Macroprudential policy and growth-at-risk

The connection between financial imbalances and severe downturns in the real economy has increasingly come to the forefront of academic and economic policy debate since the global financial and economic crisis. In times when the economy is expanding, vulnerabilities can build up in the financial system. These include excessive leverage and overpriced assets. If a negative shock were to hit such financial imbalances, the result may be unfavourable interactions between the financial system and the real economy. This could culminate in a severe recession or even a financial and banking crisis. Looking to the upturn following the coronavirus crisis, too, there is the question of the extent to which financial vulnerabilities are building up that could result in new downside risks further down the road.

This article presents the growth-at-risk approach, which models the relationship between financial imbalances and downside risk in the real economy. Downside risk in the real economy is measured using the lower end of the probability distribution for the growth rate of gross domestic product (GDP) – such as the largest decreases that occur with a 5% probability. Quantile regressions are used to show that downside risk in the real economy fluctuates over time in connection with financial stress and financial vulnerabilities.

This relationship is then studied in more detail with the help of structural quantile vector autoregressive models. These models enable the quantification of the impact of exogenous shocks on downside risk in the real economy. According to the model estimates, an abrupt deterioration in financing conditions can significantly increase the risk of severe downturns in the real economy.

The effect of financial shocks on downside risk in the real economy varies systematically depending on certain country characteristics which reflect financial vulnerabilities. For example, the probability of very large downturns in the real economy caused by financial shocks is greater, in particular, in countries with structurally higher levels of household debt and in countries whose banking systems have high foreign currency exposures.

Macroprudential policy can strengthen the resilience of the financial system and counteract the build-up of financial vulnerabilities, reducing downside risk in the real economy. However, the empirical evidence also shows that it is difficult to make real-time estimates of growth-at-risk with a longer lead time. Thus, findings from the growth-at-risk approach should always be embedded in an overall picture of the risk situation in the financial system, enabling macroprudential policymakers to respond to the build-up of vulnerabilities at an early stage.

Introduction

Especially deep recessions often linked to financial market stress

The period prior to the onset of the financial and economic crisis of 2008-09 – just like the period leading up to the sovereign debt crisis in the euro area – was characterised by years of vulnerabilities building up in the financial sectors of some countries. These vulnerabilities can be traced back to financial imbalances such as excessive leverage and overpriced assets. In the wake of these crises, the relationship between financial imbalances and severe downturns in the real economy received more attention in the academic literature and economic policy debate. Strong slowdowns in economic growth in Germany have generally been linked to stress in the financial system since at least the 1970s (see the chart below).[1] This relationship was very pronounced during the financial and economic crisis of 2008-09 in particular, and the need for measures with a greater preventive focus became clear.

Gross domestic product and episodes of stress in Germany's financial system

Year-on-year percentage change, seasonally and calendar-adjusted

Sources: Federal Statistical Office and Bundesbank calculations. **1** According to the European financial crises database; see M. Lo Duca et al. (2017), A new database for financial crises in European countries – ECB/ESRB EU crises database, ECB Occasional Paper Series No 194.

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Favourable financing conditions can foster build-up of financial vulnerabilities

The interaction between economic growth and the financial system can be heavily influenced by vulnerabilities and the systemic risk resulting from them. Vulnerabilities can build up in times when the economy is expanding. During such periods, financing conditions are typically favourable, risk premia are small, and asset prices are rising. This can produce a situation in which decisions taken by market players seem to make sense at the micro level but neglect the potential negative implications for the stability of the financial system. These "externalities" can lead to an excessive increase in leverage in the non-financial sector and risk appetite in the financial system. If substantial vulnerabilities have built up, even small shocks can trigger amplification effects through the financial system which may result in strong economic downturns. This is especially the case if there are financial constraints in the economy which have the potential to become binding in a crisis. If a negative shock hits the economy, the market price of assets falls. Falling asset prices can worsen the creditworthiness of the non-financial sector, for one thing. For another, the financial sector becomes less willing to grant loans, and there may be a supply-side credit crunch. If financial constraints become binding, risk premia can rise abruptly. The initial shock may be amplified by the interplay between falling asset prices, reduced lending and deteriorating creditworthiness. The higher the leverage of the non-financial sector and the more the financial sector reduces its risk appetite compared with an upturn, the more significant this amplification mechanism becomes.

Macroprudential policy can limit build-up of vulnerabilities

Macroprudential policy plays an important preventive role. It contributes to the stability of the financial system by identifying macro-financial vulnerabilities at an early stage and acting to counter them using the appropriate instruments. On the one hand, macroprudential policy reduces the incentives to take on excessive

1 The measure used for financial stress is based on the ECB's Country-Level Index of Financial Stress (CLIFS); see Duprey and Klaus (2015).

risk ex ante. The instruments used for this purpose are designed to help ensure that the effects of individual decisions on the stability of the financial system are taken into account. On the other hand, various macroprudential instruments, such as the countercyclical capital buffer for banks, enhance the financial system's resilience. This lowers the probability of self-reinforcing mechanisms being triggered.

Growth-at-risk approach highlights relationship between financial imbalances and strong economic downturns

This article explores the question of whether variables that reflect the build-up of vulnerabilities and short-term stress in the financial system contain information about downside risk in the real economy. In this context, downside risk in the real economy means the lower end of the probability distribution for the rate of change in GDP – such as the largest decreases that occur with a 5% probability. The growth-at-risk approach is used for this purpose. This approach examines the relationship between downside risk in the real economy and financial stress as well as financial vulnerabilities.[2]

Dynamic development of research on growth-at-risk, only few robust findings so far

The growth-at-risk approach is now being used by many central banks and international institutions, such as the International Monetary Fund (IMF). It makes it possible to quantify the impact of the build-up of vulnerabilities in the financial system and the potential occurrence of financial stress on downside risk in the real economy. However, growth-at-risk is a very new and dynamic research field. Existing studies sometimes arrive at different results regarding the extent to which robust conclusions for the probability distribution of economic growth can be derived from macro-financial variables.[3] Being aware of its limitations, the Bundesbank applies the growth-at-risk approach in its financial stability analyses alongside other methods, such as the early warning indicator for financial crises, and is constantly refining the models used for this.[4]

Financial imbalances and growth-at-risk – conceptual framework

Financial frictions can lead to strong downturns in economic growth

In 2008, the global financial crisis interrupted a period of stable economic growth and low financial market volatility that had lasted several years. Especially severe downturns of this kind with a low probability of occurrence are also known as tail events. One explanation for them is financial frictions, which can lead to non-linear economic growth. In other words, enterprises and households which would receive loans under normal circumstances are suddenly shut out of the credit market and have to restrict their consumption and investment. This exacerbates an economic downturn.[5]

Economic agents may face constraints when financing their activities, …

Both financial intermediaries and enterprises in the non-financial sector often face constraints when financing their activities (financial frictions) if, for example, they have low equity ratios or too little collateral.[6] If, for instance, the market value of equity (difference between the value of assets and of debt) in the financial sector is high, that sector has easy access to additional debt funding. During periods of economic stress, however, the value of assets declines, which means that if the value of debt remains unchanged, the market value of equity falls and access to financing is hindered. A similar financial friction restricts the debt capacity of non-financial enterprises and households. In

2 The term "growth-at-risk" was first used by Wang and Yao (2001). The concept and methods were popularised by the paper published by Adrian et al. (2019). The term is based on the financial sector concept of "value-at-risk".
3 See also Plagborg-Møller et al. (2020).
4 See Deutsche Bundesbank (2017, 2018, 2019), German Financial Stability Committee (2018) and Beutel et al. (2019).
5 Another example of a friction which can likewise bring about strong non-linearities is the effective lower bound of the short-term interest rate. See, in particular, Christiano et al. (2014) and Aruoba et al. (2017).
6 For models in which financial intermediaries face financial constraints, see, inter alia, Gertler and Kiyotaki (2010) and Gertler and Karadi (2011). Examples of models in which the financial constraint exists in the non-financial sector include Bernanke et al. (1999), Kiyotaki and Moore (1997) and Carlstrom and Fuerst (1997).

particular, their ability to take up additional financing depends on the market value of their total assets. The higher the market value of assets, the easier and cheaper it is for the non-financial sector to obtain loans from the financial sector in order to finance investment and consumption.

