Simulating a Simple Real Business Cycle Model using Excel

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Abstract

Simulating the real business cycle models is a popular topic in first-year graduate courses on macroeconomics. Usually, Maple and Matlab are used for this purpose, mainly because they can be used both for solving and for simulating the models. Strulik (2004) demonstrates that Excel can be used both for solving and for simulating a standard RBC model. In this paper, we propose a more elementary approach that might be suitable for undergraduate courses. We illustrate (i) how to solve a simple RBC model by hand and (ii) how to use Excel to simulate the solution.

Introduction

Simulating the real business cycle models (Kydland and Prescott, 1982; Long and Plosser, 1983) is a popular topic in first-year graduate courses on macroeconomics. Usually, Maple and Matlab are used for this purpose, mainly because they can be used both for solving and for simulating the models. Strulik (2004) demonstrates that Excel can be used both for solving and for simulating a standard RBC model.

In this paper, we propose a more elementary approach that might be suitable for undergraduate courses. We illustrate (i) how to solve a simple RBC model by hand and (ii) how to use Excel to simulate the solution.

A simple real business cycle model

Let $\alpha, \beta, \gamma, \delta, \rho \in (0,1)$ and z0, k0, $\sigma \in \Re+$ be given. Let $\{\varepsilon_t\}_{t=1}^{\infty}$ and $\{z_t\}_{t=1}^{\infty}$ be stochastic processes such that for each t, ε_t is an *i.i.d.* drawn (at the beginning of period t) from the normal distribution $N(0,\sigma^2)$, and z_t is a random variable defined by

$$\log z_t = \rho \log z_{t-1} + \varepsilon_t.$$

Then, consider the problem of choosing a 'plan' $\{(c_t, l_t, k_t)\}_{t=0}^{\infty}$ that maximises the expected value (evaluated at the end of period 0) of

$$\sum_{t=0}^{\infty} \beta^t \left[\log c_t + \gamma \log(1 - l_t)\right]$$

subject to

$$c_t + k_{t+1} \le z_t k_t^{\alpha} l_t^{1-\alpha} + (1-\delta)k_t \text{ for } t = 0, 1, 2,$$

The first order conditions to this problem are given by

(1) $$\frac{1}{c_t} = \beta E_t\left[\frac{\alpha z_{t+1} k_{t+1}^{\alpha-1} l_{t+1}^{1-\alpha} + 1 - \delta}{c_{t+1}}\right],$$

(2) $$c_t + k_{t+1} = z_t k_t^{\alpha} l_t^{1-\alpha} + (1-\delta)k_t,$$

(3) $$\frac{\gamma}{1-l_t} = \frac{(1-\alpha)z_t k_t^{\alpha} l_t^{-\alpha}}{c_t},$$

(4) $$\log z_{t+1} = \rho \log z_t + \varepsilon_{t+1} \quad .$$

where $E_t[X]$ represents the expected value of the random variable X evaluated at the end of period t.

We linearise (1)-(4) around the 'deterministic steady-state' (c, l, k, z) defined by

$$\frac{1}{c} = \beta \cdot \frac{1 - \delta + \alpha z k^{\alpha-1} l^{1-\alpha}}{c},$$

$$c + k = (1-\delta)k + z k^{\alpha} l^{1-\alpha},$$

$$\frac{\gamma}{1-l} = \frac{(1-\alpha)z k^{\alpha} l^{-\alpha}}{c},$$

$$\log z = \rho \log z.$$

From these equations, we get

$$\frac{k}{l} = \left(\frac{\alpha}{\frac{1}{\beta} - 1 + \delta}\right)^{\frac{1}{1-\alpha}} = \frac{(1-\alpha)\left(\frac{k}{l}\right)^{\alpha}}{\left(\left(\frac{k}{l}\right)^{\alpha} - \delta\left(\frac{k}{l}\right)\right)\gamma + (1-\alpha)\left(\frac{k}{l}\right)^{\alpha}},$$

$$c = \frac{(1-\alpha)\left(\frac{k}{l}\right)^{\alpha}(1-l)}{\gamma},$$

$$k = \frac{l\left(\frac{k}{l}\right)^{\alpha} - c}{\delta},$$

$$z = 1 .$$

By linearising (1)–(4) around (c, l, k, z), we get

$$(5)\quad -\frac{1}{c}\cdot\hat{c}_t = -\frac{\beta(1-\delta+\alpha z k^{\alpha-1}l^{1-\alpha})}{c}\cdot E_t\left[\hat{c}_{t+1}\right] + \frac{\beta(1-\alpha)\alpha z k^{\alpha-1}l^{1-\alpha}}{c}\cdot E_t\left[\hat{l}_{t+1}\right]$$

