Peter Karadi (ed.)[1]: Rethinking Business Cycle Models – Workshop at the MNB

'...whimsicality, a willingness to play with ideas, is not merely entertaining but essential in times like these. Never trust an aircraft designer who refuses to play with model airplanes, and never trust an economic pundit who refuses to play with model economies.'

Paul Krugman

'DSGE Models: A Closer Look at the Workhorse of Macroeconomics' was the title of the international workshop organised for the 8th time by the Magyar Nemzeti Bank (MNB) jointly with the London-based Center for Economic Policy Research on 3-4 September 2009. The recent sub-prime debacle, the resulting financial meltdown and the substantial policy responses gave the topicality of the event; even more so as the unexpected extent of the crisis stirred a heated debate within and outside the economics profession about the applicability and usefulness of the current business cycle models.[2] The keynote speakers of the event were professors Lawrence Christiano (Northwestern University) and Mark Gertler (New York University, NYU), who are both world-renowned for their essential and continuing contributions to the development of the current versions of business cycle models. The keynote speakers with the 15 presenters from 10 countries and their discussants provided important attempts to challenge or defend basic assumptions of the models (e.g. sticky developments in prices or rational and forward-looking expectations); argue for adding long missing factors (e.g. an explicit financial sector and imperfect credit markets) to the models, or for dropping others (e.g. money-demand) which seem non-essential. There was general agreement among the participants with Governor of the MNB András Simor, who said that in the current crisis 'we need [models of business cycles] more than ever,' but they need to be developed further to be able to analyse and quantify factors that the current crisis showed essential.

INTRODUCTION

The family of business cycle models the MNB workshop was centred around (tagged 'DSGE'- models from the abbreviation of Dynamic Stochastic General Equilibrium[3]) has become the common language of macroeconomists interested in recessions, booms and the best fiscal and monetary policy responses to them. Macroeconomists working with these – quite complicated – models generally agree that it is not enough to assume that economic agents (households, firms, banks) follow simple behavioural rules (e.g. 80% of households take foreign currency-denominated debt and 20% of them domestic), because a new policy (e.g. a change from a fixed exchange rate to a floating exchange rate regime) might make them change their behaviour (e.g. households might be less willing to take credit denominated in foreign currency that is subject to exchange rate fluctuations).[4] Rather, if the main purpose of the model is to learn something about the appropriate policy, it is suitable to assume that agents are more clever than to follow simple rules; they recognise their possibilities and the effects of various economic policies on them. These models, therefore,

[1] Péter Benczúr, Anna Naszódi, Katrin Rabitsch, Katalin Szilágyi and Balázs Világi contributed to the article.

[2] See for example a Survey of the Economist journal, a response of Chicago University professor Robert Lucas, and the resulting debate; or the debate Crisis and Macroeconomy of Hungarian economists on the eltecon blog (in Hungarian).

[3] It is a general name for any model with some basic methodological traits. While earlier models assumed some basic static behavioural equations (like individuals tend to consume a certain fraction of their current paycheck), these more complicated models assume that economic agents make dynamic and forward looking decisions, (i.e. they take into consideration not only their current income, but also their expected future income when deciding about current consumption. Also they take uncertainty (stochastic world) explicitly into consideration, meaning they buy insurances against events (e.g. fire) that would cause disruption in their consumption. The term general equilibrium means that these models are interested in the behaviour of the whole economy and not only that of the individual agents, and for this reason, they are looking for prices, wages and interest rates, where the whole economy is in an equilibrium, where the demand and supply equal in each markets and nobody want to change their decisions.

[4] It is the famous 'Lucas-critique' named after the Nobel-prize winning Chicago economist Robert Lucas, who famously recognised this problem with earlier non-micro-based business cycle models.

explicitly model the agents' behaviour consistently with the model economy.

As one of the keynote speakers, Mark Gertler emphasised it, these models were developed to explain and support policy in 'normal' times, and they were relatively successful at this. By providing a common language for macroeconomists of different schools, this framework allowed researchers to debate about and agree on the necessary ingredients that these models need in order to be able to explain essential real-world characteristics. For policy applications, the models have proved useful not only in giving some basic intuition about the appropriate policy (such as that the nominal interest rate increase should exceed the increase in inflation if policy wants to stabilise inflation (Taylor-principle), or that an appropriate fiscal policy should try to smooth tax rates over time), but they also provided tools for quantitative evaluations of the appropriate policy stance. The models, therefore, allowed policy makers to make more informed decisions. The current crisis, however, has shown that important ingredients are missing from these models: for example, standard DSGE models[5] have left out financial markets from their estimated models, even though in their 1999 article current Fed Chairman Ben Bernanke with Mark Gertler (NYU) and Simon Gilchrist (Boston University) developed the tools necessary to insert financial sector into these models and showed that the resulting 'financial accelerator' mechanism would influence the reaction of these model economies to economic shocks – i.e. financial markets matter (see below). It is clear that the current crisis cannot be understood without financial markets – either as a source or as a propagator of shocks – and proper model-based policy advice could not be made without a model that takes financial markets seriously. The number of, and the general interest in, papers in the workshop that deal with financial markets prove that macroeconomists are taking this challenge seriously and are working hard to develop the proper models.

MODELLING THE FINANCIAL SECTOR

In a perfect world with no information problems, banks and financial markets could be ignored for business cycle analysis: they can instead be considered as the extension of the central bank that uses its instruments to influence financial markets to obtain a level of market interest rates or the money supply it considers appropriate. Credit in this world would flow freely to every firm that can invest it profitably. That is probably the reason why the first generation of DSGE models has not considered it necessary to explicitly model financial markets.