… which are not binding in times of sound economic growth. Vulnerabilities can thus build up, as incentives to take on more debt and financial risks increase

Irrespective of whether the financial friction exists in the financial or the non-financial sector, it produces amplification mechanisms between the real economy and the financial system. The market value of total assets in the non-financial sector and of equity in the financial sector is subject to cyclical volatility. In times of high asset valuations and low volatility, the financial and non-financial sectors can obtain funding relatively easily. In the financial sector, this increases the incentive to take on more debt in order to enjoy greater leverage. This means that given a specific level of assets/equity, a higher level of debt is possible. Risk premia for risky investments are low, and financial intermediaries increase the loan supply. In such times, rising asset prices, low financial market volatility and highly valued collateral increase banks' solvency and lending capacity, but also their willingness to take greater risks.[7] In the non-financial sector, high asset prices and low volatility imply greater collateral quality. Debt capacity rises along with assets, meaning that enterprises and households take on more debt. Market players' decisions to take on more debt and more risk seem to make sense at the micro level, but can potentially have adverse implications for the stability of the financial system if negative shocks occur at the macro level.

When existing vulnerabilities are high, financial constraints can become binding in recessions and amplify the downturn

The leverage built up during an upturn makes the economy vulnerable. If a negative shock hits the economy, output, investment and the market price of assets all fall. If the financial or real sector is heavily indebted, even small changes in the market price of assets can lead to major equity losses. As a result, financial frictions may become binding for enterprises, households and banks, meaning that loans that would have been possible in normal times are no longer granted. First, the non-financial sector's debt capacity drops substantially. Second, the financial sector becomes less willing to grant loans, and there may be a supply-side credit crunch. Risk premia can rise abruptly on account of growing risk aversion in the financial sector, which would exacerbate a downturn in the real economy. If financial frictions become binding, they can be amplified by market liquidity frictions. The latter limit the ability to exchange investments and other assets for liquid financial assets such as deposits during periods of stress. The financial friction leads to investors increasingly and simultaneously wishing to sell assets in times of crisis in order to remain solvent. This has a negative impact on the value of asset prices. Existing market liquidity frictions can result in market illiquidity, with even stronger drops in asset prices. The latter exerts added pressure on equity, amplifying financial frictions which put more pressure on asset prices. Frictions which affect market liquidity can therefore trigger additional non-linear dynamics.[8] The initial shock can be amplified in a non-linear way by this self-reinforcing interaction between asset prices and financial and market liquidity frictions in the economy (see the chart below for a stylised depiction).[9] The vulnerabilities built up from the high leverage and weak balance sheets in the financial sector and/or the real economy can thus lead to severe recessions or even financial and banking crises.[10]

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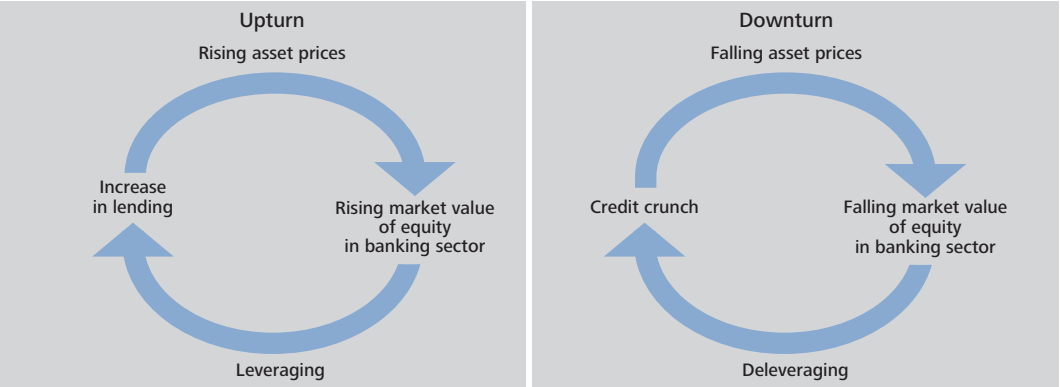
7 See Brunnermeier and Pedersen (2009), Adrian, Moench and Shin (2010) and Adrian and Shin (2014).
8 The model of Kiyotaki and Moore (2012) contains both market liquidity frictions and financial constraints. Financial constraints restrict access to additional external financing, while the market liquidity friction limits firms' ability to generate additional funds by selling financial assets in the market. Brunnermeier and Pedersen (2009) show how these two constraints interact with and reinforce each other. In their model, market liquidity constraints result in high asset price volatility brought about by fire sales. Strong downturns in asset prices resulting from market liquidity constraints in turn increase financial constraints.
9 See also He and Krishnamurthy (2013) and Brunnermeier and Sannikov (2014).
10 For an approach in which the above-described mechanism – with the addition of further model assumptions – can result in a bank run, see Gertler and Kiyotaki (2015) and Gertler et al. (2016).

Interplay between assets, creditworthiness and lending in the financial system during upturns*



* Bundesbank depiction based on T. Adrian and H. S. Shin (2010), Liquidity and Leverage, Journal of Financial Intermediation, Vol. 19, pp. 418-437.

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Macroprudential policy can reduce the risk of sharp economic downturns by limiting the build-up of vulnerabilities and increasing the resilience of the financial system

Models with financial frictions form the theoretical basis for macroprudential policy measures. By strengthening the resilience of the financial system, macroprudential instruments can help prevent financial frictions from becoming binding, thus limiting downside risks to economic growth.[11] Without macroprudential policy, economies in these models show excessive debt levels owing to financial frictions, which increases the frequency and severity of financial crises and recessions.[12] This is because the decisions made by market participants fail to take into account the potential negative repercussions for the stability of the financial system. Theoretically speaking, macroprudential instruments could prevent excessive debt and bolster economic resilience.[13] The theory suggests that the use of macroprudential instruments is particularly welfare-enhancing when its intensity is tailored to the build-up and decline of vulnerabilities. This can be achieved by means of a four-step policy cycle.[14] First, the policy objective is specified and the relevant frictions are pinpointed. The second step is to identify objectively verifiable and measurable indicators which can be used to evaluate the need for policy action. The impact of any measures on pre-defined indicators can be estimated through ex ante evaluations. Once the measures have been taken, ex post evaluations can reveal whether the objectives have been achieved and whether any unintended side effects have arisen. Information about the relationship between developments in the financial system and real economic downside risks from the growth-at-risk approach can potentially be incorporated into all four of these steps.

