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Limited information minimal state variable learning in a medium-scale multi-country model

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ABSTRACT

Rational expectations has been the dominant way to model expectations, but the literature has quickly moved to a more realistic assumption of boundedly rational learning where agents are assumed to use only a limited set of information to form their expectations. A standard assumption is that agents form expectations by using the correctly specified reduced form model of the economy, the minimal state variable solution (MSV), but they do not know the parameters. However, with medium-sized and large models the closed-form MSV solutions are difficult to attain given the large number of variables that could be included. Therefore, agents base expectations on a misspecified MSV solution. In contrast, we assume that agents know the deep parameters of their own optimising frameworks. However, they are not assumed to know the structure nor the parameterisation of the rest of the economy, nor do they know the stochastic processes generating shocks hitting the economy. In addition, agents are assumed to know that the changes (or the growth rates) of fundament variables can be modelled as stationary ARMA(p,q) processes, the exact form of which is not, however, known by agents. This approach avoids the complexities of dealing with a potential vast multitude of alternative misspecified MSVs.

Using a new multi-country euro area model with boundedly estimated rationality we show that this approach is compatible with the same limited information assumption that was used in deriving and estimating the behavioural equations of different optimising agents. We find that there are strong differences in the adjustment path to the shocks to the economy when agents form expectations using our learning approach compared to expectations formed under the assumption of strong rationality. Furthermore, we find some variation in expansionary fiscal policy in periods of downturns compared to boom periods.

1. Introduction

The dominant way to model expectations has been via model-consistent rational expectations (strong rationality). Whilst rational expectations (RE) can be taken as a theoretically well-founded polar case, resorting to only them is not unproblematic. It is well known that rational expectations can give rise to a multiplicity of solutions, sometimes terminal or transversality conditions may be enough to produce a unique solution but these conditions are always somewhat arbitrary. Rational expectations have also been criticised as these assume too much information on the part of agents. Furthermore, it is well known that there have been difficulties in using large models that incorporate RE for forecasting, although there has recently been significant advances in using DSGE models for forecasting at policy-making institutions (e.g., Riksbank, Norges Bank, Bank of Finland, Czech National Bank and the ECB).

Whilst rational expectation has been the dominant way to model expectation over the last forty years, the literature on learning goes back almost as far as the rational expectation literature. Early works on learning include Friedman (1975), Townsend (1978, 1983), Frydman (1982), Bray (1983) and Bray and Kreps (1984). These works focused almost exclusively on the stability properties of very small models, usually only one market. These models investigated a situation often referred to as 'rational learning' as it is assumed that agents know the true structure of the model being investigated but simply have to learn the parameter values. Given the extreme nature of the rational learning assumption the literature quickly moved to a more realist assumption of boundedly rational learning where agents are assumed to use only a limited set of information to form their expectations and do not know the complete structure of the model. Some early examples from this literature include DeCanio (1979), Radner (1982) and Bray and Savin (1986), and these examples focused on a case where the learning rule was the full reduced form of the model. Later papers began to use a learning rule which

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contained only a subset of the full set of reduced form variables and to define the idea of E-stability, when the parameters of the learning process converge to a fixed point (Evans, 1989; Evans and Honkapohja, 1994, 1995, 2001). Marcet and Sargent (1988, 1989) make the important link between E-stability and a conventional rational expectation equilibria (REE): when E-stability is attained the model has also reached a REE.

The learning literature (Evans, 1986; Woodford, 1990) has pointed out that often a particular learning specification will produce a unique solution and of course given the association of an E-equilibria with a REE, this implies that a particular REE is being chosen without recourse to these arbitrary transversality conditions. This illustrates that learning can bring positive advantages from an analytical standpoint. However it is important to note that if the specific form of the learning process produces different solutions then the choice between these solutions (and implicitly the corresponding REE) is still being made on the basis of a largely arbitrary decision. This motivates much of the argument presented in this paper that the choice of the form of the learning rule itself can be crucially important.

In the adaptive learning literature a standard assumption is that agents form expectations by using the correct model of the economy, but do not know the parameters (Evans and Honkapohja, 2001), i.e. agents have perfect knowledge about the structure of the economy and hence know the correct specification of the REE minimal state variable solution (MSV) (see McCallum, 1983). However, in contrast to the RE solution, they have imperfect knowledge about the true values of the structural parameters and the implied parameter values of the true MSV solution. Hence, although correctly specified, the perceived law of motion (PLM) that agents use in updating their expectations deviates from the true MSV solution. Instead, the adaptive learning literature assumes that agents act like econometricians by continuously re-estimating and updating the parameters of the PLM taking into account observed expectation errors and all new information. Under these assumptions the actual law of motion (ALM) gradually converges to the model consistent RE solution. However, as discussed e.g. by Slobodyan and Wouters (2009), the short- and medium-run dynamics of the model may crucially depend on how much the initial estimates of the parameters deviate from those of the RE solution and, hence, may introduce non-voluntary arbitrariness into the dynamics of the estimated model.

