Can 'Sunspots' Explain the Asian Financial Crisis?

By

Deok-Ki David Kim*

School of Economics and Political Science
The University of Sydney
Sydney, NSW 2006
Australia

E-mail: d.kim@econ.usyd.edu.au

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ABSTRACT

One of the most striking historical observations in recent years was the unprecedented collapse of several East Asian economies including, most notably, Thailand, Malaysia, South Korea, and Indonesia during 1997-98, widely known as the Asian financial crisis. Subsequent to this observation, researchers have put forward many explanations as to what led these economies to the collapse. The following, often closely related to one another, have been thought of as the major causes of the crisis: moral hazard by domestic banks and firms due to government guarantees, excessive exposure to short-term debts, financial panics and speculative attacks, fundamental macroeconomic imbalances, and inconsistent government policies, just to name the usual suspects.

Understanding why the crisis occurred is important in answering much debated questions such as "Was the crisis waiting to happen?" or "Are the economic fundamentals eventually to be blamed?" For example, Radelet and Sachs (1998) argue that the crisis could be due to self-fulfilling expectations of international investors (and wrong government policies) rather than fundamental macroeconomic imbalances. While several researchers such as Burnside et al. (2001) and Corsetti et al. (2000) developed models to explain the Asian crisis and showed theoretical conditions under which a currency crisis may be triggered, quantitative studies that attempt to show what can replicate the crisis are very rare.

This paper examines the role of 'animal spirits' or more precisely 'sunspots' in the context of the Asian financial crisis, by extending Farmer and Guo's (1994) indeterminacy model of business cycle to a small open economy and applying the model to East Asian data. While Guo and Sturzennegger (1998) considered a two-country version of the Farmer and Guo model to account for observed cross-country macroeconomic correlations, no explicit consideration has been given to the case of a calibrated quantitative model of a small open economy. The extended model can be used to answer the question as to whether belief shocks can account for recent economic fluctuations in Malaysia and South Korea. The main findings of the paper are as follows. First, 'sunspots' alone in a small open economy equilibrium business cycle model seem to have an ability to explain the drastic fall in output in the recent financial crisis in Malaysia and South Korea. Second, while the model economy exhibits a strong recovery it is not observed in the data. Third, as Lahiri (1998) showed using a continuous time Ramsey growth model, multiple equilibria seem to arise more naturally in a small open economy. This provides an important insight into the role of expectational uncertainty in understanding the Asian financial crisis, at least from a business cycle perspective.

Keywords: Self-fulfilling expectation, Asian Financial Crisis, DSGE model, Calibration

1. Introduction

Over the last decade, the stochastic growth model has been established as a major workhorse in macroeconomic research. Researchers have developed variants of stochastic growth or more precisely the dynamic stochastic general equilibrium (DSGE) models in order to examine various quantitative properties in macroeconomic data, and in particular, business cycles. These models typically rely on explicit microeconomic foundations with such features as optimizing economic agents, market clearing, perfectly competitive markets, and unique rational expectations equilibrium allocations.

However, recent work by Farmer and Guo (1994) explores the possibility that multiple equilibria can arise in an otherwise standard real business cycle (RBC) model. The possibility of multiple equilibria or indeterminacy of unique equilibrium in DSGE models gives rise to two important implications.

First, it is possible to construct an equilibrium business cycle model in which the model economy is subject to non-fundamental belief shocks or 'animal spirits', displaying macroeconomic features originally envisaged by Keynes, and may even be called truly Keynesian in this particular sense.[1] Second, the possibility of multiple equilibria arising in such models implies that, as envisaged by Farmer (1998), there might be a role for government over the course of business cycles in choosing different equilibrium allocations [see Guo and Lansing (1998) for a quantitative exercise on this].[2] While the analytical framework is the same, the models of this kind are in stark contrast with the real business cycle model whose basic premise is that business cycles are characterised by unique equilibrium allocations and are hence Pareto efficient.

While there was a substantial progress in extending closed economy RBC models to an open economy setting over the last decade, it was not until the recent work by Guo and Sturzennegger (1998) that the ability of multiple equilibria to account for observed international data was examined.[3] Along with the quantitative implications of models

[1] Keynes emphasized the role of 'animal spirits' in macroeconomics.

[2] These authors show how a different tax policy leads to either a saddle path or indeterminacy in a closed economy.

[3] Representative work in this research program includes Backus et al. (1992), Mendoza (1991), and Baxter and Crucini (1993).

with indeterminacy, researchers have also made a progress in showing that obtaining indeterminacy in a neoclassical model is not as difficult as it was once thought to be.[4] Recent work along these lines in an open economy setting includes Lahiri (1998) and Weder (2001). These authors show using a variant of neoclassical growth model in continuous time that indeterminacy is easier to obtain in a small open economy than in closed economy models due to the consequences of perfect international capital mobility. There have been very few attempts to explore business cycle implications of indeterminacy in an open economy setting.[5] This paper attempts to contribute to the literature by providing one quantitative exercise in this vein.

One of the most striking observations in recent years was the unprecedented collapse of many Asian economies including most notably Thailand, Malaysia, South Korea, and Indonesia in 1997-98, popularly known as the Asian financial crisis.[6] Following this observation, researchers have put forward many explanations as to what led these economies to the collapse. The following, which are often closely inter-related, have been thought of as the major causes of the crisis: moral hazard by domestic banks and firms due to government guarantees, excessive exposure to short-term debts, financial panics and speculative attacks, fundamental macroeconomic imbalances, and inconsistent government policies, just to name the usual suspects.
Understanding what can explain the crisis is important to answer much debated questions such as “Was the crisis an inevitable consequence?” or “Did weak economic fundamentals trigger the crisis?” In this regard, researchers such as Radelet and Sachs (1998) were quick to point out that the crisis could be due to self-fulfilling expectations of international investors (and wrong government policies) rather than fundamental macroeconomic imbalances. While several researchers, [for example, Burnside et al. (2001), Corsetti et al. (2000)] developed models to explain the Asian crisis and showed theoretical conditions under which a currency crisis may be triggered, studies that quantitatively explain the Asian crisis are very rare.

