VICTORIA UNIVERSITY OF WELLINGTON

GRADUATE SCHOOL OF BUSINESS AND GOVERNMENT MANAGEMENT

WORKING PAPER SERIES 10/92

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November 1992

ISSN 0114 7420
ISBN 0 475 11454-X

A STOCHASTIC OVERLAPPING GENERATIONS REAL BUSINESS CYCLE MODEL OF A SMALL OPEN ECONOMY*

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* I would like to thank the participants of the Seminar Programme of the Victoria University of Wellington, Economics Group for their comments. I am especially grateful to Viv Hall for various useful comments.

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ABSTRACT

A stochastic, discrete time version of Blanchard's model of Perpetual Youth (Blanchard [1985]) is extended to an open economy with both tradable and nontradable goods. Some illustrative numerical simulations, based on parameter values taken from the existing real business cycle literature, are used to evaluate the comparative impact of productivity shocks on the tradable and nontradable goods sectors. It is shown that productivity shocks on the traded good sector leads to a positive correlation between aggregate output and the trade balance - aggregate output ratio. In contrast, productivity shocks on the non-traded good sector produces a negative correlation when the intertemporal elasticity of substitution between the current and future consumption is greater than the temporal elasticity of substitution between traded and non-traded good consumption.

Keywords: Real Business cycle, Small open economy, Tradable and nontradable goods, Overlapping generations.

Journal of Economic Literature Classification: C10, C61, E32, F32

I. INTRODUCTION

During the last decade, the "real business cycle" (RBC) approach pioneered by Kydland and Prescott (1982), Long and Plosser (1983), and King and Plosser (1984) has been very influential on subsequent research into macroeconomic fluctuations. Early real business cycle models used a neoclassical model of capital accumulation augmented by choice of labour supply. Models were rather simple in the sense that they were restricted to closed economies with a single commodity and no government. The only source of uncertainty considered was shocks to production technology. Even with this simple framework the models could replicate main features of business cycle regularities very well and generated a lot of enthusiasm and controversy. Major criticisms of real business cycle models have been directed at the nature and magnitude of the productivity shocks. Since productivity shocks are not directly observable, Solow residual measures have generally been used to measure the productivity shocks. McCallum (1989) points out that "[i]f the [Solow residuals] were actually a proxy for observable variables that have been omitted from the models ... then the interpretation and conclusions of the work would be quite different ..."

Recent real business cycle research has been directed toward incorporating features omitted in early models. For example there have been a number of key pieces of research that have applied the real business cycle approach to an open economy. These include Backus, Kehoe and Kydland (1991), Baxter and Grucini (1989), Cardia (1991), Kim and Loungani (1992), and Mendoza (1991). In an open economy extension, one of the issues is to see whether these models could explain stylised open economy features such as a high correlation between national saving and investment and the countercyclical or acyclical behaviour of the trade account balance. These stylised open economy features have been documented, for example, in Feldstein and Horioka (1980), Tesar (1991), and Backus and Kehoe (1991). Another issue is to check whether the incorporation of additional features absent in early real business cycle models would reduce the reliance of models on unobservable productivity shocks. In this respect, Cardia (1991) considers monetary and fiscal policy shocks, Kim and Loungani (1992) consider energy price shocks, and Mendoza (1991) considers world real interest rate shocks.

With respect to the second issue, basic results from existing research are quite surprising. They conclude that the inclusion of additional features doesn't help much in explaining GDP fluctuations. Kim and Loungani (1992, p.186) conclude that "the inclusion of energy price shocks leads to only a modest reduction in the RBC model's reliance on unobserved technology shocks." Cardia (1991, p.411) argues that "monetary and fiscal shocks play a minor role." Mendoza (1991, p.809) points out that "moderate shocks to [the world's real interest rate] have minimal effects on the equilibrium stochastic process of the model."

It should be noted that the models used in Cardia (1992) and Mendoza (1991) have a single composite commodity only and therefore cannot address the implications of commodity terms of trade shocks. Kim and Loungani (1992) consider energy as an imported raw material, but in their model there is also a single final consumption good. For a small open economy like New Zealand, the fluctuation in relative prices at which the economy can sell its output in the world market has been considered by many as one of the main sources of macroeconomic fluctuations. In order to analyse the relative importance of terms of trade shocks versus productivity shocks, it is essential to have a model with multiple consumption goods. By having a model with importables, exportables and nontradables, we can analyse the dynamics generated by the terms of trade and real exchange rates. As a step toward developing a real business cycle model of a small open economy with multiple goods, in this paper we devise a model with nontraded as well as traded goods.