Empirical link between financial imbalances and growth-at-risk

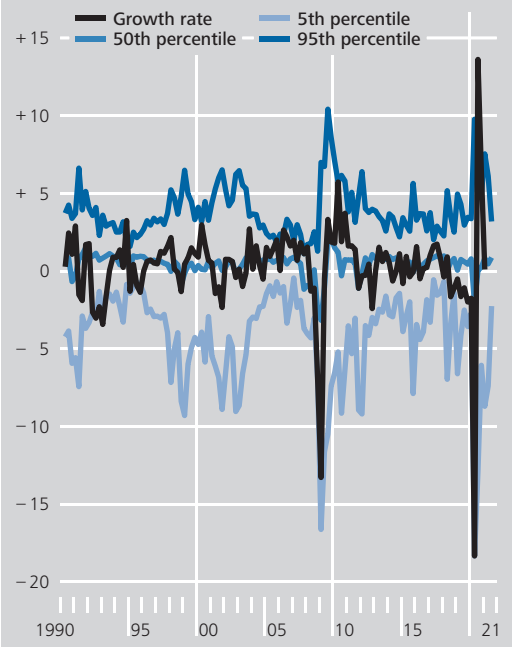
Empirical studies show link between developments in the financial markets and depth of recessions

Periods in which macro-financial imbalances have built up are often followed by severe recessions and financial crises.[15] Strong credit growth can also predict sharp declines in bank equity prices.[16] Moreover, a study for the United States shows that periods of very low credit risk premia and optimistic expectations about future financing terms often give way to periods of weak economic growth.[17] In add-

11 See, inter alia, Brandao-Marques et al. (2020), Carney (2020), Duprey and Ueberfeldt (2020), Galán (2020), Cechetti and Suarez (2020), Suarez (2020) and International Monetary Fund (2019).
12 See, inter alia, Lorenzoni (2008) and Bianchi (2011).
13 See Bianchi et al. (2012), Bianchi et al. (2016) and Farhi and Werning (2016).
14 See Buch et al. (2018) and Buch (2020).
15 See, for example, Kaminsky and Reinhart (1999), Schularick and Taylor (2012), Gourinchas and Obstfeld (2012), Claessens et al. (2011a) and Mian et al. (2017).
16 See Baron and Wong (2017).
17 See López-Salido et al. (2017).

Growth-at-risk estimation for Germany*

Quarterly average of the month-on-month percentage change



Sources: Chicago Board Options Exchange, Federal Reserve Bank of Chicago and Bundesbank calculations. * Actual quarterly growth rates of industrial production in Germany as well as their estimated percentiles conditional on the Chicago Fed National Financial Conditions Index (NFCI) and the CBOE Volatility Index (VIX).

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ition, credit crunches lead to more serious recessions, with the subsequent economic recovery taking place more slowly compared with recessions that are not accompanied by credit crunches.[18] Part of the empirical growth-at-risk literature also investigates the extent to which macro-financial developments are linked to the occurrence of extreme events a few years later. Although exceptionally favourable financing conditions are accompanied by low downside risks in the short term, in the medium term, this relationship is reversed, with economic downturns that are especially severe becoming more likely.[19] The severity of these downturns also depends on the degree and dynamics of private sector debt, developments in real estate prices and the accumulation of current account deficits.[20] Above-average levels in these measures signal that significantly larger downside risks to the real economy are to be expected in a few years' time. This is consistent with the early-warning characteristics that earlier empirical studies identified for debt and house price indicators.[21]

Fluctuations in financial markets may indicate higher downside risks

The extent to which cyclical downside risks are correlated with changes in financial stress can be estimated using the growth-at-risk approach, which analyses how the estimated 5% quantile of the growth in industrial production fluctuates as financial stress rises and falls (for details about the model used, see pp. 73-74).[22] Financial stress is measured using an indicator of financial conditions and an indicator of financial market uncertainty. These indicators combine a large quantity of relevant information and are influenced by monetary policy and fiscal policy, amongst other factors. The adjacent chart shows the development of the 5th, 50th and 95th percentiles of the probability distribution of German industrial production conditional on these indicators as well as the values actually recorded for the observation period. It illustrates that the conditional downside risks (5th percentile) fluctuate significantly more strongly than the median (50th percentile) or the corresponding upside risks (95th percentile). It is clear, for instance, that the downside risks were particularly high during and after the global financial and economic crisis of 2008-09. This indicates that financial market variables have an asymmetrical impact on the conditional probability distribution of industrial production, which supports theories in which financial and market liquidity frictions can suddenly become binding.

The link outlined for Germany between elevated financial stress and growing real economic downside risks can be observed across a large number of countries. The upper chart on p. 71 depicts the average path of measures of

18 See Jordà et al. (2013) and Claessens et al. (2011a, b).
19 For a panel analysis of 11 advanced economies, see Adrian et al. (forthcoming). Brandao-Marques et al. (2020) and International Monetary Fund (April 2021) present similar results based on a broader panel of countries.
20 See Duprey and Ueberfeldt (2020), Galán (2020) and Aikman et al. (2021).
21 See the references in footnotes 15 to 18.
22 See also Deutsche Bundesbank (2020).

Observation that indicators of financial stress rise sharply before and during recessions holds true for many countries and time periods

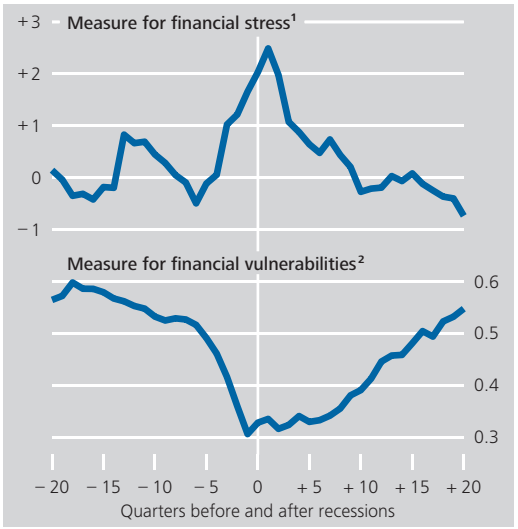
financial stress (top) and financial vulnerabilities (bottom) before and after recessions.[23] The path of both measures reflects the average across all time periods and countries observed.[24] The point in time at which the recession begins is standardised to zero.[25] There are signs that the measure for financial stress rises sharply during recessions and then falls again. The measure for vulnerabilities, which captures the simultaneous rise in debt and asset prices (equity, debt and real estate prices) largely mirrors this. In times of low financial stress, financial vulnerabilities build up in accordance with the theory on the expected impact of financial frictions.

Growth-at-risk analysis reveals a robust link between abrupt deteriorations in financing conditions and the probability of severe economic slumps

Owing to the close (inverse) relationship between financial stress and the build-up of financial vulnerabilities, both measures are used to estimate growth-at-risk models in the literature. The upper section of the adjacent bottom chart calculates growth-at-risk by making it conditional on the measure for financial stress, whilst in the lower section, growth-at-risk is conditional on the measure for financial vulnerabilities. The chart shows the 5th percentile of the average growth rate of GDP across the countries and periods analysed. In both cases, it falls significantly during the recessions. The key finding from this analysis is that there is a robust statistical relationship across a large number of countries and periods between an abrupt deterioration in financing conditions and the probability of severe economic slumps. Moreover, the estimation results indicate that the earliest point at which growth-at-risk starts

Financial stress and financial vulnerabilities before and after recessions

Index values



Sources: ECB and Bundesbank calculations. **1** Based on the ECB's Country-Level Indicator of Financial Stress (CLIFS); see T. Duprey and B. Klaus (2015), Dating systemic financial stress episodes in the EU countries, ECB Working Paper Series, No 1873. **2** Based on a financial cycle indicator developed by the Bundesbank and the ECB; see Y. S. Schüler, P. P. Hiebert and T. A. Peltonen (2020), Financial cycles: Characterisation and real-time measurement, Journal of International Money and Finance, Vol. 100, No 102082.