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[4] It is common in literature that the terms ‘indeterminacy’ and ‘multiple equilibria’ are used interchangeably. The terms ‘sunspots’, ‘self-fulfilling prophecies’, ‘belief shocks’, and ‘animal spirits’ are also used interchangeably to indicate shocks that are unrelated to economic fundamentals.
[5] Guo and Sturzennegger (1998) explored indeterminacy in the two-country setting, but not in a small open economy. The purpose of their work was to account for observed international correlations in consumption and output, which standard models could not explain.
[6] Singapore, Philippines, Taiwan, and Honk Kong were also affected with varying degrees of severity.

One interesting work that motivates using a model with the feature of multiple equilibria explored in this paper is Carranza and Galdon-Sanchez (1998). They show using an overlapping generations model that the multiplicity of equilibria is more likely to arise in middle-income economies than either rich-income or low-income economies. The fact that most countries affected by the Asian financial crisis can be categorized as mostly middle-income countries motivates searching for an explanation of the crisis using a quantitative model of multiple equilibria.

This paper is motivated by whether the theoretical possibility of indeterminacy in a small open economy can provide an empirically plausible explanation for business cycle fluctuations in East Asia – in particular during the period of the recent financial crisis. However, unlike equilibrium business cycle models in a closed economy, extending such a modeling approach to an open economy setting has encountered a number of challenges. In particular, constructing a small open economy model itself is seen to be more difficult, among other things, in the treatment of time preference, as a small open economy cannot have a real interest rate that is independent of the world interest rate. Correia et al. (1995) show that if the rate of time preference is fixed, there can be an infinite number of steady states that are compatible with any given level of foreign assets. Hence, it is essential to pin down some parameter and steady state values for a unique steady state around which the model can be linearized and solved.[7]

While the model developed in this paper is basically a small open economy version of Farmer and Guo (1994), the way the model is developed and studied is to be distinguished from earlier work on several grounds. First, the model economy in this paper displays growth whereas both Farmer and Guo's and Guo and Sturzennegger's models abstract from growth. Second, the model introduces interest rate shocks in addition to productivity and sunspot shocks. Third, the model is solved using a new

[7] Although researchers such as Mendoza (1992) and Schmit-Grohe (1998) endogenize the time preference to ensure a well-defined steady state, so that the model linearization is possibly more accurate, this practice has often been criticized on the ground that it has the counter-intuitive implication that economic agents become increasingly time impatient as their wealth level rises. Moreover, Kim and Kose (2001) demonstrate that there is little quantitative difference between the fixed time preference model, as is assumed in this paper, and the endogenous counterpart. Recent work by Schmit-Grohe and Uribe (2001) also confirm this.

method proposed by Sims (2001) [8], which can be used to solve models even with singular matrices. The solution methods proposed by King, Plosser and Rebelo (2001) and Farmer (1998) are not applicable to models with a singular matrix, which often arises in small open economy models.[9]

Finally, the model is calibrated in order to match economic fluctuations in a developing economy in East Asia. The choice of country to calibrate is guided by the hypothesis in the international finance literature that financial crises and the consequent economic fluctuations could be due to self-fulfilling beliefs. That is, the quantitative exercise allows one to examine to what extent the recent Asian crisis can be attributed to factors unrelated to economic fundamentals.

2. The Model

The model presented in this section is based on Farmer and Guo (1994) and the main departure from their model is that it is a small open economy model unlike theirs, a closed economy model. The model is also a standard dynamic stochastic equilibrium model of small open economy, except for the fact that the model economy is characterized by increasing returns. Note that there is no government sector in the model.

Preferences

Representative households are assumed to maximize their lifetime discounted utility derived from consumption (C) and leisure (L)

$$E_0 \sum_{t=0}^{\infty} \rho^t U(C_t, L_t)$$

where the momentary utility is specified as

$$U(C_t, L_t) = \frac{C_t^{1-\sigma}}{1-\sigma} - A \frac{N_t^{1-\chi}}{1-\chi} \qquad (1)$$

[8] This standard solution outlined in this technique however assumes that only the fundamental shocks matter. However, this solution can be easily modified to include 'non-fundamental' or endogenous shocks in the solution of the model.
[9] King and Watson (1998) note that the singularity of matrix in a system of difference equations is common in open economy models.

where N_t is labour supply, which is normalized such that $N_t = 1 - L_t$, σ is the coefficient of relative risk aversion with respect to consumption , χ ($\leq$ 0) denotes the labour supply elasticity, and A is a positive preference parameter.

subject to

$$K_{t+1} + C_t \leq w_t N_t + (1 - \delta + r_t) K_t + \Omega_t \qquad (2)$$

for t = 1, ... , ∞.

Firms pay wages (w) and rents (r) to households, and Ω_t represents non-zero profits received by a representative household from the ownership of the firm.

In the calibrated version of the model, σ is set to 1, which implies that the utility derived from consumption is log linear, for analytical convenience. Note that if χ is set equal to 0, this utility function collapses to that of Hansen's (1985) indivisible labour model.

Technology

The economy is characterized by monopolistically competitive households producing intermediate goods using an increasing returns to scale technology.

$$Y_{it} = Z_t K_{it}^{\alpha} (\gamma_x^t N_{it})^{\beta}$$

where $\alpha + \beta > 1$, and γ_x denotes the labor augmenting technical progress.

The intermediate goods produced this way are combined, in a competitive final sector, using the Stiglitz-Dixit technology

$$Y_t = \left(\int_0^1 Y_{it}^{\mu} di \right)^{\mu} \qquad 0 < \mu < 1.$$

where μ represents the degree of monopoly power due to imperfect substitutability in intermediate inputs. Note that if μ = 1, the technology collapses to a competitive model.

The aggregate technology for this economy can be expressed as

$$Y_t = Z_t K_t^{\alpha} (\gamma_x^t N_t)^{\beta} \tag{3}$$

Benhabib and Farmer (1994) show that in this economy labour's share and capital's share of national income are equal to the constants $\mu\beta$ and $\mu\alpha$, respectively. This implies that the factor shares of capital and labour are

$$a = \mu\alpha$$

and (4)

$$b = \mu\beta$$

That is, if $0 < \mu < 1$, it is possible to have a + b < 1 and $\alpha + \beta > 1$, implying the possibility of positive profits.[10]

Capital accumulation follows[11]

$$K_{t+1} = (1-\delta)K_t + I_t \tag{5}$$

Resource Constraints

The small open economy faces the resource constraint

$$C_t + I_t + B_{t+1} = Y_t + B_t(1 + r_t) \tag{6}$$

Asset markets are assumed to be incomplete in this economy, with a one period bond being the only foreign asset (debt) held by domestic residents. B_t denotes the purchases (holdings) of bonds by the home country resident at time t.

