Search theory and applied economic research

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Introduction

In the summer of 2002, the Swiss National Bank (SNB) hosted the "SNB-Fed Cleveland Workshop on Monetary Economics". Recent years have seen the development of the search-theoretic approach to monetary theory. It has established itself as an important strand of monetary theory in a very short space of time, although it has yet to exert a significant influence on the empirical models that are typically used for monetary policy analysis. This is why the conference organisers, David Altig (Federal Reserve Bank of Cleveland), Aleksander Berentsen (University of Basel) and Thomas Jordan (SNB) decided that the event should focus on linking search theory with applied economic research.

This summary article first briefly examines the objectives and challenges of search theory before discussing briefly the conference papers.

1 Search theory

Search theory attempts to explain the use of money as a response to information frictions that make trade difficult. Neil Wallace, one of the pioneers of search theory, linked the approach to a laboratory. Search economists can be compared with biologists who control all of the conditions in their laboratory. They are interested in the "atoms" – the individual economic subjects – and how they handle money. They are concerned with when money is used to exchange goods, and which frictions can make barter exchange difficult or even impossible. Their aim is to develop a understanding of the exchange process and the role of money. By contrast, traditional macroeconomists – and central bankers – have more in common with doctors in an accident and emergency unit. They take the existence of money as given and are mainly concerned how monetary policy affects the economy. The activities of the laboratory researchers tend to be seldom discussed outside the laboratory. A brief discussion of the nature of search theory therefore follows.

1.1 The nature of search theory

Search theory[1] is a comparatively young branch of economic research that looks into the conditions for the creation or failure of money. Money has three functions: It is a means of exchange, a unit of account and a store of value. The second and third of these are relatively easy to incorporate into a model. Modelling the transaction function, however, is much more complicated as Karl Brunner and Alan Meltzer once observed: "One of the oldest unresolved problems of monetary theory is to explain the use and holding of money."[2] The difficulty in modelling the use of money lies in the fact that money is not a consumption good. The benefit gained from holding money is derived only indirectly, through the purchase of goods. A model in which money is appropriately represented must thus contain a microeconomic theory of exchange. Most macro models neglect the details of the exchange process, however. Instead, they impose some shortcuts to get a demand for money by assuming that real money balances are productive: money throws off utility directly, or, as in

1 Labour market theory includes a theory of the same name which is not linked to the one used here.

2 Quoted from Nagatani (1978, p. 1).

transaction cost models, frees resources that can be used productively or, as in cash-in-advance models, is an input into the activity of consuming or investing (Wallace 2001). Theses shortcuts do not permit to investigate why a loss of confidence in a currency can occur, the consequences of such a currency crises for trade, the emergence or disappearance of parallel currencies, or the preconditions for the successful launch of a new currency (e. g. the Euro).

Search economists endeavour to close these gaps in traditional theory. One of the central aim of the search approach is to find out which frictions are responsible for money being essential. Money is essential if its use allows the economy to achieve certain allocations that would be impossible to achieve without it. In a frictionless Walrasian economy, there are no information problems. Any agent can enter into a contract with any other agent and can also enforce this contract at no cost. In such an economy, money is not essential.

Another important aim of search theory is to investigate the extent to which the shortcuts of traditional macroeconomics described above do not contain hidden inconsistencies. There is also the question of the validity of empirical studies that are based on these shortcuts. An important hypothesis of search theory is that the microeconomic structure of the economy, and the financial sector in particular, affect the transmission mechanism and thus the effectiveness of monetary policy. It emerges from the search papers discussed at the conference, for example, that the effects of monetary policy depends on whether or not bonds are accepted as a means of payment (see Shi), and that the loss of welfare associated with inflation is much greater if the details of the exchange process are also taken into account (see Lagos and Wright).

In a series of pioneering articles, Kyotaki and Wright (1989, 1991, 1993) outlined the search-theoretic approach. In a typical search-theoretic model, heterogeneous agents are matched pairwise at random. The typical exchange problem arises – the absence of a double coincidence of wants. The search approach demonstrates how a generally accepted medium of exchange mitigates this problem and thereby increases welfare. Elements of the environments in search models are the properties of the goods produced and consumed, the number of agents, the matching function, and the type of information frictions. Endogenous variables are, for example, the agents' search intensities and their level of specialisation. The most important decision, however, is the decision to accept or reject the medium of exchange in each particular trade.

