Discussion of Cogley and Nason's “Output Dynamics of Real-Business-Cycle Models”

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Abstract: This paper briefly summarizes “Output dynamics of Real Business Cycle Models” by T. Cogley and M. Nason. We show how they came to the conclusion that standard RBC models could not reproduce two stylized facts about GNP. We then discuss what we liked about the paper and show some of the impact it had on subsequent research.

Introduction

The main objective of the Cogley Nason paper is to determine whether the theoretical models on real-business-cycles (RBC) are consistent with the two following stylized facts on output growth:

1) “GNP growth is positively autocorrelated over short horizons and has weak and possibly insignificant negative autocorrelation over longer horizons” (Cogley and Nason, 1995).
2) “GNP appears to have an important trend-reverting component that has a hump-shaped impulse response function” (Cogley and Nason, 1995).

The authors demonstrate with their analysis that standard RBC models fail to reproduce autocorrelation function of output growth and impulse response functions of output to permanent and transitory shocks. Since they show that the internal propagation mechanisms of such models are rather weak, these results challenge the existing standard RBC models.

The paper by Cogley and Nason focuses on the periodicity of output, although this is only a part of the business-cycle phenomenon. Two other aspects of business cycles, namely co-movements of other variables and volatilities of series, are left out of the consideration. Hence the analysis doesn’t allow for comparison between the movements of output growth and movements of consumption and investment for example.

I. Stylized facts about Output Dynamics

The authors instigate their analysis by looking at the U.S. data on GNP growth, and check whether the stylized facts indeed are present in this data.

When looking at the autocorrelation function, the data follows the expected pattern and thus confirm the first stylized fact: Positive autocorrelation of the output growth at lags one and two and no significant autocorrelation at higher orders. Moreover, the spectral decomposition
of the variance of output growth has a peak that ranges from 2.33 to 7 years per cycle. This indicates that the largest part of output-growth fluctuates indeed at business cycles frequency, as defined by King and Rebelo (1999). They define the business cycle as “those fluctuations in economic time series that have periodicity of eight years or less”.

When looking at the impulse-response function, the authors confirm the second stylized fact: A hump shaped impulse response function of output for both, permanent and transitory shocks. They use the VAR technique developed by Blanchard and Quah (1989) to extract permanent and transitory shocks to GDP from the data. The use of this technique for such a decomposition is quite standard and is applied in many other studies, e.g. Benhabib and Wen (2004).

II. Real-Business-Cycle Models

The RBC models investigated in this paper are distinguishable by their different propagation mechanisms. First, the authors focus on propagation mechanisms based on capital accumulation and intertemporal substitution. Second, the authors investigate different types of adjustment lags or costs. ¹

II. a. Capital accumulation and intertemporal substitution

The typical economy in this first class of the author's selection of models consists of a representative individual whose aim it is to maximize an infinite sum of rewards stemming from a consumption-leisure decision.

Furthermore, there is a profit maximizing firm that produces a consumption good using a Cobb-Douglas production technology. Technological change happens through a constant growth in labor productivity plus a shock that affects this growth rate positively or negatively. This shock is thought of as a permanent one, since it durably affects the growth rate.

Finally, there is a government whose expenditures influence total demand. These expenditures also underlie a stochastic process and are high when technological progress is low, and vice-versa. This shock is temporary, since it affects the demand at a certain date. In the absence of shocks in future periods, demand returns to its usual level. The effect on output, however, is possibly somewhat longer lasting due to intertemporal substitution.

The authors now simulate these model economies. From the Blanchard Quah decomposition of GDP growth and hours worked, they have a series of 140 permanent and a series of 140 transitory shock terms affecting the economy between 1954:1 until 1988:4. They use the empirical variance of these series to draw 1000 series of each shock. These disturbances can

¹ The test methodology proposed by Cogley and Nason are later also applied in other literature e.g. in Benhabib and Wen (2004), thereby providing the existing literature with a useful tool.
be fed in the models to yield data on output growth for 1000 model economies, for each of which they calculate autocorrelation functions (ACF) and impulse-response functions (IRF).