This implies that the trade balance is defined as

[10] Note that μ indicates the degree of monopoly power, and if $\mu = 1$, this economy collapses to a standard constant returns to scale economy characterised by perfect competition. In equilibrium, the profits will be driven to zero.

$$NX_t = Y_t - C_t - I_t = B_{t+1} - B_t(1+r_t) \quad (7)$$

By combining the aggregate resource constraint with the capital accumulation equation, we obtain the following equation for capital accumulation equation

$$K_{t+1} = (1-\delta)K_t + Y_t - C_t + [B_{t+1} - B_t(1+r_t)] \quad (8)$$

Exogenous Processes

Productivity and interest rates are assumed to follow a first-order continuous Markov processes.

Technical progress is assumed to follow a first order autoregressive process

$$Z_{t+1} = Z_t^{\theta}\varepsilon_{z,t+1} \quad (9.1)$$

where $\varepsilon_{z,t} : \ iid(0, \sigma_z^2)$

Real interest rate is also assumed to follow an AR(1) process

$$R_{t+1} = R_t^{\pi}\varepsilon_{r,t+1} \quad (9.2)$$

where $\varepsilon_{r,t} : \ iid(0, \sigma_r^2)$

Finally, a no Ponzi game condition is imposed to rule out the possibility of an infinite amount of foreign borrowing.

$$\lim_{t\to\infty} E_0\left(\frac{B_{t+1}}{(1+r_t)^t}\right) = 0 \quad (10)$$

Balanced Growth Path and the Model Equilibrium

Since this model exhibits a nonstochastic growth and the solution method requires the economy to be stationary, the model economy needs to be transformed into a stationary form. The first step is to find a balanced growth path around which to linearize the model economy.

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[11] No adjustment cost of investment is assumed in this model as the only purpose of adding it is to

Since the model exhibits increasing returns, transforming the economy into a nonstochastic stationary economy requires dividing the equations by ϕ^t rather than by γ_x, where $\phi \equiv \gamma_x^{\beta(1-\alpha)}$.

This implies that the effective rate of time preference, ρ^*

$\rho^* = \rho\phi^{1-\sigma}$ for $\sigma \neq 1$

$\rho^* = \rho$ for $\sigma = 1$

Hence, the equations (3), (5), and (8) can be written as follows.

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

$$y_t = Z_t k_t^{\alpha} N_t^{\beta}$$

$$\phi k_{t+1} = y_t + (1-\delta)k_t - c_t + [\tilde{B}_t(1+r_t) - \phi\tilde{B}_{t+1}]$$

where $y_t \equiv \left(\frac{Y_t}{\phi^t}\right)$, $c_t \equiv \left(\frac{C_t}{\phi^t}\right)$, $k_t \equiv \left(\frac{K_t}{\phi^t}\right)$, and $\tilde{B}_t \equiv \left(\frac{B_t}{\phi^t}\right)$

The Lagrangian for the optimization problem can be written as follows.

$$\text{Max } \mathbf{L} = E_0 \sum_{t=0}^{\infty} \rho^{*t} \{U(c_t, L_t) + \lambda_t[y_t - c_t - \phi k_{t+1} + (1-\delta)k_t + B_t(1+r_t) - \phi B_{t+1}\}$$

First Order Conditions:

$$c_t: \quad MU_{c_t} = \lambda_t \tag{11}$$

$$N_t: \quad MRS_{c,L} = \frac{MU_L}{MU_c} = MP_N = w_t \tag{12}$$

$$\Rightarrow \quad A\frac{c_t}{N_t^{\chi}} = b\frac{y_t}{N_t}$$

$$k_{t+1}: \quad \phi\lambda_t = \rho^* E_t\left\{\lambda_{t+1}\left(a\frac{y_{t+1}}{k_{t+1}} + (1-\delta)\right)\right\} \tag{13}$$

dampen the volatility of investment, which is of marginal importance in the chapter.

Subsituting (1)* and (2)*,

$$\phi\left(\frac{1}{c_t}\right)=\rho^{*}E_t\left\{\frac{1}{c_{t+1}}\left(a\frac{y_{t+1}}{k_{t+1}}+(1-\delta)\right)\right\} \tag{14}$$

$$\lambda_t: \qquad \phi k_{t+1}=y_t+(1-\delta)k_t-c_t+[\tilde{B}_t(1+r_t)-\phi\tilde{B}_{t+1}] \tag{15}$$

$$\tilde{B}_{t+1}: \qquad \phi\lambda_t=\rho^{*}E_t\lambda_{t+1}(1+r_{t+1}) \tag{16}$$

Using (1)*, the equation (6)* can be written as

$$\phi\left(\frac{1}{c_t}\right)=\rho^{*}E_t\left\{\frac{1}{c_{t+1}}(1+r_{t+1})\right\} \tag{17}$$

Substitute (3)' into (2)* to eliminate y.

$$A\frac{c_t}{N_t^{\chi}}=b\frac{Z_t k_t^{\alpha}N_t^{\beta}}{N_t} \tag{18}$$

Solving for N

$$N_t=\left[\frac{A}{b}\frac{c_t}{Z_t k_t^{\alpha}}\right]^{\Phi} \tag{19}$$

where $\Phi \equiv 1/(\beta+\chi-1)$

Use (17) to eliminate N from equation (14),

$$\frac{\phi}{c_t}=E_t\left\{\frac{\rho^{*}}{c_{t+1}}\left(aZ_{t+1}k_{t+1}^{\alpha-1}\left[\frac{A}{b}\frac{c_t}{Z_t k_t^{\alpha}}\right]^{\beta\Phi}+(1-\delta)\right)\right\}$$

