# DNB Research Program 2020

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# Content

# Monetary policy

The global financial crisis had a profound impact on the practice of monetary policy in a range of countries. The crisis challenged important elements of the pre-existing dominant view that monetary policy should be aimed at price stability and should use just one instrument: a short-term policy interest rate. Being confronted with a massive financial crisis and its repercussions as well as stubbornly low inflation rates, central banks resorted to a large number of unconventional policy tools. When they encountered the effective lower bound (ELB), central banks extended the set of assets they were willing to purchase, these operations being known generically as Quantitative Easing (QE). This changed the composition and vastly increased the size of their balance sheets.

In light of these changes, four sets of important questions arise:

## 1. Effects of unconventional monetary policies

Although a substantial amount of research suggests that unconventional policies have contributed to increasing output growth and inflation, less is known about their impact on the exchange rate and how this in turn affects the macro economy (changing exchange rate pass-through to inflation). In addition, more research is needed on the (unintended) consequences of unconventional monetary policies on: housing markets, risk taking by financial institutions and markets, zombie-lending (misallocation of capital), and the behaviour of (different types of) consumers (e.g. due to shortfalls in the pension system). With interest rates still at or close to the ELB the effectiveness of unconventional monetary policies going forward increasingly depends on fine-tuning the fiscal-monetary policy mix while controlling sovereign risk.
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## 2. The new normal for monetary policy

Important changes in the economy, notably the low level of inflation and sluggish economic growth, created new challenges for monetary policy decision-making. A major issue here is that some key variables (like the natural rate and expectations) are non-observable, while they play a key role in theoretical models. Important questions include: how reliable are estimates of the natural real rate of interest and its drivers; can monetary policymakers influence the natural rate, and if so, how? What is the role of expectation formation in relation to wage and price dynamics? To address these issues, a proper theoretical framework is needed, in which the uncertainty about key variables is taken into account. If and when economic conditions turn more favourable, how should monetary policy be normalized (exit from QE; should central banks eventually return to the traditional mode of intervening at the short end of the market; what is the optimal size and composition of the central bank balance sheets) and what operational framework is best suited to effectively and efficiently transmit the desired monetary stance?
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## 3. Dynamics of inflation

It seems that the dynamics of wage and price inflation has changed. This raises several important questions: do we need new theories to explain (wage) inflation, what is the role of (expected) fiscal policy in this regard, what is the role of technological developments (ICT), globalization and changes in market structures (platforms, contestability), how do changes in labour market composition affect wage growth, is central bank independence enough to deliver price stability? Has the relationship between the output gap, unemployment and (wage) inflation dynamics fundamentally changed? If so, how should the Phillips curve be modelled? What determines the equilibrium labour income share on the macro and sectoral level?

How are (inflation) expectations formed? What is the role of inflation expectations in wage and inflation dynamics? What are the implications of these issues for the ECB's monetary policy – and in particular for the appropriateness of its current strategy?

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## 4.  Credit supply

In the aftermath of the crisis, credit supply by euro area banks dropped. This raises several issues: Why are banks not lending (demand or supply constraints)? What can monetary policy do to stimulate bank lending? What is the relationship between capital and liquidity requirements and bank lending? What are the consequences of lower access to bank credit for small and medium-sized enterprises in the euro area? What impact does a distressed banking sector have on productivity growth? For the last two questions: what can be learned from the US where banks were recapitalized much faster after the crisis? In order to address several of these questions, high priority will be given to develop theoretical models for realistically modelled monetary policy in which debt overhang of firms and/or banks is combined with demand shocks. Such models can also be used to analyse asymmetric effects of monetary policy in a heterogeneous monetary union and can give guidance for identification in empirical work on several of the issues raised above.

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**Theme 1**  Effects of unconventional monetary policies

New projects                                                    Continued projects

# New projects

## 1. Monetary policy effects when interest rates are negative: What do bank stock prices tell us?
Joost Bats, Massimo Giuliodori (University of Amsterdam) and Aerdt Houben

The prolonged period of negative interest rates may have implications for the performance of banks, as retail deposit rates are sticky at the zero lower bound. This may 'reverse' accommodative monetary policy when negative interest rates reduce bank profitability and lending. Backward-looking indicators such as the net interest margin suggest the implications of negative interest rates for bank performance are so far limited. However, these indicators do not yet reflect the full impact of negative interest rates, which takes time to materialize due to longer-dated fixed rate assets. This paper proposes an alternative approach and uses high-frequency data to explore the impact of negative interest rates on a forward-looking indicator: bank stock prices.

## 2. The impact of providing information on monetary policy on inflation expectations and trust in the ECB
Nils Brouwer and Jakob de Haan

Using experimental data gathered via the DHS, we address two research questions. First: does providing information about the ECB's (unconventional) monetary policies enhance trust in the ECB? And secondly, does this information lead to inflation expectations which are closer to the inflation target of the ECB?

## 3. Unintended effects of quantitative easing: An assessment of the safety premium channel
Gavin Goy, Dennis Bonam and Ansgar Rannenberg (NBB)

The objective of this project is to show that quantitative easing, when aimed at purchasing long-term government bonds, can have contractionary effects insofar as long-term government bonds are considered as exceptionally safe and liquid, and thereby hold a safety premium over other assets. As QE reduces the supply of such safe assets, the safety premium rises which implies an increase in the spread on other assets,

through which potential contractionary effects of QE may ensue. Of course, these effects may be offset through other positive effects of QE, such as lowering the term premium. However, in times of excessive stress, when demand for safe assets is particularly high, and during a liquidity trap, when long-run yields are already low, the contractionary effects may dominate. We aim to illustrate the safety premium channel of QE in a sticky price general equilibrium model with financial frictions. We also show that, if the safety premium channel is very strong, it may be better to gear QE towards the purchase of assets that do not hold a safety premium, such as private bonds.

## 4. A structural investigation of quantitative easing
Gavin Goy, Gregor Boehl (Goethe University) and Felix Stroebel (Goethe University)

Did the measures of unconventional monetary policy conducted during the Great Recession induce real effects? We seek to answer this question by using an estimated medium scale DSGE model featuring a banking sector, financial frictions and the endogenously binding effective lower bound on interest rates (ELB) to decompose the US dynamics. We conclude that from 2009 to 2015 the overall quantitative easing (QE)

measures increased output about 0.5 percent. While the effects of measures of liquidity provision were negligible, both the bond and MBS purchases had positive impact on consumption. Forecasts suggest that, through the link between banks balance sheet and investment, shutting down the QE program will have a strong recessionary "hangover" effect, leading to a net-decrease in output for the years after the end of QE.

## 5. QE and portfolio rebalancing in a monetary union
Renske Maas, Kostas Mavromatis, Serdar Kabaca (Bank of Canada) and Romanos Priftis (Bank of Canada)

We use a two country DSGE model for a currency union with portfolio rebalancing to analyze the effects of QE in a monetary union. We aim to quantify the effects of asymmetric behavior from the investors' side first, and, second, from the governments' side following a drop in the supply of long-term assets. Households in each region (Core and Periphery) can hold short- and long-term assets issued by both regions. Importantly, home and foreign assets, but also assets issued within the same region, are imperfect substitutes. Such structure allows for endogenous term premia which depend on the direction of portfolio rebalancing. We account for various asymmetries by allowing home bias coefficients in households' portfolios to different across the two regions as well as different fiscal policy stance.