The presence of both nontradables and tradables generates dynamics that are not present in models with a single tradable good. An open economy's adjustment to productivity shocks on the nontradable goods sector can be very different from the adjustment to productivity shocks on the tradable goods sector. Kim (1990) analyses a two-period model of a small open economy endowed with both tradable and nontradable goods in each period. Consumption smoothing implies that a temporary increase in the endowment of tradable goods would improve the trade account balance. In this economy, if supply shocks happen to the tradable goods sector only, the trade balance would be procyclical. If the temporary positive supply shock happens to the nontradable goods sector instead of the tradable goods sector, whether the balance of trade deteriorates or improves depends on the relative size of the intertemporal elasticity of substitution in consumption and the temporal elasticity of substitution between tradables consumption and nontradables consumption. The intuition is the following. In a small open economy, the world rate of interest is fixed in terms of tradable goods. But the real interest rate relevant for the intertemporal consumption decision is the one measured in terms of consumption baskets. If there is a temporary increase in the output of nontradable goods, the price of current period nontradables would fall relative to the price of future period nontradables. This makes the domestic real interest rate lower than the world real interest rate. As a result, consumption is tilted toward the current period and the balance of trade is adversely affected. But the same shock also implies that the price of nontradables falls relative to the price of tradables. Consumption is tilted toward nontradables and the balance of trade is favourably affected. The net effect on the balance of trade depends on the relative size of the intertemporal elasticity of substitution and the temporal elasticity of substitution between tradables and nontradables.

In this paper, we set up an infinite period, stochastic model of a small open economy which produces both tradable and nontradable goods. We compare the dynamics generated by technology shocks on tradable goods production and on nontradable goods production. Since the magnitude of production and investment is endogenous in this model, implications for behaviour of the trade balance are not so clear cut as in the model with endowments only. But the model captures the key differences in dynamic adjustments. The remainder of the paper is organised as follows. In Section II, we specify a model of a small open economy which produces both tradable and nontradable goods. The model is an extension of the one used in Cardia (1991) which is a discrete time, open economy, stochastic version of Blanchard (1985). Our strategy for carrying out the numerical simulations is also explained. In Section III, the simulation results are used to compare the dynamics implied by the productivity shocks on each of the tradable and nontradable goods sectors. Concluding remarks are presented in Section IV.

II. THE MODEL

The following two sector small open economy model is based on the discrete time version of Blanchard (1985), but is extended to include both traded and nontraded goods and productivity shocks.

II.1 Production Decision

Consider a small open economy which produces both tradable goods and nontradable goods. In our description of the economy, variables or parameters relevant to tradable goods and nontradable goods are distinguished by the superscripts T and NT. Production of output takes place in each industry x (x = T or NT) by combining domestic labour N^x and a capital good K^x specific to that industry. It is affected by a technology shock A^x. The technologies used to produce goods are assumed to be Cobb-Douglas,

$$Y_t^x = A_t^x (K_t^x)^{1-\phi^x} (N_t^x)^{\phi^x}, \tag{1}$$

where $0 < \phi^x < 1$. Labour's distributive share is given by the parameter ϕ^x. It is assumed that an investment in period t becomes a capacity increase in period t. Capital depreciates at a rate of d, so capital and gross investment, I^x, are related by:

$$I_t^x = K_t^x - K_{t-1}^x + d^x K_t^x . \tag{2}$$

Extra cost is required in adjusting the level of capital stock. It is given by:

$$\frac{\psi^x}{2} (K_t^x - K_{t-1}^x)^2 / K_t^x ,$$

where $\psi^x > 0$.