,which can be written as

$$\frac{\phi}{c_t}=E_t\left\{\left(DZ_{t+1}^{m}k_{t+1}^{g-1}c_{t+1}^{d-1}+\frac{\tau}{c_{t+1}}\right)\right\} \tag{20}$$

where the composite parameters are defined as follows. [12]

$$D \equiv \Theta a \rho^*$$

$$\Theta \equiv \left(\frac{A}{d}\right)^d$$

$$d \equiv \beta\Phi$$

$$m \equiv 1 - d$$

$$g \equiv \alpha m$$

$$\tau \equiv \rho^*(1-\delta)$$

$$\Phi \equiv 1/(\beta + \chi - 1)$$

Similarly, equation (5)* can be written as

$$\phi k_{t+1} = \Theta Z_t^m k_t^g c_t^d + (1-\delta)k_t - c_t + [\tilde{B}_t(1+r_t) - \phi \tilde{B}_{t+1}]$$

Now the equations of interest for the model resolution are

$$\phi k_{t+1} = \Theta Z_t^m k_t^g c_t^d + (1-\delta)k_t - c_t + [\tilde{B}_t(1+r_t) - \phi \tilde{B}_{t+1}] \tag{1*}$$

$$\frac{\phi}{c_t} = E_t\left\{\left(D Z_{t+1}^m k_{t+1}^{g-1} c_{t+1}^{d-1} + \frac{\tau}{c_{t+1}}\right)\right\} \tag{2*}$$

$$\phi\left(\frac{1}{c_t}\right) = \rho^* E_t\left\{\frac{1}{c_{t+1}}\left(1 + r_{t+1}\right)\right\} \tag{3*}$$

and the equations of motion for exogenous variables

$$Z_{t+1} = Z_t^{\theta} \varepsilon_{z,t+1} \tag{4*}$$

$$R_{t+1} = R_t^{\pi} \varepsilon_{r,t+1} \tag{5*}$$

Equations (1*) through (5*) above are nonlinear and hence linearized.

[12] Benhabib and Farmer (1994) show that, for this economy to have indeterminacy, β-1 > χ.

The linearized system can then be written as follows.

$$\begin{pmatrix} \hat{k}_t \\ \hat{b}_t \\ \hat{c}_t \\ \hat{Z}_t \\ \hat{r}_t \end{pmatrix} = \mathbf{J} \begin{pmatrix} k_{t+1} \\ b_{t+1} \\ c_{t+1} \\ Z_{t+1} \\ r_{t+1} \end{pmatrix} + \mathbf{R} \begin{pmatrix} \hat{\varepsilon}_{\mathbf{Z,\ t+1}} \\ \hat{\varepsilon}_{r,t+1} \\ E_t[\hat{k}_{t+1}] - k_{t+1} \\ E_t[\hat{b}_{t+1}] - b_{t+1} \\ E_t[\hat{c}_{t+1}] - c_{t+1} \\ E_t[\hat{Z}_{t+1}] - Z_{t+1} \\ E_t[\hat{r}_{t+1}] - r_{t+1} \end{pmatrix}$$

or

$$\tilde{\mathbf{A}}_{\mathbf{0}} \begin{pmatrix} \hat{k}_{t+1} \\ \hat{b}_{t+1} \\ \hat{c}_{t+1} \\ \hat{Z}_{t+1} \\ \hat{r}_{t+1} \end{pmatrix} = \tilde{\mathbf{A}}_{\mathbf{1}} \begin{pmatrix} k_t \\ b_t \\ c_t \\ Z_t \\ r_t \end{pmatrix} + \tilde{\mathbf{R}} \begin{pmatrix} \hat{\varepsilon}_{\mathbf{Z,\ t+1}} \\ \hat{\varepsilon}_{r,t+1} \\ E_t[\hat{k}_{t+1}] - k_{t+1} \\ E_t[\hat{b}_{t+1}] - b_{t+1} \\ E_t[\hat{c}_{t+1}] - c_{t+1} \\ E_t[\hat{Z}_{t+1}] - Z_{t+1} \\ E_t[\hat{r}_{t+1}] - r_{t+1} \end{pmatrix}$$

where J, R, Γ_0 and Γ_1 are the matrices of coefficients.

The above system of equations cannot be solved using conventional techniques such as King, Plosser and Rebelo (1988) or Farmer (1998) because the matrix Γ_0 is singular due to the fact that the Euler equations for consumption and foreign assets are linearly related. However, Sims (2000) proposes a solution technique that can be used to solve linear rational expectations models even with singular matrices. To use this technique, the above system of expectational difference equations is re-cast into the form

$$\Gamma_0 S(t+1) = \Gamma_1 S(t) + \tilde{C} + \Psi z(t+1) + \Pi \eta(t+1)$$

where

S is a vector of state variables, $S \equiv \{\hat{k}, b, \hat{c}, \hat{Z}, r\}$, z is a vector of exogenous shocks to to the two forcing variables, technological progress and the real interest rate, $z \equiv \{\tilde{\varepsilon}_Z, \varepsilon_r\}$,

η is a vector of endogenous expectational shocks to the model, which is replaced by V below,

Ψ is a 5 by 2 matrix of coefficients to $\{\tilde{\varepsilon}_Z, \varepsilon_r\}$,

Π is a 5 by 5 matrix of coefficients to {V},

$\tilde{C}$ is a vector of constants, and in this case it is a (5 by 1)' vector of zeros, and

Note that both Ψ and Π are submatrices of $\tilde{R}$ above.

$$\text{Define } V_{t+1} = \begin{pmatrix} E_t[\tilde{k}_{t+1}] - k_{t+1} \\ E_t[\tilde{b}_{t+1}] - b_{t+1} \\ E_t[\tilde{c}_{t+1}] - c_{t+1} \\ E_t[\tilde{Z}_{t+1}] - Z_{t+1} \\ E_t[\tilde{r}_{t+1}] - r_{t+1} \end{pmatrix}$$

Assuming no fundamental uncertainty and noting that the state variables $\tilde{k}_t$ and b_t are pre-determined,

$$\text{let} \quad V_{t+1} = \begin{pmatrix} 0 \\ 0 \\ e_{t+1} \\ 0 \\ 0 \end{pmatrix}$$