An important exception from this was the model of Bernanke, Gertler and Gilchrist, 1999 (BGG) that abandoned the unrealistic perfect information assumption and assumed that firms know more about their own profitability than the banks they want to borrow from. Banks need to pay monitoring costs if they want to observe the firms' profitability. As it was shown earlier by Townsend, 1979, this setup justifies the standard debt contracts between banks and firms: the borrowing firm promises to pay interest to the bank, and, in case it becomes insolvent, the bank – in a standard default procedure by paying the monitoring cost – observes all its assets and collects everything it can. For this contract to be acceptable for the bank, the interest rate it receives in good times should cover its opportunity costs (government interest) plus the expected value of its losses in the case of default. This way the model can capture and explain the interest rate premium (the excess interest rate the borrower pays over the risk free interest) generally observed in real world debt contracts. But the model can say more than this: it shows that in (general) equilibrium this premium will be dependent on the proportion of the firms' own funds (net worth) to the amount it intends to borrow. The lower its own funds are, the higher the premium will be, as it reduces the expected amount the bank can recover in the case of default. The authors show that this leads to an economy level 'financial accelerator' mechanism that influences the propagation of standard business cycle shocks: a negative shock leads to lower investment and lower price of capital, which, in turn, causes losses for firms and reduces their net worth. But this increases their borrowing costs that make them to invest even less. This 'credit channel' thus amplifies the effects of the original shocks. The authors show that this amplification effect is quantitatively important for standard values of the model parameters.

Both of the keynote speakers presented variants of the 'financial accelerator' model and argued that it offers a fruitful starting point for incorporating financial markets into the business cycle models. Lawrence Christiano presented a recent paper that he is working on with Roberto Motto (European Central Bank, ECB) and Massimo Rostagno (ECB). The main aim of the paper is to insert financial markets and banks into the standard business cycle model with a rich set of shocks and potential propagation mechanisms and use financial market data (including stock markets, monetary aggregates and interest rate premium) to identify which shocks and mechanisms help most in explaining the data. A new shock the keynote speaker introduced to his model is a 'risk shock' that influences the riskiness of credit, leading to worsened credit conditions:

[5] Christiano, Eichenbaum, Evans, 2005, or Smets and Wouters, 2007.

higher premium and lower credit levels. The reason is that a higher risk level increases the potential difference between firms, which – because of the specific assumptions of the model[6] – makes the potential losses of the banks higher. Even news about future risk shocks can strongly influence stock markets and the real economy, according to the model. The authors show that this shock helps explain the behaviour of financial market variables (such as the stock market and the interest rate premium), and has significant effects on real variables (e.g. output and investment). These results underline, according to the authors, that financial markets matter not only as propagators of shocks – as the standard BGG model suggested – but also as independent sources of shocks. A further important message of his speech was that explicitly modelling the money supply process (i.e. the liability side of the banking sector) either as a source of shocks or as a propagation mechanism does not seem to matter. This supports the conventional view that dropping money from the analysis – and assuming that monetary policy sets interest rates directly – is sufficient for general questions of business cycle research (see, for example, Woodford, 2003), and the current crisis does not seem to invalidate this result.

It was also the asset side of the central bank's balance sheet (e.g. buying mortgage backed securities) and not its liability side (e.g. increased bank reserves) that Mark Gertler in his keynote speech found important for understanding the current crisis and the unconventional monetary policy response. In his presentation, he admitted that the recent 'credit-easing' policy of the US Federal Reserve indeed led to substantial increases in the narrow definitions of money (M0: cash and bank reserves increased by close to $1 trillion). But he emphasised that, contrary to 'normal' times, this entailed a much smaller increase in broader money aggregates (M1: cash and bank deposits outside the banking system increased by less than $300 billion), which might be considered potentially inflationary. The main reason for this is that US banks now hold unusually high amounts of reserves at the Federal Reserve (an increase of $800 billion). Through this, they practically finance the central bank in its credit operations. It should also be noted that the Fed now pays positive interest on these reserves, and by changing the reserve rate it can keep these reserves at the central bank and thus can avoid unintended increases in the money supply during the normalisation of the financial markets. Besides bank reserves, the Fed is further financed by short-term debt issued by the Treasury under the Supplementary Financing Program. From these sources the Fed is providing credit to various sectors of the economy. The Fed's policy, therefore, can be considered more as substituting the private sector in financial intermediation ('credit easing') than increasing the money supply in the economy ('quantitative easing'), as was also explained by Fed Chairman Ben Bernanke in an earlier speech.

In this vein, Mark Gertler continued his speech by presenting the results of a paper he is working on with Peter Karadi (MNB) which explicitly models the banking sector and shows how this credit easing policy can be inserted into a financial accelerator model. In this model, the banks are the 'interesting' agents that face credit constraints (not the firms as in the BGG model). The reason for this in the paper is moral hazard: the chief executive of the bank can divert a certain fraction of the capital. The model household knows about this, and restricts the amount of credit a certain bank can obtain relative to its net worth, ensuring that no stealing happens in equilibrium. This modelling technique leads to a financial accelerator mechanism that is equivalent to the one of BGG: there will be an interest rate premium in the economy that is caused by the credit constraint of the banks which becomes tighter if their net worth drops relative to their assets (i.e. their leverage ratio increases).

To model the current unconventional monetary policy of the Fed, the model assumes that the central bank can offer credit to firms without the same credit constraints that banks face. On the other hand, the model assumes that the government is not as good at allocating funds as banks, consequently, it loses a certain fraction of the direct credit it provides as an efficiency loss.