Given these test simulations, Cogley and Nason would like to answer to following question: Do the model ACFs and IRFs correspond to what is observed in the data?

To be more precise, Cogley and Nason calculate a statistic that allows them to compare autocorrelations of order 1 to 8 of the growth rate and thus to test the first stylized fact. The hypotheses of their test are:

\[ H_0: \text{The model and the sample have the same ACF} \]
\[ H_a: \text{The Model and the sample do not have the same ACF} \]

None of the models under consideration exceeds a p-value of 5%; the null hypothesis is therefore rejected. This becomes more evident if one looks at the plot of the sample and model ACF (c.f. Figure 3 in the original paper). Whereas the sample is featured by positive and significant autocorrelations of the growth rate at lags one and two, the model is not able to reproduce this serial autocorrelation.

Moreover, when we look at the spectral decomposition of output growth, every frequency contributes to the variance of output growth with equal weight according to the model. The model is thus not able to generate business-cycle like growth rates.

Similarly to the ACF test, the authors test the IRF of the permanent and the transitory shock. While in two out of three models, the \( H_0 \) hypothesis cannot be rejected at a 5% level for the permanent shock, it is clearly rejected for the transitory shock in all of the three models. Indeed, the transitory shock in the simulations has only a very small impact on the growth rate of the output.

The authors interpret these results for the Christiano Eichenbaum (1992) model and explain why it fails to account for more interesting dynamics: If the technology shocks follow a random walk, then the total factor productivity also follows a random walk. A model that is able to reproduce the stylized facts would transform these uncorrelated events of total factor productivity growth into an output growth rate that is serially correlated. This does not happen.

As a matter of fact, the authors show that the impulse response function of the permanent shock can be decomposed into a shock and a propagation part. Yet, the propagation part is such that it does nearly not amplify or modify the permanent shocks.

Furthermore, the propagation part of the transitory shock can be shown to be simply a constant. The Christiano Eichenbaum Model does not propagate the transitory shocks at all. It simply attenuates them. Output dynamics of growth are therefore closely related to shock dynamics.

Finally, the authors ask the question of what external sources of dynamics would make the Christiano-Eichenbaum model pass the tests. The authors exhibit only one way: The
government spending shocks need to follow an AR (2) process, which conflicts with what is observed in the data. Moreover, the variance of the error terms needs to be 3.5 times higher than what is observed in the sample.

II. b. Gestation and employment lags and capital/labor adjustment costs

Since the models in this first class do not reproduce the stylized facts, the authors proceeded by testing a second type of models. This second type is featured by additional assumptions on the production function. Like before, they test whether these new model specifications can endogenously generate business-cycle dynamics in output and so improve propagation mechanisms.

First, the authors examine models with gestation lags (time-to-build models) and capital adjustment costs (q-theoretic models). The idea behind these models is to propagate shocks by spreading the response of investment over time. A time-to–build model assumes that it takes time (app. 3 quarters) to install new capital. The main assumption regarding q-theoretic models is that the marginal cost of installing new capital is an increasing function of the rate of investment. Both approaches do alter the flow of investment relative to the baseline model, but the change in the flow is small relative to the stock of capital. Consequently, gestation lags and capital adjustment costs would have to seriously affect investment in order to have significant impact on the short-term dynamics of capital. The capital stock is what matters for production, so gestation lags and capital adjustment costs do not generate serial correlation or business-cycle periodicity in output.

Second, the authors look at models that include employment lags and labor adjustment costs. They follow a similar logic as those with capital adjustment lags but are somehow more successful to reproduce the stylized facts.

One example of these kinds of model is the Burnside et al. (1993) employment lag model. Its authors assume that firms must choose the size of the labor force before observing the current state of the economy but they can vary the intensity of work effort after observing the current state. Effort adjustments are more costly (higher payments, lower marginal productivity) than employment adjustments. Therefore, when firms experience a positive technology shock, their optimal response is to spread labor adjustments over several periods. This helps to propagate shocks over time. A labor adjustment cost model assumes that marginal cost of adjusting employment is a linear function of its rate of change.

