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Long-run growth uncertainty

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ABSTRACT

Observed macroeconomic forecasts display a positive correlation between expectations of long-run growth of endogenous variables (e.g., output) and cyclical activity. Existing business cycle models appear inconsistent with the evidence. This paper presents a model of the business cycle in which households have imperfect knowledge of long-run growth rate of endogenous variables and continually learn about these growth rates. The model features comovement and mutual influence between households' growth expectations and market outcomes. It can replicate the evidence on growth forecasts and suggests that optimism and pessimism about long-run growth rates is a crucial ingredient in understanding business cycle fluctuations.

1. Introduction

Economic agents and policymakers in reality face uncertainty about the (unobserved) long-run growth rate of *endogenous* economic variables (e.g., income, aggregate output, and asset prices) analyzed in general equilibrium business cycle models. Agents' perceived long-run growth determines consumption and financial investment decisions as well as the formulation of monetary and fiscal policy by policymakers. Observed macroeconomic forecasts – documented in Section 2.1 – display gradual learning by economic agents that give rise to very persistent gaps between forecasts of long-run growth of endogenous variables and the corresponding trend growth estimate constructed, e.g., from the Hodrick–Prescott (HP) filter. More importantly, Section 2.2 demonstrates, for the first time to our knowledge, a *positive* correlation between expectations of long-run output growth (or output per hour growth) and detrended aggregate output, consumption, investment and hours.

Perhaps surprisingly, existing business cycle models – including full and imperfect information rational expectations (RE) models and adaptive learning (AL) models – do not consider this long-run growth uncertainty. These models, as explained later, appear inconsistent with the evidence mentioned above. The paper develops a real business cycle (RBC) model where agents have imperfect knowledge of the long-run growth rate of endogenous variables and continually learn about these growth rates. The model can replicate this evidence and suggest an important role for shifting long-run growth expectations in business cycle fluctuations.

Clearly, agents in full-information RE models have exact knowledge of the long-run growth rate. A separate class of models entertain weaker informational assumptions where agents are uncertain and learn about the *exogenous* (productivity) process, e.g., Edge et al. (2007) and Boz et al. (2011). However, this type of learning models do not produce persistent gaps between forecasts of long-run growth rate of endogenous variables and the actual long-run growth rates of

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these variables, as a consequence of RE. This suggests a separate role for learning of endogenous variables. Moreover, these models produce constant long-run growth forecasts which do not correlate with cyclical activity.[1]

A large class of models replace RE by AL and analyze the resulting empirical performance, such as Milani (2007) and Eusepi and Preston (2011). These AL models, however, assume that agents learn about detrended endogenous variables. We show that this widely adopted methodology in the AL literature effectively assumes that agents have *exact* knowledge about the long-run growth of endogenous variables (as under RE). Again, in this type of models, the long-run growth forecasts are constant and the correlation between long-run growth forecasts and cyclical activity is *zero* by construction, which is inconsistent with the evidence on long-run forecasts.

Our model differs from existing models by relaxing households' knowledge of the long-run growth of endogenous variables. Agents do not have sufficient information to derive the equilibrium mapping from primitives (e.g., preferences and technology) to the long-run growth rate of endogenous variables; instead they approximate the equilibrium mapping by extrapolating historical patterns in observed data. Their subjective beliefs may not be the same as the true equilibrium distribution. They forecast variables that are exogenous to their decision problems and make optimal economic decisions under their subjective beliefs, in line with Preston (2005, 2006), Eusepi and Preston (2011) and Adam and Marcet (2011).

During economic expansions (recessions), households tend to extrapolate from past observations and hence are optimistic (pessimistic) about long-run growth rates of the economy. Households make optimal economic decisions based on this optimism (pessimism). The resulting equilibrium outcomes reinforce agents' optimism (pessimism) about long-run growth rates. The self-referential property – comovement and mutual influence between the long-run growth expectations and market outcomes – is crucial to produce the positive correlation between long-run growth forecasts and cyclical activity present in the data.

The results of this paper are similar in spirit to Adam et al. (2015) which documents a positive correlation between stock price growth expectations (at different horizons) and price dividend ratio (which may be interpreted as detrended stock prices) in U.S. stock markets. They show RE asset pricing models tend to produce a negative correlation between expected returns and price dividend ratio. Taking their paper and ours together, learning about the (trend) growth of endogenous variables is the key to producing these positive correlations and in explaining phenomena that are puzzling from the viewpoint of RE. The interplay of growth expectations and market outcomes is crucial in explaining the boom-bust cycle in U.S. stock markets (see Adam et al., 2015), equity pricing facts in the U.S. (see Adam et al., 2016) and house prices in major industrialized economies (see Adam et al., 2012).

Our learning model suggests a crucial role for optimism and pessimism about long-run growth rates in understanding business cycle fluctuations. Business cycle models with RE usually rely on large exogenous shocks to reproduce salient features of cyclical fluctuations. This is viewed as unrealistic by many economists, e.g., Cochrane (1994) and Kocherlakota (2009). Learning strongly amplifies the response of aggregate activities to economic shocks. To match the HP-filtered output volatility in the data, our learning model requires 47% smaller standard deviation of productivity shocks relative to the RE version of the model. The relative volatility of growth rate of productivity shocks to output is 0.143 in the learning model, which is close to the value 0.131 estimated in Burnside et al. (1996). The learning model also (1) generates 119% and 50% higher standard deviation in hours and investment relative to the RE version of the model and is closer to the data, (2) produces positive comovement between consumption, investment, working hours and output, and (3) improves the internal propagation by producing the degree of positive autocorrelation observed in output growth as well as the growth of consumption, investment and hours present in the data.

The rest of the paper is organized as follows. Section 2 presents evidence on observed forecasts and Section 3 the model setup. Our learning model is described in Section 4 and the quantitative results are presented in Section 5. Section 6 shows that full and imperfect information RE models are inconsistent with this evidence. Section 7 shows that existing AL models appear inconsistent with the evidence. Section 8 concludes.

2. Observed macroeconomic forecasts and cyclical fluctuations

This section documents evidence on observed long-run growth forecasts and their positive comovement with cyclical macroeconomic variables that we seek to quantitatively replicate with our learning model.

2.1. Long-run growth forecasts

This section presents forecasts of the long-run growth rate of real gross domestic product (GDP) and real output per hour. In the left panel of Fig. 1, the solid line is the U.S. annual real GDP growth from 1991 to 2014. The dashed line is the HP-filtered trend output growth with a smoothing parameter of 100.[2] Three proxies for real-time forecasts of long-run output growth are also plotted. One proxy is the real-time potential output growth estimates prepared by the U.S. Council of Economic Advisors (CEA), reported in its annual Economic Report of the President (ERP) and published in January (or February) of each year.[3] The second

[1] An exception is the case when trend productivity growth contains a unit root, this correlation is then *counterfactually negative*; see Section 6.2.

[2] Edge et al. (2007) interpret the HP-filtered estimate as a long-run trend growth estimate.

[3] Potential output growth is viewed as output growth in the long-run. Therefore, the CEA also regards the estimates as the long-run growth forecasts in the annual ERP.