and capital growth at the time of the global financial crisis were very different in the countries in the sample, reflecting the diverse dynamics of the crisis and the heterogeneity of the measures taken to mitigate the negative consequences of the crisis. In the years after the crisis, modest output growth in all the sample countries was accompanied by negligible TFP growth. The results remain robust after numerous robustness checks, including different methodologies and parametrisations used to identify which assumptions are most important for the results and which are less important. To get a better idea of how different parameters affect the results, simulations are used to generate the distributions of TFP across the sample countries.

The paper discusses the contraction in the CEE economies during the years after the global financial crisis in the context of the slowdown in TFP. Alternative explanations are possible however, and Akcigit & Ates (2020) point out for example that aggregate productivity growth, as the essential source of sustainable economic growth, is supported by business dynamism and factor reallocation. They bring evidence of declining business dynamism and entrepreneurship in the USA over the past several decades, which in turn might be related to increasing market concentration and a decline in the intensity of knowledge diffusion. Emerging economies might suffer in addition to declining transmission of knowledge from the low availability and high cost of credit, especially for small and medium-sized firms (Kukk & Levenko, 2020).

The main contribution of this paper alongside providing reliable data on the capital stock and the TFP series in a sample of CEE countries is to give an insight into the differences in growth patterns over time, with the idea of finding which factor contributed the most to the slowdown after the crisis. The paper shows that the growth rates of output after the global financial crisis were modest mostly because the contributions of TFP growth were small. In this context, it could be interesting to speculate on whether TFP is procyclical, countercyclical or acyclical, and to what extent it is affected by the type of shock. According to textbook theory of the real business cycle, TFP is a measure of changes in technology and as such it should be affected by a supply shock. However, TFP is also called a “measure of our ignorance” (Abramovitz, 1956, p. 11) as it is the share of output growth that cannot be explained by other factors of production. Explaining the dynamics of TFP and its causal relations with

movements in output is beyond the scope of this paper, but the yearly patterns of TFP across the sample appear to exhibit procyclicality even when capital utilisation is included in the calculations.

Growth accounting is a conceptually simple exercise, but it requires careful collection of data and sound judgement in how the methodology is applied, and it can be stated that the resulting figures are very informative estimates of TFP growth, given the available data. The estimations of how production factors contribute to aggregate productivity can give insights into the overall dynamics of the economies being examined, and the slowdowns in economic growth. The main contributions of the paper are in providing new and reliable capital stock series, taking the capital utilisation rate into account, and building on that by computing figures for TFP growth for a set of CEE countries.

The paper was presented at the 16<sup>th</sup> Annual Conference of the European Economic and Finance Society in 2017 in Ljubljana, Slovenia and at the 9<sup>th</sup> International Conference Challenges in Enlarged Europe in 2017 in Tallinn, Estonia. Before being published in *Post-Communist Economies*, an earlier version of this paper was issued in the Eesti Pank Working Paper series (No. 8/2017).

## 2 Expectations and consumption

Consumption and saving are among the key performance indicators extensively studied at both the macro and micro levels; see Mikesell & Zinser (1973), Balassa (1993), Loayza et al. (2000), and Meghir & Pistaferri (2011) to name but a few. Publication II, “Perceived uncertainty as a key driver of household saving”, focuses on how labour income uncertainty affects the saving behaviour of households, examining realised uncertainty and uncertainty in expectations about the future separately. The paper uses a dynamic panel of 22 European countries and applies system GMM on the aggregate country-level data.

The method used makes it possible to account for the endogeneity of the right-hand side variables and to address Nickell bias (Wooldridge, 2010, chs. 5 and 8; Nickell, 1981). The sample period includes several business cycles in the years 1996-2017. Since the macroeconomic environment has changed quite substantially over the past few decades, it is important to get an updated view of the drivers of household saving in Europe as saving behaviour is a flip side of household consumption, and as such it could be thought of as an important determinant in the dynamics of output growth.

According to textbook consumption theories like the Permanent Income Hypothesis or the Life-Cycle Hypothesis, a recession in which incomes decline gives a good excuse for dissaving (Friedman, 1957; Ando & Modigliani, 1963). Nevertheless, household saving rates have grown quite substantially since the global financial crisis both in Europe and in the USA. The same kind of behaviour has been observed during the Covid-19 crisis, which makes the topic particularly relevant. It is of note that increases in saving rates appear to be accompanied by increases in expectations of unemployment; see Figure 2.