$$+\frac{\beta(\alpha-1)\alpha z k^{\alpha-1}l^{1-\alpha}}{c}\cdot\hat{k}_{t+1} + \frac{\beta\alpha z k^{\alpha-1}l^{1-\alpha}}{c}\cdot E_t\left[\hat{z}_{t+1}\right] ,$$

$$(6)\quad c\hat{c}_t + k\hat{k}_{t+1} = (1-\alpha)zk^{\alpha}l^{1-\alpha}\cdot\hat{l}_t + \frac{k}{\beta}\cdot\hat{k}_t + zk^{\alpha}l^{1-\alpha}\cdot\hat{z}_t ,$$

$$(7)\quad -\frac{\gamma l}{(1-l)^2}\cdot\hat{l}_t = -\frac{(1-\alpha)zk^{\alpha}l^{-\alpha}}{c}\cdot\hat{c}_t + \frac{\alpha(1-\alpha)zk^{\alpha}l^{-\alpha}}{c}\cdot\hat{k}_t$$

$$-\frac{\alpha(1-\alpha)zk^{\alpha}l^{-\alpha}}{c}\cdot\hat{l}_t + \frac{(1-\alpha)zk^{\alpha}l^{-\alpha}}{c}\cdot\hat{z}_t ,$$

$$(8)\quad \hat{z}_{t+1} = \rho\hat{z}_t + \varepsilon_{t+1} ,$$

where $\hat{c}_t \equiv \frac{c_t - c}{c}$, $\hat{l}_t \equiv \frac{l_t - l}{l}$, $\hat{k}_t \equiv \frac{k_t - k}{k}$, and $\hat{z}_t \equiv \frac{z_t - z}{z}$.
From (7), we get

$$\hat{l}_t = \frac{-\frac{(1-\alpha)zk^{\alpha}l^{-\alpha}}{c}\cdot\hat{c}_t + \frac{\alpha(1-\alpha)zk^{\alpha}l^{-\alpha}}{c}\cdot\hat{k}_t + \frac{(1-\alpha)zk^{\alpha}l^{-\alpha}}{c}\cdot\hat{z}_t}{\frac{\alpha(1-\alpha)zk^{\alpha}l^{-\alpha}}{c} - \frac{\gamma l}{(1-l)^2}} .$$

Thus, we can use it to eliminate $\hat{l}_t$ and $\hat{l}_{t-1}$ from (5) and (6). Then, (5), (6) and (8) can be written in a matrix form as

$$(9)\quad \begin{bmatrix} a_{11} & 0 & 0 \\ a_{21} & a_{22} & a_{23} \\ 0 & 0 & a_{33} \end{bmatrix}\begin{bmatrix}\hat{c}_t \\ \hat{k}_t \\ \hat{z}_t\end{bmatrix} = \begin{bmatrix} b_{11} & b_{12} & b_{13} \\ 0 & b_{22} & 0 \\ 0 & 0 & b_{33} \end{bmatrix}\begin{bmatrix}\hat{c}_{t+1} \\ \hat{k}_{t+1} \\ \hat{z}_{t+1}\end{bmatrix} + \begin{bmatrix} 0 & b_{11} & b_{13} \\ 0 & 0 & 0 \\ 1 & 0 & b_{33} \end{bmatrix}\begin{bmatrix}\varepsilon_{t+1} \\ E_t\left[\hat{c}_{t+1}\right] - \hat{c}_{t+1} \\ E_t\left[\hat{z}_{t+1}\right] - \hat{z}_{t+1}\end{bmatrix},$$

where

$$a_{11} \equiv -\frac{1}{c},$$

$$b_{11} \equiv -\frac{\beta(1-\delta+\alpha z k^{\alpha-1}l^{1-\alpha})}{c} + \frac{\frac{\beta(1-\alpha)\alpha z k^{\alpha-1}l^{1-\alpha}}{c}}{\frac{\alpha(1-\alpha)zk^{\alpha}l^{-\alpha}}{c} - \frac{\gamma l}{(1-l)^2}}\cdot\frac{(1-\alpha)zk^{\alpha}l^{-\alpha}}{c},$$

$$b_{12} \equiv \frac{\beta(\alpha-1)\alpha z k^{\alpha-1}l^{1-\alpha}}{c} + \frac{\frac{\beta(\alpha-1)\alpha z k^{\alpha-1}l^{1-\alpha}}{c}}{\frac{\alpha(1-\alpha)zk^{\alpha}l^{-\alpha}}{c} - \frac{\gamma l}{(1-l)^2}}\cdot\frac{\alpha(1-\alpha)zk^{\alpha}l^{-\alpha}}{c},$$

$$b_{13} \equiv \frac{\beta\alpha z k^{\alpha-1}l^{1-\alpha}}{c} + \frac{\frac{\beta(1-\alpha)\alpha z k^{\alpha-1}l^{1-\alpha}}{c}}{\frac{\alpha(1-\alpha)zk^{\alpha}l^{-\alpha}}{c} - \frac{\gamma l}{(1-l)^2}}\cdot\frac{(1-\alpha)zk^{\alpha}l^{-\alpha}}{c},$$