The paper captures some important features of the current crisis by assuming that it was triggered by a 'capital quality shock': the value of the housing stock was not as high as market participants expected. A drop such as this in a standard model without a financial sector would result in a short-lived recession with higher investment quickly increasing the capital to its previous levels. With an explicitly modelled financial sector, however, the drop in the value of capital translates into a drop in the banks' net worth (amplified by their leverage), which reduces their ability to obtain funds and thus to provide the credit that would be necessary for a speedy recovery. Their gradual deleveraging makes the recession more prolonged. Through providing direct credit to the economy, the central bank can substantially reduce the severity and length of the recession caused by the shock. The paper shows that for relatively low efficiency costs (less than 40 basis points yearly) optimal policy fully substitutes for private intermediation during the

[6] The lognormal distribution of firm level shocks.

crisis, while for higher efficiency costs it is optimal not to provide direct credit at all. This result justifies the Fed's behaviour (also required by law), namely, that it only provides credit to very high grade debtors with sufficient collateral (where the efficiency or default costs can be expected to be very low).

In his workshop presentation of his paper written jointly with S. Boragan Arouba (University of Maryland), Frank Schorfheide (University of Pennsylvania) challenged the conventional wisdom that the role of money can be ignored in these DSGE models. He argued that a possible reason why standard methods[7] found such a small role for money is the simplistic way they quantified the reason for money demand. The presented paper explicitly models the role of money (applying results of search-based monetary theory introduced by Kiyotaki-Wright, 1989): it assumes that there is a sector in the economy where the one-shot and anonymous nature of trade makes money necessary – as credit is inadmissible and the chances of a successful barter are very low. The estimated model implies that this sector matters quantitatively and mainly because a positive interest rate is a distortionary tax on money holdings, welfare considerations should be a factor supporting a lower inflation target.

LEARNING IN BUSINESS CYCLE MODELS

Since the 1970s, it has been assumed in most academic macroeconomic models that key economic agents' expectations are based on a sophisticated knowledge of the working of the economy and all available relevant information. This approach of describing expectations is the rational expectations (RE) hypothesis. This assumption is justified by the belief that if agents formed their expectations naively, there would be unexploited profit opportunities; however, in a market economy such phenomena do not survive in the long run.

The RE hypothesis has important implications accepted by even the non-academic community: For example, the importance of central banks' credibility and expectations management in the conduct of monetary policy can be derived from RE. On the other hand, in a world where economic agents form their expectations simply by extrapolating some past experience without any forward-looking considerations the above issues would be much less important.

Despite its appealing properties, the RE assumption has problematic features as well. It implies that economic agents' forecasts are always unbiased and have only unsystematic errors. However, empirical evidence contradicts these strong requirements.

Recently, there is a growing macroeconomic literature which wants to refine our knowledge on expectations formations. It wants to get rid of the most extreme characteristics of the RE hypothesis, without returning to the assumption of naive and purely backward-looking expectations. While, according to the RE hypothesis, economic agents always use the best possible forecasting models and know precisely the appropriate parameter values of these models, the new literature of learning assumes that agents' forecasting models have limited abilities and the exact values of the parameters are discovered only gradually. In the workshop three papers were presented on learning and expectations.

Sergey Slobodan (CERGE-EI, Prague) and Raf Wouters (National Bank of Belgium) estimated and compared different versions of a DSGE model with and without RE using US data. They replaced RE with different forecasting algorithms in their DSGE model and analysed how deviation from the RE hypothesis influenced the empirical properties of the model. They find that replacing RE with learning improves significantly the empirical fit of the model, and, especially, inflation dynamics are explained much better. They also demonstrated that learning leads to substantial time variation in the parameters of the forecasting algorithms: the beliefs about the dynamics of the inflation process turn out to be very important for the overall performance of the model.

Arturo Ormeno (Universitat Pompeu Fabra) presented a paper on how the information content of survey expectations of inflation can be used in estimating DSGE models. He estimated a DSGE model using US data and found that the ability of the model to explain the cross correlation of inflation and survey inflation expectations data was very weak. Then, he specified a forecasting model based on learning and estimated it using survey expectations. He demonstrated that survey expectations can be approximated by simple models with few regressors where private agents heavily discard past information. Furthermore, he combined the DSGE model with the above forecasting model and re-estimated it. He found that the empirical fit of the model complemented with learning improved significantly. To summarise, both papers suggest that it is a promising research agenda to replace RE by learning algorithms in DSGE models.

Cosmin Ilut (Duke University) tried to resolve the uncovered interest rate parity (UIP) puzzle. According to the UIP

[7] The standard methods assume that the real value of money provides some direct utility for the households that hold them (money-in-the-utility), or that households need money in advance to buy consumption goods (cash-in-advance).

hypothesis, periods when the domestic interest rate is higher than the foreign interest rate should be followed by periods of domestic currency depreciation. An implication of UIP is that a regression of realised exchange rate changes on interest rate differentials should produce a coefficient of 1. However, empirical studies strongly reject this conjecture. This anomaly is called the UIP puzzle. Although it is possible to explain the UIP puzzle by models with RE, they do not provide plausible solutions.

Instead, in the presented paper agents' knowledge is more limited than the requirements of the RE hypothesis. They do not know exactly the statistical process governing interest rate differentials. Moreover, it is assumed that they form their conjecture on the properties of the above process in a pessimistic way: they try to prepare for the worst-case scenario. As a consequence, agents, who want to invest in the higher interest rate bond by borrowing in the lower interest rate bond underestimate the future interest rate differential: they believe that it is more likely that observed increases in the investment differential have been generated by temporary shocks, while decreases are reflecting more persistent shocks.

