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Real Business Cycles Theory

Research on economic fluctuations has progressed rapidly since Robert Lucas revived the profession's interest in business cycle theory**.** Business cycle theory is the theory of the nature and causes of economic fluctuations

The new Classical paradigm tried to account for the existence of cycles in perfectly competitive economies with rational expectations. It emphasized the role of imperfect information, and saw nominal shocks, in the form of monetary misperceptions, as the cause of cycles.

The new Classical theory posed a challenge to Keynesian economics and stimulated the development of both the New Keynesian economics and RBC theory.

Keynesian economics has generally accepted the idea of rational expectations, but emphasizes the importance of imperfect competition, costly price adjustment and externalities and considers nominal shocks as predominant impulse mechanism.

RBC theory views cycles as arising in frictionless, perfectly competitive economies with generally complete markets subject to real shocks. RBC models demonstrate that, even in such environments, cycles can arise through the reactions of optimizing agents to real disturbances, such as random changes in technology or productivity. Coordination failures, price stickiness, waves of optimism or pessimism, monetary policy, or government policy generally are not needed to account for business cycles.

Further more, such models are capable of mimicking the most important empirical regularities displayed by business cycles.

In this part of course, I will describe the background of RBC theory, the key features of RBC models and outlines a simple, prototype RBC model.

The strongest criticisms to RBC models are first, there is no independent corroborating evidence for the large technology shocks that are assumed to drive business cycles and second, RBC models have difficulty in accounting for the dynamic properties of output because the propagation mechanisms they employ are generally weak. Thus, while RBC models can generate cycles, these are, as a general rule, not like the cycles observed.

I) Some Facts about Economic Fluctuations

Business cycles vary considerably in terms of amplitude and duration, and no two cycles appear to be exactly alike. Nevertheless, these cycles also contain qualitative features or regularities that persistently manifest themselves. The one very regular feature of these fluctuations is the way variables move together. Cooley and Prescott[1] report some features of the business cycle based on U.S time series:

- The magnitude of fluctuations in output and aggregate hours of work are nearly equal.

[1] Thomas F. Cooley and Edward C. Prescott 1995."Economic Growth and Business Cycles." Frontiers of Business Cycle Research. Princeton University Press.

- Employment fluctuates almost as much as output, while overage weekly hours fluctuate considerably less.
- Consumption of nondurables and services is smooth, fluctuating much less than output.
- Investment, or production of durables generally, is far more volatile that output.
- The capital stock much less variable than output and is largely uncorrelated with output.
- Productivity is slightly procyclical but varies considerably less than output.
- Wages vary less than productivity.
- The correlation between average hourly compensation and output is essentially zero.
- Government expenditures are essentially uncorrelated with output.
- Imports are more strongly procyclical than exports.

Other features of the business cycle are:

- Output movements in different sectors of the economy exhibit a high degree of coherence;

- Velocity of money is counter cyclical in most countries, and there is considerable variation in the correlation between monetary aggregates and output. Long term interest are less volatile than short-term interest rates, and the latter are nearly always positively correlated with output, but the correlation of longer-term rates with output is often negative or close to zero.
- Prices appear to be counter cyclical.

II) The Basic Real Business Cycles Model

The neoclassical model of capital accumulation, augmented by shocks to productivity, is the basic framework for RBC analysis. RBC theorists contend that the same theory that explains long-run growth should also explain business cycles. Thus, RBC theory can be seen as a development of the neoclassical growth theory of the 1950s.

1) The basic Features of Real Business Cycle Models are:

- They adopt a representative agent framework, on a representative firm and household.
- Firms and households optimize explicit objective functions, subject to the resource and technology constraints that they face.

- The cycle is driven by exogenous shocks to technology that shift production function up or down. The impact of these shocks on output is amplified by intertemporal substitution of leisure; a rise in productivity raises the cost of leisure, causing employment to increase.
- All agents have rational expectations and there is continuous market clearing. There are complete markets and no informational asymmetries.

2) The Model

The economy consists of a large number of identical, price taking firms and a large number of identical, price taking, households, which are infinitely lived.