We consider a QE shock. Our model accounts for the different country size and as such can approximate the ECB's capital key. We consider a QE shock which affects each country individually, according to its size. We then proceed to the design of optimal quantitative easing and derive the optimal capital key weight. We show that the latter is decreasing in degree of substitutability between short- and long-term assets as well as in the degree of substitutability between peripheral and core long-term bonds.

# Continued projects

### 1. Asset bubbles in risky assets
Nander de Vette

This paper assesses the relation between asset pricing bubbles in equity and credit markets. Risk premia on equity and credit instruments are closely linked as they both reflect a compensation per unit of default risk. We try to formally identify asset pricing bubbles in equity and credit markets and subsequently gauge the effect of QE on bubble contagion. More specifically, using a reduced form approach and a bubble identification method we shed light on how the portfolio rebalancing channel of QE influenced overvaluation in risky assets (equities and credit), and whether it had a similar impact on risk perceptions.

### 2. QE and (international) portfolio rebalancing
Tom Hudepohl and Renske Maas

The portfolio rebalancing channel is often cited in literature as one of the most important, and perhaps one of the most effective channels through which QE can affect the economy. Most studies that look at portfolio rebalancing consider the euro area as a closed economy. However, QE also comes with important open-economy aspects. In order to address the open character of the euro area, we will look at international portfolio rebalancing. Addressing the question of international portfolio rebalancing will be done in two ways. One particular way investors can resort to portfolio rebalancing is by means of carry trades. By taking a look at the positions of euro area investors, we will investigate the impact of QE on carry trades. This will first be done by looking at whether euro area investors increased their risk-taking via an increase in exposure on liquid instruments in other currencies. Second, we will look at whether euro area investors resorted to international portfolio rebalancing by increasing instrument risk on their balance sheets.

### 3. Risk management principles for central banks: Towards a better understanding of interest rate risks in the central bank balance sheet
Michael Kurz, Dirk Broeders and Paul Wessels

The aim of this project is to contribute to the understanding of interest rate risks in central bank balance sheets within a structural model of the economy. Interest rate risk in central bank balance sheets may result from asset-liability mismatches as a consequence of quantitative easing. Since central banks cannot hedge such interest rate risk due to their unique position in financial markets and their mission, it is important to better understand interest rate risks in central bank balance sheets in a broader economic context. This will be achieved by building on and extending structural (DSGE) models from the academic literature, that are usually used to model optimal interest rate corridor width.

### 4. Spillover effects of PSPP in the euro area
Anna Samarina, Yvo Mudde and Robert Vermeulen

This paper evaluates the entire Public Sector Purchase Program (PSPP) in the euro area and examines its effects on government bond yields, using monthly data over the period 03/2015-12/2018 for 10 euro area countries. We distinguish the effects of domestic (own and close substitutes) purchases from the spillover effects of government bond purchases in other euro area countries. The spillovers from other countries are studied on the basis of the country's credit rating and bond's maturity segment.

**Theme 2**  The new normal for monetary policy

New projects                                              Continued projects

# New projects

### 1. Drivers of the Euro area economy: A nonlinear semi-structural approach

Gavin Goy, Claus Brand (ECB), Carlos Montes-Galdon (ECB), Mario Porqueddu (ECB) and Mate Toth (ECB)

What are the long-term drivers of the euro area economy? To answer this question, we estimate a non-linear semi-structural model with stochastic volatility for the euro area. We show how lower productivity growth, rising risk aversion as exemplified by a rise in the convenience yield and demographics have contributed to a fall in the natural rate of interest. Together with a decline in neutral inflation this explains the observed fall in nominal rates to historical lows. Using the model, we also document a declining elasticity of inflation to demand shocks.

### 2. Non-linearities in the IS curve

Jan Willem van den End, Paul Konietschke, Anna Samarina and Irina Stanga

This project examines empirically the relationship between interest rates and expenditures, known as the IS-curve. We investigate whether the coefficient of the IS-curve relation (intertemporal elasticity of substitution) is different in the low interest rate environment. In particular, we test whether the IS-curve displays non-linearities with respect to a low level of the interest rate and if so, at what interest rate levels such kinks in the curve may occur. For this purpose, we estimate smooth-transition local projections for 7 economies (U.S., euro area, and 5 largest euro area countries) over the period 1980-2019. We consider different interest rates measures (nominal vs. real, long- vs short-term) and different GDP components (output gap, consumption, investment, savings), as well as account for additional factors (financial variables). Our results can shed light on the possible flattening of the IS-curve that might be related to income effects becoming more dominant than substitution effects at low interest rates. The research can enhance our understanding of monetary policy effectiveness at the zero lower bound.

### 3. Nowcasting Dutch GDP with Machine Learning Methods

Andreas Pick

This paper compares the GDP nowcasting abilities of seven methods in a pseudo real-time setting. The analysis covers Dutch real GDP over the years 1992-2018 using a broad data set of monthly indicators and dives into the performance and interpretability of models based on factors, shrinkage, and ensemble learning. Combining the random forest and mixed-data sampling model yields the most precise approach to nowcast GDP. Inspection of the forecast contributions suggests that potential nonlinear and interaction effects might be driving the superior results of the random forest.

# Continued projects

## 1. Fear of secular stagnation and the natural interest rate
Paolo Bonomolo and Valentina Gavazza (Stockholm University)

What is the role of expectations and pessimism in explaining the low and persistent pattern of interest rates after the financial crisis? Potential output is not directly observable: when a recession occurs, it is not clear if the effects are permanent (like in a secular stagnation) or transitory. The more the agents are pessimistic, the higher the probability they attribute to the first scenario, leading to a lower natural interest rate. We quantify the contribution of pessimism on the natural rate in Europe and the U.S., estimating a DSGE model under the assumption that agents cannot observe whether shocks to technology are permanent or transitory. We model pessimism as ambiguity aversion in the sense of Klibanoff Marinacci and Mukerji (2005).

## 2. Detecting liquidity traps
Paolo Bonomolo, Yildiz Akkaya (Konjunkturinstitutet) and Ingvar Strid (Sveriges Riksbank)

Major economies experienced a period of low interest rates and low inflation. A possible explanation is that they fell in a liquidity trap. This is an equilibrium situation in which the policy rate is at the effective lower bound and inflation fluctuates around a negative or very low value. Ending in a liquidity trap is a big risk for the policy maker and we develop an econometric strategy to quantify this risk. We show that the methodology is able to recognize when the probability of converging to a liquidity trap is high before the interest rate approaches the lower bound.

## 3. Re-assessing monetary policy shocks
Paolo Bonomolo, Björn van Roye (ECB) and Alistair Dieppe (ECB)

We develop a framework to quantify the effects of monetary policy taking into account the possibility of a structural decrease in the growth rate of GDP. When such a situation occurs, we have two consequences: i) the natural interest rate is lower: ii) part of the variation in GDP growth is attributed to structural factors that are independent of monetary policy. Both these effects downplay the estimated effects of monetary policy.

## 4. Now-casting under structural change
Maurice Bun, Jos Jansen (Ministry of Finance) and Jasper de Winter

Policy makers and economic agents have to make decisions based on incomplete and inaccurate information about current economic conditions. For this reason, the now-casting of key economic aggregates, i.e. forecasting their current state, is of great importance. The recent now-casting literature has developed an extensive toolkit to summarize large amounts of statistical information observed at different frequencies and with non-synchronous release dates. In this project we analyse the robustness of several now-casting models to structural change. We furthermore correct for structural change by including intercept corrections and evaluate the predictive ability of the resulting models.