1.2 Monetary research gains from a micro foundation

If we understand the conditions under which monetary exchange takes place, we gain a more consistent and in-depth understanding of the functioning of a monetary system. The primary benefits of a micro foundation stem from the following two factors:

(a) In a frictionless economy, money plays no role. Models that assume frictionless (Walrasian) markets while assuming the use of money contain hidden inconsistencies. Such inconsistencies can be avoided if the model is based on explicit micro foundation (Wallace, 2001).

(b) Micro foundation allows us also to gain a deeper insight into core questions of monetary economics. These include: What effects do monetary shocks have on the different sectors of the economy? Which economic subjects (e.g. companies/households or rich/poor subjects) bear the costs of inflation? How do the microeconomic structures of the financial sector affect the impact of monetary policy (the role of inside money and outside money is also significant here)? Why is the acceptance of new digital means of payment (e-cash, etc.) so limited? How can a new currency be launched successfully? What are the economic ramifications of a common currency or dollarisation, as is currently taking place in some Latin American countries.

1.3 The relationship between search theory and classical macro monetary theory

Search theory and classical macro monetary theory are largely complementary, but how this relationship will develop in the future remains to be seen. Search theory applies the bottom-up principle by specifying the details of the environment and in particular the exchange process. It deals explicitly with the various information frictions that characterise economic life. Individual behaviour is central to this. By contrast, macroeconomics is based on the top-down principle. It concentrates (given the inherent utility of money) on simulating and forecasting aggregate data.

While the "why" question (reasons for the existence of monetary systems) preoccupies search economists, traditional macro economists are asking "what can be done" (economic policy). The answers are not independent of each other.

2 Conference papers

This section looks more closely at the conference papers[3]. They can be downloaded at the *www.moneyworkshop.ch* webpage for further reading.

The papers on search theory will be discussed first. These can be interpreted as justification for the micro approach to monetary theory, and an explicit treatment of a range of information frictions[4]. This type of micro-level analysis

- allows inconsistencies to be avoided and permits a more in-depth insight into monetary theory (Wallace);
- explains why good money drives out bad, and vice versa (Camera, Craig, Waller);
- enables to investigate the impact of monetary policy, dependent on whether fiat money[5] is the only accepted means of exchange, or whether bonds are also used (Shi);
- permits the development of a tractable search-model of fully divisible money that also allows policy analyses (Lagos and Wright).

The conference papers that can be classified under traditional macro monetary economics looked at the following issues:

- the influence on monetary policy of an inaccurate estimate of potential output (Jordan, Kugler, Lenz, Savioz);
- inflation and inequality (Albanesi);
- interpreting different types of shock in a general equilibrium model (Altig, Christiano, Eichenbaum, Linde);
- share prices and monetary policy (Carlstrom, Fuerst);
- why are some monetary unions successful and others not? (Chari, Kehoe).

2.1 Papers on search theory

The number and heterogeneity of micro-based monetary models is increasing fast. In ***"General Features of Monetary Models and their Significance"***, Neil Wallace proposes a way for classifying models with "nice micro foundations". He starts by defining two conditions for "nice models". Firstly, the way in which agents (the buyers and sellers of goods) use money must be modelled explicitly. Secondly, money must be essential, i.e. there are certain allocations that can only be achieved when agents use fiat money. "Cash-in-advance" models and those which incorporate real balances as arguments of production or utility functions fail this first necessary condition. Models which describe one of the many other feasible ways of goods exchange without money fail the second necessary condition. The reason that only models which fulfil these two conditions can be described as "nice" is that they help to avoid implicit inconsistencies. They also provide new insights. In a monetary model in which money is essential, we cannot simultaneously make the assumption of perfect credit markets, because these require perfect and complete information. This forces us to include imperfections of the credit markets in any model of money. If a lack of transparency (monitoring) is assumed, implementation of fiscal policies are affected because collecting taxes is made much more difficult. In other words, the characteristics that make money essential also determine the way in which the credit markets work and the feasibility of economic policy measures.

