EUROPEAN CENTRAL BANK

EUROSYSTEM

RESEARCH BULLETIN
No 12, Spring 2011

NEW METHODOLOGIES FOR SYSTEMIC RISK MEASUREMENT

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The financial crisis has illustrated the importance of timely and effective measures of systemic risk. The ECB and other policy-making institutions are currently devoting much time and effort to the development of tools and models which can be used to monitor, identify and assess potential threats to the stability of the financial system. In this article, we present three such models recently developed in DG-Research. The first model uses a framework of multivariate regression quantiles to assess the contribution of individual financial institutions to systemic risk. The second model aims to infer the unobserved drivers of systemic risk from observed data, combining them to form coincident and early warning indicators. The third model assesses whether the housing market in a given country is overheating, by comparing price developments with fundamentals.

An understanding of systemic risk is central to macro-prudential supervisory and regulatory policies. Quantitative measures of systemic risk can be helpful in the identification and assessment of threats to financial stability. This article reviews three models which can be used for such purposes.

The first section describes an econometric framework used to estimate the contribution of individual financial institutions to overall system risk. Since the failure of systemically important financial institutions can inflict severe negative externalities on the whole financial system, as well as the real economy at large, supervisory bodies must be able to identify such potential sources of instability if they are to take appropriate policy action.

The second section discusses how macro-financial and credit risk data can be filtered in order to construct indicators of systemic risk. "Credit risk bubbles" are detected in episodes during which credit risk conditions decouple significantly from underlying macro-financial fundamentals. This approach can be usefully applied as an early warning signal for macro-prudential purposes.

The third section presents a model with which to assess vulnerabilities in the housing market. Housing bubbles represent a major source of systemic risk, as although they build up only gradually over time, they typically burst suddenly, to the detriment of the economy as a whole. The model examined in this article makes use of data on house prices and macro-economic fundamentals to derive the probabilities of overheating in various European housing markets.

VAR for VaR: measuring systemic risk using multivariate regression quantiles

In the current debate on systemic risk, great emphasis has been placed on the question of how to measure whether an institution is of systemic importance. In particular, it has been argued that since the failure of a systemically important financial institution could produce severe negative externalities with a bearing on the whole financial sector, the supervision of financial institutions should, among other things, take into account the spillover of risks within the financial system. The regulatory constraints imposed on firms should therefore reflect their overall systemic importance.

The events of the past three years have highlighted how regulating the risk of financial institutions in isolation does not necessarily prevent excessive risk taking in the aggregate. From a macro-prudential perspective, the focus should be on the contribution each institution makes to overall system risk. A popular means by which to assess the systemic importance of a financial institution is to look at the sensitivity of its Value at Risk (VaR) to shocks to the whole financial system.[1]

Regulating the risk of financial institutions in isolation does not necessarily prevent excessive risk taking in the aggregate.

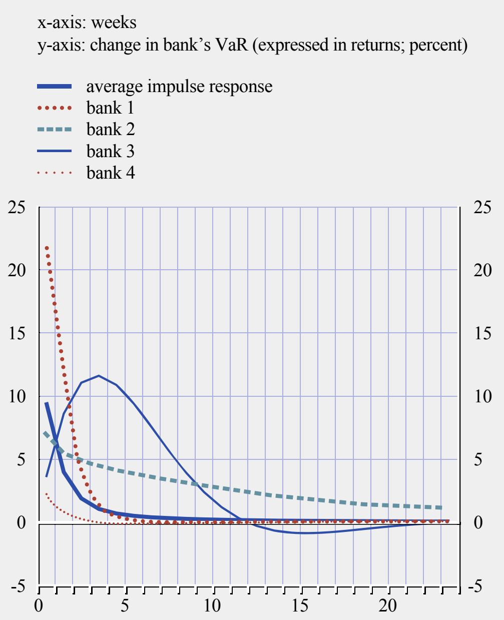
White, Kim and Manganelli (2010) propose a novel method by which to estimate such sensitivity. The methodology is based on a vector autoregressive (VAR) model, in which the dependent variables are the VaR of individual financial institutions and of the overall market, which depend on (lagged) VaR and past shocks. The authors demonstrate the

1 See, for instance, Adrian and Brunnermeier (2009), Acharya et al. (2009), and Engle and Brownlees (2010).

way in which the parameters of the model can be estimated using multivariate regression quantiles. Regression quantile estimates are known to be robust to extreme values, which typically are a feature of financial market data. A multivariate version allows researchers to measure directly tail dependence among the random variables of interest. By casting regression quantiles in a VAR framework, it is possible to estimate the spillover and feedback effects among the variables of the system, as well as the long-run VaR equilibria and associated impulse response functions.

Chart 1 presents an application of this methodology. It displays the average impulse response of a sample of 230 financial institutions from around the world. The horizontal axis measures the time (expressed in weeks), while the vertical axis measures the increase in VaR of individual financial institutions (expressed in percentage returns) as a reaction to a shock equal to 1% of the market VaR. The analysis shows that when markets are hit by such a shock (a shock equal to 1% VaR occurs once every 100 weeks, i.e. about once every two years), the average VaR of individual financial institutions increases by almost 10 percentage points. The impact of the shock fades gradually over time, until it is absorbed entirely after about eight weeks.

Chart 1 VAR for VaR impulse responses



Source: Thomson Reuters Datastream and authors' calculations.

To illustrate the cross-sectional variation in responses, the figure also shows the impulse response function of four selected financial institutions. The VaR of bank 1 is initially the most vulnerable to global market shocks, but shocks are also absorbed faster than they are by other financial institutions in the sample. The VaR of bank 2 is relatively stable. The VaR of bank 3 is the most vulnerable overall to global shocks, as demonstrated by the long hump shape of its impulse-response. Finally, bank 4 exhibits very little tail correlation with the market. Regulation may need to take account of the heterogeneity in vulnerability across the financial institutions illustrated.