## 5. Look for the stars: Estimating the natural rate of interest
Irma Hindrayanto, Mengheng Li and Siem Jan Koopman (Free University Amsterdam (VU))

The natural rate of interest (r*) and the growth rate of potential output are important policy benchmarks widely used by central banks to determine the

stance of an economy. It is well recognized that r* is subject to low-frequency fluctuations as shown in the seminal paper of Laubach and Williams (2003). To track its evolution over time in a parsimonious manner, we propose a 2-stage multivariate unobserved components (MUC) model with similar cycles. In the first stage we pin down the time-varying trend growth rate of real output using Okun's law. In the second stage we model the necessary gap variables using similar cycles and insert the calculated trend growth rate in the full MUC model to estimate r*. We apply our model to US, UK and EA data.

## 6. Estimating behavioural learning equilibria

Kostas Mavromatis, Cars Hommes (University of Amsterdam) and Tolga Ozden (University of Amsterdam)

We estimate NKE models under a simple misspecification learning equilibrium that arises from expectational frictions. The representative agent does not know the true underlying mechanism of the economy, but acts as an econometrician and uses a simple univariate sample autocorrelation learning rule to form her expectations about the future state of the economy. Over time, she learns the best univariate rule and her expectations become self-fulfilling, giving rise to Behavioural Learning Equilibria (BLE). Under fairly general conditions, we show that NKE

models can be estimated under a BLE using standard Bayesian estimation methods without using projection facilities. We apply our estimation approach to two models that are commonly used in the literature: the baseline 3-equation NKPC à la Woodford (2003), and the workhorse Smets-Wouters (2007) model. Our results show that the empirical fit and forecasting performance of both models under BLE improve compared to the Rational Expectations models, while we observe important differences in our parameter estimates and the propagation mechanism of the model.

## 7. Estimating DSGE models with finite horizons

Kostas Mavromatis, Joep Lustenhouwer (Bamberg University), Mike Tsionas (Lancaster University) and Giorgio Motta (Lancaster University)

We augment the Smets-Wouters (2007) model to account for households' and firms' bounded rationality. In particular, we assume that both form decisions up to a finite number of periods to the future. We estimate the model using a novel estimator. Our estimates show that the planning horizon of agents varies from 20 to 25 quarters ahead. Moreover, given the finite horizon in agents' decisions, we show that the responses of output, inflation and investment in the U.S. are more pronounced following fundamental shocks.

## 8. Forecasting with large panel data sets

Andreas Pick

This research project investigates methods for forecasting with large panel data sets. An application is that of Bernoth and Pick (2011, JBF), who investigate forecasts of banking and insurance vulnerabilities. The current project aims to further the understanding of forecasting in such data sets, to develop new forecasts, and compare those forecasts to existing forecasting methods.

**Theme 3**  Dynamics of inflation

Continued projects

# Continued projects

### 1. Private beliefs formation and macroeconomic risk
Paolo Bonomolo, Guido Ascari (University of Oxford and University of Pavia) and Leonardo Melosi (Federal Reserve Bank of Chicago)

We study how the time variation in the expectation formation process affects the dynamics of inflation. The goal is to understand the determinants of inflation expectations, and quantify the risk that a shift in expectations can lead to high inflation. First, we identify the empirical determinants of the expectation formation process and its time variation through a time-varying parameter VAR. Then, we build a model with time-varying expectations to study the relation between expectations and macroeconomic instability.

### 2. Non-linearity in the long-run Phillips curve
Paolo Bonomolo and Guido Ascari (University of Oxford and University of Pavia)

In a situation with low inflation and the nominal interest rate at the lower bound, the Central Bank may affect inflation expectations by increasing the inflation target. We focus on a particular risk of such a policy: a negative impact on potential output. The presence of

staggered prices and wages may imply a suboptimal level of production: if firms do not set their price optimally, they end up adjusting the quantity produced. We estimate how this inefficiency depends on the level of long-run inflation (the inflation target) using both time series and structural models.

### 3. On the sources of business cycle fluctuations in small open economies
Paolo Bonomolo, Vesna Corbo (Sveriges Riksbank) and Jesper Lindé (Sveriges Riksbank)

We study how much small open economies are dependent on global factors. We use Swedish data (and in a later phase, possibly Dutch data) to quantify the big role of financial linkages in explaining the dynamics of GDP and inflation after the financial crisis. In particular, when global financial stress increases, the effects are similar to a supply shock: inflation and GDP move in opposite direction. This can account for the so called "twin puzzle": the missing disinflation during the financial crisis, and the low inflation during the financial recovery.

### 4. Inflation fluctuations and liquidity constraints
Jakob de Haan, Emmanuel de Veirman and Irina Stanga

This project is motivated by two factors. First, in the eurozone as well as in the Netherlands, core inflation has declined relatively little during the Great Financial Crisis and its aftermath and is increasing relatively little during the current recovery. Second, it is likely that liquidity constraints were more pronounced during the Great Financial Crisis and its aftermath than at other times. We link these two factors by investigating how liquidity constraints affected firms' pricing actions in the Netherlands, not unlike what Gilchrist et al. (AER 2017) do for the United States. We use a micro data set on prices and liquidity of Dutch firms, which we construct for this purpose.

### 5. Heterogeneity in inflation forecasts
Kostas Mavromatis, Jakob de Haan, Cars Hommes (University of Amsterdam), Domenico Massaro (Catholic University of Milan) and Adriana Cornea Madeira (University of York)

We use a unique dataset on Consensus Forecast data to analyse inflation and output growth dynamics accounting for heterogeneity in expectations.

Specifically, respondents in our dataset are called upon forming expectations about inflation, output growth, interest rates and other macro aggregates in the US, one and two years ahead. Our dataset contains monthly forecasts of individuals and spans from 1989 to 2017. We develop and estimate a behavioural model of inflation dynamics with heterogeneous agents. Heterogeneity in agents refers to their forecasting rules. Each agent has her own forecasting rule but we allow agents to switch among those rules over time, depending on the forecasting performance of each rule in the past. We experiment with both forward-looking and backward-looking forecasting rules.

## 6.  Does it matter how you target? Performance of point, band, and range targets for inflation

Anna Samarina

We construct a new database of inflation targets for 55 countries over the period 1990-2018. We distinguish three types of inflation targets used by central banks: point target, point target with a tolerance band, and range target. Using this database, we examine how effective are different types of targets in achieving price stability. That is, whether the distinction between inflation target types matters for inflation performance, its volatility, and expectations.

**Theme 4**  Credit supply

New projects

# New projects

## 1. The impact of negative interest rates on bank intermediation

Jorien Freriks and Jan Kakes

This project studies the effect of negative interest rates on bank intermediation and the transmission of monetary policy. Using bank-individual data (IBSE, IMIR), we investigate to how changes in interest rates affect banks' deposit and lending rates, as well as corresponding interest rate margins. In addition, we relate these effects to bank-specific characteristics, such as their funding profile, size and risk profile.

## 2. IBRN project on consequences of low interest rates

Anna Samarina, David-Jan Jansen and Jakob de Haan

This new IBRN project examines the consequences of low and/or negative interest rates on bank profits, bank funding and bank credit. Using confidential data, project teams will estimate the same models for the participating countries.