$$a_{21} \equiv c + \frac{(1-\alpha)\alpha z k^{\alpha}l^{1-\alpha}}{\frac{\alpha(1-\alpha)zk^{\alpha}l^{-\alpha}}{c} - \frac{\gamma l}{(1-l)^2}}\cdot\frac{(1-\alpha)zk^{\alpha}l^{-\alpha}}{c},$$

$$a_{22} \equiv -\frac{k}{\beta} - \frac{(1-\alpha)\alpha z k^{\alpha}l^{1-\alpha}}{\frac{\alpha(1-\alpha)zk^{\alpha}l^{-\alpha}}{c} - \frac{\gamma l}{(1-l)^2}}\cdot\frac{\alpha(1-\alpha)zk^{\alpha}l^{-\alpha}}{c},$$

$$b_{22} \equiv -k,$$

$$a_{33} \equiv \rho,$$

$$b_{33} \equiv -1.$$

In what follows, we use Farmer's (1999) method to solve the linearised system (9). From (9), we get

$$(10)\quad \begin{bmatrix}\hat{c}_t \\ \hat{k}_t \\ \hat{z}_t\end{bmatrix} = M_0\begin{bmatrix}\hat{c}_{t+1} \\ \hat{k}_{t+1} \\ \hat{z}_{t+1}\end{bmatrix} + M_1\begin{bmatrix}\varepsilon_{t+1} \\ E_t\left[\hat{c}_{t+1}\right] - \hat{c}_{t+1} \\ E_t\left[\hat{z}_{t+1}\right] - \hat{z}_{t+1}\end{bmatrix},$$

where

$$M_0 \equiv \begin{bmatrix} a_{11} & 0 & 0 \\ a_{21} & a_{22} & a_{23} \\ 0 & 0 & a_{33} \end{bmatrix}^{-1}\begin{bmatrix} b_{11} & b_{12} & b_{13} \\ 0 & b_{22} & 0 \\ 0 & 0 & b_{33} \end{bmatrix},$$

$$M_1 \equiv \begin{bmatrix} a_{11} & 0 & 0 \\ a_{21} & a_{22} & a_{23} \\ 0 & 0 & a_{33} \end{bmatrix}^{-1}\begin{bmatrix} 0 & b_{11} & b_{13} \\ 0 & 0 & 0 \\ 1 & 0 & b_{33} \end{bmatrix}.$$

Note that

$$\begin{bmatrix} a_{11} & 0 & 0 \\ a_{21} & a_{22} & a_{23} \\ 0 & 0 & a_{33} \end{bmatrix}^{-1} = \begin{bmatrix} \frac{1}{a_{11}} & 0 & 0 \\ -\frac{a_{21}}{a_{11}a_{22}} & \frac{1}{a_{22}} & -\frac{a_{23}}{a_{22}a_{33}} \\ 0 & 0 & \frac{1}{a_{33}} \end{bmatrix}$$

Thus,

$$M_0 = \begin{bmatrix} a_{11} & 0 & 0 \\ a_{21} & a_{22} & a_{23} \\ 0 & 0 & a_{33} \end{bmatrix}^{-1}\begin{bmatrix} b_{11} & b_{12} & b_{13} \\ 0 & b_{22} & 0 \\ 0 & 0 & b_{33} \end{bmatrix}$$

$$= \begin{bmatrix} \frac{1}{a_{11}} & 0 & 0 \\ -\frac{a_{21}}{a_{11}a_{22}} & \frac{1}{a_{22}} & -\frac{a_{23}}{a_{22}a_{33}} \\ 0 & 0 & \frac{1}{a_{33}} \end{bmatrix}\begin{bmatrix} b_{11} & b_{12} & b_{13} \\ 0 & b_{22} & 0 \\ 0 & 0 & b_{33} \end{bmatrix}$$

$$= \begin{bmatrix} \frac{b_{11}}{a_{11}} & \frac{b_{12}}{a_{11}} & \frac{b_{13}}{a_{11}} \\ -\frac{a_{21}b_{11}}{a_{11}a_{22}} & -\frac{a_{21}b_{12}}{a_{11}a_{22}} + \frac{b_{22}}{a_{22}} & -\frac{a_{21}b_{13}}{a_{11}a_{22}} - \frac{a_{23}b_{33}}{a_{22}a_{33}} \\ 0 & 0 & \frac{b_{33}}{a_{33}} \end{bmatrix} \equiv \begin{bmatrix} m_{11} & m_{12} & m_{13} \\ m_{21} & m_{22} & m_{23} \\ 0 & 0 & m_{33} \end{bmatrix}.$$