Models with "nice micro foundations" can be distinguished by three general features:

(a) the *extent and kind of idiosyncratic uncertainty*. Search models often look at situations in which the agents have differing holdings of money or goods. The inequality between economic subjects in terms of the money and goods they hold is attributable to their different opportunities to trade. These, in turn are founded on different forms of uncertainty, which are modelled as random meetings between agents or preference-related shocks.

(b) the *degree of monitoring (degree of transparency)*, which depends on whether or not past actions are observable and can therefore be regarded as common knowledge. The degree of monitoring determines the degree of friction on the credit market. Without monitoring, nobody would want to grant credit – although where monitoring is perfect, money cannot be essential. Since credit and

3 All of the papers referred to here are drafts.

4 For a general overview of the arguments in favour of the micro foundation, see Wallace (2001).

5 "Fiat money" is a medium of exchange that is intrinsically worthless.

money are both tangible realities, a consistent "middle way" approach to monitoring must be found for a "nice" model.

(c) the *size of the trading group*, e.g. trading in pairs or centralised trade. This feature determines the range of potential trading outcomes.

To understand the creation of money, we must spell out what happens when two goods compete against each other for the status of money. The costs of holding money determine which money will be regarded as bad, and which as good. Good money entails a smaller risk of devaluation than bad money. Gresham's law states that bad money drives out good. This runs counter to the observation that, in many developing countries, there are more dollars than the countries' own, weak currencies in circulation. This resulted in Hayek's hypothesis (1976) that good money drives out bad.

In ***"Gresham's Law versus Currency Competition"*** Gabriele Camera, Ben Craig and Chris J. Waller attempt to explain the dichotomy. They propose a search-theoretical model for a country with two currencies with different levels of risk. The authors examine the conditions under which either Gresham's law or Hayek's currency competition would prevail as the model equilibrium. It becomes clear that it is more difficult to establish Gresham's spending behaviour as the equilibrium. Indeed, Gresham prevails only if it is assumed that the relative cost disadvantage of bad money is comparatively small. The relative cost disadvantage of bad money lies in the strategy pursued by the buyers of goods, who spend the risky money first in order to transfer the risk to the seller. The latter demands a higher price for assuming this risk, which results in a loss of consumption for the buyer. Depending on the extent of this loss, the buyer has an incentive to use the less risky (good) money. Although this model is relatively abstract, it still gives a practical insight into the scope and timescale of dollarisation in developing countries. It shows in numerical terms how the home currency's velocity of circulation begins to decline only when the risk associated with it increases, or the markets suffer from growing frictions.

Sometimes, government bonds compete with domestic and foreign currencies as a means of exchange. In ***"Nominal Bonds and Interest Rates in Search Economy"*** Shouyong Shi looks into the role of interest-bearing, risk-free government bonds. In traditional monetary theory, it is assumed that only fiat money will be accepted as a means of payment in the goods market. This assumption is viable only if the effectiveness of monetary policy measures does not depend upon it. To investigate this, Shi presents two models in which fiat money exists in equilibrium with interest-bearing, default-free government bonds. In the first model, matured bonds are used as a perfect substitute for money. Such models are characterised by a continuum of equilibria. In the second model, there are no matured bonds in circulation in the market for goods, so there is only one stationary equilibrium. This model does not have any constraints that would prevent matured bonds circulating as a means of payment in the market for goods in the same way as money. Furthermore, in both models, in equilibrium newly issued interest-bearing bonds are traded at a discount equivalent to the rate of interest.

Shi looks into the effect of a range of monetary policy actions, whereby open market operations result in particularly large differences. In the first model, a steady increase in bond sales on the open market raises inflation while real output and consumption remain unchanged. By contrast, in the second model a sale of bonds has an impact in real terms. As money is withdrawn from the economy, inflation falls and real output rises. Shi uses this to demonstrate that monetary policy has different effects depending on whether money alone is used as a means of payment or bonds are also accepted on the market for goods. Consequently, the role of bonds as a means of payment cannot be fixed exogenously but must be determined endogenously within the model.