# Financial stability and financial regulation

The financial crisis has also led to major changes in financial sector supervision. Micro-prudential requirements have become stricter, although there is also a tendency (at least in some countries) towards less regulation. Within the euro area, the SSM has become responsible for banking supervision, but not for supervision of other financial institutions. Nowadays most central banks have become responsible for maintaining financial stability. A wide array of macro-prudential instruments can be applied, but so far, there is only limited experience. Early detection of (systemic) risks is important to successfully use both micro- and macro-prudential instruments. This calls for a further development of quantitative tools (using granular data) that can inform policymakers on (systemic) risk both in the banking and non-banking financial sector, such as early warning indicators, financial or credit cycle models, contagion mechanisms, and stress test models. As residential and commercial properties make up a substantial part of non-financial private sector assets, and relate to a significant share of financial sector lending and investment, developments in these markets have a profound impact on economic and financial stability. It is important to better understand the strong boom-bust pattern in the housing market, the causes of the slow reaction of the supply side of the housing market, and the relationship of the housing market with the business cycle.

In light of this, several important questions arise concerning financial stability and financial regulation including:
Which tools and policies can help to reduce the pro-cyclicality of the housing market? How do macro-prudential policy changes and regulatory reforms affect the transmission mechanism of monetary and macro-prudential policy? What is the impact of a country's financial structure (bank-based vs. market-based financing) on systemic risk? What is the impact of "fintech" and financial innovation (like CoCos) on the sustainability of the (successfulness of) business models of financial institutions and what are the implications for financial services provision, the sustainability of business models of financial institutions, financial markets, financial stability and micro- and macro-prudential supervision? How does financial criminality impact the reputation of financial institutions and prudential risks? Do developments like low interest rates, high levels of debt and leverage, and increasing protectionism threaten financial stability?
■ Projects 2020

## **Theme 5**  Financial Stability and financial regulation

New projects

Continued projects

# New projects

### 1. Detecting anomalous payment flows in large value payments system TARGET and LVTS

Timothy Aerts, Segun Bewaji (Payments Canada), Shaun Byck (Payments Canada), Ronald Heijmans and Ellen van der Woerd

This paper aims at detecting anomalous payment flows at individual bank level in large value payment systems in Europe (TARGET2) and Canada (LVTS). We use transaction data of TARGET2(-NL) from 2008 to 2019 and LVTS from 2002 to 2019. It builds on earlier work by Triepels, Daniels and Heijmans (2018) and Sabetti and Heijmans (2020). These papers used an autoencoder (neural network) to detect outliers. A part that is missing in these papers is that the history of payment flows is not accounted for. As a consequence, these model setups will not detect a continuous and increasing outflows as an anomaly. To capture the history of payment flows, we will look at long short-term memory (LSTM) and Gated Recurrent Units (GRU). We will test both model setups and compare them to the standard autoencoder. Besides, we compare results against a very simple method which takes flows which are in the 4 sigma. The model performance is tested for both the Canadian and the European LVPS. Comparing the differences between

markets allows for checking how universal a model setup is or not. In order to test our model, we test it on both out of sample outliers and simulated data.

### 2. Are there arbitrage possibilities in the trade of crypto currencies?

Timothy Aerts, Segun Bewaji (Payments Canada), Ronald Heijmans, Jeff Stewart and Ellen van der Woerd

Crypto currencies receive much attention lately as a potential means of payments in the near future. Especially since the announcement of the Libra coin by Facebook. The question is whether these or at least some of the cryptos are a suitable means of payments. Two aspects that are relevant in this discussion is their trading value against fiat currency and the volatility of the price. To get a better understanding of crypto currencies as a means of payments we study the volatility of the most traded cryptos (e.g. top 100) on the exchange Binance and the possibility for arbitrage. Different algorithms will be tested in order to detect this arbitrage possibility.

### 3. Recourse and (strategic) mortgage defaults: Evidence from changes in laws governing the housing market

Alin Andries (Alexandru Ioan Cuza University), Anca Copaciu (National Bank of Romania), Radu Popa (National Bank of Romania), and Razvan Vlahu

Since the onset of the global financial crisis in 2007, mortgage default rates rose in an unprecedented way, and many homeowners, from both sides of the Atlantic, saw their homes foreclosed. Moreover, in the aftermath of the housing downturn, mortgage debt held by vulnerable households has been identified as one of the main amplifiers of the spillover effects to the real economy. Nevertheless, the default rates in Europe were markedly lower than in the U.S. One key reason for this pattern is the fact that mortgages in Europe are recourse loans. Lenders in Europe can claim a borrower's personal (unsecured) assets, as well as future income, when the market value of her house upon foreclosure does not cover the mortgage debt. In contrast, many U.S. states are non-recourse. In this paper we exploit the event of changes in laws governing the housing market in a small economy and identify the triggers for mortgage loan defaults. More precisely, we use credit registry information to study the effects of changes in the recourse law in Romania.

This event is uniquely suited to study the incentives for mortgage default in a dynamic setting as it changed the status of mortgages from recourse to non-recourse, giving borrowers the possibility to fully settle their liabilities in relation with the credit institution by simply transferring the mortgage ownership to the lender (i.e., "walk away"), without any deficiency judgments.

## 4. How does the relationship between the loss-given-default (LGD) and the probability of default (PD) affects the cyclical behaviour of the Dutch banks' regulatory capital?
Laurence Deborgies Sanches and Marno Verbeek (Erasmus University Rotterdam)

Most published research uses the defaulted bond market to establish the existence of a negative relationship between the default rate and the recovery rate (one minus loss-given-default (LGD)). This correlation is derived from the common dependence of the default and recovery rates on a systematic factor identified as being the state of the macro-economy. In an economic downturn, the value of the assets pledged as collateral declines reducing the value of the collateral in a period where borrowers' probabilities of default (PD) increase. The resulting credit risk is then amplified in a portfolio of corporate bonds. However, bank loans LGDs are fundamentally different from

bond LGDs which are determined from market values. Specifically, to calculate their LGD, banks use the discounted value of all cash-flows involved until the withdrawal of the defaulted loans from their balance sheet. Hence, the hypotheses retained to calculate their LGD like, the discount rate, if the LGD is either synchronised with the cycle (cyclical LGD) or averaged over the cycle (a-cyclical LGD) or, determined from a worst-case scenario (downturn LGD), are important factors that may blur the predicted effect of the collateral value on the recovery. Moreover, numerous papers have shown that the credit rating philosophy (point-in-time or through-the-cycle) used to estimate the PD risk aggregate plays an important role in the cyclicality of bank capital requirements. Finally, if loan contracts are renegotiated, the relationship between the PD and LGD may be negative; the PD rise but the resulting LGD would fall. The final effect on the cyclicality of the bank regulatory capital is thus undetermined. This situation is complicated by the fact that banks' lending activity involves different types of debtors (sovereign, financial institutions, corporate and retail). Each of them responds differently with a different timing to the evolution of their macroeconomic environment. The aim of our study is to investigate the consequence of such a complex situation on the cyclicality of the Dutch banks' required capital by using a confidential regulatory dataset as collected by DNB.