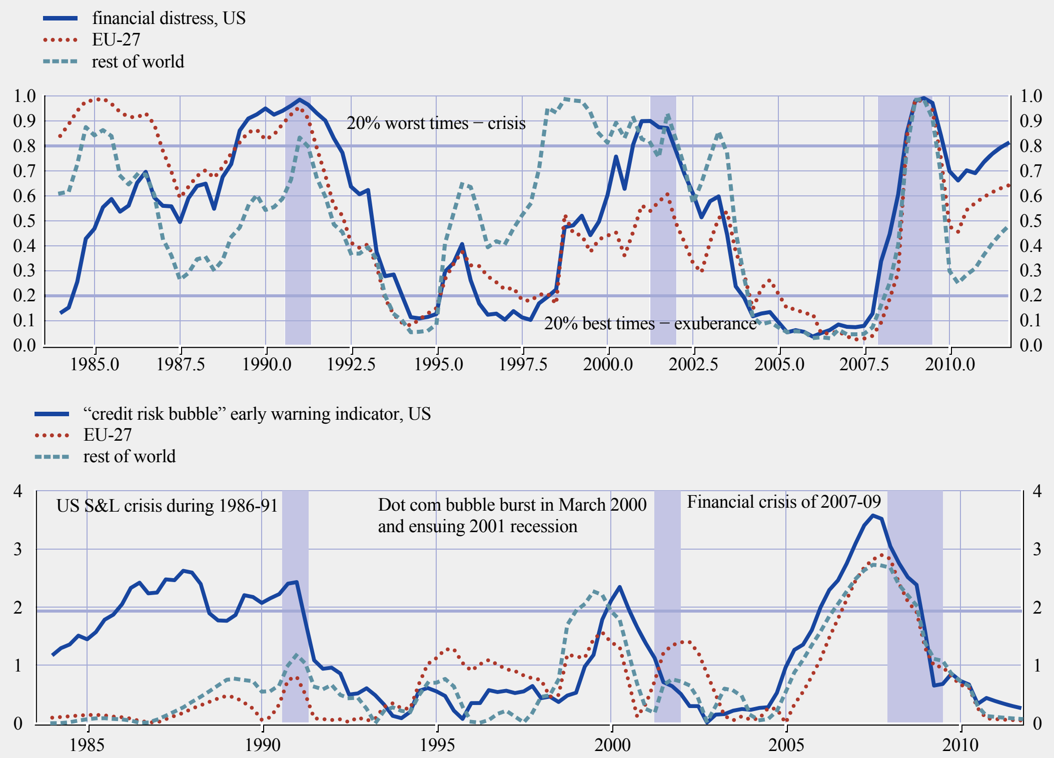
Warning signals based on unobserved risk factors

Credit risk from correlated exposures is a dominant source of risk in the banking book. As a result, time-varying credit risk conditions matter for the profitability and solvency of financial intermediaries, and therefore overall financial stability.

Schwaab, Koopman and Lucas (2010) study how macro-financial fundamentals and credit risk conditions interact to yield clusters of financial firm failures. Important sources of systematic variation (as contagion risk, the business cycle, the default cycle, shifts in credit supply etc.) are unobserved and time-varying, and act simultaneously on credit risk conditions. Unobserved risk factors can be estimated from macro and credit risk data using recent empirical methods. After estimating the possible latent drivers of financial distress, these can then be combined to form coincident indicators of financial distress, as well as forward-looking early warning indicators.

In recent contributions, Borio and Drehmann (2009) and Borio (2010) explain the paradox of systemic risk: the financial system can appear to be at its strongest precisely when it is most vulnerable. Credit growth and asset prices are exceptionally high, leverage measured at market prices is deceptively low, and risk premia and volatilities

Chart 2 Good times vs bad times indicator (top), and credit bubble indicator (bottom)



Sources: Moody's Default and Recovery Database, KMV CreditEdge and Compustat. Author's calculations.

are small when the level of risk is at its peak. What appear to be indicators of low risk are actually signs of aggressive risk-taking. This is the main reason why macro stress tests can easily lull policy-makers into a false sense of security: being based on current conditions, they underestimate the potential cost if the impact of excessive risk-taking were to be revealed. Therefore, simply knowing whether current financial risk conditions should be considered to be "normal", "exceptionally good", or "exceptionally bad", is valuable.

The top panel of Chart 2 plots transformed estimates of financial sector failure rates. Three economic regions are considered: the United States, the European Union and the rest of the world.[2] Values above 80% indicate exceptionally bad times (a "crisis"), values below 20% indicate exceptionally good times ("exuberance"), and values between 20% and 80% represent normal times. Shaded areas indicate recessionary periods in the United States, according to the National Bureau of Economic Research (NBER). We note in particular the very low values of this indicator in many parts of the world from 2004 to 2007, the years leading up to the most recent financial crisis. Similarly, the low indicator values in the mid to late 1990s for the United States preceded the bursting of the dot.com asset price bubble in 2000, which contributed to the 2001 recession. The knowledge that financial risk conditions are exceptionally low can alert policy-makers to the need to investigate whether financial imbalances are accruing in the background.

The bottom panel of Chart 2 plots a "credit risk bubble" early warning indicator. The indicator captures the extent to which local stress in a given economic region and industry (the financial industry in this case) differs from that which macro-financial fundamentals would suggest. The indicator is constructed as the absolute value of a standard normal

2 *Due to space constraints, we refer to Schwaab, Koopman and Lucas (2010) for the construction of the indicators, data considerations and estimation methodology. Credit risk data for the two non-US areas is less numerous compared with that available for the United States.*

covariate, such that values above 1.96 are deemed "exceptional". Systematic credit risk conditions can decouple from macro-financial fundamentals. Such a decoupling may be caused by, for example, unobserved shifts in credit supply, such as changes in the access to credit.

The bottom panel demonstrates that in the past a significant and persistent decoupling of risk conditions from fundamentals has preceded financial and macroeconomic distress. This suggests that the careful monitoring of time-varying credit risk and macro-fundamental conditions is of key importance for forward-looking macro-prudential policy. The latent risk factor model employed is a versatile statistical framework, enabling both coincident and forward-looking systemic risk assessments, despite caveats regarding its complexity and specific modelling choices. The above interpretation implicitly distinguishes between "good" and "bad" credit shocks in that it assumes only changes in credit supply (and not demand) drive the deviations of risk conditions from fundamentals and that they become problematic only once the identified deviations have become statistically and economically significant.