Analysing the impact of monetary policy in a search-theoretical model is a major challenge. ***"A Unified Framework for Monetary Theory and Policy Analysis"*** by Ricardo Lagos and Randall Wright aims to develop a framework in which money is essential but which also allows monetary policy issues to be studied, as is the case with standard macro models. This requires a search model with perfectly divisible money.[6] In previous search models with perfectly divisible money the distribution of money holdings and the pattern of exchange have turned out to be analytically intractable and the research therefore has focused on numerical simulations. One exception is Shi (1997), who reduced the complexity considerably by introducing the concept of large households. Lagos and Wright employ another trick for the sake of simplification. Unlike conventional search-theoretical models, they assume that agents after trading in the search market have access to a centralized market for money, where they can adjust their money holdings. This centralised trading ensures that all agents in each

6 The following analytical difficulties emerge in a search-theoretical model with perfectly divisible money. Firstly, there is a non-degenerate distribution of money holdings, which makes it very difficult to investigate the model analytically. Secondly, the law of one price no longer applies, because the outcome of negotiations depends on the money holdings of the randomly matched agents. To avoid this problem, earlier search-theoretical models assumed that money is indivisible and imposed certain restrictions on how much money an agent can hold. As a result, these models were of limited use to analyse monetary policy issues. Lagos and Wright (2002) attempt to avoid these difficulties while retaining the essence of the search models.

period hold the same amount of fully divisible money in the search market. Their trick therefore generates a degenerated distribution of money holdings allowing them to focus on a representative agent. This representative agent structure offers the great benefit that the model is tractable, while retaining the essence of the search models, and so analysing monetary policy becomes much simpler.

To demonstrate that their model is also suitable for empirical studies of monetary policy issues, the two authors calibrate their model in order to estimate the (negative) welfare effects of inflation[7]. To their surprise, they find that these are much greater than forecast by Walrasian macro models. The authors show that, at the exchange level, inflation causes much larger distortions than had previously been thought. Consequently, a monetary theory that has a micro foundation and is based on explicit information frictions may make quantitative statements that are very different to those of traditional macroeconomics.

2.2 Papers not classified under the search approach

In the new SNB strategy, inflation forecasts serve as the main indicator for guiding monetary policy. Every forecast suffers from the same dilemma, however – the results can only be as reliable as the data used to produce them. A major test of the suitability of models and the behavioural rules derived from them is to investigate how the results they produce react to a change in input data. In ***"Measurement Errors in GDP and Forward-Looking Monetary Policy: The Swiss Case"*** Thomas J. Jordan, Peter Kugler, Carlos Lenz and Marcel Savioz examine how aggregate output should be weighted in forward-looking monetary policy rules given the assumption that the output figures are subject to measurement errors. In practice, these measurement errors are due primarily to data revisions and inaccurate estimates for the most recent data. Measurement errors in the consumer price index are thus less significant, because inflation data is collected more frequently and is subject to less revisions. To shed light on this area, the authors use a small structural VAR model. In the absence of measurement errors, there is a trade-off between the volatilities of inflation and output. If monetary policy attaches great importance to stabilising output, the volatility of inflation will rise. Conversely, if inflationary targets are regarded as more important, considerable output volatility will be the result. However, any error in the output figure means that this trade-off will cease to apply to every output weighting. Indeed, if output is weighted heavily, then the volatility of inflation will not actually fall, but rise instead. Furthermore, it is shown that an incorrect assessment of potential output has the same effect as an incorrect estimate of actual output. Monetary policy decision-makers respond to a signal that is incorrect, producing an increase in the volatility of both output and inflation.