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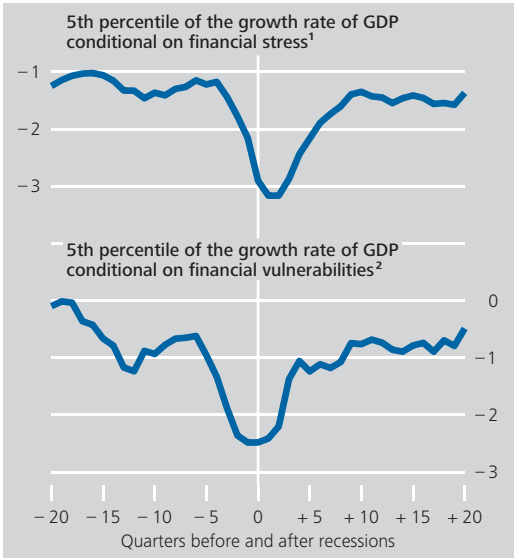
Growth-at-risk before and after recessions

Quarter-on-quarter change as a percentage



Sources: European Central Bank and Bundesbank calculations. **1** Based on the ECB's Country-Level Indicator of Financial Stress (CLIFS); see T. Duprey and B. Klaus (2015), Dating systemic financial stress episodes in the EU countries, ECB Working Paper Series, No 1873. **2** Based on a financial cycle indicator developed by the Bundesbank and the ECB; see Y. S. Schüler, P. P. Hiebert and T. A. Peltonen (2020), Financial cycles: Characterisation and real-time measurement, Journal of International Money und Finance, Vol. 100, No 102082.

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23 The measure used for financial stress is based on the ECB's Country-Level Index of Financial Stress (CLIFS); see Duprey and Klaus (2015). The measure for financial vulnerabilities is based on a financial cycle indicator of the Bundesbank and the ECB; see Schüler et al. (2020a).
24 The countries observed are France, Germany, Italy, Japan, Spain, Sweden, the United Kingdom and the United States over the period from the first quarter of 1970 to the first quarter of 2019 insofar as the relevant data are available (unbalanced panel).
25 The following simplified method is used in order to date recessions uniformly across different countries. The start of the recession is dated as the first quarter in which the GDP growth rate was negative. The end of the recession is dated as the third consecutive quarter in which GDP growth was positive again.

to fall sharply is five quarters before the start of a recession. The increased likelihood of a severe economic slump is therefore indicated fairly shortly before the outbreak of a recession.[26] Because macroprudential measures usually require a longer lead time before they take effect, such signals could come too late. Interpreting the signals in real time poses an additional challenge. This means that macroprudential policy measures need to be implemented before growth-at-risk estimates indicate strong downside risks in order to counteract the build-up of vulnerabilities in good time. Macroprudential measures that make the financial system more resilient to shocks should be taken in "good times", and thus much earlier than growth-at-risk models are normally able to show, in order to limit the risk of negative shocks being amplified through financial frictions in "bad times".

The transfer of financial shocks to growth-at-risk and the role of financial imbalances

Causal effects of stress in the financial markets and downside risks can be identified using econometric methods …

The results obtained so far indicate a statistical relationship between real economic downside risks and financing conditions. The analyses have not yet revealed whether there is also an economic and causal relationship between the variables. This is also true for the potential direction of impact: although a slump in economic activity may, on the one hand, be caused or amplified by stress in the financial markets, on the other hand, the financial markets might also respond to deteriorations in the real economy or greater uncertainty regarding the future economic outlook with turmoil and increased volatility. To gain a better understanding of the impact of time-varying financing conditions on the economy, researchers in this area use structural vector autoregression (SVAR) models. These linear multi-equation models can capture the dynamic relationships between a large number of key macroeconomic variables. The residual values of the various individual equations can be used to identify the drivers of the model, i.e. the structural economic shocks. The aim is to observe the impact of exogenous shocks on the system in isolation and to estimate their relative importance.

… which are able to model the overall distribution of economic growth

The majority of SVAR models used in the applied economic research model the dynamic relationship of the averages of each variable, while the distribution of the variables around the average only depends on the statistical properties of the residual values. Model classes that model the dynamic relationships of the individual quantiles of the variables separately can be used to analyse changing dynamic correlations between financing conditions and economic growth at different points of the probability distribution of economic growth.[27] To this end, methods have recently been developed in the academic literature that expand the above-mentioned quantile regressions using dynamic multi-equation models. These models are called structural quantile vector autoregression (structural QVAR) models (see the box on pp. 76 f. for a more detailed explanation of the methods and an additional application).[28]

Structural QVAR models can capture relationship between financing conditions and distribution of economic growth

To capture the dynamic relationship between financing conditions and the distribution of economic growth in the short and medium term, a model of this type is estimated for Germany for the period from the first quarter of 1983 to the second quarter of 2019 with the following endogenous variables: the US excess bond premium (EBP), German GDP, German employment figures, the German Consumer Price Index, euro area key interest rates, and

26 The difficulty of predicting growth-at-risk over longer periods is discussed, inter alia, in Brownlees and Souza (2021) and Plagborg-Møller (2020).
27 Alternatively, models with stochastic volatility can be used. See Carriero et al. (2020) for information about estimating the risk of extreme events using Bayesian VARs with stochastic volatility.
28 The method described and used in this article is based on Schüler (2020b). See also Beutel et al. (2020). A further approach to estimating structural QVAR models can be found in Chavleishvili and Manganelli (2019).

Estimating growth-at-risk using quantile regressions: methodological background

Growth-at-risk is measured as a pre-defined quantile at the lower end of the distribution of a real economic growth rate. Real economic growth can be measured here as the growth rate of, for instance, gross domestic product (GDP) or industrial production. Growth-at-risk is then often measured as the 5% quantile of the distribution of this growth rate conditional on certain explanatory variables. By estimating various quantiles, the entire conditional distribution can also be approximated. Quantile regressions are a widespread method of estimating quantiles of variables.[1]

In quantile regressions, the conditional quantile of a variable Y is modelled as a linear function of a vector of conditioning variables X:

$$q_{Y,\tau}(X) = X'\beta.$$

Here, $q_{Y,\tau}(X)$ is the τ quantile of Y conditional on X, defined as:

$$P(y_{t+h} \leq q_{Y,\tau}(X); X_t = X) = \tau.$$

This means that the probability, conditional on X at time t, that Y at time $t+h$ is less than or equal to the considered quantile, is exactly τ, i.e. 5%, for instance.

In order to put this concept into operation, the parameter vector β must be estimated. The estimated parameter vector $\hat{\beta}$ minimises the sum, weighted with the chosen value τ, of the absolute value of the deviations $u_{t+h} = y_{t+h} - X_t\beta$:

$$\hat{\beta} = argmin \sum_{t=1}^{T-h} (\tau 1_{u_{t+h} \geq 0} |u_{t+h}| + (1-\tau) 1_{u_{t+h} < 0} |u_{t+h}|),$$

where $1_{(.)}$ is an indicator function which assumes the value of 1 if the condition is met and 0 otherwise. This "loss function" penalises more severely those deviations which should be less likely given the quantile to be estimated. For instance, if a 5% quantile is to be estimated, exactly 5% of the values in the sample should be less than or equal to the quantile and 95% of the values greater than it. It is exactly this aim which is achieved by the described loss function: values under the 5% quantile increase the function value to be minimised more strongly than values above the 5% quantile. The robustness of the estimate increases with the number of available observations. This approach can be used to estimate various growth-at-risk models depending on the choice of the variables Y, X and τ.