Hence, on average, next period investors are surprised to observe a higher interest rate differential than expected. This updating effect creates the possibility that next period the agent finds it optimal to invest even more in the investment currency because this higher estimate raises the present value of the future payoffs of investing in the higher interest rate bond. Increased demand will drive up the value of the investment currency, contributing to a possible appreciation of the investment currency. Thus, an investment currency could see a subsequent appreciation instead of a depreciation, as predicted by UIP.

In financial economics there are several phenomena labelled as puzzles, since the RE paradigm cannot explain them efficiently. This paper also reveals that to refine modelling expectations is a fruitful research programme with a huge potential for explaining these financial anomalies.

PRICE STICKINESS

Abandoning the classic assumption of fully flexible prices allowed DSGE models to better explain observed characteristics of the business cycle – especially the estimated responses to monetary policy shocks – and made these models able to explain the role of monetary policy in stabilising business cycles. The elegant results on developments in the inflation rate, however, are based on a potentially restrictive assumption for the price setting behaviour of individual firms: they are allowed to reset their prices only at randomly arriving times (when the 'Calvo-fairy' touches their shoulder, named after Guillermo Calvo a professor of Columbia University who developed the model). An important question of the profession ever since is whether this assumption is really restrictive in terms of the general questions of these models. The general agreement is that during 'normal' times in a relatively low inflation environment, these models capture the important characteristics of price stickiness. This question was also asked by Bernardo Guimares and Anton Nakov at the workshop.

Anton Nakov (Banco de Espana, BE) and his co-author James Costain (BE) examined the effect of monetary policy shocks on output in a model that abandons the Calvo assumption and replaces it with a less restrictive assumption of menu costs: the firms are allowed to change their prices any time they feel it necessary after paying a small fixed cost (reprinting the menu). This so-called 'state-dependent pricing' assumption relative to the standard 'time-dependent pricing' assumption has been given a prominent role in recent debates, when Robert Lucas (Chicago) and Mikhail Golosov (MIT) in their 2007 paper showed that standard menu cost models – calibrated to hit basic characteristics of the observed consumer price data – would imply negligible output effects on monetary policy shocks. In his presentation, Anton Nakov challenged this result – in lockstep with other papers by Gertler and Leahy, 2007 and Midrigan, 2008. He presented a model with maintaining the intuitive property that firms are more likely to change their prices if it is more profitable, but allowed the data to shape the exact behaviour of this probability. This modelling technique allowed him to take into consideration extra characteristics of the observed price change distribution that Golosov and Lucas failed to match (such as the amount of small price changes). Extending the model this way would be of great importance: as the authors show, this more realistic menu cost model would imply similar output responses to monetary policy shocks as a standard Calvo model.

In a paper written with Kevin Sheedy (LSE), Bernardo Guimaraes (London School of Economics) addresses the issue of observable frequent sales in consumer prices. Standard DSGE models assume relatively infrequent price changes (in every 9 months on average); but if we look at time series of prices, sales make these price changes more frequent (in every 4 months). Price changes because of sales, however, are substantially different from infrequent and permanent 'regular' price changes: during sales, prices drop by a relatively large amount and a week or two later they return exactly to their previous value. This fact prompted many authors to drop sales from their analysis. In his presentation, Bernardo Guimaraes gave an elegant theoretical reason to support this claim.

Their model recognises that there can be two substantially different types of consumers: some that are loyal to certain brands and some that are bargain hunters: they will look for the cheapest product, irrespective of its brand. The authors built a model that rationalises stores holding occasional sales: they are setting higher prices for their loyal customers at some points in time and lower prices occasionally for the bargain hunters. The important finding of the paper is that even if we assume that firms can set sales prices fully flexibly, it would not influence the standard DSGE results on the limited inflation effects of monetary policy shocks. The reason is that for a firm offering sales, it is more important how other firms also offering sales set their prices than for it to respond optimally to the monetary shock: a response to a monetary shock would result in the firm losing too many bargain hunter customers.

ESTIMATION OF BUSINESS CYCLE MODELS

Standard medium-scale DSGE models, such as that of Smets and Wouters (2007), contain a high number of parameters and shocks that need to be estimated. The Bayesian estimation technique, which is now standard in the literature, obtains parameter estimates by combining the authors' prior knowledge on the parameters[8] with the information content of the data. If the estimates are close to the priors, it suggests that the data does not contain enough extra information on the parameters, or the parameters are weakly identified. Smets and Wouters (2007) showed that their model's forecasting ability is competitive with non-theoretical, data-based approaches, which is an important achievement, but if key parameters are weakly identified, then caution is necessary in the policy application of these models.

The presentation by Nikolay Iskrev (Banco de Portugal) dealt with evaluating the strength of identification in DSGE models. Parameters are unidentifiable or weakly identified if the economic features they represent have no empirical relevance at all, or only very little. This may occur for two reasons. First, those features are not important at all, or only moderately important on their own. Second, they are redundant. If a parameter is redundant, then there is another parameter, or another set of parameters that can take over its role. When some parameters are not identifiable or only weakly identifiable, then different values of these parameters would make our sample be observed with almost equal probability.[9]

The paper by Iskrev develops a new framework for analysing parameter identification that can tell us not only if a parameter is unidentifiable based on the information matrix, but also the reason for the lack of identification. The main advantage of the methodology is that it does not involve timely simulation, as opposed to the method proposed by Canova and Sala (2009). This feature makes the method suitable for analysing large and complicated models. After introducing this methodology, Iskrev (2009) applies it to the Smets and Wouters (2007) model.