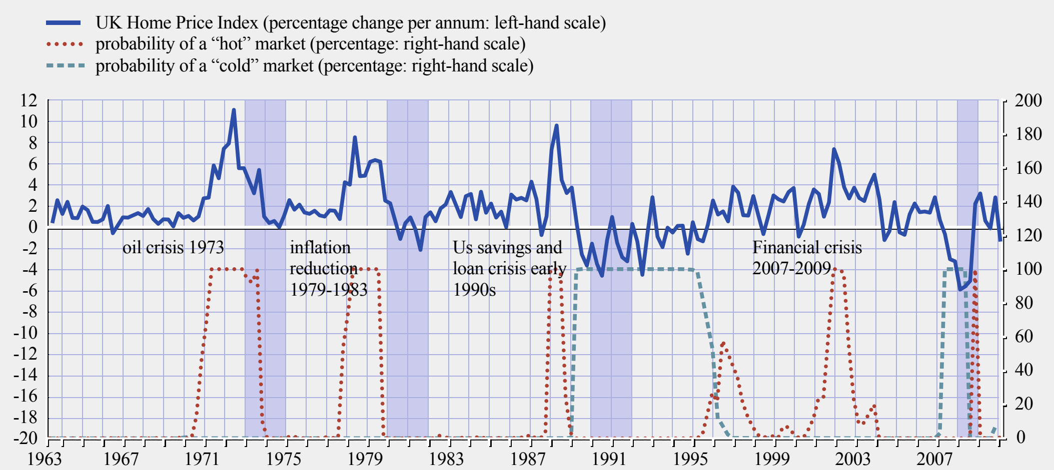
A housing price indicator for Europe

Housing markets are historically prone to boom and bust episodes. A striking case in point is the US housing market, where the current marked downturn in housing prices was preceded by a prolonged rise in housing prices which began in the early 2000s. Some European housing markets – including those in Spain, Ireland and the United Kingdom – experienced a similar pattern. Housing bubbles form gradually over time and may burst suddenly, producing detrimental effects on intermediaries, markets and indeed the economy as a whole. Corradin and Fontana (2011) have devised an empirical model to capture these unusual price dynamics and assess the vulnerability of housing markets.

A natural candidate to differentiate between periods of different house price dynamics is a Markov-switching model. In particular, a model specification that allows the mean rate of house price growth to switch between regimes appears to capture adequately the essential dynamics of housing prices. In addition, from a policy perspective, it is crucial to identify episodes in which the dynamic behaviour of house prices differs markedly from the behaviour that is implied by underlying economic fundamentals. In cases where a long-run equilibrium relationship between house prices and fundamentals is discernible, deviations can theoretically feed into the short-run dynamics of house price changes.

The approach chosen here is to use a Markov-switching model to characterise changes in the parameters of an error-correction model (see Hall, Psaradakis and Sola (1997)). The

Chart 3 UK housing prices and the probability of being in a "hot" or "cold" regime



Sources: Nationwide and Corradin S. and A. Fontana (2011) calculations.

system is assumed to be in either a stable state, in which deviations from the long-run equilibrium tend to vanish over time via a conventional error-correction mechanism, or in an unstable state, in which no such corrections take place. The model first identifies episodes in which house prices are markedly different from what certain macroeconomic fundamentals would imply. Then it estimates model parameters and state probabilities for the United Kingdom, Spain, Italy, the Netherlands, Ireland, Sweden and Denmark.

The model identifies episodes in which house prices differ from fundamental values

This section presents results for the United Kingdom. Chart 3 depicts the pronounced cyclicality in the quarterly real house price growth rate for the United Kingdom over the period 1964–2010. A model specification that allows three regimes ("hot", "normal" and "cold") appears to capture well the dynamics of UK housing prices. Prices increased substantially over the period considered. Chart 3 shows the estimated probability of a "hot" (red line) or "cold" (blue line) housing market (the "normal" state is the complement). Four pronounced booms in 1971-1974, 1977-1979, 1988-1989 and 2002-2004 stand out. Also, two price declines in 1990-1996 and in 2007-2008 are evident. Overall, "hot" housing market states in the United Kingdom tend to occur relatively frequently, but tend to be short in duration. Most of the time, the probability of a certain state is approximately either 0% or 100%, meaning that the model clearly identifies the regimes. In addition, the analysis based on the error correction mechanism suggests that "hot" regimes coincide with a dramatic increase in disposable income and a decrease in interest rates. Nevertheless, these regimes are associated with situations in which housing prices persistently diverge from their long-run trend.

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WHAT CAN THE DIAMOND-MORTENSEN-PISSARIDES MODEL TELL US ABOUT THE CONDUCT OF MONETARY POLICY IN THE EURO AREA?

By Kai Christoffel

Incorporating a Diamond, Mortensen and Pissarides (DMP) labour market, which has search and matching frictions, in a standard macroeconomic model allows labour market issues with great relevance for the conduct of monetary policy, to be addressed in a systematic way. In particular, such a model facilitates the identification of labour market shocks liable to have a bearing on inflation and output, and permits an analysis of how structural reforms in the labour market may affect the transmission mechanism of monetary policy.

Peter Diamond, Dale Mortensen and Christopher Pissarides were recently awarded the Nobel Prize in Economic Sciences for their analysis of markets with search frictions.[1] Central to the argument underpinning their research is the observation that market participants have to undergo a costly and time-consuming search process before a successful match can be formed between, for instance, a firm and a suitable customer.

As regards labour markets, the fact that there is a search process allows the modelling of labour-market flows, which can explain the existence of unemployment in equilibrium. Furthermore, the existence of search costs enables the introduction of various types of wage bargaining. Recent research has shown that, when incorporated in the prevailing class of macroeconomic models, the DMP approach to modelling the labour market has important implications for the analysis of monetary policy. Specifically, such models offer an insight into the role of the labour market in the monetary transmission mechanism and the importance of labour-market structures in determining inflation. Furthermore, the explicit modelling of labour-market rigidities opens the door to the analysis of the impact of structural reforms on the dynamics of output, inflation and unemployment.