An example that illustrates this point is a growth-at-risk model designed to gauge the downside risk to industrial production in Germany attributable exclusively to financial stress using available short-term data. Unlike measures such as the Bundesbank's weekly activity index (WAI),[2] the focus of the model is not to measure or predict the business cycle but to operationalise the above-described interplay between financial market developments and downside risks to the real economy from the perspective of the growth-at-risk approach.[3] To this end, various quantiles of industrial production growth with a frequency and forecast

1 See Koenker and Bassett (1978).
2 The WAI is based on Eraslan and Götz (2020).
3 See also Adrian et al. (2019). For an assessment of the forecast quality of growth-at-risk models, see Brownlees and Souza (2021) and Plagborg-Møller (2020).

horizon of one month are estimated. These quantiles are conditioned on the US National Financial Conditions Index (NFCI) and the VIX volatility index. These measures are available at a weekly frequency and reflect global funding conditions and uncertainty in the financial markets, which play a key role for Germany, too, owing to an integrated international capital market.[4] The quantile regression is estimated over the January 1990 to October 2020 period. By estimating a series of quantiles, the entire conditional distribution function can be approximated.

4 The last available weekly data of the VIX and the NFCI for a given month are used in the quantile regressions.

the German financial stress index CLIFS.[29] The EBP is the residual component of the credit risk premium adjusted for the influence of the projected probability of default of the enterprises and economic activity. It can therefore be interpreted as risk appetite within the financial system.[30] The effects of an unexpected deterioration in global financing conditions on the different quantiles of the probability distribution of economic growth can be quantified using the structural QVAR model. Here, shocks to the US EBP are used to proxy shocks to global financing conditions.[31] The US dollar plays a pivotal role as a financing currency for international financial intermediaries and as an anchor currency for portfolios worldwide. As a result, US financing conditions are a key factor for the global financial cycle and financing conditions around the world.[32]

The influence of the financial shock on growth-at-risk in Germany can be estimated using what are known as quantile impulse response functions. These depict the response of the various quantiles of the probability distribution of the endogenous model variables following shocks to financing conditions. Impulse response functions for various scenarios are derived from the structural QVAR model (see the chart on p. 75). The first scenario analyses the dynamic response at median economic growth in Germany to a shock to global financing conditions originating from the United States. This scenario can be interpreted as the typical response of the financial sector and real economy in Germany. The results of the "median scenario" show that a sudden rise in the EBP of 200 basis points would lower the median (i.e. the 50th

Estimation results for Germany suggest that a shock to financing conditions would significantly reduce average future economic growth

29 Prior to 1999, EONIA is linked to the shadow interest rate as used by Krippner (see https://www.ljkmfa.com/). German consumer price index data are taken from the IMF.
30 The construction of the EBP and the impact of an unexpected deterioration of the EBP on the US economy is described in Gilchrist and Zakrajšek (2012).
31 For methods that treat the EBP as an exogenous financial shock, see, inter alia, Stock and Watson (2012) and Del Negro et al. (2020).
32 See Miranda-Agrippino and Rey (2020).

percentile) of economic growth in Germany by up to 0.8 percentage point in the first quarter. Here, the simulated rise in the EBP roughly corresponds to the rise that was seen in the United States during the 2008 financial crisis. Four quarters later, the median of the growth distribution returns to its original value. Financing conditions in Germany would also deteriorate significantly, which may be a reason for the negative economic impact of the global financial shock. These results from the median scenario are consistent with the existing literature on the international transmission of US financial shocks.[33]

Probability of especially severe downturns in economic growth rises to an even greater extent, however

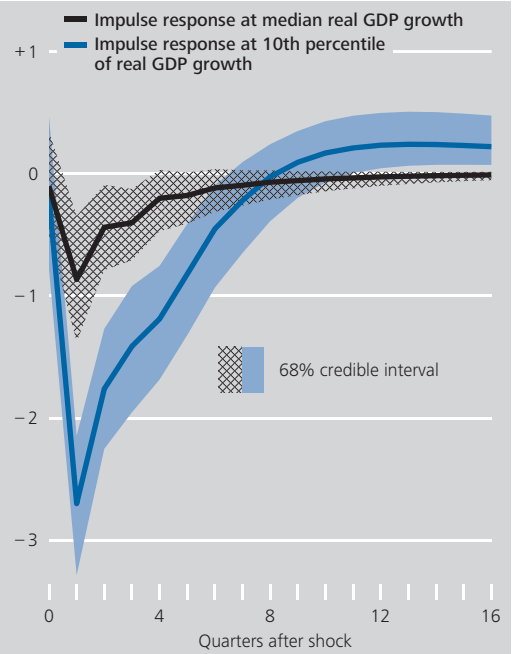
The second scenario investigates how GDP growth behaves at the bottom 10th percentile.[34] A considerably stronger response to a rise in the EBP is seen at the 10th percentile of GDP growth than at the median of the distribution. The 10th percentile of GDP growth is thus around 2.5 percentage points below the baseline. As the unconditional 10th percentile of GDP growth stands at -0.5%, this means that German GDP growth would, with a conditional probability of 10%, stand at -3% or lower in the first quarter following a global financial shock. After this shock, the bottom 10th percentile of GDP growth also remains below its historical baseline for a considerably longer period of time than the median. Only after around eight quarters does growth-at-risk return to its baseline. The impulse response functions thus suggest that a global financial shock can have a non-linear impact on the distribution of economic growth and that the probability of especially severe economic downturns rises considerably.

Results can also be confirmed for a broad cross-section of countries

This non-linearity can also be confirmed for a broad cross-section of countries. For this, the structural QVAR is expanded into a multi-country model (known as a panel SQVAR, or PSQVAR). This allows the impulse response functions at the 10th percentile of economic growth to be estimated for a large number of countries (details on the model and its results can be found on pp. 76 f.). For the cross-section

Impact of a global financial shock on German GDP growth*

Percentage points



Sources: IMF, Federal Reserve Board and Bundesbank calculations. * Impulse response functions following a negative financial shock that causes the US excess bond premium to rise by one standard deviation.

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of advanced and emerging economies, as is also the case for Germany, it appears that a global financial shock significantly increases growth-at-risk on average across all countries. Here, there are considerable differences in the magnitude of the effect between the individual economies. These differences can be linked to various country-specific characteristics that depict financial vulnerabilities. In this way, it is possible to determine whether there is a relationship between the financial vulnerability of a country and its growth-at-risk following an unexpected deterioration in global financial conditions over a cross-section of multiple countries.

The results suggest that financial vulnerabilities have an impact on the transmission of global

33 See Miranda-Agrippino and Rey (2020).
34 In the literature, both the 5th and 10th percentiles are used as a measure of downside risk. Due to the larger number of coefficients to be estimated in the structural QVAR model, the 10th percentile is used here.