1) The representative household maximises the expected value of

$$U = \sum_{t=0}^{\infty} \beta^t U(c_t, 1 - l_t)$$

U(.) is the instantaneous utility function of the representative household, and $0<\beta<1$ is the discount factor. The instantaneous utility has two arguments. Consumption per member of the household, c, and leisure per member which is the difference between the time endowment per member (normalized to 1 for simplicity) and the amount each member works, l_t.
Notice that for simplicity it has been assumed that the household's utility function is separable between c and $1- l_t$. This implies that the marginal utility of consumption does not depend on leisure and vice versa.
For simplicity, U (.) is log-linear in the two arguments:

$$U_t = \ln c_t + \theta \ln(1 - l_t) \qquad \theta > 0,$$

2) The inputs to production are capital, (K), labour (L), and technology (A). The production function is Cobb-Douglas, and output in period t is:

$$Y_t = K_t^{1-\alpha}(A_t L_t)^{\alpha} \qquad 0 < \alpha < 1$$

The resource constraint: output is divided among consumption (C), and investment (I).

$$C_t + I_t = Y_t$$

The low of motion of capital is:

$$k_{t+1} = (1 - \delta)k_t + i_t$$

3) First generation of RBC theory regards stochastic fluctuations in factor productivity as the predominant source of fluctuations in economic activity. Exogenous productivity shocks are the only impulse mechanism that these models originally incorporated.
It is this emphasis on productivity changes as the predominant source of cyclical activity that distinguishes these models from their predecessors and rivals. In particular, the

absence of a role for demand-side innovations coupled with the assumption of competitive markets marks a clear break from the traditional Keynesian theory where changes in investment spending are the main determinants of output in the short run.

- The model assumes that the technology evolves as a random walk with drift :

$$\ln A_t = \ln A_{t-1} + g + \varepsilon_{at}$$
$$\varepsilon_{at} \rightarrow (0, \sigma^2)$$

Where g is the rate of technology progress, and ε_{at} represents a technology shock and it is white nose disturbances.

- The importance of exogenous productivity changes in economic theory can be traced to the seminal work of Robert Solow (1956,1957) on the neoclassical growth model that appeared in the 1950s.
- However, it's Solow's work on estimating the sources of economic growth that has proved most influential in the RBC literature. If markets are competitive and there exist constant returns to scale, then the growth of output from the aggregate production function is:

$$g_y = \alpha g_l + (1-\alpha) g_k + z$$

- Where g_y, g_l and g_k are the growth rates of output, labour, and capital respectively, α is the relative share of output of labour, and z measures the growth in output that cannot be accounted for by growth in labour and capital. Thus z represents multifactor productivity growth and has been dubbed the Solow residual.
- The SR has accounted for approximately half the growth in output in the USA. This residual is not constant, but fluctuates significantly over time. It is well described as a random walk with drift plus some serially uncorrelated measurement error.

3) Computing equilibrium:

a) Firms maximize their profits

- The firm rents capital and hire labour in each period.

$$\underset{K_t, L_t}{Max} \left[K_t^{1-\alpha} (A_t L_t)^{\alpha} - rK_t - wL_t \right] \qquad \forall t$$

$$w_t = \alpha \left(\frac{K_t}{A_t L_t} \right)^{1-\alpha} A_t,$$

$$r_t = (1-\alpha) \left(\frac{A_t L_t}{K_t} \right)^{\alpha}$$

Firm maximises its profit, labour and capital are paid their marginal products. Given constant returns to scale, in equilibrium profits will be equal to zero.

b) The household maximizes its utility subject to the resources constraint

Household will choose consumption, investment, and hours of work at each date to maximize the expected discounted value of utility, given their expectations over future prices subject to sequences of budget constraints and the law of motion for the household's capital stock:

$$\max_{c_t, l_t, i_t} E\left[\sum_{t=0}^{\infty} \beta^t U(c_t, 1 - l_t)\right]$$

$$\text{s.t} \qquad c_t + i_t \leq w_t l_t + r_t k_t$$

$$k_{t+1} = (1 - \delta) k_t + i_t$$

The Lagrange is :

$$\underline{\ell} = E_t \beta^t \left\{ \ln c_t + \theta \ln(1 - l_t) + \lambda_t (k_t^{1-\alpha} (A_t l_t)^{\alpha} - c_t - k_{t+1} + (1 - \delta) k_t) \right\}$$

$$c_t : \qquad \frac{1}{c_t} - \lambda_t = o$$

$$l_t : \qquad \frac{-\theta}{1 - l_t} + \alpha \lambda_t \frac{Y_t}{l_t} = o$$

$$k_{t+1} : \qquad -\lambda_t + E_t \left(\lambda_{t+1} \frac{Y_{t+1}}{k_{t+1}} + (1 - \delta) \right) = 0$$

$$\lambda \qquad Y_t - c_t - i_t = 0$$

c) The consistency of individual and aggregate decisions, that is the conditions:

$c = C$, $i = I_t$, $k = K$, $l = L$

d) The aggregate resource constraint: $C + I = Y$

4) Resolution of the model

The steady state rates of growth of consumption, output, investment and capital per capita are all equal to the growth rate of labour augmenting technical progress. Since time devoted to work is bounded by the endowment, it cannot grow in the steady state. In order to solve this problem, four steps are necessary:

- Transform the problem so that the solution is stationary over time. The following change of variables achieves this purpose:

$$\hat{C}_t = \frac{C_t}{A_t}, \quad \hat{Y}_t = \frac{Y_t}{A_t}, \quad \hat{I}_t = \frac{I_t}{A_t}, \text{and} \quad \hat{K}_t = \frac{K_t}{A_{t-1}}$$

- Compute the steady state values: chocks are equal to zero and we eliminate the tine index.

$$K_t = K_{t+1} = \ldots = K$$
$$C_t = C_{t+1} = \ldots = C\ldots$$

- A linear approximation of the F.O.C of the choice problem about the steady state. This yields a set of linear difference equations.

$$f(x') = f(x) + f'(x)(x' - x) + \ldots$$

- Resolution of the dynamic linear problem.

5) Calibration

The basic idea in the RBC literature is to use long-run evidence and microeconomic estimates to calibrate the parameters of the model. Typical estimates for the share of labour in output are $\alpha = 2/3$, for the quarterly rate of physical depreciation are $\delta = 0.025$ and for the discount factor across one quarter, $\beta = 0.99$. The growth rate $g = 1.004$. Based of the average division of time between work and leisure, $\theta = 2$. Given a value for α and time series data on Y_t , K_t , and L_t it is possible to back-out the Solow residual:

$$\ln Y_t = (1-\alpha)\ln K_t + \alpha \ln L_t + \alpha \ln A_t$$
$$\Rightarrow \ln A_t = \frac{1}{\alpha} Y_t - \frac{1-\alpha}{\alpha} \ln K_t - \ln L_t$$

Using this residual time series, one can estimate the technology shock process described above.

Given this calibration and a computer program which solves the model, we can compute the impulse response function of various aggregates, and the correlations and relative comovements of the aggregate variables implies by the model and compare them with those in the real economy.

III) Implications

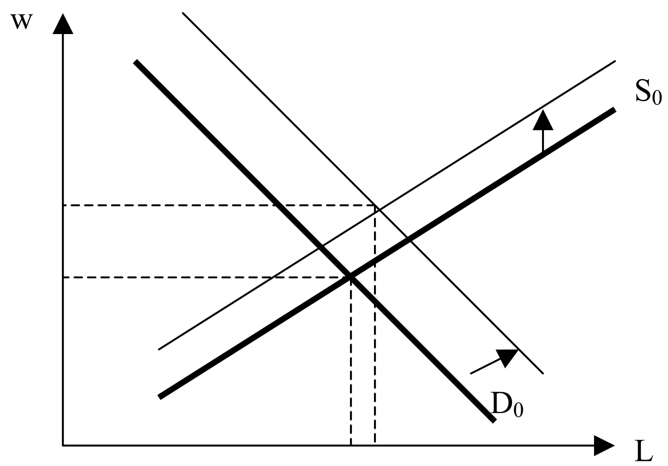
- RBC models replicate the relative volatilities of consumption, investment and output observed in the data.

- One labor market regularity that poses problems for RBC models is the so-called ‘‘ productivity puzzle.” If productivity shocks drive the cycle, employment and productivity would be highly correlated, and this is exactly what RBC models predict, usually the correlation between hours and productivity in theses models is above 0.9. In reality, productivity and employment are negatively correlated for most economies. For the U.S the correlation is roughly zero.

- They predict very strong procyclicality of wage and not enough procyclicality of employment. In reality, employment (or total hour worked) is almost as variable as output, and strongly procyclical, while real wages are at best mildly procyclical.