In contrast to the other models studied in the paper, employments lags and labor adjustment cost models endogenously generate autocorrelation in output growth. They thus pass the Cogley Nason (CN) test for the first stylized fact. Yet, they still fail the CN test for the second stylized fact: the models now overstate the short-term response of output to technology shocks and still understate its response to transitory shocks. Although the models generate the

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2 Quarterly net investment is only 0.4 percent of the capital stock, on average.
3 The labor adjustment model is an expansion of the q-theoretic model.
right qualitative response to transitory shocks, the authors conclude that it is strongly damped and much too small in magnitude. Thus, they must rely on implausibly large transitory shocks to match the large transitory impulse response found in the data.

III Discussion

What we like about this paper is the fact that it is an easily understandable paper that has had substantial impact on the literature of RBC models at that time. For example, more recent literature refers to the finding of Cogley and Nason as “the Cogley–Nason puzzle” (Barañano and Paz Moral, 2003) or “the Cogley-Nason criticism of RBC models” (Benhabib and Wen, 2004). Although their paper has been influential, Schmitt-Grohe (2000) claims that the discrepancy between actual and theoretical autocorrelation functions was first pointed out by King et al. (1988). Moreover, also others have criticized standard RBC models. For example Watson (1993) shows that the standard business cycle model is not able to generate fluctuations with hump-shaped spectra for aggregate growth rates observed in the U.S. economy. In accordance with the findings of Cogley and Nason, also Rotemberg and Woodford (1996), and Wen (1996) show that the standard model lacks an internal mechanism to propagate shocks, which leads to trivial dynamics.

This major criticism on standard RBC models has led to the development of more complex models which are consistent with the stylized facts, according to Fève and Matheron (2005). Such models extend the RBC models by including for example job search costs, factor hoarding, external increasing returns and indeterminacy, sticky wages, etc. (Fève and Matheron (2005). Although such extensions can improve the performance of the standard models, a major drawback is that the original models lose their simplicity.

As an example, a noticeable stream of research was conducted in direction of including labor hoarding (labor effort) and capacity utilization. The latter adjustment was inspired by the fact that data show a very low volatility of capital stock across business cycles (see Figure 1), i.e. not much more capital stock is used in expansion compared to contraction. This should clearly be taken with some precautions. (e.g. Business Survey Data show that capacity utilization follows a similar pattern as output growth). Burnside and Eichenbaum (1996) explored a model with capital utilization⁴ and labor hoarding (factor hoarding model). They showed that these two features significantly enhance the ability of the model to propagate shocks through time, and that it is also capable of producing a humped shape response technology shocks.

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⁴ They used electricity use as a proxy for capital utilization.
Last, in the stream of research motivated by this paper, Fève and Matheron (2005) showed that a simplified Kydland-Prescott (1982) can pass the CN test. Two changes were made with respect to original model. They relaxed the constraint of current and future leisure choices to be intertemporally substitutable\(^5\). Also, they added a transitory preference shock (labor wedges), instead of government expenditure shock\(^6\). A slightly different model specification, already available at that time, could have altered the Cogley and Nason findings. Yet again, the recentness of Fève and Matheron study is a nice example that CN test is still present in current macroeconomic research.

As to potential extensions of this line of research, it might be of some interest to perform a CN test for RBC models that examine explicitly industry and services. These two sectors proved to have somehow different dynamics across the business cycle. On the one hand, as estimated by Shapiro (1986), employment of production workers appears to be more cyclically sensitive than employment of non-production workers. On the other hand, adjustment costs for non-production workers are substantial while they are negligible for production workers.

Additionally, from the point of view of a macroeconomics student it would be nice to know why these models have been retained. In particular, throughout their work, the authors illustrate their points on the basis of the Christiano-Eichenbaum model. We wonder why the authors do not test the very influential Kydland Prescott 1982 model.

\(^5\) Their estimates show that labor supply is subject to strong intertemporal complementarities.
\(^6\) According to Fève and Matheron labor wedges shock is observationally equivalent to tax shock on labor income, or more generally, other distortions on the labor market. Additionally, they argue that transitory shocks are mainly needed for labor market fluctuations while technology shocks are much more important for output dynamics.
References