Note that

$$M_0 - \lambda I = \begin{bmatrix} m_{11}-\lambda & m_{12} & m_{13} \\ m_{21} & m_{22}-\lambda & m_{23} \\ 0 & 0 & m_{33}-\lambda \end{bmatrix}$$

and

$$\left|M_0 - \lambda I\right| = (m_{11}-\lambda)(m_{22}-\lambda)(m_{33}-\lambda) - m_{12}m_{21}(m_{33}-\lambda)$$

$$= (m_{33}-\lambda)(m_{11}m_{22} - m_{12}m_{21} - (m_{11}+m_{22})\lambda + \lambda^2).$$

Thus, the eigen values of M_0 and a corresponding matrix Q of eigen vectors are given by

$$\lambda_1 \equiv \frac{m_{11}+m_{22} - \sqrt{(m_{11}+m_{22})^2 - 4(m_{11}m_{22} - m_{12}m_{21})}}{2},$$

$$\lambda_2 \equiv \frac{m_{11}+m_{22} + \sqrt{(m_{11}+m_{22})^2 - 4(m_{11}m_{22} - m_{12}m_{21})}}{2},$$

$$\lambda_3 \equiv m_{33},$$

and

$$Q = \begin{bmatrix} m_{12} & m_{12} & \frac{m_{12}m_{23} - m_{13}(m_{22}-\lambda_3)}{(m_{11}-\lambda_3)(m_{21}-\lambda_3) - m_{12}m_{21}} \\ \lambda_1 - m_{11} & \lambda_2 - m_{11} & \frac{m_{21}m_{13} - m_{23}(m_{11}-\lambda_3)}{(m_{11}-\lambda_3)(m_{21}-\lambda_3) - m_{12}m_{21}} \\ 0 & 0 & 1 \end{bmatrix} \equiv \begin{bmatrix} q_{11} & q_{12} & q_{13} \\ q_{21} & q_{22} & q_{23} \\ 0 & 0 & 1 \end{bmatrix}.$$

Then,

$$Q^{-1} = \frac{1}{q_{11}q_{22} - q_{12}q_{21}} \begin{bmatrix} q_{22} & -q_{12} & -q_{22}q_{13} + q_{12}q_{23} \\ -q_{21} & q_{11} & q_{21}q_{13} - q_{11}q_{23} \\ 0 & 0 & q_{11}q_{22} - q_{12}q_{21} \end{bmatrix},$$

and

$$M_0 = Q \begin{bmatrix} \lambda_1 & 0 & 0 \\ 0 & \lambda_2 & 0 \\ 0 & 0 & \lambda_3 \end{bmatrix} Q^{-1} \quad .$$

By pre-multiplying both sides of (10) by Q^{-1}, and by putting

$$\begin{bmatrix} x_t^1 \\ x_t^2 \\ x_t^3 \end{bmatrix} \equiv Q^{-1} \begin{bmatrix} \hat{c}_t \\ \hat{k}_t \\ \hat{z}_t \end{bmatrix} \quad ,$$

we obtain

$$\begin{bmatrix} x_t^1 \\ x_t^2 \\ x_t^3 \end{bmatrix} = \begin{bmatrix} \lambda_1 & 0 & 0 \\ 0 & \lambda_2 & 0 \\ 0 & 0 & \lambda_3 \end{bmatrix} \begin{bmatrix} x_{t+1}^1 \\ x_{t+1}^2 \\ x_{t+1}^3 \end{bmatrix} + Q^{-1} M_1 \begin{bmatrix} \varepsilon_{t+1} \\ E_t[\hat{c}_{t+1}] - \hat{c}_{t+1} \\ E_t[\hat{z}_{t+1}] - \hat{z}_{t+1} \end{bmatrix} \quad .$$

Taking the expected value of both sides evaluated at the end of period t,

$$\begin{bmatrix} x_t^1 \\ x_t^2 \\ x_t^3 \end{bmatrix} = \begin{bmatrix} \lambda_1 & 0 & 0 \\ 0 & \lambda_2 & 0 \\ 0 & 0 & \lambda_3 \end{bmatrix} \begin{bmatrix} E_t[x_{t+1}^1] \\ E_t[x_{t+1}^2] \\ E_t[x_{t+1}^3] \end{bmatrix} \quad .$$

It follows that for each $T>0$, $x_t^1 = \lambda_1^{\,T} E_t[x_{t+T}^1]$. Also, it can be shown that $|\lambda_1| < 1$. Thus,

$$x_t^1 = \lim_{T\to\infty} \lambda_1^{\,T} E_t[x_{t+T}^1] = 0 \quad ,$$

so that

$$q_{22}\hat{c}_t - q_{12}\hat{k}_t + (q_{12}q_{23} - q_{22}q_{13})\hat{z}_t = 0 \quad .$$