So, the model can be expressed as the following linear system

$$\tilde{\mathbf{A}}_0 \begin{pmatrix} \tilde{k}_{t+1} \\ \tilde{b}_{t+1} \\ \tilde{c}_{t+1} \\ \tilde{Z}_{t+1} \\ \tilde{r}_{t+1} \end{pmatrix} = \tilde{\mathbf{A}}_1 \begin{pmatrix} k_t \\ b_t \\ c_t \\ Z_t \\ r_t \end{pmatrix} + \tilde{\mathbf{C}} + \mathbf{\Phi} \begin{pmatrix} \hat{\varepsilon}_{Z,t+1} \\ \hat{\varepsilon}_{r,t+1} \end{pmatrix} + \mathbf{\Pi} \left(V_{t+1}\right) \qquad \text{(Sys.1)}$$

Policy functions for other variables:

Other variables in the model are then determined as a linear function of the state variables {k, b, c}. The relationship is captured by the coefficients matrix M_{os} below. The system denoted (Sys. 1) combined with (Sys. 2) containing other endogenous variables such as hours, output, average productivity, investment, and net exports is a state space system, which can be simulated for a set of sequences of shocks $\{\hat{\varepsilon}_{z,t},\ \varepsilon_{r,t},\ \text{and}\ \hat{V}_t\}$.

$$\begin{pmatrix} \hat{N}_t \\ \hat{y}_t \\ \widehat{ap}_t \\ \hat{i}_t \\ \widehat{nx}_t \end{pmatrix} = M_{OS} \begin{pmatrix} \hat{k}_t \\ \hat{b}_t \\ \hat{c}_t \\ \hat{Z}_t \\ \hat{r}_t \end{pmatrix} \qquad \text{(Sys. 2)}$$

3. Data and Calibration

The model is calibrated to Malaysian data.[13] The data were taken from the IMF's *International Financial Statistics* on CD-ROM, which are quarterly series of national accounts from 1991 to 2000. The calibration strategy adopted in this paper is not standard and follows Hansen and Prescott (1993). These authors calibrated the parameters and steady states in their model to match the actual values for a particular year for the US economy with the aim of examining whether the calibrated model economy can also display the recession experienced by the US economy in 1990-91.

Since the model presented in the previous section does not have a government sector, the data for output is obtained as the sum of final private consumption, gross fixed investment, and net exports of goods and services. In calibrating the model to data, the steady state values are set equal to 1996:1 values. Choosing a different year such as 1994 or 1995 as the steady state makes little difference to simulation results obtained.

To obtain a measure of real interest rate for the small open economy, which cannot be independent of the world real interest rate, I infer from the real return from holding bonds as implied in the model and the data for the net foreign assets. It suggests a value of 12.15 percent annually. Although it seems a bit too high, this is in line with

[13] A forthcoming version of this paper will consider a number of other East Asian countries.

the values used by Correia et al. (1995) and Neumeyer, P. and Perri, F. (1999), who studied small open developing economies which can only borrow at interest rates with positive country risk premiums.[14]

The average annual growth of output for the data period is 6.95 percent, and this implies that $\phi = 1.069$ or (1.68% quarterly). Given the values of ϕ and r* as determined above, the rate of time preference can be calibrated using the bond pricing equation. In the steady state, the equation implies that $\rho = \phi/(1 + r^*) = P_B \phi$. This suggests the value of effective rate of time preference, $\rho = 0.963$ annually or 0.991 quarterly.

In choosing parameter values for α, β, and μ, I consider two sets of values: the benchmark values used by Farmer and Guo (1994) and Guo and Sturzenegger (1998) and the values based on factor shares of capital for Malaysia estimated by Sarel (1997).

(i) Benchmark values:

$\alpha = 0.46$ and $\beta = 1.33$

$\mu = 0.53$, where $1/\mu$ is the price mark-up over marginal cost.

Using these values, the capital and labour shares are determined, respectively, as a = 0.24 and b = 0.70, implying the monopoly profits set equal to 6 percent of national income in the increasing returns to scale economies.

(ii) Based on Sarel' s (1997)[15] estimates:

$a = 0.32$, $0.62 \leq b < 0.68$

This still requires the values of either μ or α and β to be chosen by the researcher. The following range of μ is considered: $0.53 \leq \mu < 1$. The values of α and β are then determined by the relationship given by (4), $a = \mu\alpha$ and $b = \mu\beta$.

The model can be experimented with lower values of α, β, and μ, following some recent studies which show that the model may display indeterminacy even for much

[14] Both Correia et al. (1995) and Neumeyer and Perri (1999) set r* at values above 10 percent per annum.
[15] It is to be noted, however, that Sarel' s estimates are based on the assumption of constant returns to scale of the aggregate production function.

smaller magnitudes of increasing returns than suggested by the conventional calibration studies.[16] For depreciation rate, the commonly used value of 0.025 quarterly is chosen following Correia et al. (1995) and Neumeyer and Perri (1999). Other steady state ratios are then endogenously determined based on the first order conditions and actual values for 1996.

The persistence parameters of the two exogenous variables, the total factor productivity measured by the Solow residual and the real interest rate, are estimated from data. The quarterly data from 1991 to 2000 suggest the following values: θ = 0.88 and π = 0.34. However, the annual data that includes early years since 1962 suggest θ = 0.99 and π = 0.68, implying an almost unit-root technical progress and more persistent evolution of interest rates. Both sets of parameter values are examined in the calibration and the simulation of the model.

Obtaining a measure of the belief shock as defined by $E_t[c_{t+1}] - c_{t+1}$ in this paper is not straightforward. Guo and Sturzennegger (1998) and other researchers typically use survey data on consumer and business sentiments. Since such data are not generally available for developing countries, the data representing $E_t[c_{t+1}] - c_{t+1}$ is obtained by making use of the fact that it reflects unforecastable random errors unrelated to other variables. To obtain this series Blanchard's method (1993) is used. The technical details are outlined in the Appendix A. Figure 1 shows a plot of the consumption shock obtained as an independently and identically distributed series.