Impact of global financial shocks on downside risks to growth in an international panel

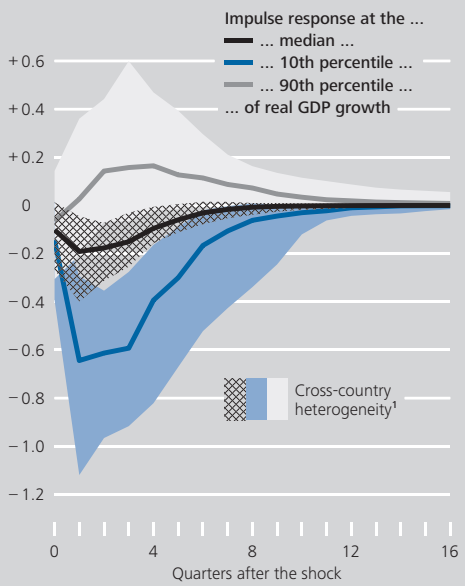
If global financial shocks of the kind seen during the global financial and economic crisis in 2008-09 materialise, there can be downside risks to the global economy. It is possible to quantify such downside risks from a global financial shock using an international panel dataset based on a structural quantile vector autoregressive (QVAR) model.[1] This structural QVAR model allows analysts to depict non-linear relationships between the endogenous variables. In particular, it enables an assessment to be made of the impact of a global financial shock on the different percentiles of the probability distribution of real gross domestic product (GDP) growth. As a result, it is possible to determine the growth-at-risk effects of the shock at the lower end of the GDP distribution, making the model particularly suitable for identifying downside risks.

The analysis is based on an international panel of 44 countries in total.[2] Two steps are used to determine the impact of a global financial shock. In the first step, a QVAR model is estimated for each country over a period extending from the first quarter of 1980 until the fourth quarter of 2018. The model estimation uses Bayesian methods with a non-informative prior distribution for the coefficients, and models the US excess bond premium (EBP),[3] real GDP growth, consumer price inflation and the short-term interest rate of the country in question. The EBP is used to proxy global financing conditions on account of the key role played by the United States in global financial markets.[4] The second step is to estimate panel quantile impulse responses. This is done using a mean group estimator based on average country-specific impulse responses.[5]

To depict a typical financial shock, the structural QVAR model is used to simulate an unexpected increase in the EBP by one standard deviation. The shock is identified by applying a Cholesky decomposition to what is known as the co-exceedance matrix of the residuals from the structural QVAR model, with the EBP being ordered first.[6] The results are robust to other identification assumptions.

Impact of a global financial shock on GDP growth in a multi-country model*

Percentage points



Sources: IMF, Federal Reserve Board and Bundesbank calculations. * Impulse responses to a negative financial shock that causes the US excess bond premium to increase by one standard deviation. 1 One standard deviation around the country average of impulse responses.

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1 The approach used here is based on Beutel et al. (2021) and Schüler (2020).
2 See Beutel et al. (2021) for details on the country sample and data sources.
3 See Gilchrist and Zakrajšek (2012).
4 The EBP measures the average credit risk premium in the US corporate bond market. Its advantage is that it represents a comparatively exogenous residual variable, making it particularly suitable for identifying exogenous financial shocks. See Gilchrist and Zakrajšek (2012).
5 See Pesaran and Smith (1995).
6 See Koenker and Portnoy (1990).

The model estimates suggest that downside risks to the global real economy increase significantly if there is an unexpected deterioration in global financing conditions. It is already evident at the median of the probability distribution of GDP growth that an unexpected increase in the EBP by one standard deviation is accompanied by a decline in GDP growth of around 0.2 percentage point relative to the baseline (see the chart on p. 76). Four quarters later, the median of the growth distribution returns to its baseline value. If the model implied only a shift in the distribution of GDP growth following a shock, the effects at the median (50th percentile) and in the bottom 10th percentile (and also in the top 90th percentile) would be identical. However, the impact of the simulated shock at the lower end of the GDP distribution is significantly stronger than it is at the median, with GDP growth at the 10th percentile dropping by around 0.7 percentage point below the baseline one quarter after the shock. By contrast, a financial shock has a considerably smaller impact on GDP growth at the median. Overall, the distribution of GDP growth conditional on the financial shock is therefore skewed to the left, compared with the unconditional distribution, and the downward risks increase. The effects at the lower end of the distribution are stronger for countries with comparatively high banking system exposures in foreign currency, and for countries with heightened levels of household sector debt and with fixed exchange rate regimes (see the adjacent table).

Impact of various country characteristics on the size of the GDP response to a global financial shock

Explanatory variable[1]	Coefficient	Standard error
Financial openness	– 0.001	(0.006)
Exchange rate regime	0.161***	(0.053)
Household debt	– 0.034**	(0.016)
Level of financial market development	– 0.015	(0.017)
Banking system exposures in foreign currency	– 0.054***	(0.018)
Financial ties with the United States	0.012	(0.029)
Trade links with the United States	– 0.013	(0.019)
Constant	0.976	(1.862)
Observations	44	
R^2	0.46	

Sources: International Monetary Fund, Federal Reserve Board and Bundesbank calculations. **1** Estimation results of a least squares regression of the sum of impulse responses by GDP growth at the 10th percentile of the distribution over the first four quarters on the following country characteristics: a country's financial openness, as measured by the de facto measure for openness of Lane and Milesi-Ferretti (2007); the exchange rate regime, according to the classification of Ilzetzkiet et al. (2019) (where countries with floating exchange rate regimes are assigned a higher value); household debt, as measured by a country's maximum loan-to-value (LTV) ratio weighted by the home ownership ratio; the level of financial market development, according to the classification of the IMF financial markets development index; banking system exposures in foreign currency, as measured by the percentage of total banking system exposures according to Cesa-Bianchi et al. (2018); and a country's financial ties and trade links with the United States.

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Response of growth-at-risk to financial shocks is stronger in countries with higher degrees of financial vulnerability

financial shocks to the distribution of economic growth. For example, the probability of severe downturns in the real economy is greater, in particular, in countries with higher levels of household debt as well as those with banking systems that have higher foreign currency exposures. These outcomes confirm the theoretical mechanisms that financial vulnerabilities create the preconditions that allow negative shocks to trigger extreme events through feedback effects.

Macroprudential policy and growth-at-risk

The theoretical and empirical evidence for the relationship between financial imbalances and growth-at-risk suggests that macroprudential policy measures to limit the build-up of vulnerabilities may reduce downside risks to the real economy.

Empirical studies suggest that macroprudential policy can limit the emergence of vulnerabilities …

Empirical studies show that macroprudential policy can have an impact on debt dynamics and lending growth in the private sector as well as property price dynamics.[35] Effective macroprudential policy can, for example, counteract excessive debt in the private sector. The findings from the multi-country model in the previous section, too, suggest that macroprudential policy can reduce downside risks to the real economy. This can be achieved by limiting the build-up of excessive debt and lowering the extent of risk-taking. This reduces the vulnerability of the economy to unexpected shocks to financing conditions, as it weakens the feedback effects arising from financial frictions. In addition, it may be possible to mitigate reinforcing effects throughout the financial system by loosening macroprudential instruments during periods of acute stress, for example by lowering countercyclical capital requirements in order to prevent financial frictions from becoming binding and the banking system as a whole from excessively restricting lending.

… and is thus in a position to limit downside risks to the economy

In the academic literature, there are studies that more directly estimate the relationship between macroprudential policy and growth-at-risk.[36] While these studies differ in terms of the utilised datasets, investigated groups of countries, and analysed macroprudential instruments, they all reach the same main conclusion: tightening macroprudential instruments leads, with a time lag of around two to three years, to a significant reduction in future downside risks (growth-at-risk). At the same time, although the associated effects on both the median and the upper quantiles of GDP growth are negative, they are smaller, or even statistically insignificant, in absolute terms. While this suggests that there is a certain degree of macroprudential trade-off, theoretical models show that the use of macroprudential instruments in the presence of financial frictions may increase welfare. Furthermore, the estimation results point towards the effectiveness of macroprudential interventions being dependent on cyclical factors. For example, if macroprudential instruments are tightened during a boom in the financial cycle, this leads to a greater reduction in future downside risks.