Figure 2. The saving rate and unemployment expectations in the euro area.

Note: The saving rate (left scale) and annual change in unemployment expectations in the euro area computed as the difference between positive and negative answers (right scale)

Sources: Eurostat [table codes: nasq\_10\_ki, ei\_bsc0\_m]



Uncertainty about the future dynamics of labour income if labour market conditions deteriorate is associated with the precautionary motive for saving. The need to build up a reserve against unforeseen contingencies, as defined by Keynes (1936), is one of the main incentives for households to save. This is also confirmed by more recent data from surveys like the Survey of Consumer Finances run by the Federal Reserve Board in the USA, or the Household Finance and Consumption Survey conducted in Europe.

Precautionary saving is typically explained by the concavity of the utility function of consumption, implying that increased uncertainty is followed by higher expected marginal utility for a given value of expected consumption (Romer, 1996, ch. 7). The precautionary motive can be also considered in the context of the cost of real options, meaning that firms put their investment decisions on pause while households reduce their consumption, mainly at the expense of durables; see Barrero & Bloom (2020) for an overview.

The precautionary motive of saving for households is investigated in Publication II in the framework of the buffer-stock saving model of Carroll (1997). To explain fluctuations in household saving, Carroll combines uncertainty about labour income, the impatience of consumers, and the target wealth-to-income ratio. The pattern where consumers save while their wealth is below their target wealth-to-income ratio and spend when it is above is called buffer-stock saving behaviour. Carroll's (1997) model is close to the models developed by Houthakker & Taylor (1970), Taylor (1971), Zeldes (1989) and Deaton (1992). What makes Carroll's buffer-stock saving model different from earlier theories is that it incorporates uncertainty in the form of unemployment expectations.

The main focus of Publication II is on the role of labour market uncertainty when saving decisions are made. A key contribution of the paper is that it distinguishes between realised labour income uncertainty and expectations about future uncertainty, and shows that both components of perceived uncertainty are economically and statistically significant for the dynamics of household saving. The paper gives evidence that expectations affect household saving in Europe, and so it might be of interest for policymaking since consumers' expectations can be influenced, and through this, their behaviour can too.

In the literature on saving, uncertainty is frequently modelled in a fairly straightforward manner. Macroeconomic variables such as the inflation rate or the unemployment rate are often used as proxies for macroeconomic uncertainty (Gupta, 1987; Loayza et al., 2000; Bande & Riveiro, 2013). A key contribution of Publication II is that the modelling of uncertainty is approached in a more elaborate way.

The paper decomposes labour income uncertainty into two components, one that accounts for actual change in labour market conditions and the other that covers the perceived expectations about possible changes. To get at those expectations, the paper uses data from the Joint Harmonised EU Consumer Survey, which is one of the novelties of this study as survey data are not typically used in macroeconomic studies.

The correlation between unemployment expectations and the lead of the unemployment rate is different from zero at around 0.26, which would be expected as both indicators are tightly connected to the dynamics of the labour market. However, the co-movements are not very strong as households might not be very accurate in their forecasts for labour market developments, but their perception of these developments still affects their saving behaviour.

As mentioned above, the unemployment rate is often used to construct proxies for labour income uncertainty. The unemployment rate can be thought of as a two-dimensional indicator of uncertainty. An increasing unemployment rate signals that there is a higher probability of workers being laid off, and at the same time it is a signal of a higher probability of reduced future income.

For that reason, it is important to distinguish between the unemployment rate in levels and the rate in first differences, as these are proxies for different processes. A high unemployment rate correlates with a lower income, and so saving could be expected to fall because there is a reduced ability to save. Equally, a positive change in unemployment indicates uncertainty about the future, and saving could be expected to grow in response to precautionary motives. In other words, the level of unemployment is a proxy for labour income, while a change in the unemployment rate is a proxy for uncertainty about labour income.

The main specification of the model estimated in the paper includes changes in unemployment as an explanatory variable while a specification with unemployment in levels is estimated as a robustness check. The unemployment rate in levels, indicating the capacity to save, is not statistically significant whenever income growth is present in the model as a more direct proxy for the capacity to save.