Thus, the solution to the linearised system (10) is given by

(11) $\hat{c}_t = \dfrac{q_{12}}{q_{22}} \cdot \hat{k}_t + \left(q_{13} - \dfrac{q_{12}q_{23}}{q_{22}} \right) \cdot \hat{z}_t ,$

(12) $\hat{k}_{t+1} = \dfrac{a_{21}\hat{c}_t + a_{22}\hat{k}_t + a_{23}\hat{z}_t}{b_{22}} ,$

(13) $\hat{z}_{t+1} = \rho\hat{z}_t + \varepsilon_{t+1} .$

Recall that from (7), we have

(14) $\hat{l}_t = d_1\hat{c}_t + d_2\hat{k}_t + d_3\hat{z}_t \quad ,$

where

$$d_1 \equiv \frac{1}{\dfrac{\alpha(1-\alpha)zk^{\alpha}l^{-\alpha}}{c} - \dfrac{\gamma l}{(1-l)^2}} \cdot \frac{(1-\alpha)zk^{\alpha}l^{-\alpha}}{c},$$

$$d_2 \equiv \frac{1}{\dfrac{\alpha(1-\alpha)zk^{\alpha}l^{-\alpha}}{c} - \dfrac{\gamma l}{(1-l)^2}} \cdot \frac{\alpha(1-\alpha)zk^{\alpha}l^{-\alpha}}{c},$$

$$d_3 \equiv \frac{1}{\dfrac{\alpha(1-\alpha)zk^{\alpha}l^{-\alpha}}{c} - \dfrac{\gamma l}{(1-l)^2}} \cdot \frac{(1-\alpha)zk^{\alpha}l^{-\alpha}}{c}.$$

Given the values of z_0, k_0, and $\{\varepsilon_t\}_{t=1}^{\infty}$, we can use (11)–(14) to simulate the evolution of c_t, l_t, k_t, and z_t.

Simulating the model using Excel

Step 1. (Figure 1) Choose the values of parameters, α, β, γ, δ, ρ, and σ. Here, we use the same values as in Table 2 of King and Rebelo (1999: 955).

	A	B	C	D	...
1	**A simple real business cycle model**				
2	**Parameter values**				
3	α =	0.333			
4	β =	0.984			
5	γ =	3.48			
6	δ =	0.025			
7	ρ =	0.979			
8	σ =	0.0072			
⋮					

Figure 1

Step 2. (Figure 2) Calculate the deterministic steady-state (c, l, k, z). Since

$$\frac{k}{l} = \left(\frac{\alpha}{\dfrac{1}{\beta} - 1 + \delta} \right)^{\frac{1}{1-\alpha}} \quad ,$$

enter

=($B$3/(1/$B$4-1+$B$6))^(1/(1-$B$3))

in cell D3. Similarly, enter the formulas for l, c, k, and z in cells D4–D7.

	A	B	C	D	...
1	**A simple real business cycle model**				
2	**Parameter values**		**Deterministic steady-state**		
3	α =	0.333	k/ell =	22.892336	
4	β =	0.984	ell =	0.1936226	
5	γ =	3.48	c =	0.4383911	
6	δ =	0.025	k =	4.4324736	
7	ρ =	0.979	z =	1	
8	σ =	0.0072			
⋮					

Figure 2

Step 3. (Figure 3) Enter the formulas for the components of matrices A, B, and M_0, the eigen values of m_0, and the components of matrix Q. For instance, since

$$\hat{z}_1 = \rho\hat{z}_0 + z\varepsilon_1,$$

$$\hat{k}_1 = \frac{a_{21}\hat{c}_0 + a_{22}\hat{k}_0 + a_{23}\hat{z}_0}{b_{22}},$$

enter

= -$B$17*$B$15/($B$13*$B$18)+$B$20/$B$18

in cell D17.

Step 4. (Figure 4) Enter 0 in the cells from A30 to J30.

Step 5. Enter =A30+1 in cell A31.

Step 6. Enter =NORMINV(RAND(),0,$B$8^2) in cell B31.

Step 7. (Figure 5) Enter the formulas for $\hat{z}_1$, $\hat{k}_1$, $\hat{c}_1$, and $\hat{l}_1$ in cells C31–F31. For instance, since

	A	B	C	D	E	F	⋯
⋮							
13	a11=	−2.281068	m11=	1.2915427	q11=	−0.070003526	
14	b11=	−2.946097	m12=	−0.070004	q12=	−0.070003526	
15	b12=	0.1596828	m13=	−0.332143	q13=	−0.563836736	
16	b13=	0.7576402	m21=	0.9728256	q21=	−0.420400422	
17	a21=	4.382138	m22=	0.709151	q22=	−0.161991325	
18	a22=	−5.817814	m23=	−1.039019	q23=	−0.772919895	
19	a23=	−4.49295	m33=	1.0214505			
20	b22=	−4.432474					
21	a33=	−0.979					
22	b33=	−1					
23			λ1=	0.8711423	d1=	−10.76589984	
24			λ2=	1.1295514	d2=	3.585044647	
25			λ3=	1.0214505	d3=	10.76589984	
⋮							