The results indicate that the parameters in the Smets and Wouters (2007) model are quite poorly identified. This finding is in line with that of the previous literature, e.g. Canova and Sala (2009). Thus, it may be concluded that this and other similar models are indeed nearly overparameterised, as it has also been argued by Chari, Kehoe, and McGrattan (2009). One could overcome the problem of weak identification either by modifying the model, or by collecting richer data. The proposed method of Iskrev is useful at identifying how the model should be changed and what kinds of data are needed for a better identification. And even if one does not include new data in the analysis explicitly, Bayesian estimation can provide a coherent way of incorporating some additional information making the estimates and the policy conclusions more reliable.

OPTIMAL MONETARY POLICY

A theoretically appealing feature of dynamic stochastic general equilibrium (DSGE) models is the existence of a well-defined welfare measure. Consequently, the models can be solved for optimal (welfare-maximising) policies. The paper presented by Katalin Szilágyi (MNB), written jointly by Zoltán M. Jakab, Henrik Kucsera and Balázs Világi, explores optimal monetary policy in a DSGE model for Hungary. While the solution to the optimal policy problem is a useful benchmark for monetary policy evaluation, it is not operational from a central bank's perspective. To make the results easier to interpret, the paper approximates the welfare-maximising policy rule with a set of simple rules that react only to observable variables.

The main conclusions are as follows.

Compared to the optimal policy, the empirical rule implies too much variability of nominal variables. This is a natural consequence of the modest estimated feedback coefficient to

[8] Coming from microeconomic estimates or previous time series data.

[9] Or in other words, the likelihood function is not sensitive to the changes of these parameters. Therefore, one way to analyse which of the parameters of a model are identifiable is to look at the likelihood function, or a transformation of the likelihood function, like the Fisher information matrix.

inflation. Optimal rules that respond to a few standard and observable variables (simple rules) can approximate the fully optimal policy well – that responds to everything – if they respond strongly to domestic inflation.

Once monetary policy reacts to changes in domestic inflation, it should not target the nominal exchange rate separately. This result depends heavily on the paper's assumptions about the production process and the role of imports in the economy.

Including wage inflation in the policy rule implies significant improvement in welfare. This suggests that the welfare loss associated with sticky wage setting is more severe than those related to nominal rigidities in product markets.

The results of the paper build on some crucial assumptions (a high share of imports in the export sector's marginal cost, perfect exchange rate pass-through for import prices, broadly similar production process for the domestic and the export sector, no imported consumption). Further research is needed to examine these assumptions and check the robustness of its conclusions to relaxing them.

An essential component of the welfare measures and hence optimal monetary policies is the level of the 'output gap', which is the distance of the current income level from a theoretically defined potential level that would prevail if prices and wages were flexible and there were no shocks causing inefficiencies in the economy (such as shocks to the price-markups firms add to their prices over their costs). Potential output, however, is not observable, consequently, Ulf Söderström (Sveriges Riksbank), in a paper written with Luca Sala and Antonella Trigari (both at Bocconi University, Italy), present a DSGE model-based method that helps obtain estimates. Their main result is that their estimated potential output level is close to the ones that are usually obtained by standard time-series smoothing techniques (e.g. the HP filter). This result is important, because, theoretically, potential output could develop more erratically than actual output, and then smoothing would produce a wrong result.

A potential caveat of the paper, however, as suggested by Lawrence Christiano during the discussion of the paper, is that assuming temporary shocks, as it is standard in these models, may be an important reason why the authors obtain potential output series that is smoother than output; if they assumed permanent shocks instead, then potential output might turn into a much more volatile series. A further important conclusion of the authors is that their estimates do not seem to imply high estimation uncertainty, consequently, for a given model, they can be fairly sure about where the potential output lies. A fact that makes this result weaker, though, is that different model specifications (such as reinterpreting a shock from a leisure-preference shock – that is efficient – to a wage markup shock – that is inefficient – which both influence the labour market outcome similarly) may lead to substantially different potential output estimates. The authors argue that if central bankers do not have strong preconceptions about structural shocks, these uncertainties about the potential output estimates should make them increase the weight they put on inflation stabilisation relative to the one they put on closing the unobserved output gap.

Carlos Thomas (Bank of Spain), in a paper written jointly with Javier Andrés (University of Valencia) and Óscar Arce (Economic Bureau of Prime Minister), calculated optimal monetary policy in a model with two distinct financial frictions. In their model, i) borrowing requires real estate as collateral, so its price development influences the agents' borrowing ability and ii) banks are assumed to have some monopoly power, so their lending rate is higher than the deposit rate in equilibrium. The two types of frictions generate interesting interactions in the model: an expected rise in house prices, for example, leads to lower lending rates through its effect on banking competition. In the model, households and entrepreneurs differ by their level of patience: the less patient entrepreneurs are willing to pay to households for their savings. The authors find that these financial frictions introduce both new terms to the central bank's welfare function[10] and new trade-offs. This implies that the central bank should try to counteract the effects of the financial frictions even if this makes it deviate from its standard inflation and output-gap stabilisation objective. A practical problem with the results, however, is that the new terms the central bank should respond to are unobservable, and there are not yet observable variables that could provide good enough proxies for them. Quantitatively, furthermore, the effects of the financial frictions were found to be small for the model calibration, consequently, for small shocks these frictions might not yet provide enough reason for deviations from standard rules.

[10] Besides inflation and the output gap terms it should try to make sure that the heterogeneity between entrepreneurs and households in terms of consumption and real estate holdings are kept as small as possible over the business cycle.