If most shocks hitting the economy shift the production function and alter the marginal product of labour then, ceteris paribus, the shifts in labour demand should trace out an upward-sloping labour supply function in real wage-employment space. Because micro studies suggest that the wage elasticity of labour supply is low, much of the adjustment to a productivity shock should be borne by wages, rather than employment.
To understand this recalls that the improvement in technology has two effects in the labour market:

- it increases the marginal product of labour, thereby shifting the labour demand curve out
- it raises current consumption (if the wealth effect dominates), causing the labour supply curve to shift in.
- The net result depends on the relative shifts in these two curves



If the demand curve shift dominate, then equilibrium employment and hence output tend to rise. If the supply curve shift dominates then employment will tend to fall, offsetting the increase in output caused by A. Obviously, to fit the facts on procyclicality of employment one would like the demand curve shift to dominate. However, note that in either case wage are going to be strongly procyclical, since both shifts cause wage to rise.

- In a world where cycles are caused by productivity shocks, the correlation between productivity and output should be high. In reality the correlation is moderate for most economies, for the U.S. estimates range from 0.4 0.6 depending on the sample period. In many RBC models, the correlation is 0.9

- Labour's share of income moves countracyclically over the cycle. However, if technology is Cobb-Douglas, labor's share is constant over the cycle.

- Finally, there is no unemployment in RBC models. Even where RBC models do succeed in accommodating unemployment, it is always voluntary.

IV) Extensions

- In RBC models, technology shocks are assumed to a) affect all sectors of the economy equally, and b) to affect the productivity of all factors of production equally, regardless of the vintage of capital or the age and skill levels of labor. If productivity innovations primarily affect only a particular sector, one must consider a multisectoral economy that produces many heterogeneous goods.

- RBC assumption is productivity shocks are exogenous and uninfluenced by other economic factors. Charles L.Evans[2](1992), demonstrates that money, interest rates, and government spending Granger cause Solow residual, and between one quarter and one half of the variance of the productivity impulse can be attributed to aggregate demand shocks. Hence the measured aggregate productivity impulses do not behave as a strictly exogenous stochastic process. These findings indicate the role of productivity shocks in generating economic fluctuations has been overstated in the RBC literature.

- In the standard competitive model, labor effort is implicitly assumed to be constant level, and therefore, independent of the wage level. The wage is set in the market.
- A crucial feature of preferences is the non-time separable utility function that admits greater intertemporal substitution of leisure. Gary Hansen (1985): worker is constrained to work for a fixed amount of time or not at all, so that all changes in hours are brought about a by changing employment. Because the length of the

[2] Charles L.Evans[2] " Productivity shocks and real business cycles" Journal of monetary Economics 29 (1992):

working is fixed, the marginal utility of leisure is constant. In this case the marginal benefit of working cannot be brought into equality each period by adjusting labor supply smoothly between periods. Under these circumstances, a representative agent will want to work as much as possible when the wage is high, so that the economy as a hole behaves like a hypothetical agent with infinite elasticity of substitution of leisure, even though individual agents have diminishing marginal utility of leisure. In presence of this non-convexity in labor supply, the variability of hours rises considerably: indeed, in this model hours turn out to be far more variable relative to productivity than in the U.S. economy.

- Jang-Ok cho and thomas Cooley (1988) address this problem by allowing agents to decide both on hours and whether to participate in the labor force at all. This extension improves the performance of the model in some areas. In particular, the ratio of the standard deviation of aggregate hours to the standard deviation of productivity produced by the model is virtually identical to that found in American data, around 1.4, whereas in Hansen's model the figure is around 2.7, because hours are so volatile in his framework.

- Cogley and Nason(1995)[3] found that many RBC models have weak endogenous propagation mechanisms and do not generate observed output dynamic via their internal structure. The output dynamics are:
    - GNP growth is positively autocorrelated over short horizons and has weak and insignificant negative autocorrelations over longer horizons.
    - In response to a permanent shock, output rises gradually and reaches a plateau after about six years.
    - In response to a transitory shock, output rises for a few quarters and then returns to its stochastic trend. This means that a substantial portion of the variation in output growth is due to transitory fluctuations.

- This has lead to the development of models where nominal rigidity is assumed and technology shocks are supplemented by additional disturbances like monetary and government policy actions.

- These papers consider (1) monetary shocks that affect output through price misperception in a Lucas (1972) informational "island" framework; (2) a cash-in-advance constraint on the purchase of consumption goods, so inflation acts as a tax on consumption
- RBC models that incorporate some nominal rigidity are important for two reasons. First, their properties suggest that nominal rigidity may well be an important missing element in standard RBC models. Second, such models introduce important Keynesian features into RBC model analysis. They consequently bridge the dichotomy between two very different schools of thought in macroeconomics.

[3] Timothy Cogley and James M.Nason (1995), " output Dynamics in real Business Cycle Models", The American Economic Review, Vol.85 N0.3