Figure 3

	A	B	C	D	E	F	⋯
⋮							
29	t	$\varepsilon(t)$	(z(t)-z)/z	(k(t)-k)/k	(c(t)-c)/c	$(\ell(t)-\ell)/\ell$	
30	0	0	0	0	0	0	
31	1						
⋮							

Figure 4

	A	B	C	D	E	F	⋯
⋮							
29	t	$\varepsilon(t)$	(z(t)-z)/z	(k(t)-k)/k	(c(t)-c)/c	$(\ell(t)-\ell)/\ell$	
30	0	0	0	0	0	0	
31	1	5.68E–05	5.68E–05	0	−7.21E–06	−0.00138773	
⋮							

Figure 5

$\hat{z}_1 = \rho \hat{z}_0 + z\varepsilon_1,$

$\hat{k}_1 = \frac{a_{21}\hat{c}_0 + a_{22}\hat{k}_0 + a_{23}\hat{z}_0}{b_{22}},$

enter

=$B$7*C30+$D$7*B31|

in cell C31, and

=($B$17*G30+$B$18*D30+$B$19*C30)/$B$20

in cell D31.

Step 8. Copy the cells A31–F31 into subsequent rows. Then we obtain a simulated time series of $z_1, \hat{k}_1, \hat{c}_1$, and $\hat{l}_1$.

Let

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

$$y_t \equiv c_t + i_t,$$

$$i \equiv k - (1-\delta)k = \delta k,$$

$$y \equiv c + k - (1-\delta)k = c + \delta k,$$

$$\hat{y}_t \equiv \frac{y_t - y}{y} = \frac{c\hat{c}_t + k\hat{k}_{t+1} - (1-\delta)k\hat{k}_t}{y},$$

$$\hat{i}_t \equiv \frac{i_t - i}{i} = \frac{k\hat{k}_{t+1} - (1-\delta)k\hat{k}_t}{i},$$

$$r_t \equiv \alpha z_t k_t^{\alpha-1} l_t^{1-\alpha} - \delta = \alpha(z\hat{z}_t + z)(k\hat{k}_t + k)^{\alpha-1}(l\hat{l}_t + l)^{1-\alpha} - \delta,$$

$$w_t \equiv (1-\alpha)z_t k_t^{\alpha} l_t^{-\alpha} = (1-\alpha)(z\hat{z}_t + z)(k\hat{k}_t + k)^{\alpha}(l\hat{l}_t + l)^{-\alpha},$$

$$w \equiv (1-\alpha)zk^{\alpha}l^{-\alpha},$$

$$\hat{w}_t \equiv \frac{w_t - w}{w} = \frac{(1-\alpha)(z\hat{z}_t + z)(k\hat{k}_t + k)^{\alpha}(l\hat{l}_t + l)^{-\alpha} - w}{w}.$$

By considering these variables together with $z_1, \hat{k}_1, \hat{c}_1$, and $\hat{l}_1$, one can create a table and a figure (Figures 6 and 7) similar to Table 3 and Figure 10 of King and Rebelo (1999).[1]