The DMP approach to modelling the labour market facilitates the assessment of the role of the labour market in the monetary transmission mechanism and the role of labour-market structures in determining inflation.

Search and matching frictions in the canonical dynamic stochastic general equilibrium model

The labour market is widely recognised as a market in which frictions inhibiting the formation of successful matches between participants are particularly important, and a substantial component of the search and matching literature consequently focuses on the labour market. Indeed, dynamic general equilibrium models are increasingly concerned with the assessment of the role of the labour market. This class of model – whether in the form of a real business cycle or dynamic stochastic general equilibrium (DSGE) model – can be seamlessly combined with a DMP labour market model.[2]

By contrast with a standard model in which all labour market fluctuations occur along the hours-worked margin, the DMP approach allows for the modelling of labour market flows both into and out of employment. Job losses in the form of separations of firms and workers imply a flow of workers from employment to unemployment. Firms, for their part, decide on an individual basis whether to post vacancies. Both the firm that posts a vacancy and the worker who engages in a job search face a certain probability that their activities will result in a successful match. With each additional agent that joins the search, the chances decrease of other searchers finding a match. These externalities can imply

1 For a general appraisal of the work of Diamond, Mortensen and Pissarides, see the Nobel Prize background document published by the Royal Swedish Academy of Sciences (2010). Further useful references include the seminal articles by Diamond (1982), and Mortensen and Pissarides (1994) and the textbook by Pissarides (2000).

2 See Merz (1995), Andolfatto (1996) and Trigari (2009).

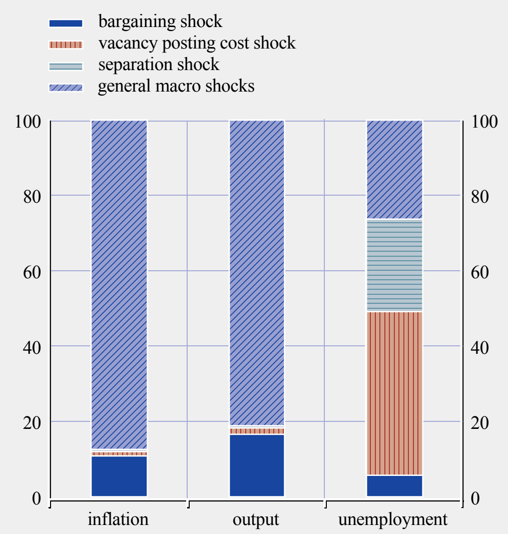
an inefficiently low level of search activity. Once firms and workers have established a match and start production, they face a positive surplus from their employment relationship.[3] The existence of this surplus provides a rationale for the introduction of various forms of wage bargaining. The degree of transmission of economic shocks to the labour market is mainly determined by the profit levels a firm is expecting to secure from production, and these, in turn, determine the vacancy posting activities of that firm.

Modelling the euro area labour market: shocks and frictions

The euro area labour market is characterised by various frictions and structural rigidities, of which many can be analysed within the framework of the DMP model. Frictions which hamper job creation that can be introduced into the model include the cost of posting a vacancy and the degree of efficiency at which firms and workers find a match. Job protection measures can either be modelled as a purely exogenous separation probability or can be viewed more explicitly as a factor influencing the endogenous separation decision of firms.[4] Different assumptions regarding the wage bargaining process allow flexibility in the approximation of wage-setting practices in the euro area. It is important to note that, according to the standard model, wage rigidities increase employment fluctuations but only affect inflation indirectly via labour market flows rather than directly via the wage to production cost channel. However, in a modified version, firms and workers bargain over the hourly wage alone, and firms are then left to decide on the number of hours the worker will work at the agreed rate of pay.[5] This introduces a wage channel to inflation, providing a framework within which to analyse the importance of labour markets in determining inflation. A recent survey paper provides an overview of the modifications to the standard DMP labour market model carried out thus far within a DSGE framework and assesses their success in explaining labour market data.[6]

Before answers can be derived to the questions of relevance for the conduct of monetary policy, a model has to be quantified. To this end, Christoffel, Kuester and Linzert (2009) provide an estimated model for the euro area, which allows the identification of the drivers behind the fluctuations observed in key macroeconomic variables, such as inflation, output and unemployment. According to the estimated model, a significant component of any variation in inflation and output is attributable to labour market shocks (see Chart 1). After a positive wage bargaining shock, workers receive higher wages, implying an increase in both production costs and inflation. To counteract inflationary pressures, the central bank may increase interest rates, thereby curbing domestic demand. Unemployment then increases because the fall in expected profits entails a reduction in the search activities of firms. The impact of other labour market shocks is largely contained within the labour market. Fluctuations

Chart 1 Labour-market shocks and general macroeconomic shocks



Source: Christoffel, Kuester and Linzert (2009).
Note: This chart depicts the percentage share in inflation, output and unemployment fluctuations attributable to certain structural shocks (e.g. a wage bargaining shock). For details on the methodology, see Christoffel, Kuester and Linzert (2009).

3 The reason for this positive surplus lies in the fact that the matching assumption constrains free entry into the market and allows for positive ex post profits.
4 Compare Fujita and Ramey (2007) for a treatment of vacancy costs, Krause and Lubik (2006) on allowing employed workers to search for a new job, and den Haan et al. (2000) on introducing the possibility for firms to lay off workers in order to maximise their profits.
5 For more details, see Trigari (2004) and Christoffel and Linzert (2010).
6 See Christoffel et al. (2009). This survey was prepared within the ESCB network on wage dynamics (WDN). A survey article by Smets and Lamo (2010) on the findings of this network can be found in ECB Research Bulletin No 10.

in the unemployment rate are explained jointly by labour market shocks and general macroeconomic shocks, such as technology and demand shocks.

Using a quantitative model, it is also possible to answer the question of how labour market reforms may affect the economy and the transmission mechanism of monetary policy, as illustrated in Chart 2a (left column), which shows responses to an expansionary monetary policy shock for different labour market specifications. For example, structural reforms which raise labour market flows by decreasing hiring costs have a significant impact on the level of equilibrium unemployment but only a limited effect on the transmission mechanism of monetary policy. Reduced hiring costs result in a rise in vacancy posting activity and the job-finding rate. As a result, the unemployment rate and number of job seekers will decrease, and so the probability of success will diminish for each vacancy notice. Together, reduced hiring costs and a diminished chance of success for each vacancy notice leave the dynamics of unemployment largely unaffected.[7] Consequently, the wage dynamics are not strongly affected and the inflation response is very close to the baseline response.