We assume that international financial markets are perfectly integrated so that the small economy faces the world rate of interest, r, which is measured in units of tradables. The representative firm in each industry x maximises the expected present discounted value of profits:

$$\underset{\{K_{t+j}^x, N_{t+j}^x\}}{\text{Maximise}} \; E_t \sum_{j=0}^{\infty} (\frac{1}{1+r})^j \{ Y_{t+j}^x - w_{t+j}^x N_{t+j}^x - \frac{\psi^x}{2} [(K_{t+j}^x - K_{t+j-1}^x)^2 / K_{t+j}^x] - I_{t+j}^x \}, \tag{3}$$

with K_{t-1} given, and w^x being the real wage rate measured in units of good x. E_t is the expectation operator term conditional on information available at time t. Substituting (1) and (2) into (3) and differentiating with respect to K_{t+j}^x, j = 0, 1, ... gives the system of stochastic Euler equations:

$$\begin{aligned} & Y_{K,t+j}^x - \psi^x (K_{t+j}^x - K_{t+j-1}^x)/K_{t+j}^x] + \frac{\psi^x}{2} [(K_{t+j}^x - K_{t+j-1}^x)/K_{t+j}^x]^2 \\ & \quad - (1 + d^x) + \frac{1}{1+r} \{ \psi^x (K_{t+j+1}^x - K_{t+j}^x)/K_{t+j+1}^x + 1 \} = 0, \qquad j = 0, 1, \ldots \end{aligned} \tag{4}$$

subject to the transversality condition

$$\begin{aligned} & \lim_{T \to \infty} (\frac{1}{1+r})^T \{ Y_{K,t+T}^x - \psi^x (K_{t+T}^x - K_{t+T-1}^x)/K_{t+T}^x \\ & \qquad + \frac{\psi^x}{2} [(K_{t+T}^x - K_{t+T-1}^x)/K_{t+T}^x]^2 - (1 + d^x) \} = 0. \end{aligned}$$

Y_K^x is the marginal product of capital in industry x. Differentiation with respect to N_t^x gives:

$$w_t^x = Y_{N,t}^x , \tag{5}$$

where Y_N^x is the marginal product of labour in industry x. We can rewrite (4) and express investment as a function of the expected present discounted value of the marginal revenues accruing to the firm,

$$K_t^x - K_{t-1}^x = E_t\{\sum_{j=0}^{\infty} (\frac{1}{1+r})^j [Y_{K,t+j}^x + \frac{\psi^x}{2}[(K_{t+j}^x - K_{t+j-1}^x)/K_{t+j}^x]^2 - d^x] - 1\}\frac{K_t^x}{\psi^x}$$

$$= (q_t^x - 1)\frac{K_t^x}{\psi^x}. \tag{6}$$

By taking $E_t q_{t+1}^x - (1 + r)q_t^x$, we have

$$E_t q_{t+1}^x = (1 + r)\,[q_t^x - Y_{K,t}^x - \frac{\psi^x}{2}[(K_t^x - K_{t-1}^x)/K_t^x]^2 + d^x]. \tag{7}$$

The variable q^x is a measure of Tobin's q.

II.2 Consumption Decision

Our consumer decision specification is based on the discrete time version of Blanchard's (1985) finite probability of death model, as extended to include multiple consumption goods. Individuals are assumed to maximise expected utility as follows:

$$\underset{\{C_{t+j}^T, C_{t+j}^{NT}, L_{t+j}\}}{\text{Maximise}} \; E_t \sum_{j=0}^{\infty} (\frac{1}{1+\rho})^j \{\log[(C_{t+j}^T)^{-\mu} + (C_{t+j}^{NT})^{-\mu}]^{-1/\mu} + v\log(L_{t+j})\} \tag{8}$$

where $\rho > 0$, $v > 0$, and $\mu > -1$. C^x (x = T or NT) stands for consumption of good x, L for leisure, and ρ is the subjective discount rate. This particular form of utility function implies that the inter-temporal elasticity of substitution is equal to one and the intra-temporal constant elasticity of substitution between traded and nontraded goods is equal to $1/(1+\mu)$. We normalise the endowment of time so that $N^T + N^{NT} + L = 1$, where N^x (x = T or NT) is the time allocated to work in industry x. Each individual faces a probability of death. We denote the probability that an individual survives from one period to the next by γ, which, in order to facilitate the aggregation, is assumed to be independent of the individual's age. Thus the probability that an individual survives the next j periods is γ^j. The expected remaining life of an individual is given by

$$\sum_{j=0}^{\infty} j\gamma^j = \frac{\gamma}{(1-\gamma)^2},$$

and as γ goes to one, life expectancy goes to infinity. This is the standard infinite horizon case. There are other sources of uncertainty (shocks to technologies) in addition to an uncertain life horizon in this model. Since we are assuming a constant probability of death the latter source of uncertainty can be separated out. We can rewrite the individual's maximisation problem as follows:

$$\sum_{j=0}^{\infty} \left(\frac{\gamma}{1+\rho}\right)^j E_t\{\log[(C_{t+j}^T)^{-\mu} + (C_{t+j}^{NT})^{-\mu}]^{-1/\mu} + v \log(L_{t+j})\}. \tag{9}$$