Impact of macroprudential policy on growth-at-risk remains subject of current research

Even if the analyses from the literature on growth-at-risk and the impact of macroprudential policy do produce valuable findings, there are some limitations that must be taken into consideration during the practical application of the individual approaches and their results. For example, the quantitative relationships be-

35 A comprehensive overview of the literature is provided, for example, by Galati and Moessner (2018) and Aikman et al. (2018). Araujo et al. (2020) conduct a meta-analysis of 58 of the most significant research articles on the effects of macroprudential policy measures. The majority of the results indicate that instruments that lead to a tightening of lending standards (such as upper limits on loan-to-value or debt-service-to-income ratios) have a greater dampening effect on credit and property price dynamics than capital and liquidity requirements on banks, for example.

36 See Brandao-Marques et al. (2020), Duprey and Ueberfeldt (2020), Franta and Gambacorta (2020), Aikman et al. (2021), Galán (forthcoming) and International Monetary Fund (2021). In an ongoing project, the ESRB expert group "Macroprudential Stance – Phase III" is investigating the impact of macroprudential measures on growth-at-risk in the EU as well as the possibilities for formulating metrics on macroprudential stance based on empirical analyses. For more information, see also Suarez (2021).

tween macroprudential measures and growth-at-risk found in these analyses are largely not causal in nature, but are instead primarily reflections of statistical correlations.[37] As the relationships between policy measures and future downside risks are estimated in reduced form, it is difficult to reach any conclusions on the relevance of individual transmission channels. The macroprudential policy indicators used are – due to limited data availability, short time periods and differences in the individual instruments – likewise incomplete. For example, the utilised indicators mostly only measure the frequency of macroprudential interventions, not their magnitudes. Ultimately, the fact that the results are largely based on data from European, non-European and emerging market economies may limit their applicability to Germany.

Outlook

Growth-at-risk examines relationship between financial imbalances and downside risks to the economy

Since the developments before and during the global financial crisis and the European sovereign debt crisis at the latest, the issue of the relationship between financial imbalances and real economic downturns has taken greater prominence in economic research and economic policy debate. At many central banks and international institutions, the concept of growth-at-risk is applied to investigate whether financial vulnerabilities and short-term stress in the financial system can provide information on the probability of particularly sharp downturns in economic growth.

Shocks to financing conditions increase probability of very deep recessions

Within the scope of the econometric application of the growth-at-risk concept for Germany, it can be seen that an abrupt deterioration in financing conditions is linked to downside risks to the real economy. More detailed analyses show that there is a causal relationship between unexpected deteriorations in financing conditions and the probability of deep recessions. Initial findings on the impact of macroprudential policy suggest that instruments that mitigate the build-up of vulnerabilities – such as excessive debt and increased risk appetite – may reduce downside risks to the real economy. However, the empirical evidence also shows that it is difficult to make real-time estimates of growth-at-risk with a longer lead time. For this reason, policy recommendations derived from the growth-at-risk concept should always be incorporated into an overall picture of the state of the financial system as a whole so that macroprudential policy can respond to a build-up of vulnerabilities in good time. This would limit the risk of shocks being excessively amplified by the financial system.

Macroprudential policy may counteract build-up of financial vulnerabilities and thus reduce downside risks to real economy

37 An exception in this regard are the studies by Brandao-Marques et al. (2020) and Duprey and Ueberfeldt (2020). In a preliminary step, these authors extract the unsystematic (exogenous) component of macroprudential policy before it is fed into the univariate quantile regression of the growth-at-risk model.

List of references

Adrian, T., N. Boyarchenko and D. Giannone (2019), Vulnerable Growth, American Economic Review, Vol. 109(4), pp. 1,263-1,289.

Adrian, T., F. Grinberg, N. Liang, S. Malik and J. Yu, The Term Structure of Growth-at-Risk, American Economic Journal: Macroeconomics, forthcoming.

Adrian, T., E. Moench and H. Shin (2010), Macro Risk Premium and Intermediary Balance Sheet Quantities, IMF Economic Review, Vol. 58(1), pp. 179-207.

Adrian, T. and H. Shin (2014), Procyclical Leverage and Value-at-Risk, Review of Financial Studies, Vol. 27 (2), pp. 373-403.

Aikman, D., J. Bridges, S. Hacioglu Hoke, C. O'Neill and A. Raja (2021), Credit, capital and crises: a GDP-at-Risk approach, CEPR Discussion Paper, No 15864.

Aikman, D., A. Haldane, M. Hinterschweiger and S. Kapadia (2018), Rethinking financial stability, Bank of England working paper, No 712.

Araujo, J. D., M. Patnam, A. Popescu, F. Valencia and W. Yao (2020), Effects of Macroprudential Policy: Evidence from Over 6,000 Estimates, IMF Working Paper, No 20/67.

Aruoba, S. B., L. Bocola and F. Schorfheide (2017), Assessing DSGE model nonlinearities, Journal of Economic Dynamics and Control, Vol. 83 (C), pp. 34-54.

Baron, M. and W. Xiong (2017), Credit Expansion and Neglected Crash Risk, Quarterly Journal of Economics, Vol. 132(2), pp. 713-764.

Bernanke, B. S., M. Gertler and S. Gilchrist (1999), The Financial Accelerator in a Quantitative Business Cycle Framework, Handbook of Macroeconomics, Vol. 1, pp. 1,341-1,393.

Beutel, J., L. Emter, N. Metiu, E. Prieto and Y. S. Schüler (2021), Dilemma in Mean, Trilemma in Tail: The Global Financial Cycle and Macroeconomic Tail Risks, mimeo.

Beutel, J., S. List and G. von Schweinitz (2019), Does machine learning help us predict banking crises?, Journal of Financial Stability, Vol. 45, https://doi.org/10.1016/j.jfs.2019.100693.

Bianchi, J. (2016), Efficient Bailouts?, American Economic Review, Vol. 106(12), pp. 3,607-3,659.

Bianchi, J. (2011), Overborrowing and Systemic Externalities in the Business Cycle, American Economic Review, Vol. 101(7), pp. 3,400-3,426.

Bianchi, J., E. Boz and E. G. Mendoza (2012), Macroprudential Policy in a Fisherian Model of Financial Innovation, IMF Economic Review, Vol. 60(2), pp. 223-269.

Bianchi, J., C. Liu and E. G. Mendoza (2016), Fundamentals news, global liquidity and macroprudential policy, Journal of International Economics, Vol. 99, pp. 2-15.

Brandao-Marques, L., Q. Chen, C. Raddatz, J. Vandenbussche and P. Xie (2019), The Riskiness of Credit Allocation and Financial Stability, IMF Working Paper, No 19/207.

Brownlees, C. and A. B. Souza (2021), Backtesting global Growth-at-Risk, Journal of Monetary Economics, Vol. 118, pp. 312-330.

Brunnermeier, M. K. and L. H. Pedersen (2009), Market Liquidity and Funding Liquidity, Review of Financial Studies, Vol. 22(6), pp. 2,201-2,238.

Brunnermeier, M. K. and Y. Sannikov (2014), A Macroeconomic Model with a Financial Sector, American Economic Review, Vol. 104(2), pp. 379-421.

Buch, C. M. (2020), Evidenzbasierte Wirtschaftspolitik, speech delivered at the 8th Conference for Social and Economic Data in Berlin, 2 March 2020.

