



Empirical calibration of adaptive learning[☆]



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ABSTRACT

Adaptive learning introduces persistence in the evolution of agents' beliefs over time, helping explain why economies present sluggish adjustments towards equilibrium. The pace of this learning process is directly determined by the gain parameter. We document and evaluate gain calibrations for a broad range of model specifications with macroeconomic data, also developing alternative approaches to the endogenous determination of time-varying gains in real-time. Our key findings are that learning gains are higher for inflation than for output growth and interest rates, and that calibrations to match survey forecasts are lower than those derived according to forecasting performance, suggesting some degree of bounded rationality in the speed with which agents update their beliefs.

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1. Introduction

The practice of modeling expectations through the use of adaptive learning in macroeconomic models has become increasingly popular in the recent applied literature.¹ By allowing persistence in the evolution of agents' beliefs over time,

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¹ For some time the literature on adaptive learning developed with a focus on the theoretical debate about the convergence of learning to rational expectations equilibria (see [Evans and Honkapohja, 2001](#)). The seminal contribution in the applied literature is [Sargent \(1999\)](#), with a study on the role of learning by the monetary authority in the evolution of US inflation rates, followed by [Marcet and Nicolini \(2003\)](#), who showed how learning can help explain the recurrence of hyperinflation episodes observed in several South-American countries during the 1980's. The literature that followed then unfolded into two main strands: policy-oriented studies of particular episodes of macroeconomic turmoil (mainly the US Great Inflation period during the 1970's; see, e.g., [Bullard and Eusepi, 2005](#); [Orphanides and Williams, 2005](#); [Primiceri, 2006](#); [Sargent et al., 2006](#); [Milani, 2008](#)); and business cycles modeling studies ([Williams, 2003](#); [Huang et al., 2009](#); [Chevillon et al., 2010](#); [Eusepi and Preston, 2011](#); [Slobodyan and Wouters, 2012](#); [Milani, 2007](#); [Milani, 2011](#); [Milani, 2014](#); [Ormeño and Molnár, 2015](#)).

adaptive learning provides an alternative² explanation for the common observation of inertia in the dynamics of macroeconomic variables. Importantly, the persistence introduced by learning is directly related to the calibration of the learning algorithm assumed to represent the process through which agents update their beliefs. The implementation of this recursive algorithm requires the pre-specification of a sequence of learning gain values, or of a mechanism through which these gains are determined in real-time. This paper is devoted to investigate this issue empirically, particularly aiming to provide a guide for applied researchers on plausible calibration values of the learning gain.

For applied purposes, the importance of the gain is related to its role in determining the statistical properties of the evolution of agents' beliefs. While adaptive learning establishes a new channel for the dynamic dissipation of structural and expectational shocks throughout the economy, the intensity of these effects is directly determined by the value of the learning gain. On one hand, higher gains can be associated with higher degrees of variability in agents' beliefs, which could ultimately improve the explanatory power of models with learning; on the other, it is under smaller gain values that learning becomes more sluggish, hence increasing the persistence of deviations from the equilibrium path.³

In this context, our main contribution in this paper is the documentation of plausible gain calibrations according to their quality in forecasting macroeconomic variables and in matching survey forecasts. Moreover, we explore different elements of interest for applied research, such as: several model specifications; a proper account of real-time data restrictions; alternative foundations for an endogenous determination of the gains; and different roles for the gains. Although our results indicate that the gain calibrations are sensitive to all of these features, one of our most important findings is that the gains should be allowed to differ for different variables requiring forecasting in order to reflect their own statistical properties. We also find that calibrations to match survey forecasts are found to be lower than those derived according to the forecasting performance, suggesting the existence of some degree of bounded rationality in the speed with which agents update their beliefs.

1.1. Approach and main results

In order to shed some light on the gain calibration issue we develop an empirical framework that mimics a real-time learning-to-forecast process. We document renewed numerical calibrations of the gains for empirical applications with US quarterly data on inflation, output growth, and interest rates. One key feature in our analysis is our coverage of a broad range of model specifications to represent agents' beliefs: we explore all possible combinations of the variables above in vector autoregressive (VAR) forecasting models with up to four lags. This is motivated in Section 3 by the pervasive possibilities of misspecification introduced by the adaptive learning approach, particularly with respect to agents' perceived laws of motion (PLM).⁴ Regarding the learning algorithm, our focus is on the least squares (LS) algorithm, which has received most of the attention in the literature.

Using such framework, detailed in Section 4, we conduct several gain calibration exercises covering data over the period from 1981 to 2012; data from earlier periods are used to initialize the learning algorithm and the calibrations. We segment the calibrations according to different assumptions in the determination of the learning gains, particularly with respect to the measure used for their selection and their variation over time. Regarding the selection measure, we distinguish between two alternatives depending on the reference data: actual-based calibrations are selected by maximizing the accuracy of the forecasts; survey-based calibration, instead, are selected by maximizing the resemblance of the learning-based forecasts to those obtained from surveys with professional forecasters.

These calibrations are documented in Section 5, where we find evidence of a great degree of heterogeneity in the gain calibrations, depending mainly on the variable forecasted and the lag length of the forecasting model. Inflation presented the highest gain calibrations, followed by output growth and interest rates, with maximum averaged values on VAR(1) models of about 0.11, 0.02, and 0.005, respectively; we associate inflation's prominence to a higher degree of non-stationarity in its determination, hence requiring a higher learning gain to track its time-varying properties. These calibrations then tended to decrease as the VAR lag order increased, which indicate that the non-stationarity captured by the higher gain values under the more restricted specifications can be due to model misspecification. Interestingly, the calibrations on the forecasting models of interest rates were found to be very small, suggesting that the real-time tracking provided by learning adds little predictive content to the estimates obtained in the pre-evaluation sample period.

Another key finding from the documented gain calibrations is that the actual-based approach leads to higher gain calibrations than the survey-based. As we discuss later, this result indicates that the professional forecasters learn at a slower

² Common extensions to add persistence in the standard framework of dynamic stochastic general equilibrium (DSGE) models include consumption habits, price indexation and adjustment costs (Christiano et al., 2005), or more directly through the introduction of persistent structural shocks (Smets and Wouters, 2007).

³ This is consistent with a well known trade-off between speed and accuracy of recursive estimation from the engineering literature: on one extreme, tracking can be slower than the system actual time variations, but with less noisy estimates; on the other extreme, tracking can be made as rapid as the time-varying context, but with estimates much more contaminated by noise (see Benveniste et al., 1990). On the link between gain values and the degree of variability in agents' beliefs see also Carceles-Poveda and Giannitsarou (2007).

⁴ It is important to note that although we are not evaluating the effects of learning within a particular structural model, our focus on multiple PLMs also allows us to obtain results that are useful for a wide range of applications of adaptive learning in macroeconomics; namely, we hope our results provide some guidance on plausible calibrations for the introduction of learning in models where agents are assumed to form expectations about the variables under analysis here.

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