ECONOMIC FLUCTUATIONS IN EMERGING MARKETS: ARE THEY DIFFERENT?

Modelling the behaviour of emerging economies has always been controversial: these countries often follow erratic policies, face such distortions and market failures that make the standard frameworks (be it a real business cycle, RBC, or a New-Keynesian DSGE model) inapplicable. In particular, the seminal small open economy RBC model of Mendoza (1991) has turned out to suffer from many empirical shortcomings. The most well-known empirical regularities are the excessive volatility of consumption relative to GDP, the strong countercyclicality and persistence of the net exports to GDP ratio.[11]

Recent advances, however, have shown that a small set of modifications can go a long way in explaining these empirical regularities. There are two main approaches: Aguiar and Gopinath (2007) proposed an explanation based on the properties of the productivity process, while Neumeyer and Perry (2005) put the emphasis on financial frictions. These two papers have prompted an active research line in understanding the key differences between emerging and industrial economy 'business cycles'. To see the main issues, let us briefly look at the details of the two competing explanations.

Aguiar and Gopinath (2007) have shown that adding shocks to the trend component of productivity leads to more volatile consumption and more countercyclical net exports. The intuition is simple: a trend shock leads to an increase in the lifetime income of consumers. As they want to smooth the extra consumption it allows, they will borrow against their future income. This results in countercyclical net exports. Since part of the increase in current consumption is financed from future earnings, the change in consumption is higher than the change in current output, hence the excess consumption volatility. If the trend component of productivity is more volatile in emerging than in industrial economies, that can explain the differences in business cycle facts.

A competing explanation is due to Neumeyer and Perry (2005), where the explanation is based on financial frictions. In their model, the real interest rate is decomposed into an international rate and a country risk component. Country risk is endogenous (i.e. it is influenced by productivity developments), but it also amplifies the impact of productivity shocks through a working capital constraint.[12] This can also explain the same regularities.

The main question thus became whether one can replace the explanation that 'the permanent component of productivity is more volatile in emerging than in industrial countries' with a more structural interpretation. A leading candidate is that emerging markets are special in their limited access to international financial markets (country risk), in their financial underdevelopment (credit constraints). The interaction of productivity and financial market developments would lead to the observed empirical regularities, and this would also make the aggregate productivity series look as if it had a more volatile trend component. It would thus lead to a 'weak RBC' interpretation: 'Shocks impinging upon emerging countries are numerous and of different natures, but may be interpreted as an aggregate shock to total factor productivity. In addition, the neoclassical model is a good framework for understanding the transmission of such shocks.'[13]

The two most direct ways to proceed are either to run horse races between productivity-based and financial friction-based explanations, or to estimate encompassing models and examine the relative importance of the two factors. The winning explanation is ambiguous so far: Aguiar and Gopinath (2006) add a restricted version of endogenous interest rate spreads (driven only by the transitory component of productivity) to their benchmark model and find that this kind of financial friction cannot replace the trend shock explanation. Cicco, Pancrazi and Uribe (2007) allow for exogenous interest rate shocks and an estimated elasticity of the country premium to indebtedness. They find that such a model completely eliminates the need for having more volatile trend productivity shocks in emerging economies. Chang and Fernandéz (2009) – the paper included in the workshop's programme, presented by Andrés Fernandéz from Rutgers University (US) – carry out a very careful Bayesian estimation and model comparison exercise, in which they consider endogenous interest rate spreads, a fixed elasticity of the risk premium to indebtedness and working capital requirements. Though they do not do an explicit horse race between the two explanations, their encompassing model assigns a dominant role for financial frictions in shaping fluctuations, and trend shocks turn out to be less important.

In his discussion, Péter Benczúr of the MNB pointed out that most of the existing literature limits its attention to

[11] Benczúr and Rátfai (2005) confirm the same pattern for Central and Eastern European countries.

[12] This constraint means that firms must finance part of their wage bill in advance.

[13] Cicco, J., Pancrazi, R, and M. Uribe (2009), slides posted at http://www.columbia.edu/~mu2166/rbc_emerging/rbc_emerging.html.

comparing the US and Canada with Argentina and Mexico. As countries are highly heterogeneous in their business cycle properties,[14] one should be careful in drawing conclusions based on such a limited comparison. He also emphasised the need for having meaningful and structural financial frictions, and a complex interaction between the financial and the real side of the economy. Nevertheless, he strongly believes that a sufficiently enriched version of the basic open economy real business cycle model can explain many though far from all aspects of emerging market economic fluctuations.

INTERNATIONAL FINANCIAL MARKETS AND COUNTRY PORTFOLIOS IN OPEN MACRO MODELS

A number of papers in this year's workshop addressed open economy aspects in business cycle models. They laid out methods with which our analysis of the determinants of structure and composition of country portfolios can be improved, applied existing methods to shed light on puzzles like the equity home bias[15] or looked at the role of international financial markets assumptions for macroeconomic policy.

Behind the background of increasing international financial linkages, with gross asset and liability positions[16] having grown rapidly in the last two decades, there are a number of questions that are becoming increasingly crucial to address in models of the open economy. These include, among others, the determinants of the size and composition of gross portfolio flows; whether standard theories can account for the observed structure of portfolio holdings; or if the large size of gross positions makes it likely that the portfolio composition itself will affect macroeconomic outcomes. Work in this area of research has, therefore, focused both on improving the methods of solving for country portfolios and on applying these methods to the recurrent topics and puzzles in this literature such as, for example, the empirical findings of a strong equity home bias or a low degree of international risk sharing.[17]

Until recently, existing open economy macroeconomic models have, to a large extent, ignored portfolio composition, and have limited themselves to analysing financial linkages between countries in terms of net foreign assets, with no distinction made between assets and liabilities.