The paper finds that household saving is very persistent, with an autoregressive coefficient of around 0.8, and that saving is driven by income growth as well as by labour market uncertainty. These results are in line with previous studies. Credit availability, interest rates, inflation, and other macroeconomic and expectational variables are often included in models of household saving, but these are not found to affect household saving in the sample examined. The positive conditional correlation of income growth with saving rates can be explained by the persistence of consumption habits (Taylor 1971), while the concavity of the consumption function implies that consumption has diminishing utility with respect to income (Carroll & Kimball 1996). Given the size of the autoregressive coefficient, the long-run effects of all the drivers of household saving rates are around four times the size of their short-run effects.

Numerous robustness checks corroborate the main findings of the study and show that indicators of overall economic volatility and other expectational variables have no discernible effect on the household saving rates in the panel of European countries, while increases in the unemployment rate and in unemployment expectations can depress consumption for quite a long time. These findings may explain the slow recovery after the global financial crisis and might also be relevant during the Covid-19 crisis given sky-rocketing unemployment rates and a pessimistic economic outlook.

The paper was presented at the 20<sup>th</sup> IWH-CIREQ-GW Macroeconometric Workshop in 2019 in Halle, Germany, and at the 10<sup>th</sup> International Conference Economic Challenges in Enlarged Europe in 2018 in Tallinn, Estonia. Before being published in the *International Review of Economic and Finance*, an earlier version of this paper was issued in the Eesti Pank Working Paper series (No. 9/2018).

### 3 Measuring uncertainty

The main challenge when incorporating uncertainty into economic analysis is that it is not directly observable. This makes the need to identify a valid proxy for uncertainty a key issue when dealing with this variable. The focus of Publication III, “Rounding bias in forecast uncertainty”, is on the features of a widely-used measure of forecast uncertainty, the mean individual variance of the density forecasts of the European Survey of Professional Forecasters (SPF), a dataset that is extensively used to derive measures of perceived macroeconomic uncertainty.

The mean individual variance of density forecasts is defined as the average of the variances of individual forecasts. The variance of density forecasts is often seen as a direct measure of uncertainty and is often used in macroeconomic analysis. A noticeable shift of this indicator to a higher level at the time of the global financial crisis was expected, but it is puzzling that uncertainty, measured as the mean individual variance, has remained broadly unchanged after the crisis.

The paper seeks to shed light on the lack of counter-cyclicity in individual variance, as measures of uncertainty are known to follow business cycles quite closely. The paper analyses whether this uncertainty indicator actually quantifies changes in perceived uncertainty and provides evidence that it may be related to the modelling preferences of forecasters. As no information about the methods and models used by the experts is available at the individual level, the argumentation of the paper is based on the rounding behaviour of forecasters.

Rounding refers to the way the forecasts are presented and the probability that the numbers in them have been rounded to the nearest integer, five or ten, or have not been rounded at all. Rounding has been studied both in the economic literature and in the literature on cognition, linguistics and communication. Rounding is typically associated with a high level of uncertainty, and Krifka (2002) labelled this behavioural pattern the “Round Numbers suggest Round Interpretation” (RN/RI) principle. This principle is found to hold in consumer survey data for example (Binder, 2017). A possible positive relation between rounding and the level of perceived uncertainty is discussed in Zarnowitz & Lambros (1987) and Boero et al. (2008).

Publication III contributes to the empirical literature on forecast uncertainty by considering the puzzling lack of counter-cyclicity in the mean individual variance of the SPF forecasts after the global financial crisis. The paper first shows that the RN/RI principle is not supported by the data from the European SPF at the aggregate level, meaning that rounded forecasts have lower variance on average, which is interpreted as a lower level of uncertainty. The paper uses simulations to provide evidence that the rounding of histograms is likely to reduce the variance of density forecasts by introducing additional noise in the data, which it is then impossible for the end user to isolate.

Second, the paper analyses the relationship between the rounding of forecasts, used as a proxy for the modelling preferences of forecasters, and the uncertainty indicator based on the mean variance of individual density forecasts. The paper applies smooth transition regression analysis to ascertain whether a link between these two variables can be identified. The instrumental variable approach is used to account for the possible endogeneity of modelling preferences towards the state of the economy.

The smooth transition regression approach is an alternative to the models with structural breaks. As Dijk et al. (2002) point out, it is often difficult to distinguish

between a structural break and a nonlinearity. However, if a regime shift is under examination, a smooth transition is usually a more plausible way to model an economic process. In this particular case, where changes in the modelling preferences of forecasters are being examined, it is not likely that all of the survey participants will change their forecasting behaviour at once in the same quarter. It is more likely that forecasters update information and upgrade their forecasting methodology gradually, which will result in a smooth transition from one state to another.