Structural reforms which raise labour market flows have a significant impact on the level of unemployment but only a limited effect on the transmission mechanism of monetary policy.

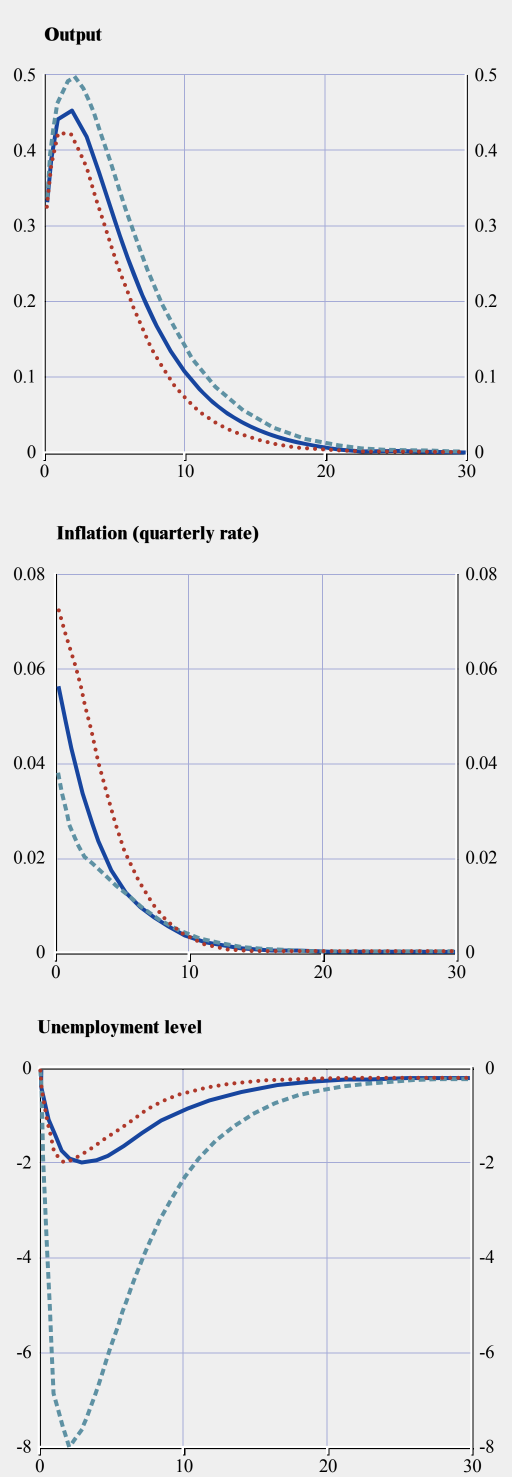
As can be seen from the right column of Chart 2b, reforms that affect wage setting directly have a more pronounced effect on inflation. With a lower degree of wage stickiness, the sensitivity of inflation to interest rate changes increases, because wages adjust more strongly.

Conclusions

Modelling the labour market as a market with search frictions (as proposed by Diamond, Mortensen and Pissarides) introduces an important element of realism and leads to an improved understanding of the monetary transmission process. Combining a macroeconomic model with a DMP labour market structure allows the identification of labour market shocks and the assessment of their role in determining inflation. In particular, those shocks that affect the wage setting process directly are found to have a strong impact on inflation. In view of the high degree of structural rigidity in euro area labour markets and the ongoing efforts to increase labour market flexibility, the model also provides a framework within which to assess the impact of structural reforms. Reforms which affect labour market flows directly are likely to have a strong impact on the level of unemployment. However, such reforms may leave the transmission of monetary policy relatively unaffected. At the same time, the implications for inflation may be more immediate with structural reforms that have a more direct impact on the wage-setting process.

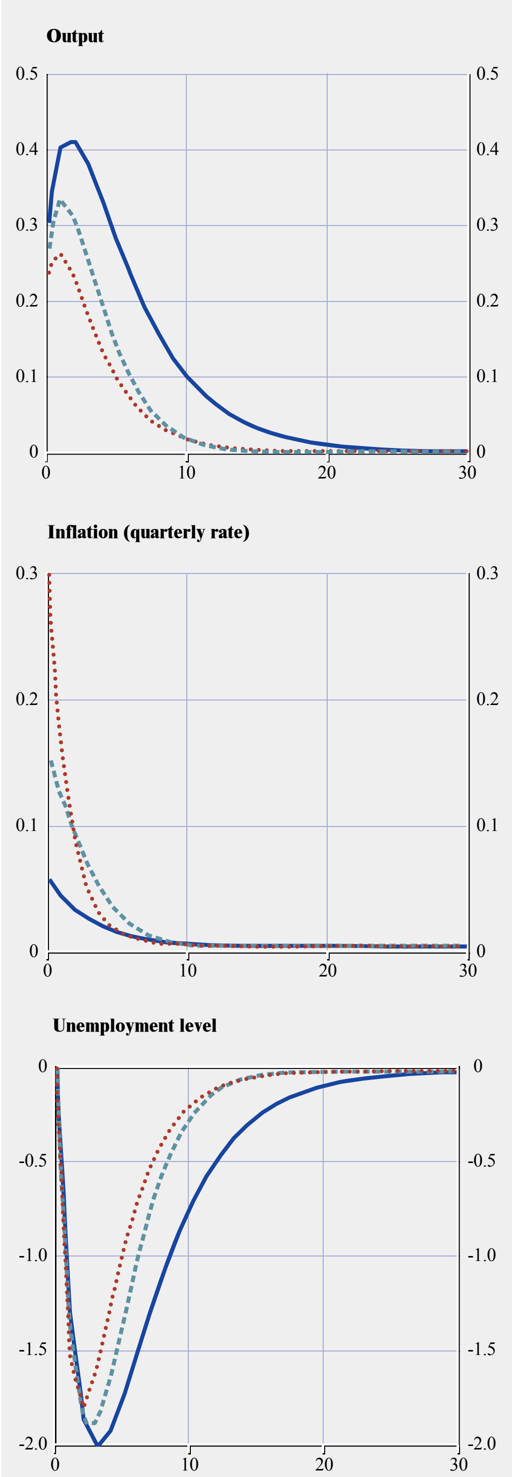
7 *Note that with lower equilibrium unemployment the percentage deviations of unemployment increase if the unemployment response remains unchanged.*

Chart 2a Responses to a monetary policy shock: different labour market specifications



Source: Christoffel, Kuester and Linzert (2009).
Note: The panel above shows the percentage response of output, inflation and unemployment to an expansionary monetary policy shock. The blue line represents the baseline model, the red dotted line a model variant with reduced unemployment benefits and the green dashed line a model variant with lower hiring costs.