To simulate the model, I only consider one source of randomness, the belief shock or the 'animal spirits'. That is, I shut down the shocks related to fundamentals.[17] Figure 2 shows whether and how the model-generated output replicates actual output for Malaysia. It is interesting to find that the model subjected only to a belief shock also displays a sharp fall in output in the 1997-98 period. One major difference is that the

[16] For example, Benhabib and Farmer (1996) and Weder (2000) show that indeterminacy can arise at values much closer to constant returns to scale using two-sector models with sector specific externalities. However, it would be of interest that whether a simple one sector model in face of international capital mobility can also display indeterminacy at much lower values of returns to scale as shown theoretically by Lahiri (1998).

[17] In addition to the sunspot shock, the productivity shock and the interest rate shock ('fundamental shocks') were also included to check whether or not the model's ability to replicate the actual output can be improved. But, no discernible improvement was observed.

model economy shows a strong recovery back to its original growth path, while this is not the case in the actual economy.

Figures 3 and 4 show the impulse responses of consumption, output, and investment of the actual data and the model generated data. A vector autoregression (VAR) of three variables with three lags is used to produce the impulse response functions. The actual data show a very strong persistence to a 1% standard deviation shock to output while the persistence is much weaker in the data implied by the model. This is precisely consistent with Figure 2, in which the recovery is rapid in the model economy.
However, the investment data show a hump-shaped response both in the model generated and actual data. It is well known that standard real business cycle model fails to generate this hump-shaped impulse response, see, for example, Cogley and Nason (1995) and Farmer and Guo (1994). The consumption response to a shock is instantaneous in the model while consumption responds slowly in the actual data. This reflects the fact that consumption is almost perfectly smooth in the model as the model assumes an intertemporal utility maximisation of the log consumption in a separable utility in face of international capital mobility.

4. Indeterminacy in a Small Open Economy

While the degree of market power and increasing returns assumed by Farmer and Guo (1994) is not a significant departure from the range of values suggested by previous empirical studies, assuming somewhat lower values in the Farmer and Guo model does not produce indeterminacy and eliminate all 'sunspot' events. This has led researchers to pursue theoretical work to focus on the degree of returns to scale required to generate indeterminacy. The theoretical research has mostly focused on the closed economy models, and explored in most cases multiple sector models with the inter-linkages across sectors. In an open economy, Lahiri (1998) and Weder (2001) show the theoretical conditions using a continuous time framework that indeterminacy is much easier to obtain in an open economy than in a closed economy model.

While this paper is not a theoretical attempt to add to this line of literature, it is of interest to see whether the theoretical possibility raised by these researchers can be confirmed in a calibrated applied model such as the one developed in this paper. The conventional way to check for the existence of indeterminacy has been, as shown by Farmer (1999), to look at whether the number of roots of the matrix J that lie outside the unit circle is greater than the number of predetermined (whose initial values are given) variables in the system. This way of checking indeterminacy is, however, not universally applicable, especially to a model with singular matrices.

However, Sims (2001) shows a simple way of doing this within his 'gensys' code, which returns a value 'eu' for checking for 'existence' and 'uniqueness'. For a system to display a rational expectations equilibrium as well as indeterminacy, the computer returned output should be 'eu' = [1;0].

The experiment taken with the model in this paper shows that the degree of returns to scale can be lowered significantly close to the level of constant returns to scale, even if the model is nothing but a simple extension of Farmer and Guo's to a small open economy. Unlike Bennett and Farmer (2000) and Benhabib et al. (2000) that all require substantial modifications in utility functions and/or sector specific externalities in multisector models in the closed economy, the small open economy can exhibit the indeterminacy more naturally, as argued by Lahiri (1998).

5. Concluding Remarks

This paper considers the possibility that a real business cycle model showing indeterminacy can be easily extended to a small open economy and then used to answer to what extent macroeconomic fluctuations can be driven by 'animal spirits'. The model is calibrated to match recent economic collapse in Southeast Asia to examine whether the model also experiences a sharp fall in output in 1997-98. The model appears to capture at least major falls in Malaysian output in the 1990s, including the crisis period. The model has, however, certain limitations to match other dimensions of the observed data in developing countries such as Southeast Asia. Especially, the model, as inherent in any RBC model and exacerbated in open economy equilibrium models, exhibits extreme consumption smoothing and rapid recovery. The use of nonseparable or more complicated utility between consumption and leisure may lower the degree of consumption smoothing to some extent. Future research will require an open economy model of indeterminacy to adopt a nonseparable utility and thus enabling to match observed consumption volatility and cross-country correlations. Adding more realistic production structure and sectoral interdependence would be a challenging but also fruitful avenue for future research.

Secondly, the model predicts a rapid recovery after the major recession in the crisis period while it is not the case in actual data. Given the model assumes a deterministic trend of output, it is of interest to see how a model showing a stochastic trend or other frictions such as real or nominal rigidity can better predict the very slow course of the economy after a major shock.

Finally, the quantitative exercise demonstrated in this paper provides an important implication for government policy. That is, appropriate government policy might be able to avert the economy from a self-fulfilling fluctuation with indeterminacy toward a unique saddle path.

Figure 1. Normalized Consumption shocks in Malaysia in the 1990s

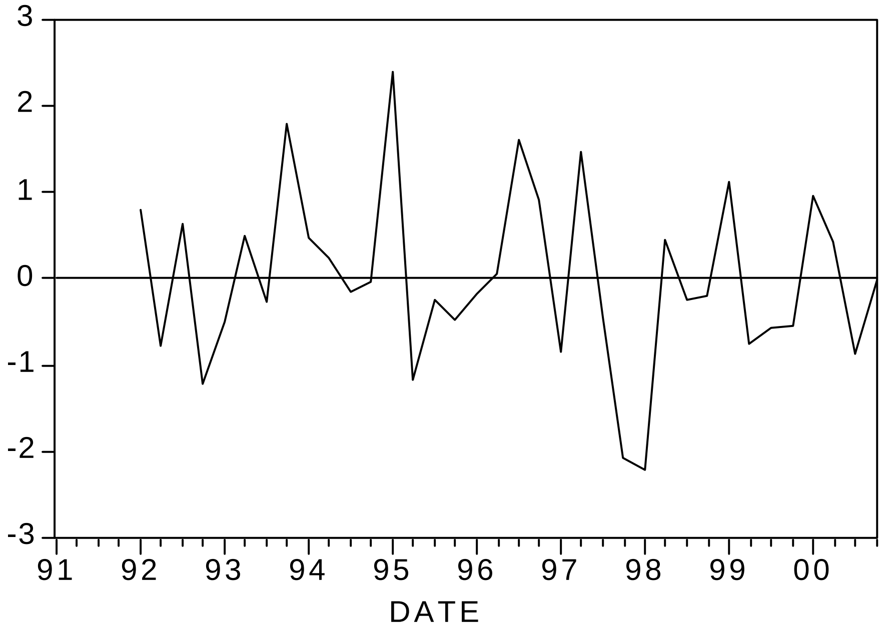


Figure 2A. Actual Output and Simulated Output from the Model (Sunspot shock only)