The underlying micro panel of forecasts is unbalanced, meaning that not all the forecasters are present in the panel for the whole period. However, selection bias is not an issue as the experts are fairly persistent in reporting their forecasts. The statement made in this paper is that rounding affects the variance of forecasts. From this point of view, it makes no difference if a forecaster changes their modelling approach or if one forecaster, who may be a rounder, is replaced in the panel by another forecaster, who may be a non-rounder.

The paper finds that the smooth increase in the level of individual variance may be attributed to changes in the modelling preferences of forecasters and these changes might perhaps have happened in response to developments in the computer software market or improved professional training, while the actual level of forecast uncertainty might have completely different dynamics. The results indicate that a widely-used measure of forecast uncertainty, the mean individual variance of density forecasts, is a noisy indicator that may be dependent on modelling preferences and the habits of professional forecasters, and for that reason it should be treated with caution as a proxy for forecast uncertainty.

The paper was presented at the Estonian Economic Association Conference in 2020 in Laulasmaa, Estonia. Before being published in *Research in Economics*, an earlier version of this paper was issued in the Eesti Pank Working Paper series (No. 2/2020).

## 4 Concluding remarks

The thesis was motivated by the aftermath of the global financial crisis when economic growth was weak and uncertainty was high. The thesis takes a closer look at the mechanics of uncertainty and various issues regarding economic measurement, contributing to applied macroeconomics, and specifically to the empirical literature on growth accounting, consumption, expectations, and data measurement. The thesis restricts its analysis to European economies as empirical evidence on this economically important region is limited compared to the number of studies on the US economy.

The thesis contains a number of contributions. Publication I decomposes output growth into the contributions of utilised capital, labour, and total factor productivity to gain insights into the dynamics of the post-recession slowdown in economic growth, while the focus of the two other papers is on macroeconomic uncertainty and expectations. Publication II examines the relationships between household saving, labour income uncertainty and other macroeconomic indicators, and provides evidence that expectations along with income growth are the two main drivers of household saving behaviour. Publication III takes a closer look at measuring uncertainty and finds that a popular uncertainty indicator is affected by the modelling preferences of forecasters, a variable that is exogenous to the dynamics of uncertainty.

Potential avenues for future studies are numerous. The growth accounting exercise can be done using data on the sectoral decomposition of output, such as data from the World Input-Output Database (Timmer et al. 2015). The saving behaviour of households can be analysed from a larger sample of countries, or saving can be decomposed into financial assets, liabilities and purchases of durables. In Publication III, the uncertainty indicator is computed in a conventional manner as a second moment of density forecasts. To enrich the analysis, third and fourth moments can be computed and analysed for the rounding behaviour of forecasters. Taking a broader perspective on the uncertainty in macroeconomics, the changed macroeconomic environment could be taken into account with possible monetary and fiscal interventions at the zero lower bound and along the flattening Phillips curve. In this context, a promising avenue for future research is the relationship between business cycles and long-term growth in new economic conditions.

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## **Abstract**

### **Uncertainty and measurement in macroeconomics**

The thesis consists of three publications covering selected macroeconomic topics with a special focus on economic uncertainty and measurement. The analysis is restricted to European economies as these countries play an important role in the global economy and are typically less studied than the US economy. While the unifying theme for the thesis is economic uncertainty and data quality, the papers focus on different topics, covering growth decomposition, consumer expectations and household saving, and issues related to measuring forecast uncertainty.

Publication I, “Total factor productivity growth in Central and Eastern Europe before, during and after the global financial crisis”, consists of a growth accounting exercise for 11 CEE countries for the years 1996-2016. The paper focuses on the contributions of production factors to economic growth in order to gain insights into the differences in economic growth in the sample countries. The main contributions of the paper are in providing reliable new capital stock series, taking account of the capital utilisation rate, and computing TFP figures for a set of CEE countries. The results indicate that TFP growth and capital deepening were the main contributors to output growth in the sample countries before the global financial crisis. During the crisis, the patterns of growth decomposition were quite heterogeneous across the countries, while weak output growth after the crisis was paired with sluggish TFP growth in all of the sample countries.