Chart 2b Responses to a monetary policy shock: different wage setting specifications



Source: Christoffel, Kuester and Linzert (2009).
Note: The panel above shows the percentage response of output, inflation and unemployment to an expansionary monetary policy shock. The blue line represents the baseline model, the red dotted line a model variant without wage rigidity and the green dashed line a model variant with an intermediate degree of wage rigidity.

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RATIONAL INATTENTION

By Bartosz Maćkowiak

Rational inattention is the idea that economic agents have only a limited capacity to process information ("limited attention") and, in the course of taking economic decisions, must therefore decide how best to allocate their attention. This article provides a brief introduction to the concept of rational inattention and describes a number of insights that macroeconomic models with rational inattention have yielded concerning business cycles and monetary policy.

The efficient allocation of scarce resources is central to all of economics. Traditionally, however, this aspect has been overlooked in analysis of how agents form expectations. In the standard rational expectations approach, the costs involved in the processing of information – costs which in practice can be considerable – are ignored. Recent literature on rational inattention takes seriously the costs of processing information. The idea of rational inattention is that, while information is abundant, attention is scarce: it is impossible for agents to take account of every piece of information they receive. In models with rational inattention, agents have limited attention and must therefore decide how to allocate attention in an optimal manner.

Let us consider an example. A household has to decide how much to consume and how much to save, as well as which goods to consume. In order to make the optimal consumption-saving decision and to buy the optimal consumption basket, the household has to know the real interest rate and the prices of all consumer goods. In principle, all of this information is publicly available. However, according to the idea of rational inattention, knowing the real interest rate and the prices of all consumer goods would require the household to absorb an impossible amount of information. The household has limited attention and it must choose how to allocate its attention in an optimal manner.

The recent literature on rational inattention follows Sims (2003) in modelling limited attention as a constraint on information flow. The idea is as follows. Each time an agent pays attention to a piece of information, a flow of information takes place. The agent cannot absorb all the available information. He or she has to decide which pieces of information merit more careful attention; that is to say, he or she has to determine the optimal allocation of information flow.

Making the idea of rational inattention operational requires a means of quantifying attention or, in other words, the flow of information. Sims (2003) proposed using tools from information theory for this purpose.

The basis for information theory is the concept of entropy. Entropy is simply a measure of uncertainty; the greater the degree of uncertainty surrounding a random variable prior to its realisation, the greater its entropy. The conditional entropy of a random variable is the uncertainty that remains about a random variable in the light of observations made concerning another random variable.

Once equipped with measures of uncertainty and conditional uncertainty, one can define a measure of information. The basic measure of information is known as "mutual information". Mutual information between a random variable X and a random variable S equals the difference between the entropy of X and the conditional entropy of X given S. Mutual information thus quantifies the extent to which uncertainty surrounding one random variable decreases as a result of observations made concerning another random variable.[1] A related concept, information flow, is used in cases where both X and S are stochastic processes.[2]

Suppose that X and S both follow a Gaussian white noise process. Then the flow of information between X and S increases in the squared correlation coefficient between X and S. Note that, in this case, the squared correlation coefficient is the only thing determining the extent of the information flow.[3]

1 *The adjective "mutual" is added, because "mutual information" is symmetric. That is, mutual information between X and S also equals the difference between entropy of S and conditional entropy of S given X.*

2 *Information flow between stochastic process X and stochastic process S measures the average per-period amount of information about one process that can be derived from observations of the other.*

3 *In general, when X and S follow serially correlated processes, information flow takes into account co-movement between X and S frequency by frequency.*

Having established a measure of information flow, we can now consider a simple problem of optimal attention allocation (see technical example below). A shop manager has to set a price for a new product. The manager knows that the profit-maximising price depends on an aggregate variable (namely the state of the business cycle) and a market-specific variable (consumers' taste). The manager has access to two pieces of information: a report concerning the state of the business cycle from the *Financial Times* and an internal marketing report concerning consumers' tastes. Rational inattention assumes that the manager cannot attend perfectly to both the business cycle report and the marketing report. He or she will therefore have to decide how much attention to pay to the business cycle report and how much to pay to the marketing report.

The basic question is: what is the optimal allocation of information flow between the business cycle report and the marketing report? A paper written jointly by Maćkowiak and Wiederholt (2009), an ECB staff member and an academic economist respectively, studies the optimal allocation of attention. The authors show that it is optimal to attend more carefully to a variable that is either more volatile or of greater importance in the objective function of the agent solving the problem. It is advisable to pay more attention to a variable that either fluctuates greatly or is of great significance.