Buch, C. M., E. Vogel and B. Weigert (2018), Evaluating Macroprudential Policies, ESRB Working Paper Series, No 76.

Carlstrom, C. T. and T. S. Fuerst (1997), Agency Costs, Net Worth, and Business Fluctuations: A Computable General Equilibrium Analysis, American Economic Review, Vol. 87(5), pp. 893-910.

Carriero, A., T. E. Clark and M. Marcellino (2020), Capturing Macroeconomic Tail Risks with Bayesian Vector Autoregressions, Federal Reserve Bank of Cleveland, Working Paper, No 20-02.

Cesa-Bianchi, A., A. Ferrero and A. Rebucci (2018), International credit supply shocks, Journal of International Economics, Vol. 112, pp. 219-237.

Chavleishvili, S. and S. Manganelli (2019), Forecasting and stress testing with quantile vector autoregression, ECB Working Paper Series, No 2330.

Christiano, L. J., R. Motto and M. Rostagno (2014), Risk Shocks, American Economic Review, Vol. 104(1), pp. 27-65.

Claessens, S., M. A. Kose and M. E. Terrones (2011a), What happens during recessions, crunches and busts?, Economic Policy, Vol. 24, pp. 653-700.

Claessens, S., M. A. Kose and M. E. Terrones (2011b), How do business and financial cycles interact?, CEPR Discussion Paper, No 8396.

Del Negro, M., M. Lenza, G. E. Primiceri and A. Tambalotti (2020), What's up with the Phillips Curve?, Brookings Papers on Economic Activity, Spring 2020, pp. 301-357.

Deutsche Bundesbank (2019), Financial Stability Review, pp. 42-44.

Deutsche Bundesbank (2018), Financial Stability Review, pp. 47-49.

Deutsche Bundesbank (2017), Financial Stability Review, pp. 45-48.

Duprey, T. and B. Klaus (2015), Dating systemic financial stress episodes in the EU countries, ECB Working Paper Series, No 1873.

Duprey, T. and A. Ueberfeldt (2020), Managing GDP Tail Risk, Bank of Canada Staff Working Paper, 2020-3.

Farhi, E. and I. Werning (2016), A Theory of Macroprudential Policies in the Presence of Nominal Rigidities, Econometrica, Vol. 84(5), pp. 1,645-1,704.

Franta, M. and L. Gambacorta (2020), On the effects of macroprudential policies on Growth-at-Risk, Economics Letters, Vol. 196, https://doi.org/10.1016/j.econlet.2020.109501.

Galán, J. E. (2020), The benefits are at the tail: uncovering the impact of macroprudential policy on growth-at-risk, Journal of Financial Stability, forthcoming.

Galati, G. and R. Moessner (2018), What Do We Know About the Effects of Macroprudential Policy?, Economica, Vol. 85, pp. 735-770.

German Financial Stability Committee (2018), Fünfter Bericht an den Deutschen Bundestag zur Finanzstabilität in Deutschland, pp. 43 ff.

Gertler, M. and P. Karadi (2011), A model of unconventional monetary policy, Journal of Monetary Economics, Vol. 58(1), pp. 17-34.

Gertler, M. and N. Kiyotaki (2015), Banking, Liquidity, and Bank Runs in an Infinite Horizon Economy, American Economic Review, Vol. 105(7), pp. 2,011-2,043.

Gertler, M. and N. Kiyotaki (2010), Financial Intermediation and Credit Policy in Business Cycle Analysis, Handbook of Monetary Economics, Vol. 3, pp. 547-599.

Gertler, M., N. Kiyotaki and A. Prestipino (2016), Wholesale Banking and Bank Runs in Macroeconomic Modeling of Financial Crises, Handbook of Macroeconomics, Vol. 2, pp. 1,345-1,425.

Gilchrist, S. and E. Zakrajšek (2012), Credit Spreads and Business Cycle Fluctuations, American Economic Review, Vol. 102(4), pp. 1,692-1,720.

Gourinchas, P.-O. and M. Obstfeld (2012), Stories of the Twentieth Century for the Twenty-First, American Economic Journal: Macroeconomics, Vol. 4(1), pp. 226-265.

He, Z. and A. Krishnamurthy (2013), Intermediary Asset Pricing, American Economic Review, Vol. 103(2), pp. 732-770.

International Monetary Fund (2021), Global Financial Stability Report, pp. 35 ff.

Jordà, O., M. Schularick and A. M. Taylor (2013), When Credit Bites Back, Journal of Money, Credit and Banking, Vol. 45, pp. 3-28.

Kaminsky, G. L. and C. M. Reinhart (1999), The Twin Crises: The Causes of Banking and Balance-of-Payments Problems, American Economic Review, Vol. 89(3), pp. 473-500.

Kiyotaki, N. and J. Moore (1997), Credit Cycles, Journal of Political Economy, Vol. 105(2), pp. 211-248.

Koenker, R. and G. Bassett (1978), Regression Quantiles, Econometrica, Vol. 46(1), pp. 33-50.

Koenker, R. and S. Portnoy (1990), M Estimation of Multivariate Regressions, Journal of the American Statistical Association, Vol. 85, pp. 1,060-1,068.

Kuttner, K. N. and I. Shim (2016), Can non-interest rate policies stabilize housing markets? Evidence from a panel of 57 economies, Journal of Financial Stability, Vol. 26, pp. 31-44.

López-Salido, D., J. C. Stein and E. Zakrajšek (2017), Credit-Market Sentiment and the Business Cycle, Quarterly Journal of Economics, Vol. 132(3), pp. 1,373-1,426.

Lorenzoni, G. (2008), Inefficient Credit Booms, Review of Economic Studies, Vol. 75(3), pp. 809-833.

Mian, A., A. Sufi and E. Verner (2017), Household Debt and Business Cycles Worldwide, Quarterly Journal of Economics, Vol. 132(4), pp. 1,755-1,817.

Miranda-Agrippino, S. and H. Rey (2020), U.S. Monetary Policy and the Global Financial Cycle, Review of Economic Studies, Vol. 87(6), pp. 2,754-2,776.

Pesaran, M. H. and R. Smith (1995), Estimating long-run relationships from dynamic heterogeneous panels, Journal of Econometrics, Vol. 68, pp. 79-113.

Plagborg-Møller, M., L. Reichlin, G. Ricco and T. Hasenzagl (2020), When is Growth at Risk?, Brookings Papers on Economic Activity, Spring 2020, pp. 167-229.

Schularick, M. and A. M. Taylor (2012), Credit Booms Gone Bust: Monetary Policy, Leverage Cycles and Financial Crises, 1870-2008, American Economic Review, Vol. 102(2), pp. 1,029-1,061.

Schüler, Y. S. (2020), The impact of uncertainty and certainty shocks, Deutsche Bundesbank Discussion Paper No 14/2020, March 2020.

Schüler, Y. S., P. P. Hiebert and T. A. Peltonen (2020), Financial cycles: Characterisation and real-time measurement, Journal of International Money and Finance, Vol. 100, https://doi.org/10.1016/j.jimonfin.2019.102082.

Stock, J. H. and M. Watson (2012), Disentangling the Channels of the 2007-2009 Recession, Brookings Papers on Economic Activity, Spring 2012, pp. 81-135.

Suarez, J. (2021), Growth-at-risk and macroprudential policy design, mimeo.

Wang, Y. and Y. Yao (2001), Measuring Economic Downside Risk and Severity: Growth at Risk, World Bank Policy Research Working Paper, No 2674.