Publication II, “Perceived uncertainty as a key driver of household saving”, focuses on household saving behaviour in the context of labour income uncertainty. The paper distinguishes between realised uncertainty and uncertainty from expectations about the future. This may be considered a key contribution of the paper. To account for expectations, the paper incorporates survey data into its analysis, which is one of the novelties of the paper. The paper uses a dynamic panel of 22 European countries and applies system GMM on aggregate country-level data. The method chosen is able to account for endogeneity and Nickell bias. The paper finds that the household saving rate is persistent and is mostly driven by income growth and labour income uncertainty, the quantitative effects of these two drivers being roughly the same. Credit availability, interest rates, and inflation have little or no effect on saving. The findings of the paper that expectations matter for the saving behaviour of households might be of importance for policymaking.

Publication III, “Rounding bias in forecast uncertainty”, examines a widely-used measure of forecast uncertainty, the mean individual variance of density forecasts derived from the European SPF dataset. The paper uses smooth transition regression analysis to show that individual variance is a function of the rounding behaviour of forecasters, and simulations to demonstrate how the rounding of density forecasts affects their variance. The paper shows that the mean individual variance of density forecasts, which is often referred to in the literature as a direct measure of uncertainty, is a noisy proxy for uncertainty and is a function of exogenous processes such as developments in the computer software market or improved professional training. The findings imply that the actual movements in forecast uncertainty might have different dynamics from what might be concluded from looking at the mean individual variance of the forecasts.

The publications of the thesis look at the developments in the European economy from different angles, decomposing economic growth and examining different features of economic uncertainty. The findings of all three publications are relevant for empirical studies, particularly studies of recessions as times when it might be important to have a precise idea of the dynamics of growth and the movements of uncertainty.

## Lühikokkuvõte

### Ebakindlus ja mõõtmine makroökonomikas

Doktoritöö koosneb kolmest artiklist, mis käsitlevad valitud makromajanduslikke teemasid, pöörates erilist tähelepanu majanduslikule ebakindlusele ja mõõtmisele. Analüüsis vaadeldakse Euroopa riikide majandusi, kuna neil riikidel on globaalses majanduses oluline roll ja neid uuritakse tavaliselt vähem kui Ameerika Ühendriikide majandust. Ehkki doktoritöö siduvaks teemaks on majanduslik ebakindlus ja kasutatavate andmete kvaliteet ja mõõtmine, keskenduvad artiklid erinevatele teemadele nagu majanduskasvu dekomponeerimine, majapidamiste säästus ja ootused ning tajutava ebakindluse mõõtmisega seotud küsimused.

Artikkel I, "Kogutootlikkuse kasv Kesk- ja Ida-Euroopas enne üleilmset finantskriisi, kriisi ajal ja pärast seda", kirjeldab majanduskasvu allikaid 11 Kesk- ja Ida-Euroopa (KIE) riigis, mis liitusid Euroopa Liiduga alates 2004. aastast. Artikli peamine panus erialakirjandusse seisneb selles, et genereeritakse uued usaldusväärsed kapitali aegread, võetakse arvesse andmeid kapitali rakendatuse kohta tootmises ja arvutatakse KIE riikide kogutootlikkus. Tulemused näitavad, et enne üleilmset finantskriisi olid valimisse kuuluvate riikide majanduskasvu peamiseks panustajaks kapitali ja kogutootlikkuse kasv. Kriisi ajal olid majanduskasvu dekomponeerimise tulemused KIE riikides üsna heterogeensed, kuid pärast üleilmset kriisi oli nõrk majanduskasv kõigi valimis sisalduvate riikide puhul seotud tagasihoidliku kogutootlikkuse kasvuga.