## 5. Shallow or deep? Detecting anomalous flows in the Canadian Automated Clearing and Settlement System using an autoencoder
Ronald Heijmans and Leonard Sabetti (Bank of Canada)

Financial market infrastructures and their participants play a crucial role in the economy. Financial or operational challenges faced by one participant can have contagion effects and pose risks to the broader financial system. This paper applies (deep) neural networks (autoenconder) to detect anomalous flows from payments data in the Canadian Automated Clearing and Settlement System (ACSS) similar to Triepels et al. (2018). We evaluate several neural network architecture setups based on the size and number of hidden layers as well as differing activation functions dependent on how the input data was normalized. As the Canadian financial system has not faced bank runs in recent memory, we train the models on "normal" data and evaluate them out of sample using test data based on historical anomalies as well as simulated bank runs. Our work highlights the challenges and trade-offs employing a workhorse deep learning model in an operational context and raises policy questions around how such outlier signals can be used by the system operator in complying with the prominent payment systems guidelines and by financial stability experts in assessing the impact on the financial system of a financial institution that shows extreme behaviour.

## 6. Growth-at-Risk
Dimitris Mokas and David-Jan Jansen

The Growth-at-Risk (GaR) framework offers a way to estimate downside tail risks to economic growth, with the important distinction that these tail risks are found to be strongly related to current macro-financial conditions. As GaR can be measured at various forecasting horizons, one thing it offers is a way of studying if macro-financial conditions have a different effect on near-term versus medium-term growth risks. We follow the recent literature on the term structure of GaR and study relevant questions to present-day policy debates in the euro area context.

## 7. Trust in financial institutions
Carin van der Cruijsen, Jakob de Haan and Ria Roerink

Trust in financial institutions is widely considered important. However, a clear overview of studies on the drivers of trust is missing. We intend to fill this gap in the literature. After discussing why trust in financial institutions is important, we turn to its measurement, where we distinguish between trust in one's own institution and trust in institutions in general (narrow-scope and broad-scope trust), and discuss how these measures differ from generalized trust (i.e. trust in other people with whom there is no direct relationship). Finally, we survey the determinants of trust in financial institutions and discuss a wide range of drivers.

# Continued projects

## 1. Systemic risk of pension funds
Rob Bauer (University of Maastricht), Dirk Broeders and Annick van Ool

Since the financial crisis changes in financial regulation have increased the safety and resilience of financial institutions. However, this does not automatically imply that the financial sector as a whole becomes safer. There is evidence of herd behaviour among pension funds, partly because of this increased intensity of financial regulation. Herd behaviour can lead to more homogeneity among pension funds which potentially harms financial stability. A simultaneous funding shortfall of many pension can have a significant impact on the real economy as a result of large-scale pension cuts. In this paper, we focus on potential trade-offs between individual and systemic risk in the pension sector and investigate how diverse diversification across pension funds can reduce systemic risk. We use a stylized model with several pension funds. Each pension fund determines its individual strategic asset allocation and we simulate the performance of all pension funds in different economic scenarios. Subsequently, we investigate whether more diverse strategic asset allocations across pension funds lead to a better performance of the pension sector as a whole. First, we exclude pricing effects for the sake of simplicity. Second, we investigate the impact of price effects which can occur as a result of institutional herd behaviour.

## 2. Foreign bias in equity portfolios
Martijn Boermans, Ian Cooper (London Business School), Piet Sercu (KU Leuven) and Rosanne Vanpee (KU Leuven)

The literature on international equity holdings distinguishes between home bias (overweighting of home stocks) and foreign bias (relative underweighting for more 'distant' countries). The two biases can be integrated into one distance-based model. This paper builds on the work on Cooper et al. (2018) to measure the foreign bias. We analyse how benchmarking explains the prior findings in the literature. We collect portfolio holdings among households in stocks. The findings are important to better explain international investment patterns and may carry implications for financial stability.

## 3. Does search for duration make investment behaviour procyclical?
Stijn Claessens (BIS) and Robert Vermeulen

We investigate, using security level data covering all euro area countries, how various classes of investors adjust their portfolios in response to changes in interest rates considering the duration of investable securities. Investors with long term liabilities, e.g. insurance companies and pension funds, face sharp increases in these liabilities when discounted with lower interest rate. This effect can trigger investors to purchase more long-term bonds with a high duration, which creates a feedback loop. The results provide information on investor behaviour during the ECB's asset purchasing programs and can provide guidance on investor responses when the ECB will decrease its balance sheet again.

## 4. Requirement on the Total Loss Absorbing Capacity for Global Systemically Important Banks
Wayne Passmore (Federal Reserve Board) and Chen Zhou

The Basel Committee on Banking Supervision identifies global systemically important banks (G-SIBs) and requires G-SIBs to hold additional common equity

as "G-SIB capital surcharges." An alternative way to increase the Total Loss Absorbing Capacity (TLAC) of G-SIBs is to issue the long-term debt (LTD) that will be written down or converted to equity on failure. The goal of this research are two folds. Firstly, we compare the two policies: G-SIB capital surcharge and TLAC LTD for risk mitigation. The goal is to investigate the optimal policy based on G-SIB capital surcharge or TLAC LTD, or their combination to maintain the expected loss of a G-SIB failure at a low level. Secondly, we evaluate quantitatively the rate of substitution between TLAC LTD requirement and capital surcharge.

## 5. Demand and supply reservation price indices for the housing market
Dorinth van Dijk and Marc Francke (University of Amsterdam)

We use the Van Dijk, Geltner & Van de Minne (DNB WP 583, 2018) method to estimate reservation price indices for buyers and sellers in the Dutch and U.K. housing market. We relate features of these indices to regional characteristics and mortgage markets. We expect that the seller reservation price index dynamics are different in regions with high mortgage debt, since these sellers might be more loss averse due to negative equity problems. We also look at the differences between commercial and residential reservation price dynamics.

## 6. Regulation, supranational bank supervision, and the corporate structure of foreign affiliates
Razvan Vlahu and Natalya Martynova (Deutsche Bundesbank)

In the context of cross-border banking, we study how differences between home and host country regulatory arrangements, as well as the introduction of a supranational supervisor, affect the corporate structure of foreign affiliates. When going abroad, banks can operate as either a subsidiary or as a branch. Subsidiaries are separate legal entities regulated and supervised by host country's authorities, thus protected by limited liability. Branches are an integral part of the parent bank, enjoying no limits on the ability to transfer funds cross-border within the banking group. They are also subject to regulation and supervision on a consolidated basis in the home country. We show that when the host country's regulation allows for both structures, foreign banks may circumvent stricter regulation abroad and prefer to operate through a branch structure. We also show how the presence of a supranational supervisor, who limits the scope of "ring-fencing" arrangements in the host country, may affect the structure of foreign affiliate. By increasing subsidiaries' ability to easily move funds cross-border, while leaving the limited liability of the affiliate unaffected, a centralized supervision may increase the preference for a subsidiary structure

## 7. Bank relationships after foreign takeover
Razvan Vlahu, Steven Poelhekke (University of Auckland) and Vadym Volosovych (EUR)

This empirical study will investigate the impact of foreign acquisitions on funding of acquired non-financial companies. Put in different words, we will try to assess whether non-financial companies who rely on funding from banks, change (completely/partially) their borrowing counterparty upon being acquired by a foreign entity. Do such firms rely on (multinational) banks for their funding and other bank services, or do they adopt the bank relationships of their new foreign owners? Do they keep both relationships and split bank services along particular lines? These questions further help to shed light on the importance of a banking system with home country multinational banks, versus a banking system with smaller domestic banks with a national scope and a set of local offices of foreign multinational banks.