Figure 2B. Actual Output vs. Model generated Output for Malaysia (all shocks)

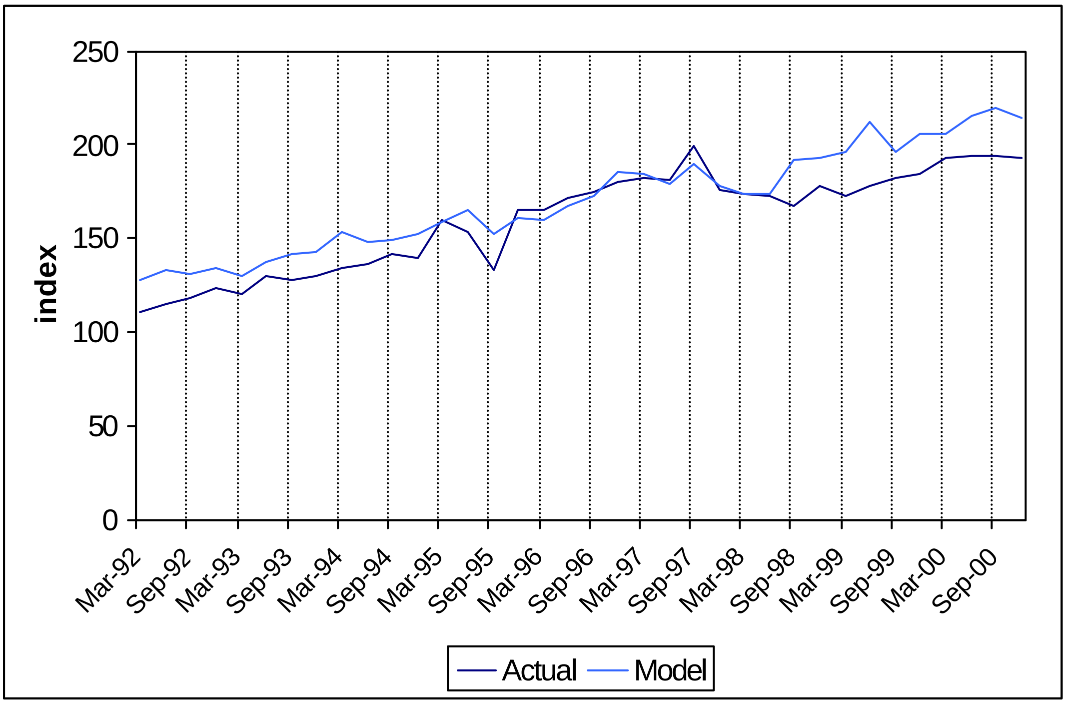


Figure 2C. Actual Output vs. Model generated Output for Malaysia (no sunspot)