Artikkel II "Tajutav ebakindlus kui peamine kodumajapidamiste säästmiskäitumist mõjutav tegur" keskendub kodumajapidamiste säästikäitumisele tööturuga seotud ebakindluse kontekstis. Uuringus eristatakse tegelikku ja tajutavat ebakindlust. Sellist lähenemist võib pidada töö põhiliseks panuseks. Tegelik ebakindlus tuleneb šoki realiseerumisest, samas kui tajutavaks ebakindluseks võib pidada tulevikus esineda võivate šokkide ootust. Uuringus kasutatakse 22 Euroopa riigi dünaamilisi paneeländmeid, mille analüüsimiseks kasutatakse GMM hinnangfunktsiooni. Valitud meetod võimaldab arvestada tunnuste endogeensuse ja Nickelli nihega. Artiklis leitakse, et kodumajapidamiste säästumäär on püsiv ning selle taga on peamiselt sissetulekute kasv ja tööturuga seotud ebakindlus, kusjuures nende kahe teguri kvantitatiivne mõju on ligikaudu sama. Laenude kättesaadavus, intressimäärad ja inflatsioon mõjutavad säästmist vähe või üldse mitte. Uuringu peamine järeldus, et tarbijaootused mõjutavad kodumajapidamiste säästmiskäitumist, võib olla oluline eeskätt poliitika kujundamise kontekstis.

Artiklis III „Ümardamise nihe majandusprognoose ümbritsevas ebakindluses“ uuritakse sellist prognoosidega seotud ebakindluse levinud mõõdikut nagu keskmine individuaalne dispersioon, mida defineeritakse kui individuaalsete prognooside dispersioonide keskmist. Uuringus kasutatakse sujuva ülemineku regressioonanalüüsi ja simulatsioonifunktsiooni, et uurida, kuidas prognooside ümardamine mõjutab nende dispersiooni. Artiklis ilmneb, et keskmises individuaalses dispersioonis, mida kirjanduses sageli nimetatakse otseseks ebakindluse indikaatoriks, on müra ning see on välisprotsessi funktsioon, nagu näiteks arvutitarkvara turu areng või paremad erialase koolituse võimalused. Analüüs näitab, et majandusprognoose ümbritseva ebakindluse dünaamika puhul ei esine säärast seletamatut kasvu, millele viitab pealiskaudne individuaalse dispersiooni vaatlus.

Dokoritöö artiklites vaadeldakse Euroopa majanduse tsükliliste kõikumiste dünaamikat erinevate nurkade alt, dekomponeerides majanduskasvu ja uurides majandusliku ebakindluse erinevaid omadusi. Kõigi kolme artikli tulemused on asjakohased empiiriliste uuringute jaoks, eriti majanduslanguste aegadel, kui võib tekkida vajadus kasvudünaamikast ja ebakindluse liikumisest täpse ettekujutuse järele.

## **Appendix 1. Publication I**

TOTAL FACTOR PRODUCTIVITY GROWTH IN CENTRAL AND EASTERN EUROPE BEFORE, DURING AND AFTER THE GLOBAL FINANCIAL CRISIS

### **Publication I**

Levenko, N., Oja, K., & Staehr, K. (2019). Total factor productivity growth in Central and Eastern Europe before, during and after the global financial crisis. *Post-Communist Economies*, Vol. 31, No. 2, 137–160. DOI: [doi.org/10.1080/14631377.2018.1460713](https://doi.org/10.1080/14631377.2018.1460713). (ETIS 1.1)

## **Appendix 2. Publication II**

### **PERCEIVED UNCERTAINTY AS A KEY DRIVER OF HOUSEHOLD SAVING**

#### **Publication II**

Levenko, N. (2020). Perceived uncertainty as a key driver of household saving. *International Review of Economics & Finance*, Vol. 65, 126–145. DOI: [doi.org/10.1016/j.iref.2019.10.005](https://doi.org/10.1016/j.iref.2019.10.005). (ETIS 1.1)



## **Appendix 3. Publication III**

### **ROUNDING BIAS IN FORECAST UNCERTAINTY**

#### **Publication III**

Levenko, N. (2020). Rounding bias in forecast uncertainty. *Research in Economics, forthcoming*. DOI: [doi.org/10.1016/j.rie.2020.08.001](https://doi.org/10.1016/j.rie.2020.08.001). (ETIS 1.1)

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2016–2018	Initiative IPG Mediabrands, analytics department, data analyst
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## Publications and working papers

- Kukk, M., & Levenko, N. (2020). Alternative financing and non-performing loans of the corporate sector in Estonia. Bank of Estonia Working Paper Series, 6/2020.
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- Levenko, N. & Staehr, K. (2016). To be or not to be in the rouble zone. Lessons from the Baltic states. *CESifo Forum*, 17(4), 34–42.

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Keel	Tase
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- Kukk, M., & Levenko, N. (2020). Alternative financing and non-performing loans of the corporate sector in Estonia. *Eesti Panga toimetised*, 6/2020.
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