Example

Let us consider the following problem of optimal attention allocation. An agent minimises the objective function:

$$E[(X_1 - Y_1)^2] + E[(X_2 - Y_2)^2].$$

The objective function is the sum of two terms. The first term is the expectation of the squared difference between an exogenous variable X_1 and the agent's action Y_1. The second term is the expectation of the squared difference between an exogenous variable X_2 and the agent's action Y_2. The variables X_1 and X_2 are assumed to be mutually independent. The agent is assumed to compute the action Y_1 as the expectation of the variable X_1 given a signal S_1. The agent is assumed to compute the action Y_2 as the expectation of the variable X_2 given a signal S_2. Formally,

$$Y_1 = E[X_1 \mid S_1] \text{ and } Y_2 = E[X_2 \mid S_2].$$

The signal S_1 equals the variable X_1 plus a random noise u_1 with standard deviation σ_1. The signal S_2 equals the variable X_2 plus a random noise u_2 with standard deviation σ_2. Formally,

$$S_1 = X_1 + u_1 \text{ and } S_2 = X_2 + u_2.$$

The agent chooses the standard deviations of the two noise terms, σ_1 and σ_2, subject to the information flow constraint:

$$I(X_1; S_1) + I(X_2; S_2) \leq \kappa.$$

The operator I denotes information flow. The information flow constraint states that the sum of the information flow between X_1 and the signal concerning X_1 and information flow between X_2 and the signal concerning X_2 cannot exceed an upper bound κ. The smaller the value of σ_1, the greater is the flow of information between X_1 and S_1. The smaller the value of σ_2, the

greater is the flow of information between X_2 and S_2. Maćkowiak and Wiederholt (2009) discuss the solution to this problem and to its more general variants. The authors show that it is optimal to receive a more precise signal concerning a variable that is more volatile or of greater importance in the agent's objective function.

What does this finding say about economic data? In normal times, firms and households pay careful attention to idiosyncratic market-specific information (e.g. firms pay attention to marketing reports and households to the prices of their favoured products), but take little notice of aggregate information, such as GDP, the price level or interest rates. The reason for this is that in normal times idiosyncratic variables are much more volatile than aggregate variables. Therefore, in normal times, while economic variables (prices and quantities) are quick to respond to market-specific disturbances, they respond only slowly to changes in monetary policy. However, as the environment changes, the optimal allocation of attention and the optimal speed of response change. For example, during a macroeconomic crisis, firms and households allocate more attention to the aggregate economy. The reason is that during a macroeconomic crisis, aggregate variables become volatile. As a result, during a macroeconomic crisis, economic variables respond more quickly than usual to changes in monetary policy.

A good central bank policy is one that not only delivers stable prices but also provides private agents with a simple, realistic picture of macroeconomic risks.

Maćkowiak and Wiederholt (2010) have developed a dynamic stochastic general equilibrium (DSGE) model with rational inattention. In this model, firms and households have limited attention and solve attention allocation problems. This DSGE model matches some features of the data that are difficult to match when using standard DSGE models. For example, this model predicts that prices respond slowly to monetary policy disturbances, fairly quickly to aggregate technology disturbances and very quickly to disaggregate disturbances. The empirical literature on price setting finds the same pattern in the data.[4] Furthermore, this DSGE model matches the inertia we see in business cycles, as do standard DSGE models. However, the source of inertia in business cycles in this model differs from that in standard DSGE models, as the source in this model is the rational inattention of firms and households to aggregate disturbances. For example, this DSGE model predicts that prices respond slowly to changes in monetary policy and consumption shows a hump-shaped response to changes in monetary policy, because both firms and households normally pay little attention to monetary policy.

The actions of the central bank affect the allocation of attention by private agents.

The DSGE model with rational inattention yields different insights concerning monetary policy compared with standard DSGE models. The main insight of interest for monetary policy provided by this model is that the actions of the central bank affect the allocation of attention by private agents. When the central bank delivers price stability, agents pay little attention to the aggregate economy. Price stability is a good outcome, because when the aggregate economy is stable private agents can focus on market-specific problems. However, there is

4 *Boivin, Giannoni and Mihov (2009) and Maćkowiak, Moench and Wiederholt (2009) find that prices respond very quickly to disaggregate disturbances; Altig, Christiano, Eichenbaum and Linde (2005) find that the price level responds fairly quickly to aggregate technology disturbances; and Christiano, Eichenbaum and Evans (1999), Leeper, Sims and Zha (1996) and Uhlig (2005) find that the price level responds slowly to monetary policy disturbances.*

then the possibility that private agents will fail to respond adequately to macroeconomic risks. In view of this, a good central bank policy is one that not only delivers stable prices but also provides private agents with a simple, realistic picture of macroeconomic risks. A thoughtful central bank communication strategy is necessary to achieve this goal.

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Box 1

SIXTH ECB CENTRAL BANKING CONFERENCE:

"APPROACHES TO MONETARY POLICY REVISITED – LESSONS FROM THE CRISIS"

On 18-19 November 2010 the ECB hosted its sixth biennial central banking conference. The title of the conference, organised under the auspices of the Executive Board of the ECB, was "Approaches to monetary policy revisited – lessons from the crisis".

In his introductory speech, Jean-Claude Trichet (President of the ECB) stressed the fact that the ECB's monetary analysis had proven its worth during the crisis, while in his keynote, Jürgen Stark (Member of the Executive Board of the ECB) reiterated the key elements of the ECB's monetary policy framework: "a quantitative definition of price stability, a medium-term orientation and a broad analytical framework, with money and credit playing an important role". Stephan Fahr, Roberto Motto, Massimo Rostagno, Frank Smets and Oreste Tristani (ECB) developed these arguments, giving an empirical demonstration of the role of the ECB's framework and the success of the institution's non-standard measures in overcoming financial market impairments. In his paper, Frederic Mishkin (Columbia University) expressed the view that "None of the lessons from the financial crisis in any way undermine or invalidate the nine basic principles of the science of monetary policy developed before the crisis". Jean Pisani-Ferry (Bruegel), Guido Tabellini (Bocconi University) and William White (Organisation for Economic Co-operation and Development) discussed these papers. White contested Mishkin's view and called for a leaning-against-the-wind approach to credit bubbles.

In his speech, Ben Bernanke (Chairman of the Federal Reserve) focused on the global imbalances endangering the current recovery. He established a link between these imbalances and sustained foreign exchange interventions in a number of emerging market economies. This topic also dominated the policy panel, on which the participants were Bernanke, Henrique Meirelles (Governor of the Central Bank of Brazil), Dominique Strauss-Kahn (Managing Director of the International Monetary Fund) and Trichet.