The ways international financial markets have been modelled and what set of available asset to allow in open economy macro models were largely constrained by technical difficulties. Portfolio theory tells us that the composition of a portfolio depends on the risk properties of the available assets. The typical approximation methods for DSGE models take the non-stochastic steady state as an approximation point, that is, they analyse the dynamic properties of the model economy around a long-run equilibrium that is reached if no disturbances hit the economy. At such point, by definition, there is nothing that distinguishes one asset from another and there is nothing that pins down what asset a country's agents would like to hold: the portfolio is indeterminate. Recently, there have been major advances in this literature: a number of authors, most notably Devereux and Sutherland (2007, 2008),[18] have suggested techniques to derive the optimal portfolio composition in dynamic macro models. They show that using standard first-order solution techniques it is possible to determine the 'near-stochastic' optimal portfolio allocation around which the non-linear dynamic model can be approximated. Furthermore, they show that using simple second-order approximation techniques, it is possible to characterise the dynamics of this portfolio.

In a paper written jointly with Luca Dedola (ECB), Giovanni Lombardo (ECB) extends the results of the Devereux and Sutherland (DS) method along several dimensions. While the DS method requires for its solution that the portfolio allocation only enter in the equilibrium conditions multiplicatively with excess returns, the authors show that in certain cases of economic interest one needs to apply a more general solution technique. This is the case, for example, if one were interested in solving a Ramsey optimal policy problem[19] with multiple agents and assets under incomplete markets. In

[14] Benczúr and Rátfai (2009) document this heterogeneity.

[15] Home equity bias refers to the strong empirical finding that countries tend to hold a large fraction of their overall equity portfolio in terms of domestic equity.

[16] That is, the stock of total external assets or the stock of total external liabilities. In contrast, the net foreign asset position is defined as the difference of gross assets over gross liabilities.

[17] The degree of international risk sharing determines how sensitive a country's consumption behaviour is in response to country specific shocks. Under full risk sharing all countries benefit equally from a shock that occurs in any country, in the sense that the utility of an extra (marginal) unit of consumption is equalised across countries. If the degree of international risk sharing is imperfect, the world allocation is inefficient in that the marginal utility of consumption in one country will be generally larger or smaller than in other countries.

[18] Tille and van Wincoop (2007) present an essentially identical solution method (by proposing iterative techniques) that allows a general class of open economy model with multiple assets to be solved using standard algorithms, while Devereux and Saito (2006), Evans and Hnatkovska (2006) and Judd et al. (2001) describe alternative solution approaches.

[19] That is, a Ramsey policy problem is a setup in which a benevolent planner (the policy-maker) that is fully aware how the economy behaves and that takes this into account, optimally chooses a policy instrument such as to maximise lifetime utility of agents.

particular, they show that when the portfolio terms appear only in such a way that they enter multiplicatively with excess returns – or in general terms that are zero at the non-stochastic steady state (the 'Zero Jacobian case') – then the DS method can be applied and the zero-order (steady state portfolio) and first-order portfolio (portfolio dynamics) can be solved separably, and in one step after another. In case this is violated and the portfolio terms also show up multiplying terms that are non-zero at steady state (the 'Singular Jacobian case'), the zero-order (constant) and first-order (dynamic) portfolio need to be solved for simultaneously, in an iterative algorithm. The paper further clarifies the relations between the Devereux-Sutherland methodology and the approach proposed by Judd and Guu (2001), showing that both approaches share the same formal foundations. In a number of examples the authors show how their extensions of the DS method are of interest not only per se, but can be used in a number of applications in economics such as solving problems of finding the optimal monetary policy (Ramsey problems), models involving some collateral constraint problems or in economies with heterogeneous agents.

A contribution that evaluates the ability to generate equity home bias in a sticky price model with capital accumulation was presented by Ebrahim Rahbari (London Business School, LBS). In the model, world agents face real exchange rate risk and human capital risk (risk from labour income). The author considers agents to be able to hold either (domestic or foreign) equities or (domestic or foreign) *nominal* bonds. Crucial for the understanding of how countries would like to hold their portfolios is to understand what types of risk can be hedged with what assets held. He shows that, in response to a productivity increase, labour income falls – when economies are faced with price rigidities – while dividends increase as a result of the now higher profits (profits increase both because of the higher productivity and the lower wage bill that needs to be paid out). As a result, domestic equity provides a high payoff at times when labour income is low, and is a good hedge against labour income risk. A similar (negative) co-movement of labour income and dividends can result from investment efficiency shocks that temporarily increase the benefits of ongoing increased investment. This decreases dividends and raises labour effort, making home equity also a good hedge in response to this type of shock. But what about hedging against real exchange rate risk? It turns out that the assumption of *nominal* bonds as available assets means that they are not very effective hedges for real exchange rate risk (nor for human capital risk), and, as a result, the position in equities will reflect both the desire to hedge human capital risk and also real exchange rate risk. Rahbari shows that even though a sticky price model with capital accumulation *can* generate a home equity bias, the portfolios are not stable, but depend strongly on specifications of preference parameters (which determine the extent of real exchange rate risk). The empirical analysis of the paper, namely, a vector autoregressive model estimated using sign restrictions,[20] seems to support the idea that home equity bias is driven by the desire to hedge human capital risk and not real exchange rate risk for a set of industrial countries.