# Sustainability

The sustainability of economic growth has become a major issue, not only for monetary policy-making but also for financial supervision. Fundamental changes in the environment could affect economic and financial stability and the safety and soundness of financial firms, with clear potential implications for monetary and supervisory policies alike. Changes in public policy to address environmental risks, as well as wider factors, such as technological innovation, may affect the economy and financial system. For instance, in view of the Paris Agreement, a major goal for governments is to reduce the emission of carbon dioxide which implies a transition towards more sustainable energy sources. This may affect the macro-economic environment for monetary policy. Likewise, it may affect the riskiness of portfolios of financial institutions (e.g. there may be a risk that carbon-intensive assets may become 'stranded' as part of a low carbon transition). These portfolios may also be affected by other possible environmental developments, such as climate change and the increasing adoption of sustainable investment practices. How can these risks be measured? Sustainability also has a socio-economic aspect, reflecting the need for the fruits of sustainable economic growth to be shared among the population. For instance, the wealth and income distribution (between households but also between production factors) is often considered an important dimension of sustainability. Likewise, sustainability may require social security arrangements (such as pensions) to be self-financed so that the risks are not transmitted to future generations.

As to sustainability, DNB research will address issues like: how will the energy transition affect economic sectors? How will (sudden) changes in the energy transition affect exposures of financial institutions and financial stability? How are climate risks priced in at financial markets? How can the energy transition be implemented efficiently and effectively, given its international dimension and sometimes conflicting (short-term) interests of jurisdictions? What role do financial markets and new financial instruments have in financing the transition? How should the energy transition and the transition towards a circular economy be financed?

As pointed out above, sustainability is more than climate risk. From that perspective DNB research will also address issues like: What are the drivers of TFP-growth at the firm or sector level? What is the contribution of access to finance, zombification, capital misallocation and inter-firm spillovers for TFP-growth at the aggregate level? How do monetary policy and macro-prudential policies affect wealth and income distribution? How does incompleteness of financial markets and the implied heterogeneity in terms of access to liquidity affect macro-economic demand? In view of several changes (like increasing share of temporary workers, reduced bargaining power of trade unions) another important issue is how will the future labour market look like. What is the relationship between income and wealth distribution and robust growth? How can the pension systems be designed (and reformed) in such a way that the risks are shared equally between generations (including future generations)?

■ Projects 2020

# **Theme 6**  Sustainability

New projects                                                    Continued projects

# New projects

### 1. A convenient truth: The convenience yield, low interest rates and implications for fiscal policy
Dennis Bonam

Some countries currently face historically low interest rates on government debt due to a positive 'convenience yield' arising from an excess demand for safe and liquid assets. This low interest rate environment has raised interest in the role of fiscal stabilization policy. We study the convenience yield and its implications for fiscal policy in a New Keynesian model where households derive utility from government bonds. We find that the convenience yield expands the set of sustainable fiscal policies and renders counter-cyclical fiscal policy successful in stabilizing business cycle fluctuations. Conveniently, fiscal policies that stabilize output rather than debt are feasible, welfare enhancing and can even reduce the risk of exploding debt dynamics if the convenience yield is positive.

### 2. Tax multipliers over the business cycle: new evidence from a narrative panel dataset
Dennis Bonam and Paul Konietschke (ECB)

We estimate the effects of tax shocks on the economy at different stages of the business cycle. We use narratively identified exogenous tax changes for a panel of advanced economies and a smooth-transition local projection model to estimate regime-dependent tax multipliers. We find that a positive tax shock has a significantly negative impact on output, yet only during a business cycle boom. A more muted response of the real interest rate and a weaker crowding-out effect on private investment during recessions can explain this (somewhat counterintuitive) result, which we explore in greater detail using a New Keynesian model with precautionary savings.

### 3. Inequality and household financial decisions
Dimitris Georgarakos (ECB), Yuriy Gorodnichenko (University of California Berkeley), Olivier Coibion (University of Texas Austin) and Maarten van Rooij

This project aims to better understand the effect of income and wealth inequality on household financial decisions (borrowing, housing investment and other spending categories) and the channels through which comparisons with peer groups affect household decisions. Also, we shed light on sustainability from the viewpoint of Dutch household perceptions about current levels of inequality.

### 4. Pricing the carbon factor for Europe's equity market
Kristy Jansen, Rianne Luijendijk, Nander de Vette and Sweder van Wijnbergen

This paper uses firm specific $CO_2$ emission data to augment the standard Fama-French three-factor model with a fourth "carbon factor". By constructing portfolios based on $CO_2$ emissions we examine whether there is a systemic return from investing in a $CO_2$ efficient European equity portfolio. In this way the paper will assess whether investors demand a carbon-specific risk premium as compensation for exposure to carbon risk. If there is no difference in pricing between $CO_2$ intensive firms and low $CO_2$ emitting firms, investors apparently do not value or possibly underestimate climate risk. If investors do price in a significant carbon factor this would have extensive consequences for the efficient allocation of investments and the cost of hedging carbon risk.

### 5. The Dutch financial sectors dependence on ecosystem services
Guan Schellekens

Since the Industrial Revolution human activities have reached levels that could damage the planet's

biophysical subsystems and processes that enable human development and economic activity. The loss of so-called ecosystem services poses risks for financial institutions that invest in firms whose business processes depend on them. On the basis of a database containing business processes' dependencies on ecosystem services this paper maps economic activities invested in by Dutch financial institutions on low, medium and high dependence on individual ecosystem services. Concentrations on specific ecosystem services and their drivers of change are identified. In this project the dependencies of financial institutions large corporate loan and securities portfolios' (~1000 billion) to 21 ecosystem services is systematically mapped. Such mappings might, in turn, lead to better estimates of the magnitude of environmental risks financial institutions are exposed to.

## 6. The effect of ESG integration on the environmental performance of stock portfolios
Guan Schellekens, Anouk Levels

Integration of Environmental Social and Governance (ESG) considerations into investment decision-making is rapidly becoming mainstream. Numerous studies have been performed to assess the impact of ESG integration on financial performance. These studies show that ESG integration has little, or potentially a slightly positive, effect on risk-adjusted returns. Little research has been done, however, on the effect of ESG integration on the environmental performance of stock portfolios. In this study we will assess the impact of ESG integration on three metrics of environmental performance: i) the contribution of the portfolio to sustainability goals, ii) the number and severity of environmental controversies associated with the firms in the portfolio and iii) the environmental damage costs associated with the portfolio. This analysis will be performed on the basis of securities holdings statistics of Dutch financial institutions.

## 7. Monetizing the environmental externalities of the Dutch economy and its supply chain
Bas Smeets (former DNB intern), Guan Schellekens, Thomas Bauwens (UU) and Harry Wilting (PBL)

Climate change and environmental degradation will have profound economic impacts. Yet, little research exists on the magnitude of total environmental damage costs and their impacts on different sectors in the Dutch economy. We compute the environmental damage costs of the Dutch economy and their impacts on the profitability of industries. Based on a global input-output analysis, we establish the environmental footprint of the Dutch economy and its supply chain for 30 environmental negative externalities. We assign a monetary value to these externalities and present a proxy for the impact of internalization of these externalities on the profitability of the industries. This project is performed by researchers from DNB, the University of Utrecht and the Dutch Environmental Assessment Agency (PBL).

## 8. Climate risks, the macroeconomy and the term-structure of sovereign bonds
Dieter Wang

We explore the relationship between climate variables and the sovereign term-structure through the macroeconomies of 39 countries. We use a two-stage empirical approach. The first-stage uses a large set of exogenous climate variables, derived from temperature and rainfall measurements, to predict GDP growth and inflation. An adaptive Lasso selects the most predictive variables for monthly macroeconomic fluctuations. The second-stage estimates the causal relationship between the climate-instrumented macro variables and term-structure factors. Using a dynamic panel model, we find that the relationship strongly depends on the cross-sectional heterogeneity, e.g. income classifications, and is influenced by major climate-related events, such as the release of IPCC reports. Quantifying climate risks in the term-structure is relevant for pension funds and banks, due to their large exposure to sovereign bonds.