Monetary policy operations, usually considered to be a technicality, became crucial during the crisis and were thus one of the key topics of the conference. Specific issues included the trade-off between providing liquidity and sustaining a certain degree of private intermediation in the money market,

and the controversy surrounding whether standard and non-standard measures should be viewed as complements or substitutes. These and other themes were discussed in policy speeches and in two papers on “Monetary policy operations: experiences during the crisis and lessons learnt”, one written by Nuno Cassola, Alain Durré and Cornelia Holthausen (ECB), and the other by Spence Hilton and James McAndrews (Federal Reserve Bank of New York). The discussants were Marvin Goodfriend (Carnegie Mellon) and Rafael Repullo (Centros de Estudios Monetarios y Financieros).

The panel on “The financial crisis: what did central bankers forget and what did they learn? A historical perspective” evoked the 19th century banking crises and the Great Depression. The participants were Harold James (Princeton University), Carl-Ludwig Holtfrerich (Freie Universität Berlin) and Marc Flandreau (Graduate Institute Geneva). Flandreau contrasted the insistence of the Bank of England in the 19th century on the use of only the best collateral in crisis periods with the widening of collateral eligibility criteria by many central banks in recent years.

During the panel discussion entitled “What shortcomings in macroeconomic and finance theory has the crisis revealed, and how should they be addressed?”, Jean-Philippe Bouchaud (Capital Fund Management and École Polytechnique) called for the use of models from the field of physics in capturing the dynamics of financial markets. Martin Eichenbaum (Northwestern University) noted that pre-crisis dynamic stochastic general equilibrium (DSGE) models did not explicitly model financial markets, because these were not needed to explain the pre-crisis macro data of the advanced economies. John Geanakoplos (Yale University) characterised the crisis as an exceptionally pronounced leverage cycle and called for further research in this area.

The contributions to this conference can be downloaded from the ECB’s website at: http://www.ecb.europa.eu/events/conferences/html/cbc6.en.html. The conference proceedings will be published in a book later this year.

Box 2

ECB-CFS CONFERENCE SUMMARY

The thirteenth conference of the research network launched by the ECB and the Center for Financial Studies (CFS) was hosted by the ECB on 27-28 September 2010 in Frankfurt am Main. The title of the conference was “Macro-prudential regulation as an approach to contain systemic risk: economic foundations, diagnostic tools and policy instruments”. The objective of the conference was to present the latest international research into major issues regarding the new macro-prudential supervisory and regulatory approach.

Following the opening address by Jean-Claude Trichet (President of the ECB), two keynote speeches were delivered. Gertrude Tumpel-Gugerell (Member of the Executive Board of the ECB) focused on how financial regulation should react to instances of widespread or systemic instability. Robert Engle (New York University (NYU) Stern Business School) presented the “NYU Stern Systemic Risk Rankings”, a system of risk measures that ranks the largest US financial institutions according to their level of risk.

The presentations in the first session focused on means by which to measure systemic risk. Baeho Kim (Korea University Business School) proposed a measure of systemic risk that focuses on the risk of failure clusters in the financial sector. Jian Yang (University of Colorado) presented an empirical framework within which to analyse the pattern of credit risk propagation across financial institutions.

In the second session, Erlend Nier (International Monetary Fund) presented an empirical analysis of the drivers of financial imbalances ahead of the global financial crisis. Pierre Monnin (Swiss National Bank) examined the relationship between the degree of banking sector stability and the subsequent evolution of real output growth and inflation. Sujit Kapadia (Bank of England) provided an overview of a RAMSI (Risk Assessment Model for Systemic Institutions) which focused on how large losses at a number of banks can be exacerbated by liability-side feedbacks, leading to system-wide instability.

In his keynote speech, Anil Kashyap (University of Chicago) summarised the recent debate on macro-prudential approaches to regulation of the banking system. He pointed out that there was no evidence that substantially higher time-varying capital requirements would have significant adverse effects on economic growth.

The third session focused on macro-prudential measures to contain systemic risk. Anton Korinek (University of Maryland) presented a dynamic model in which the interaction between debt and asset prices magnifies feedback effects in booms and busts. He argued that a Pigouvian tax on borrowing may induce leveraged agents to internalise these externalities. Julien Bengui (University of Maryland) showed that an excessive reliance on short-term debt gives rise to systemic risk in the form of amplification effects in asset prices. According to his analysis, a tax on short-term debt would alleviate this externality.

In his dinner address, Vitor Constâncio (Vice-President of the ECB) focused on macro-prudential supervision in Europe. He discussed the role of research and analytical tools in the conduct of macro-prudential policy, as well the efforts of the European System of Central Banks (ESCB) to undertake and stimulate research in support of macro-prudential policy.

The fourth session was devoted to pro-cyclical banking systems. Ignazio Angeloni (ECB) presented a framework which incorporates the banking sector in a standard dynamic stochastic general equilibrium model. He discussed the effects of monetary policy when banks are exposed to runs, as well as the interplay between monetary policy and the Basel capital requirements. José Fillat (Federal Reserve Bank of Boston) calibrated the dynamic provision system implemented by the Spanish banking regulatory system to US banks. He argued that US banks would have been in a better position to absorb their portfolios' loan losses during the recent financial turmoil if they had set aside general provisions in positive states of the economy.

John Geanakoplos (University of Yale) reviewed his recent research on how leverage cycles might naturally occur and why leverage is an important driver of boom and bust episodes in asset markets. He pointed out that central banks should actively manage system-wide leverage, by curtailing leverage in normal times and propping it up in times of uncertainty.

The last session focused on how to incorporate financial instability in aggregate models. Yuliy Sannikov (Princeton University) presented a macroeconomic model with a financial sector in which asset prices can occasionally display significant departures from their normal values, thereby generating situations that resemble downward spirals and feedback loops. Frédéric Boissay (ECB) proposed a new theoretical framework within which to analyse the link between excess liquidity and financial crises in an economic setting characterised by financial fragility.

The contributions to this conference can be downloaded from the ECB-CFS website at: http://www.eu-financial-system.org/index.php?id=96#c498.

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Imprint
The opinions expressed in this publication are those of the authors and do not necessarily reflect those of the European Central Bank. Editors: Günter Coenen, Gabriel Fagan, Philipp Hartmann and Huw Pill. Responsible editor for this edition: Huw Pill. Assistance to editors: Carina Stubenrauch.
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ISSN 1977-012X (online)