Robert Kollmann (European Centre for Advanced Research in Economics and Statistics, ECARES, Université Libre de Bruxelles), in joint work with Nicolas Coeurdacier (LBS) and Philippe Martin (Sciences Po, Paris), also analyses the issue of equity home bias using a two-country flexible price business cycle model in which agents can choose among domestic and foreign equities and domestic and foreign bonds to hedge the risks they face. Similarly to the previous contribution, the risk in this model world originates from the presence of productivity shocks and from shocks to the marginal efficiency to investment (which affect the benefits from investing an extra unit). The available assets considered are again (domestic and foreign) equities and bonds, but a crucial difference is that the latter are real bonds. In the case of real bonds, the relative return on real bonds is perfectly correlated with the real exchange rate. Therefore, bond holdings are used to hedge against movements in the terms of trade or the real exchange rate, while equity home bias, on the other hand, results from agents' incentive to hedge risk that is unrelated to movements in the terms of trade. This is, in particular, labour income risk: a home investment boom induced by temporarily higher investment efficiency leads to a decline in home dividends at a time when output and, as a result, employment increase. Local dividends and local wage income are negatively related, at a constant terms of trade. The author shows that this co-movement also finds empirical support for a set of industrial countries. The equity positions generated from the model setup are not only realistic but also stable, in the sense that they do not hinge on preference specifications: as terms of trade movements are perfectly correlated with the difference between payoffs on Home versus Foreign bonds, they are hedged through the bonds portfolio. Equity home bias is generated only because they are a good hedge against labour income risk. The paper then goes beyond the analysis of equity home bias and looks at the model's implications for portfolio dynamics,

[20] A vector autoregressive (VAR) model is an econometric model in which the times series of (several) economic variables are jointly explained by past observations of these variables. As the way these economic variables may affect each other is typically not unique, there needs to be some additional structure imposed on the VAR, that is, it needs to be identified. An identification by 'sign restrictions' imposes this structure by forcing the impulse responses (to a shock) of the VAR model to behave qualitatively (a variable should increase or decrease) as we believe they should according to what we believe to be economically meaningful.

contrasting them to a number of empirical stylised facts on international capital flows. The model is shown to perform reasonably well also in terms of matching portfolio dynamics, such as the business cycle properties of the valuation adjusted current account or the negative correlation between the change in the net equity position and the net bond position.

Katrin Rabitsch (MNB and CEU) presented a paper showing that the degree of international risk sharing across countries can be important in shaping optimal monetary policy in an open economy, and that the closed economy prescriptions of price stability as the optimal policy do not necessarily translate into the open economy. The reason for this finding is that policy-makers may not only be interested in stabilising domestic prices but also in affecting international relative prices (the terms of trade or the real exchange rate) strategically in their advantage. How to strategically affect the terms of trade depends on the amount of risk sharing obtained, which, in turn, depends on the assumptions on international financial markets together with trade elasticity – the elasticity of intratemporal substitution.[21] In particular, the author studies financial market assumptions of complete financial markets, financial autarky, and an incomplete markets-bond economy, looking over a wide range of the elasticity, and contrasts differences between policy coordination across countries and the case in which countries' policy-makers act in an uncoordinated fashion. She emphasises that (producer) price stability is a very special case, which only obtains when financial markets are complete and policy-makers act co-ordinately or when risk sharing across countries is automatically obtained through terms of trade movements, as in Cole and Obstfeld (1991). In all other cases, terms of trade considerations lead the policy-maker to deviate from price stability. Because independent policy-makers generally fail to take into account the effect of the terms of trade on the other country's welfare, there are welfare gains from coordination to be achieved. These turn out to be larger under complete risk sharing when goods are substitutes and also larger under financial autarky when goods are complements (as with very low substitution elasticities wealth effects under incomplete markets become increasingly important). Also, in a world of incomplete risk sharing a policy-maker is shown to find it optimal to manoeuvre international relative price responses that are closer to the ones that would occur in the efficient complete markets world, improving over the flexible price (but incomplete markets) allocation.

CONCLUSION

The workshop provided an excellent opportunity for researchers of business cycle models and central bankers to meet and discuss the potential of the current DSGE models, understand their caveats and agree on the necessary avenues for future research. The main conclusion of the workshop was that even though current versions of the business cycle models are useful in 'normal' times, the current crisis requires serious rethinking of the standard ingredients and policy conclusions of these models.

Financial markets, for example, should be inserted into the standard versions of these models: the already developed 'financial accelerator mechanism' provides a potentially successful method for this. The debate has already started about how central banks should optimally set their monetary policy if financial markets are present both as sources and propagators of business cycle shocks.

There is also an ongoing debate about whether the standard assumption of rational expectations, which assumes – for consistency's sake – that agents know everything about the structure of the model-economy, is too strong, and agents should rather be assumed to continuously learn about the behaviour of the economy (as economists do when facing serious recessions such as the current one).

The workshop also provided a great opportunity for researchers to present their results on topics such as the assumption of price stickiness, optimal policy questions, special issues related to open and emerging market economies, current developments in modelling international portfolio choices and problems with the estimation of these models that can greatly contribute to the structure and empirical validity of the standard DSGE models of the future.

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[21] The intratemporal elasticity of substitution determines how strongly relative consumption responds to changes in the international relative price, and thereby influences how much risk sharing is achieved across countries. As an example, if a country it hit by a favourable productivity shock, the other country can reap some of the benefits through a now lower relative price at which to buy the more productive country's goods. In an important special case Cole and Obstfeld (1991) have shown that relative price movements may lead to full risk sharing independently of the financial market structure assumed. The question of the influence of the degree of risk sharing on optimal policy in an open economy can therefore not be studied uncoupled from trade elasticity.

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