# Continued projects

## 1. A granular carbon risk stress test for portfolio
Martijn Boermans and Rients Galema (Utrecht University)

In this paper we quantitatively analyse the "carbon risk" associated with investors' stock portfolio holdings using firm-level data. We contribute to the literature by better identifying the expected stock losses associated with different climate stress test scenarios. Prior work has not considered how individual firms interact. Previous climate risk stress tests have typically grouped all firms into industry types, thus not capturing firm heterogeneity in terms of carbon emissions or the firm linkages both within and between industries. We expect that our granular stress tests on stock holdings will yield lower expected losses from climate risks than those based on a more macro-economic approach. For policy purposes it is important to have different climate stress tests results to compare outcomes for the financial system.

## 2. Zombie firms and productivity growth in the Dutch economy
Maurice Bun and Jasper de Winter

Recent theoretical and empirical research indicates the causal link between highly indebted firms (so-called zombie-firms) and economy-wide productivity growth. The evidence for the Netherlands is limited, and largely neglects feedback loops from the business cycle on the growth of the number of zombie-firms. In this research, we investigate the links between highly indebted firms and the economy-wide productivity growth for the Netherlands using a novel database containing the population of Dutch firms and their balance sheet data.

## 3. The employment effects of corporate income tax shocks: New evidence and some theory
Andrea Colciago, Vivien Lewis (Deutsche Bundesbank) and Branka Matyska (Leuven University)

We aim to assess whether cuts to corporate income tax rates can be a useful tool to boost job and business creation. We will provide empirical evidence concerning the effects of corporate tax income shock on firm creation (and destruction) and employment.

Then we will estimate reduce forms effects using panel-regressions estimated on US state data. We will then provide a DSGE model with search in the labour market and endogenous firms dynamics along the lines of Colciago and Rossi (2015), augmented with a fiscal side. The model will be aimed at addressing the main facts identified in the empirical analysis.

## 4. The interplay of financial education, financial literacy, financial inclusion and financial stability: Any lessons for the current big tech era? (title has changed)
Nicole Jonker and Anneke Kosse (Bank of Canada)

In this paper we survey the literature to i) determine the effectiveness of financial education with regard to improving financial literacy and financial inclusion, and ii) assess the impact of financial inclusion on financial stability. Based on our findings we argue that financial education can play an important role in ensuring that everyone is able to reap the benefits that fintech and big techs may bring for financial inclusion. Very careful attention should be paid, however, to the exact design of any education program to be truly effective. We also conclude that financial inclusion opportunities created by big techs might potentially introduce risks for the overall financial stability. Because of this, further

research into the risk management of big techs is warranted.

## 5. Asymmetric shocks in EMU: private or public risk sharing?
Patrick Kosterink, Dennis Bonam, Matthijs Zaal and Jakob de Haan

We examine the importance of asymmetric shocks in EMU by replicating and extending some recent work on this issue and discuss the implications for the need to have more private risk sharing (via financial markets) and/or public risk sharing by some form of European risk sharing scheme.

## 6. Monitoring the Dutch business cycle using text-mining techniques
Dorinth van Dijk and Jasper de Winter

Traditionally, the business cycle has been modelled using macro-economic time series. Recently, research has indicated the potential use of using text as data. This research aims to explore the possibilities of using Dutch newspaper articles to monitor and forecast the stance of the Dutch business cycle using recently developed text-mining techniques from the machine-learning literature.

## 7. Financial literacy and pension expectations
Maarten van Rooij, Rob Alessie (University of Groningen) and Remko Struik

A side-effect of low interest rates is that many pension funds are underfunded, have not been able to index the pensions for a number of years and may have to cut pensions when shortfalls do not recover. We investigate whether employees have updated their expectations regarding retirement age and replacement rate (both in terms of levels and uncertainty), also in view of the major policy changes since 2013 (gradual increase in statutory retirement age and reduced accrual rates). Moreover, we analyse whether the updating of pension expectations is related to financial literacy or other personal characteristics.

# Payments and market infrastructures

Both innovation-driven developments and regulatory measures like PSD2 are transforming the payments ecosystem rapidly. Payment behaviour changes, e.g. there is a downward trend in the use of cash. New players enter the scene. The market structure can change. This will affect the way the central bank can pursue its goal of promoting the smooth functioning of the payment system as well as DNB's supervisory role. Fintech may also have an impact on monetary policy transmission. Moreover, financial market infrastructures may be affected by developments in potential new payment methods or financial instruments, such as crypto-currencies and the underlying technologies. It must remain possible for over-the-counter transactions to be settled in cash as long as consumers still want this.

In the light of the changing landscape, the following research questions on payments and market infrastructures are key: Research on payment innovations, notably the block chain technology, is important, as well as research on the effects of new regulation. What drives the acceptance of traditional and new payment instruments? Is there a minimum level of cash usage below which commercial parties are not interested anymore in maintaining a good infrastructure for cash? How can we improve the banknote in terms of cost and usage? What is the impact of e-commerce on payment use? What is the influence of new regulation and "fintech" on retail payments? How much trust do people have in new and traditional payment instruments and payment service providers, and does it matter? Market infrastructures such as TARGET2, TARGET2-Securities and central counterparties produce a lot

of granular transaction data on a daily basis. How can we use that data to obtain information on a. the monetary policy implementation of the Eurosystem, b. risk indicators within an FMI and between FMIs, c. potential liquidity problems, and d. detect outliers? Many innovations in this field are technology-driven, notably the distributed ledger technology. It is key to investigate their disruptive consequences (not only in the financial sector) and to gain detailed hands-on experience of such new technologies in order to answer questions that relate to their suitability of a potential implementation by central banks and how they need to be supervised.

■ Projects 2020

## Theme 7 Payments and market infrastructures

New projects

Continued projects

# New projects

### 1.  Is there anybody out there? Detecting operational outages from LVTS transaction data

Neville Arjani (Canada Deposit Insurance Corporation) and Ronald Heijmans

This paper develops a method to identify operational outages of participants in the Canadian Large Value Transfer System (LVTS). We define an operational outage as either no or unusual low activity. We test our algorithm against a database of by participants reported outages in order to reduce false negatives. The false positives can be reduced by excluding "outages found" by the algorithm if a participant historically has no payment in a given time interval. Additionally, we can test whether participants do indeed report all their operational outages. Our method can be used by LVTS system operators and overseers to identify sources of operational risks.

### 2.  Influence of proximity of ATMs on cash and card usage

Michiel Bijlsma, Igo Boerrigter, Wilko Bolt and Nicole Jonker

The purpose of the study is to gain insight into how a higher consumer price to get cash affects consumers'

usage of cash. We use travel time to go to an ATM to get cash as a consumer price for cash, as Dutch consumers don't have to pay for cash withdrawals at the ATM. As an identification method, we intend to use sudden closures of ATMs because of explosions due to robbery attempts and closures of certain ATMs to prevent these explosions. These closures represent exogeneous shocks in the supply of cash to the public via ATMs. Changes in cash withdrawals and/or card usage by consumers living in the proximity of closed ATMs indicate the influence of the supply of ATMs on cash usage.