In ***"Inflation and Inequality"*** Stefania Albanesi traces different levels of inflation back to the income-related use of payment technologies. A range of studies has found that holding money is less costly for higher-income groups than for lower-income groups. The main reasons include marginal returns from cash management, which rise as the amount of money increases, and easier access to innovations in financial technology. These enable people to hedge against the risk of inflation. Lower-income groups generally hold a higher proportion of their assets in cash, which means that they are directly exposed

7 This is a core issue in empirical monetary theory. An overview of current research can be found in Lucas (2000).

to inflation. High inflation further adds to this inequality in income.

Cross-sectional international comparisons have clearly shown the positive correlation between inflation and inequality of income. This applies to different measures of income inequality. According to Albanesi, the correlation is rooted in the distributional conflict of fiscal policy. The government has two financing options: tax or inflation. The fiscal policy that is applied and, indirectly, the level of inflation that is ultimately accepted is decided in a political framework. This is modelled as a sequential negotiating game in which political influence is presented as a function of economic power. Lower-income groups have a greater incentive to vote against inflation, but are in a weaker negotiating position. The fact that high inflation often prevails in countries with significant income disparities is therefore attributed to differences in the volume of cash that is held, as well as the influence that the different groups wield over the political decision-making framework.

In ***"An Estimated Dynamic, General Equilibrium Model for Monetary Policy Analysis"*** David Altig, Larry J. Christiano, Martin Eichenbaum and Jesper Linde develop a dynamic general equilibrium model which incorporates a large number of frictions such as price and wage rigidities[8]. The model facilitates the study of financial market shocks (primarily monetary policy shocks) and other types of shock, such as transitory and persistent technology shocks as well as shocks related to the market power of companies or employees. Reactions to the different types of shock are modelled by VAR. The parameters of a dynamic equilibrium model are then set so that the reactions generated by the VAR model are reproduced as accurately as possible.

The results of the model show that monetary policy shocks can only explain a small part of the output variance in the data. By contrast, around half of the output variance is accounted for by technology shocks, although the latter are often long-term in nature and thus cannot be held responsible for shorter-term movements, which are ascribed to the economic cycle.

The authors also find that, in contrast to the picture painted by the classic real business cycle, a positive technology shock will lead to a rise in output, capital utilisation, investment and employment. This is due primarily to the model's assumption that the central bank will increase the money supply in the wake of a positive technology shock. Such an expansive, policy-induced money supply shock leads to a temporary rise in consumption, investment, employment and capacity utilisation. Interest rates fall. After a short-term decline, the rate of inflation gradually begins to advance, peaking around two years after the shock. In the case of a positive technology shock, the positive employment effect triggered by monetary policy offsets the negative effect of rising labour productivity.

The issue of whether or not a central bank should react to equity prices has recently gained currency. Bernanke and Gertler (2001) looked into the way in which a variety of monetary policy rules actually work, both including and excluding asset valuations. They concluded that a central bank should not react directly to asset prices, as higher equity prices raise demand and are ultimately inflationary. With the traditional Taylor rule, equity prices are therefore already considered to the extent that they impact on inflation. The authors believe that they do not need to be taken into account further. In ***"Imperfect Capital Markets and Nominal Wage Rigidities"*** Charles T. Carlstrom and Timothey S. Fuerst examine the same issue using a general equilibrium model. This assumes the capital market to be imperfect (not every credit-seeking party receives sufficient financing). Furthermore, wages are nominally rigid, Calvo-style. On the basis of these assumptions, the authors find that it is beneficial to welfare if the central bank takes equity prices into consideration, the reason being that, in imperfect markets, equity prices affect a company's ability to secure financing and may therefore have an effect on the real economy – which may in turn prompt a central bank to intervene.

Why are some monetary unions successful and others not? In ***"Time Inconsistency and the Incentives for Free-Riding in a Monetary Union"*** V. V. Chari and Patrick J. Kehoe argue that a key factor in answering this question is the time consistency of monetary policy. Time inconsistency will lead to a freerider problem. Specifically, if each state in a monetary union were to take autonomous decisions on fiscal policy, unionwide bank regulations or on labour market policy, there would be an incentive to select these non-monetary policy areas such as to generate higher inflation than if the states were to cooperate.