Much of the learning literature has focused on small, linear models where typically there is only one homogeneous/representative agent with a common information set (Milani, 2007, 2009, 2010) and, hence, the correctly specified MSV solution for the whole model can be easily derived. With large- and medium-sized models closed-form MSV solutions are difficult to attain given the large number of variables that could be included. Indeed, for non-linear models closed-form MSV solutions do not necessarily exist. Therefore, an alternative strand in the recent learning literature has been that, instead of basing their PLM on the correctly specified MSV, agents base it on a misspecified MSV solution. This approach in effect drops the assumption of common information set of rational agents that fully understand the world, and therefore is more in line with the literature of heterogeneous agents with incomplete knowledge and expectations. Although agents fail to recognise the full set of correlations, agents are still rational in the sense that they avoid systematic mistakes by being willing to learn from past mistakes and change their behaviour. Small model examples include Evans and Honkapohja (2003), and Dennis and Ravenna (2008). The larger the model the larger is the set of options among which to select a PLM. For example by including only a subset of variables or by including additional variables compared to the correctly specified MSV solution, then the selected PLM specification could be either under- or over-parameterised. A key question then becomes how to select from the various PLM when an obvious choice is not available. There has been a number of approaches to this, including choosing the explanatory variables that minimise the standard error of the regression, or ranking correlations according to their standard deviations, or identifying principal components and selecting the variables that mostly closely move with them (Beeby et al., 2004). More recently De Grauwe (2010) used a model in which agents use simple rules (heuristics) to forecast the future, but these rules are then subjected to selection mechanism, so agents endogenously select the forecasting rules that have delivered the greatest fitness in the past. Finally, an alternative approach is to do Bayesian averaging over a variety of PLM.

Our approach deviates from all the aforementioned approaches. The basic principle of our approach is that it is compatible with the same limited information assumption that was used in deriving and estimating the behavioural equations of different optimising agents. Hence, agents know the deep parameters of their own optimising frameworks, however, they are not assumed to know neither the structure nor the parameterisation of the rest of the economy. Neither do they know the stochastic processes generating shocks hitting the economy. Therefore, instead of basing their PLM on the correctly specified full model MSV, agents are assumed to base it on the single equation MSV where the fundament variable, although endogenous in the whole model, is treated as predetermined for the optimising agent. In addition, in line with the fact that most economic time series are I(1) variables, agents are assumed to know that the changes (or the growth rates) of fundament variables can be modelled as stationary ARMA(p,q) processes, the exact form of which is not, however, assumed to be known by agents. This suggests some form of heterogeneity of expectations, which could be due to cognitive limitations faced by agents in understanding the world, or that the observability of economic variables can be different across agents or that the costs of having full information are too large. This is also compatible with survey evidence showing clearly that expectations of aggregate economic variables differ across different sectors/agents, e.g. consumers and firms.

This approach implies that we avoid the conceptual difficulties encountered by DSGE models with adaptive learning based on the misspecified MSV, i.e. whilst the underlying specification and estimation of the typical DSGE model is effectively based on the optimisation of a single representative agent or a central planer who knows the structure of the whole model, the information set regarding the formation of learning is much more limited. Our approach, instead, is theoretically consistent as agents' local optimising decisions and future expectations are based on the same information set. It also avoids the complexities of dealing with a potential vast multitude of alternative misspecified PLMs.

In this paper we formalise this approach and apply it to a new multi-country model (NMCM) see Dieppe et al. (2012). The model can be characterised as an optimising agent – new Keynesian model – but in contrast to standard DSGE models, we assume limited-information and, as in De Grauwe (2010), it is more of a bottom-up approach as opposed to the standard DSGE top down approach where agents have full knowledge. In line with these limitations in the information base, all forward looking equations of the NMCM are estimated by the single equation instrumental variable method of GMM that requires rationality only under limited information.

In the following section we argue more formally that a single equation approach is more in line with the kind of bounded rationality assumed in the NMCM in defining the relevant information base for learning expectations than the approach based on the correctly specified reduced form of the whole model. Once we have presented the framework for the model and the implied estimation of the learning expectation equations, we study how the properties of the model differ from those obtained assuming perfect foresight (or model consistent) rational expectations. We further illustrate the implications by studying the impact of a fiscal policy expansion under learning expectations and under rational expectations, when the policy change is credibly announced or, alternatively, its exact nature is unannounced (or uncredibly announced). We find that the departure of learning expectations solution from the rational expectations solution has a strong impact on the short-run properties of the model whilst in