### 3.  How much liquidity would a liquidity-saving mechanism save if a liquidity-saving mechanism could save liquidity? A simulation approach for Canada's large-value payment system

Shaun Byck (Payments Canada) and Ronald Heijmans

Canada's Large Value Transfer System (LVTS) is in the process of being replaced by a real-time gross settlement (RTGS) system. A pure RTGS system typically requires participants to hold large amounts of intraday liquidity in order to settle their payment obligations. Implementing one or more liquidity-saving mechanisms (LSMs) can reduce the amount of liquidity participants need to hold. This paper investigates how

much liquidity requirements can be reduced with the different LSMs provided by the Financial Network Analytics simulation engine, using LVTS transaction data from 2018. These LSMs include: 1) Bilateral offsetting, 2) FIFO-Bypass, 3) Multilateral offsetting, and 4) a combination of all LSMs. We simulate two different scenarios. In the first scenario, all payments from Tranche 1, which are considered time-critical, are settled in a pure RTGS payment stream, while less time-critical Tranche 2 payments are settled in a payment stream with LSMs. In the second scenario, we settle all payments (Tranche 1 and 2) in the LSM stream.

### 4.  Drivers of consumers' trust in a changing retail payment ecosystem

Carin van der Cruijsen, Eric Faber and Nicole Jonker

For central banks it is key to understand what drives consumers' trust in retail payments. Retail payment systems are currently drastically changing due to PSD2, the entrance of new (BigTech) players into retail payments and other technological developments. The purpose of this research is to cast light on consumers' trust in retail payments in general, their trust in incumbents and in new players in retail payments. We study the drivers of trust, including possible privacy and safety concerns.

## 5. Scene guidance for faster and intuitive banknote authentication

Frank van der Horst, Igo Boerrigter and Jan Theeuwes (Free University Amsterdam)

People have the possibility to authenticate a banknote using public security features, but they seldom do so, because they have trust in the system. Also, in general people hardly know which security features exist. So, in order to help people in situations that authentication is needed, security features should be intuitive. This study tries to find out if the meaning of a scene on a banknote ('scene guidance') helps in faster and easier recognition. To that end we will design banknotes with and without scene guidance and test participants in a lab with eye-tracking how fast and accurate their performance is.

## 6. Account-based versus token-based/ P2P/value-based CBDC

Peter Wierts and Harro Boven

In the literature about CBDC, a distinction between account-based and token-based/P2P/value-based CBDC is often made. In this paper we will explain why this is misleading.

# Continued projects

## 1. Cryptos and illegal activities: casting light on the dark side of cryptos
Timothy Aerts, Janko Gorter and Jakob de Haan

A key policy concern at the G20 level is the misuse of cryptos to finance illicit activities. Against this background we apply graph technology to investigate transaction patterns within different crypto networks. Therewith we aim to determine the extent and nature of illegal activity in crypto markets and how this has changed over time. More knowledge on the functioning of crypto markets is needed, also to inform the public surveillance of crypto activities. The latter is becoming a reality, for example in Europe where crypto exchanges and wallet providers have been brought under the scope of anti-money laundering regulations.

## 2. E-commerce: Use, growth and pricing
Wilko Bolt and Bas Butler

E-commerce is rapidly growing. Buying online represents a technology that will fundamentally change the way industries operate. Although E-commerce sales remain a smaller percentage of overall sales than "brick-and-mortar", yet the percentage continues to increase at a (much) faster rate than overall sales. Who are the online users, how do they pay and what preferences do they have? What does it mean for market structure, competition and its effect on product pricing? How do network effects come into play? Using recent Dutch survey results ('two waves') on E-commerce this paper tries to empirically assess above questions by applying multivariate logit/probit regression models, identifying demand and preference characteristics and its potential effect on payment use, production cost, price levels and inflation ("the Amazon effect").

## 3. Virtual currencies: Dynamics and monetary aspects
Wilko Bolt and Maarten van Oordt (Bank of Canada)

Bitcoin was launched in 2009 and has recently attracted much attention from economists, financial media, and even governments. Its increased attention was fuelled by the sudden "explosion" and volatility in the exchange rate of Bitcoin by the end of 2013. Can economic theory help explaining these extreme price movements and its dynamics, and does virtual currency pose a threat or an opportunity for monetary policy? Building on Bolt and van Oordt (2018), this research project tries to further assess the dynamics and monetary aspects of virtual currency.

## 4. Liquidity efficiency in large value payment systems
Martin Diehl (Deutsche Bundesbank), Ioana Duca (ECB), Ronald Heijmans, Patrick Papsdorf (ECB) and Jan Paulick (Deutsche Bundesbank)

This project calculates several liquidity measures for many large value payment systems worldwide. From the theory a decreasing amount of available liquidity will lead to a delay of payments and vice versa. It aims at identifying the most efficient design of a large value payment system in terms of liquidity usage (including intraday credit) and timing of payments. Design features are amongst other provision of (free) intraday credit, liquidity saving mechanisms, netting and throughput guidelines. By comparing the same liquidity measures of many systems worldwide it is possible to investigate what the effect of design features are on the use of liquidity and the timing of payments. The outcome of this project can be used by FMI policy makers which investigate a future design of their large value payment system.

## 5. Pricing the payments infrastructure
Nicole Jonker, Wilko Bolt and Michiel Bijlsma

The increasing fragmentation of the payment chain due to the entrance of fintechs raises the question of which costs are actually involved and who must foot the bill (paying for payments). The payment infrastructure, which is essential to the payment system, is presently available at a relatively low price. Under PSD2, nonbank parties like account information service providers and payment initiation service providers could be able to gain free access to this infrastructure, enabling them to offer innovative services. We want to study the access and pricing of the payment system more closely, including the question of how the providers of the underlying infrastructure remain willing to keep investing in its robustness.

## 6. Contactless payments, the pain of paying, and financial troubles
Carin van der Cruijsen

An increasing number of people are using their debit card or phone to pay contactless at the point-of-sale. This is a quick and user-friendly way of paying. However, given the speed of paying a contactless payment may feel less like a real payment than a cash or standard debit card payment; the pain of paying may be lower. We use consumer survey data to examine the link between payment instrument choice, the pain of paying and financial problems. Thereby, we examine the role of age and other personal characteristics. An increasing number of people are using their debit card or phone to pay contactless at the point-of-sale. This is a quick and user-friendly way of paying. However, given the speed of paying a contactless payment may feel less like a real payment than a cash or standard debit card payment; the pain of paying may be lower. We use consumer survey data to examine the link between payment instrument choice, the pain of paying and financial problems. Thereby, we examine the role of age and other personal characteristics.

## 7. Financial literacy, trust in banks and adoption of new payment technologies
Carin van der Cruijsen and Nathanael Vellekoop (University of Toronto and SAFE)

There is a large literature describing the adoption of new technologies, as well as on the take-up of new products in consumer markets. So far, a systematic study of adoption of new payment technologies by banking clients has been lacking. The past decades there have been many developments in payment technologies. For example, in the Netherlands the use of the debit card to pay in stores has become widespread, and nowadays more than half of these debit card payments are contactless. Households can do their banking online, and since the late 2010s also with a smartphone. We use twenty-five waves of the DNB Household Survey to document the take-up of new payment technologies over time, at both the extensive and the intensive margin. Second, we describe the speed with which new payment technologies replace older technologies. Finally, we use measures of financial literacy and questions on trust in banks to explain the adoption of new payment technologies.