Economic Modelling 46 (2015) 61–69

Contents lists available at ScienceDirect

Economic Modelling

journal homepage: www.elsevier.com/locate/ecmod

Real business-cycle model with habits: Empirical investigation

Natalia Khorunzhina *

Department of Economics, Copenhagen Business School, Denmark

ARTICLE INFO

Article history:
Accepted 19 December 2014
Available online xxxx

Keywords:
Real business cycles
Habit formation

ABSTRACT

This paper empirically investigates the ability of a real business-cycle model with nonseparabilities in consumption and leisure and external habits both in consumption and leisure to fit the postwar US data. The results indicate a strong but fast-dying habit in leisure, and a somewhat weaker but more persistent habit in consumption. Intratemporal nonseparabilities in consumption and leisure play an important role in driving the response of real variables to a productivity shock. Adding capital adjustment costs to the model with nonseparabilities in consumption and leisure and external habits both in consumption and leisure changes the responses of real variables to a productivity shock, however, in a way similar to that documented for the models with capital adjustment costs and habit formation in consumption. The estimated persistence of the productivity shock is quite modest, which may be the factor that drives a procyclical response of hours worked to the positive productivity shock even when habit in consumption is strong.

Since the influential works of Constantinides (1991), Campbell and Cochrane (1999), and Heaton (1995), the use of models with habit formation in consumption is common in macroeconomic and financial literature because of their ability to match both asset-pricing and business-cycle facts.[1] The use of habits in consumption, however, comes at a cost of producing the countercyclical response of hours worked to the positive productivity shock. Researchers have argued that mainly due to the presence of habit formation and capital adjustment costs, positive productivity shocks lead to an immediate decrease in hours worked (see Francis and Ramey, 2005; Smets and Wouters, 2007). The countercyclical response of hours worked to the positive productivity shock is at odds with the observed procyclicality of aggregate hours worked and the anticipated co-movement of consumption and hours worked in the same direction in response to technology shocks. Whereas some studies have argued that the empirical evidence on the effect of a productivity shock on the labor input can also support a positive impact (e.g., Christiano et al., 2005), the problem of the countercyclical response of hours worked to the positive productivity shock remains a valid drawback of habit-formation models.

Although macroeconomic literature routinely uses models with habit formation in consumption, it does not give equal attention to models with habit formation in leisure. Researchers have shown empirically that habit formation in leisure is non-negligible (e.g., Eichenbaum et al., 1988; Kennan, 1988); however, they have left largely unexplored the ability of models with habit formation in leisure to match business-cycle facts. When the model with preferences additively separable in consumption and leisure and with exogenous habits in both variables is put to test how agents adjust consumption and labor input in response to technology shocks, Lettau and Uhlig (2000) demonstrate that the results are in contrast to favorable properties of habit-formation models claimed by earlier studies. Consumption is extremely smooth and unresponsive to shocks, whereas labor input is counterfactually smooth over the cycle, and, as discussed earlier, might even be countercyclical. Uhlig (2007) indicates that habit-formation models coupled with intratemporal nonseparabilities in preferences between consumption and leisure have the potential to provide a better match to both the observed asset markets and basic macroeconomic statistics. However, how agents adjust consumption and labor input in response to technology shocks remains unclear when preferences contain external habit-formation and intratemporal nonseparabilities in consumption and leisure.

My objective is to extend this exercise by applying the model with external habits in both consumption and leisure and with intratemporal nonseparabilities in consumption and leisure similar to the one used in Uhlig (2007) directly to the postwar US data, and estimating its parameters using maximum likelihood. The parameter values calibrated in Uhlig (2007) provide good starting values for the optimization procedure. The estimated model fits the data well. The empirical results suggest that (i) both consumption and leisure appear to be strongly habit forming (the parameter of habit strength in consumption is 0.83, whereas the one for leisure is 0.96), and (ii) habit formation in consumption is estimated to be persistent, whereas habit in leisure is not.

I investigate whether the model with habits in consumption and leisure is capable of producing meaningful responses of real variables

* Tel.: +45 38152403.
E-mail address: nk.eco@cbs.dk.

[1] See Otrok et al. (2002) for challenging habit-formation models to provide a robust account for the equity premium puzzle.

http://dx.doi.org/10.1016/j.econmod.2014.12.020
0264-9993/

to a productivity shock. Using the estimated parameters, I conduct model simulations to investigate how the consumption and labor-input paths look when consumers choose consumption and hours worked optimally in response to a more fundamental shock in the presence of habit formation. The strength and persistence of the habit-formation process greatly influence the impulse responses of the real macroeconomic variables. Consistent with Christiano et al. (2005), I obtain the hump-shaped response of consumption to a productivity shock. Including habit formation in leisure allows for augmenting the immediate effect realized because of a strong but fast-dying habit in leisure with a somewhat weaker but more persistent effect of habit in consumption. Ignoring habit in consumption while allowing for habit in leisure can generate responses of real variables similar to those that we observe in the full model. Interestingly, it is possible to obtain the hump-shaped response of consumption as in Christiano et al. (2005) by allowing for habit formation in leisure only. This result is driven by the complementarity effect of consumption and leisure. The next experiment examines how the findings change with the inclusion of capital adjustment costs in the model. Once the model is augmented with capital adjustment costs, the responses of real variables to a productivity shock change dramatically, with the key result that hours worked immediately decline in response to a positive productivity shock. The negative reaction of labor input in the model with adjustment cost disappears once habit in consumption is ruled out but habit in leisure remains. These findings suggest that in the presence of nonseparabilities in consumption and leisure, habit in leisure is an important model feature for a procyclical response of hours worked to a positive productivity shock; however, it may not be strong enough to counteract a substantial instantaneous negative impact of a combination of habit in consumption and adjustment cost on labor input.