	A	B	C	D	E	F	G	H	I	J
1	A simple real business cycle model									
2	Parameter values		Deterministic steady-state							
3	α=	0.333	k / ell =	22.892336						
4	β=	0.984	ell =	0.1936226						
5	γ=	3.48	c =	0.4383911						
6	δ=	0.025	k =	4.4324736						
7	ρ=	0.979	z =	1						
8	σ=	0.0072	y =	0.549203						
9			i =	0.1108118						
10			w =	1.8919194						
11			r =	0.0162602						
12										
13	a11=	−2.281068	m11=	1.2915427	q11=	−0.070003526				
14	b11=	−2.946097	m12=	−0.070004	q12=	−0.070003526				
15	b12=	0.1596828	m13=	−0.332143	q13=	−0.563836736				
16	b13=	0.7576402	m21=	0.9728256	q21=	−0.420400422				
17	a21=	4.382138	m22=	0.709151	q22=	−0.161991325				
18	a22=	−5.817814	m23=	−1.039019	q23=	−0.772919895				
19	a23=	−4.49295	m33=	1.0214505						
20	b22=	−4.432474								
21	a33=	−0.979								
22	b33=	−1								
23			λ 1=	0.8711423	d1=	−10.76589984				
24			λ 2=	1.1295514	d2=	3.585044647				
25			λ 3=	1.0214505	d3=	10.76589984				
26										
27										
28										
29	t	ε (t)	(z(t)−z)/z	(k(t)−k)/k	(c(t)−c)/c	(ell(t)−ell)/ell	(y(t)−y)/y	r(t)−r	(w(t)−w)/w	(i(t)−i)/i
30	0	0	0	0	0	0	0	0	0	0
31	1	3.468E−05	3.4682E−05	0	−7.97E−06	0.000459197	0.000341	1E−05	−0.00011819	0.001721
32	2	5.765E−05	9.1601E−05	4.304E−05	−2.45E−06	0.001166881	0.0008842	3E−05	−0.00028238	0.004392
33	3	−1.35E−05	7.6141E−05	0.0001518	4.808E−05	0.00084613	0.000691	2E−05	−0.00015496	0.003235
34	4	−5.89E−05	1.5617E−05	0.0002288	9.53E−05	−3.74849E−05	6.682E−05	−7E−06	0.000104299	−4.6E−05
35	5	2.807E−05	4.3357E−05	0.000222	8.596E−05	0.00033713	0.0003421	5E−06	5.01871E−06	0.001356
36	6	4.818E−05	9.0631E−05	0.0002503	8.734E−05	0.00093279	0.0007962	2E−05	−0.00013649	0.0036
37	7	8.673E−06	9.7401E−05	0.0003341	0.000122	0.000933034	0.000831	2E−05	−0.00010193	0.003636
38	8	−4.6E−05	4.9377E−05	0.0004166	0.0001687	0.000209079	0.0003276	−4E−06	0.000118468	0.000956
39	9	−4.26E−05	5.7595E−06	0.0004301	0.0001845	−0.000382815	−0.000106	−2E−05	0.000276491	−0.00126
40	10	5.345E−06	1.0984E−05	0.0003879	0.0001651	−0.000268619	−3.9E−05	−2E−05	0.000229623	−0.00085
41	11	0.0001319	0.00014264	0.0003571	0.0001215	0.001507495	0.001267	4E−05	−0.00024008	0.005799
42	12	−1.05E−05	0.00012918	0.0004931	0.0001834	0.001184016	0.0010831	2E−05	−0.00010071	0.004643
43	13	5.453E−05	0.000181	0.0005968	0.0002163	0.0017594	0.0015533	4E−05	−0.00020568	0.006842
44	14	−2.64E−05	0.00015076	0.000753	0.0002907	0.00119239	0.0011968	2E−05	4.56667E−06	0.004781
45	15	0.0001127	0.00026025	0.0008537	0.0003091	0.002534558	0.0022351	6E−05	−0.00029852	0.009855
46	16	−9.88E−05	0.00015598	0.0010787	0.0004303	0.000913818	0.0011247	2E−06	0.000210844	0.003872
47	17	−1.09E−05	0.00014179	0.0011485	0.0004637	0.000651413	0.0009587	−8E−06	0.000307222	0.002917
48	18	6.672E−05	0.00020553	0.0011928	0.0004682	0.00144813	0.0015686	2E−05	0.000120586	0.005922
49	19	−1.26E−05	0.00018861	0.001311	0.0005232	0.001097939	0.0013575	2E−06	0.000259486	0.004658
50	20	1.242E−05	0.00019707	0.0013947	0.0005574	0.001120601	0.0014089	6E−07	0.000288239	0.004778
51	21	−1.61E−05	0.00017682	0.0014792	0.0005986	0.000762231	0.0011778	−1E−05	0.000415388	0.003469
52	22	−8.35E−06	0.00016476	0.001529	0.0006229	0.000549465	0.0010404	−2E−05	0.000490711	0.002692
53	23	2.063E−05	0.00018193	0.0015581	0.0006315	0.000745794	0.0011982	−1E−05	0.000452197	0.00344
54	24	6.423E−05	0.00024234	0.0016051	0.0006379	0.001495337	0.0017742	7E−06	0.000278851	0.00627
55	25	1.27E−05	0.00024995	0.0017217	0.0006866	0.001471602	0.0018048	3E−06	0.000333133	0.006229
56	26	5.263E−05	0.00029733	0.0018344	0.0007244	0.001978666	0.002228	2E−05	0.00024937	0.008176
57	27	0.0001206	0.00041166	0.001993	0.0007666	0.003323224	0.0032919	5E−05	−3.0227E−05	0.013282
58	28	6.43E−05	0.00046732	0.0022752	0.0008758	0.0037589	0.0037321	6E−05	−2.5377E−05	0.015032
59	29	−2.31E−05	0.00043445	0.0025941	0.0010212	0.002983335	0.0032882	3E−05	0.000305158	0.012257
60	30	−4.33E−05	0.00038199	0.0028357	0.0011376	0.002030906	0.0026809	−6E−06	0.000649473	0.008786
61	31	9.447E−05	0.00046844	0.0029845	0.0011821	0.003016737	0.0034744	2E−05	0.00045772	0.012543