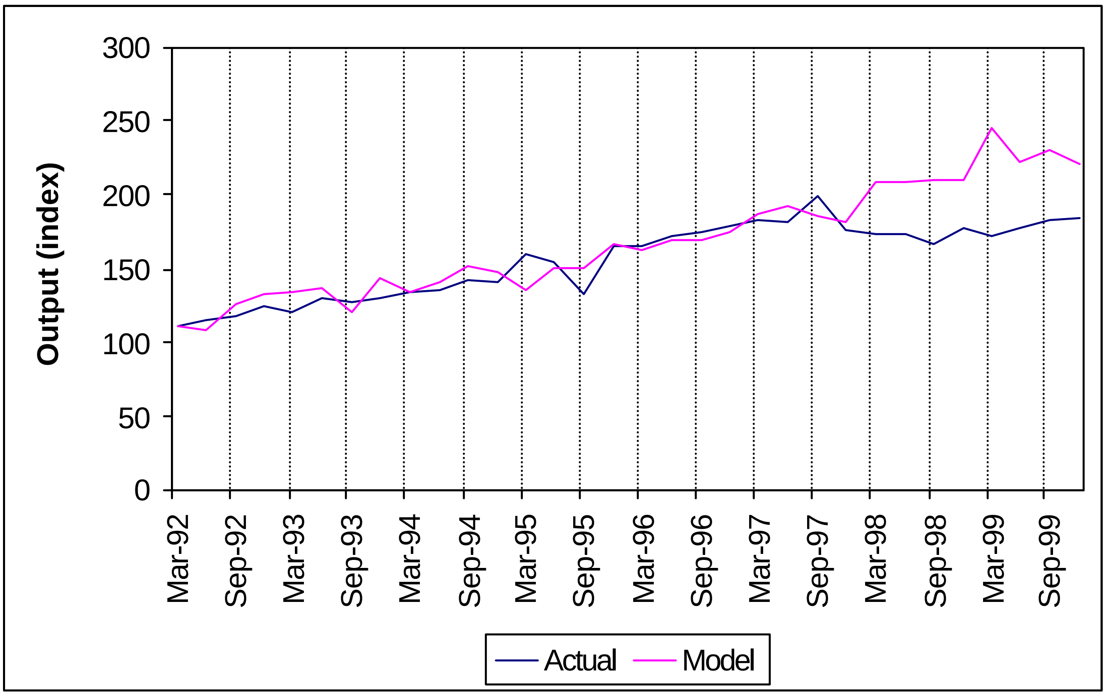


Figure 3. Impulse Responses from the actual data

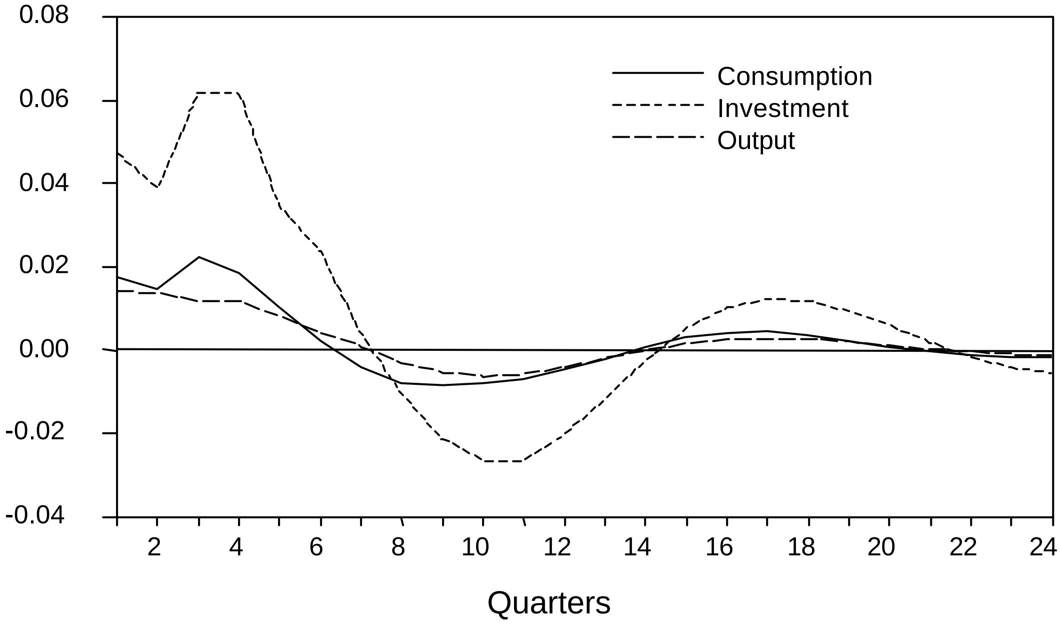
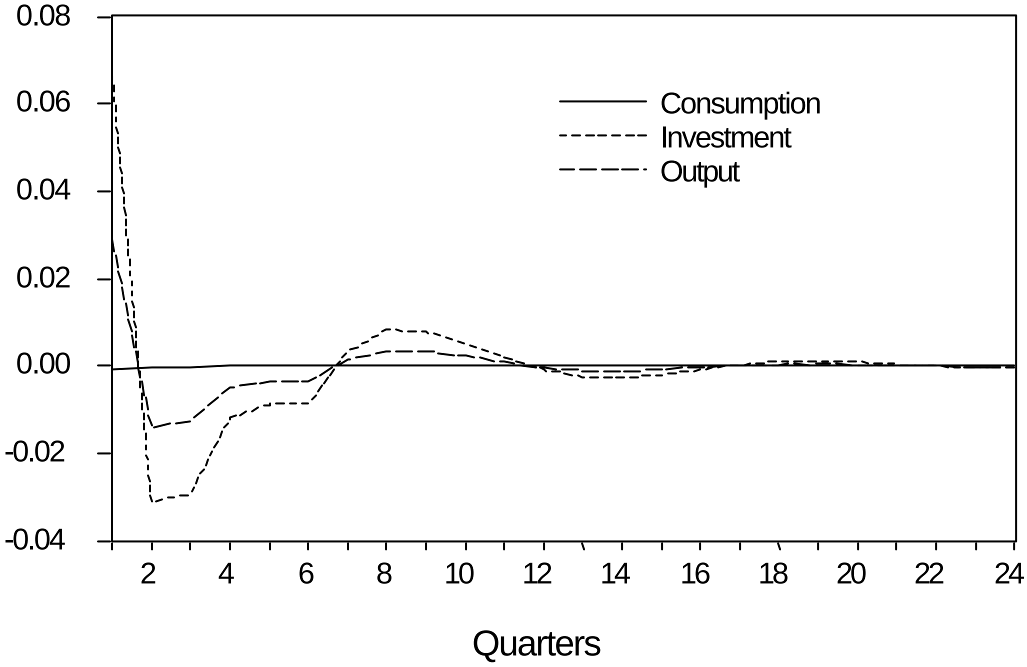


Figure 4. Impulse Responses from the simulated model



Appendix. Obtaining Empirical Consumption Shocks

The technique used to obtain empirical consumption shocks follows Blanchard (1993). First, I take the components of GDP, and then induce stationarity of these variables. For consumption, investment, and government spending, I take log-differences of the series, C, I, and G. The net export series is divided by trend output, obtained by fitting an exponential trend to GDP. The transformed series are {Δlog C, Δlog I, Δlog G, and NX/Y^{trend}}.

Second, I run a vector autoregression (VAR) of four transformed variables with a constant term, a dummy, and 3 lags of each variable in each equation.

Blanchard (1993) argues that treatment of trend or the incorporation of cointegrating relations is of little interest when the focus is on the residuals from each equation.

Third, I regress Δlog Y on Δlog C, Δlog I, Δlog G, and NX/Y^{trend}, and then use the residuals from this equation, denoted ε_t^y.

Fourth, I regress ε_t^c on ε_t^y using ε_t^g as an instrument to estimate the effects of ε_t^y on ε_t^c where ε_t^c denote residuals or forecast errors to consumption equation of the VAR(3) system.

Since ε_t^c represents the error term contemporaneously correlated with ε_t^y, it cannot be taken as a consumption shock. To obtain a consumption shock, the following are assumed: (1) ε_t^c only depends on ε_t^y, not on any other residuals contemporaneously or within a quarter, and (2) ε_t^g, the residuals to the government spending equation in the VAR are exogenous.

That is,

$$\varepsilon_t^c = \beta_{cy}\, \varepsilon_t^y + \hat{e}_t^c$$

Now interpret $\hat{e}_t^c$ as a "consumption shock". Although $\hat{e}_t^c$ may be still cross-correlated, it would be much less so than ε_t^c.

The estimates of consumption shocks thus obtained are then normalized using standard deviations of the shocks, to ensure that the shocks are identically and independently distributed with mean 0 and a constant variance.

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