Along with joint estimation of the parameters of the strength and persistence of habits in leisure and consumption, I also estimate other standard parameters of real business-cycle models, including the persistence of the productivity shock. The estimated persistence of the shock is moderate, similar to the value found in Otrok (2001). I show that it is possible to obtain a positive reaction of hours worked after a positive productivity shock, if the shock is not too persistent, even with a strong habit formation in consumption or a high adjustment cost of investment, but not with a combination of those. Further, I find that the persistence parameter of the productivity shock is one of the important factors that determines the sign of the effect of hours worked on the positive productivity shock.

The plan of the paper is as follows. Section 1 describes the model. Section 2 outlines the estimation procedure. Section 3 discusses results and examines the business-cycle implications for the model. Section 4 concludes.

1. Model

The infinitely lived representative household has preferences described by the expected utility function:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \frac{\left((\mathrm{C}_t - \mathrm{H}_t)\left(a + (\mathrm{L}_t - \mathrm{F}_t)^{\nu}\right)\right)^{1-\gamma} - 1}{1-\gamma}, \quad (1)$$

where a, ν, and γ are parameters satisfying $\nu > 0, \gamma > \nu/(\nu+1)$ to ensure monotonicity and concavity on the domain, and $0 < \beta < 1$ is a discount factor. C_t and L_t denote consumption and leisure of the representative household, and H_t and F_t are exogenous habits in consumption and leisure, respectively. The representative household maximizes its preferences over the choice of consumption and leisure, taking as given exogenous habits that evolve according to

$$\mathrm{H}_{t+1} = (1-\zeta)\phi C_t + \zeta \mathrm{H}_t, \quad (2)$$

$$\mathrm{F}_{t+1} = (1-\xi)\varphi \mathrm{L}_t + \xi \mathrm{F}_t, \quad (3)$$

where $0 < \zeta < 1$ and $0 < \xi < 1$ are the persistence parameters, and ϕ and φ are habit-strength parameters on consumption and leisure accordingly.

The representative household is endowed with initial capital and one unit of time per period to be used as leisure (L) or labor (N):

$$1 = \mathrm{L}_t + \mathrm{N}_t. \quad (4)$$

The economy consists of a large number of identical, price-taking firms that hire labor (N) and rent capital (K) from households, and produce output (Y) according to the Cobb–Douglas technology:

$$\mathrm{Y}_t = \mathrm{K}_t^{\alpha}(\mathrm{Z}_t \mathrm{N}_t)^{1-\alpha}, \quad (5)$$

where $0 < \alpha < 1$. The technological innovation $\mathrm{Z}_t = e^{gt}e^{z_t}$ grows at rate g at steady state, and its stochastic fluctuations around the growth path are assumed to follow an AR(1) process:

$$z_t = \rho z_{t-1} + \varepsilon_t, \quad (6)$$

where $0 < \rho < 1$ and ε_t are i.i.d. $\mathcal{N}\left(0, \sigma_\varepsilon^2\right)$. Output is divided among consumption (C) and investment (I), with the latter being used to finance next-period capital for the firms:

$$\mathrm{Y}_t = \mathrm{C}_t + \mathrm{I}_t \quad (7)$$

$$\mathrm{K}_{t+1} = (1-\delta)\mathrm{K}_t + \mathrm{I}_t, \quad (8)$$

where $0 < \delta < 1$ denotes the depreciation rate.

One can show that there exists a steady state in the detrended variables. I transform the variables as $c_t = \ln\left(\mathrm{C}_t/\overline{\mathrm{C}}\right)$ and similarly, h_t, y_t, k_t, i_t, l_t, f_t, and n_t, where bars denote steady states. To analyze the dynamic implications of the model, I log-linearize the system of equations characterizing the equilibrium. The linearized equations can be solved using the method developed by Sims (2001). The state of the economy is given by the vector $[h_t, f_t, k_t, z_t]$. The solution for the dynamic system is a linear vector function Ψ, such that $[y_t, c_t, i_t, n_t, l_t, h_{t+1}, f_{t+1}, k_{t+1}] = \Psi([h_t, f_t, k_t, z_t])$.

2. Estimation procedure

To estimate the model, I use quarterly US data, drawn from the Federal Reserve Bank of St. Louis' FRED website. The sample period runs from 1948:I through 2004:IV. Data on real personal consumption expenditures in chained 2000 dollars provide the measure of C. Data on real gross private investment in chained 2000 dollars provide the measure of I. Data on hours worked by all persons in the nonfarm business sector provide the measure of N. All data series are seasonally adjusted, expressed in per capita terms, and HP-filtered. I construct three observable stationary variables: hours worked, the growth rate of aggregate consumption, and the growth rate of aggregate investment.

I estimate the model's structural parameters via maximum likelihood using the Kalman filtering algorithm. I link the behavior of three observable series on consumption, investment, and hours worked to a vector of unobservable state variables that assumes a single structural shock. To incorporate additional shocks, I allow for measurement errors in the observable series. Following Sargent (1989) and Ireland (2004), I impose serial correlation on the measurement errors in the observable data:

$$u_{jt} = \rho_j u_{jt-1} + {}_{jt}, \quad E\left(jt\,{}^{t}jt\right) = \sigma_j^2, \quad j = c, i, n,$$

where ϵ_{ct}, ϵ_{it}, and ϵ_{nt} are mutually orthogonal white noises with variances chosen to yield standard deviations of u_{ct}, u_{it}, and u_{nt} indicating the presence of moderate measurement error in the observed data. The estimation results reveal that the structural parameter estimates do