	K	L	M	N	O	P	Q
1		s.d.	r.s.d.	f.o.a.	c.c.w.o.		
2	Output	0.001757	1	0.955087	1		
3	Consumption	0.00107	0.609302	0.998294	0.752513		
4	Investment	0.0061839	3.520488	0.905196	0.892558		
5	Labor Input	0.0015579	0.886934	0.892788	0.803438		
6	Real Wages	0.001056	0.60107	0.980935	0.477931		
7	Real Interest Rate	6.94E−05	0.039511	0.944795	−0.14406		
8	Productivity	0.000264	0.150113	0.979596	0.969922		
9							
10	s.d.: standard deviation						
11	r.s.d.: relative standard deviation						
12	f.o.a.: first-order autocorrelation						
13	c.c.w.o.: contemporaneous correlation with output						

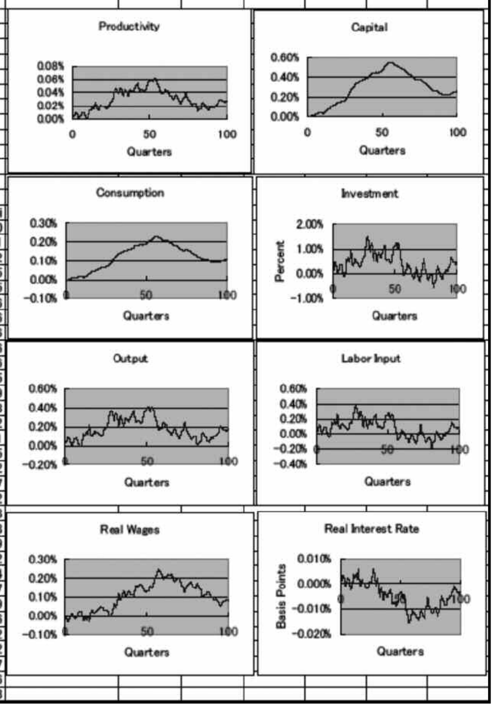

Figure 6

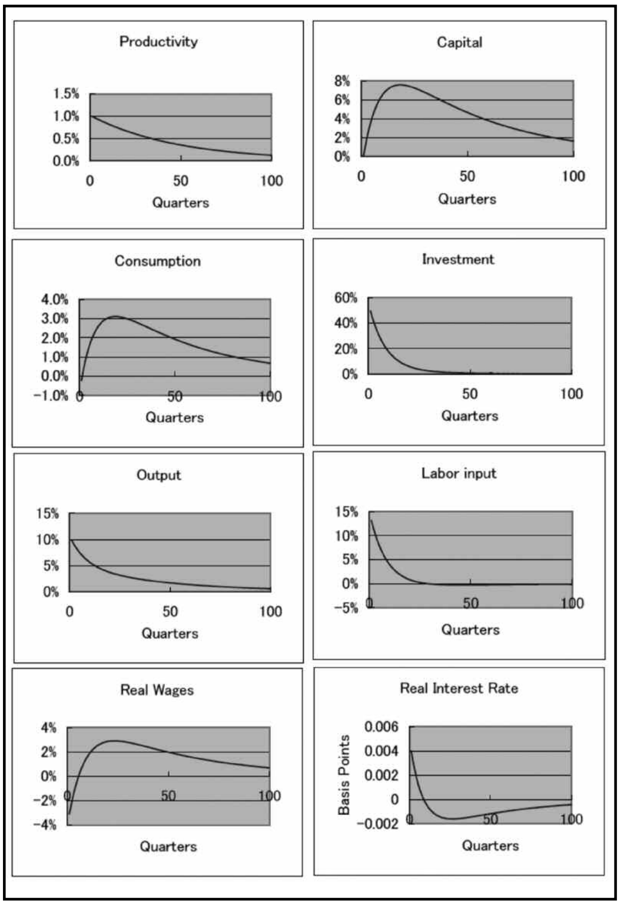

Figure 7

Notes

1 Sample Excel files are available at http://member.social.tsukuba.ac.jp/hokari/

References

Farmer, R.E.A. (1999) *Macroeconomics of Self-fulfilling Prophecies*, 2nd ed, MIT Press.

King, R.G., and S.T. Rebelo (1999) 'Resuscitating real business cycles' in *Handbook of Macroeconomics*, volume 1B, by J.B. Taylor and M. Woodford (Eds), Elsevier, 927–1007.

Kydland, F. and E. Prescott (1982) 'Time to build and aggregate fluctuations', *Econometrica* 50, 1345–1371.

Long, Jr., J.B. and C.I. Plosser (1983) 'Real business cycles', *Journal of Political Economy* 91, 39–69.

Strulik, H. (2004) 'Solving rational expectations models using Excel', *Journal of Economic Education* 35, 269–283.

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