While the individual states enjoy the benefits of a more loose economic policy, the costs that are incurred later must be borne by the union in the form of higher inflation. This time inconsistency can be avoided if non-monetary policy is subjected to cer-

8 Wage rigidity was modelled like in Calvo (1983), meaning that, at any given time, only a certain proportion of employees are in a position to change their wages. Other wages develop in parallel with inflation.

tain constraints, such as a borrowing limit. However, if a monetary union succeeds in operating a time consistent monetary policy (either through an independent central bank or by coordinating fiscal policy, etc.), borrowing limits are unnecessary and possibly harmful. Consequently, the right strategy for safeguarding a monetary union becomes directly dependent on the scope and strength of the cooperation between members states on non-monetary policy issues. The highest-profile example of this model in practice is the European economic and monetary union (EMU). Other applications were also discussed. For example, the model could be used to analyse the moral hazard problem of the International Monetary Fund (IMF).

3 Concluding remarks

The conference covered a broad spectrum of current research papers. In the future, it would be worth trying to bring the "laboratory" and the "A&E department" closer together. Some acute "emergencies" would seem to beg closer study. For example, the tools offered by search theory would be a suitable means of rethinking the monetary policy transmission mechanism and paying greater attention to the analysis of information frictions which have an asymmetric effect on monetary policy. Current euro-related issues would be another topic for investigation. How, for instance, will eastward expansion of the EU affect confidence in the euro, and its stability? What will competition between the euro and the dollar for the status of the global currency bring? Finally, work could be done to identify reasons for the success or failure of new means of payment, such as e-cash. It would be desirable if the theoretical concepts of the search approach could in future be applied increasingly to practical issues, thus bringing us closer to the goal of a better understanding of a monetary system.

Bibliography:

Bernanke, B. and Gertler, M. 2001. Should Central Banks Respond to Movements in Asset Prices. *American Economic Review Papers and Proceedings* 91:253–257.

Calvo, G.A. 1983. Staggered Prices in a Utility-Maximizing Framework. *Journal of Monetary Economics* 12: 383–398.

Hayek, F.A. von. 1976. Denationalisation of Money. *Hobart Paper Special 70*. *Institute of Economic Affairs London*.

Kyotaki, N. and Wright, R. 1989. On money as a medium of exchange. *Journal of Political Economy* 97: 927–954.

Kiyotaki, N. and Wright, R. 1991. A contribution to the pure theory of money. *Journal of Economic Theory* 53: 215–235.

Kiyotaki, N. and Wright, R. 1993. A search-theoretic approach to monetary economics. *American Economic Review* 83: 63–77.

Lucas, R.E. 2000. Inflation and Welfare. *Econometrica* 68: 247–274.

Nagatani, K. 1978. *Monetary Theory*. North Holland.

Shi, S. 1997. A divisible Search Model of Fiat Money. *Econometrica* 64(1): 75–102.

Wallace, N. 2001. Whither Monetary Economics. *International Economic Review* 42(4): 847–869.

Papers presented at the conference:

Albanesi, S. February 2002. Inflation and Inequality.

Altig, D., Christiano, L.J., Eichenbaum, M. and Linde, J. June 16, 2002. An Estimated Dynamic, General Equilibrium Model for Monetary Policy Analysis. Preliminary and incomplete draft.

Camera, G., Craig, B. and Waller, C.J., January 2002. Gresham's Law versus Currency Competition.

Carlstrom, Ch.T. and Fuerst., T.S. June 11, 2002. Imperfect Capital Markets and Nominal Wage Rigidities. Preliminary and incomplete draft.

Chari, V.V. and Kehoe, P.J. June 2002. Time inconsistency and the incentives for free-riding in a monetary union.

Jordan, T.J., Kugler, P., Lenz, C. and Savioz, M. May 2002. Measurement Errors in GDP and Forward-Looking Monetary Policy: The Swiss Case. Preliminary Draft.

Lagos, R. and Wright, R. April 9, 2002. A Unified Framework for Monetary Theory and Policy Analysis.

Shi, S. 2002. Nominal Bonds and Interest Rates in Search Economy.

Wallace, N. June 11, 2002. General Features of Monetary Models and their Significance.