Because of the finite probability of death, the effective interest rate relevant for individual decision making is $(1 + r)/\gamma$. Individuals are assumed to face the following budget constraint:[1]

$$W_{t+1} = \frac{1+r}{\gamma}(W_t + w_t^T N_t^T + p_t w_t^{NT} N_t^{NT} - C_t^T - p_t C_t^{NT}), \tag{10}$$

where W is the financial wealth and p is the relative price of nontradable goods. The rate of interest, r, and the level of financial wealth are measured in units of tradables. Financial wealth is composed of shares in domestic firms (V^T, V^{NT}) and bonds issued by foreigners (B). Therefore

$$W_t = B_t + V_t^T + V_t^{NT} = B_t + q_t^T K_{t-1} + q_t^{NT} K_{t-1}. \tag{11}$$

The first-order condition of household maximisation implies the following intra-temporal and inter-temporal substitution conditions. Intra-temporal substitution conditions are:

$$\frac{(C_t^{NT})^{-(\mu+1)}}{(C_t^T)^{-(\mu+1)}} = p_t, \tag{12}$$

$$\frac{v\,(1-N_t^{NT}-N_t^T)^{-1}}{[(C_t^T)^{-\mu}+(C_t^{NT})^{-\mu}]^{-1}(C_t^T)^{-(\mu+1)}} = w_t^T, \tag{13}$$

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1 For convenience at this stage, this model does not include a government sector. Domestic government bonds and interest on them do not therefore appear explicitly in this budget constraint.

$$\frac{v\,(1-N_t^{NT}-N_t^T)^{-1}}{[(C_t^T)^{-\mu}+(C_t^{NT})^{-\mu}]^{-1}(C_t^{NT})^{-(\mu+1)}} = w_t^{NT}. \tag{14}$$

Note that (12), (13), and (14) implies

$$w_t^T = p_t w_t^{NT}. \tag{15}$$

Inter-temporal substitution conditions are

$$E_t \frac{[(C_t^T)^{-\mu}+(C_t^{NT})^{-\mu}]^{-1}(C_t^T)^{-(\mu+1)}}{[(C_{t+1}^T)^{-\mu}+(C_{t+1}^{NT})^{-\mu}]^{-1}(C_{t+1}^T)^{-(\mu+1)}}$$

$$= E_t \frac{[(C_t^T)^{-\mu}+(C_t^{NT})^{-\mu}]^{-1}(C_t^{NT})^{-(\mu+1)}}{[(C_{t+1}^T)^{-\mu}+(C_{t+1}^{NT})^{-\mu}]^{-1}(C_{t+1}^{NT})^{-(\mu+1)}} = \frac{1+r}{1+\rho} \tag{16}$$

Since the intertemporal elasticity of substitution is equal to one, the propensity to save out of total wealth is constant. It can be shown that:

$$C_t = (1 - \frac{\gamma}{1+\rho})(W_t + H_t) \tag{17}$$

where

$$C_t = C_t^T + p_t C_t^{NT} \text{ and} \tag{18}$$

$$H_t = \sum_{j=0}^{\infty} (\frac{\gamma}{1+r})^j\, E_t(w_t^T N_t^T + p_t w_t^{NT} N_t^{NT}). \tag{19}$$

H_t is the present value of all the current and future wage earnings and is therefore the human wealth. C_t is the expenditure (measured in units of tradable goods) on all of the consumption goods. $\frac{\gamma}{1+\rho}$ corresponds to the propensity to save out of wealth.

From equation (17), we get

$$E_t C_{t+1} - \frac{1+r}{\gamma} C_t = (1 - \frac{\gamma}{1+\rho})(E_t W_{t+1} - \frac{1+r}{\gamma} W_t + E_t H_{t+1} - \frac{1+r}{\gamma} H_t). \tag{20}$$

II.3 The Aggregate Macro-model

Population is normalised so that at birth every cohort consists of one individual who is assumed to be born without debt. Due to death the size of each cohort of age a becomes γ^a. For any variable s, the relation between per-capita aggregate magnitude, s^A, and the value for individual, s^I, is given by

$$s^A = \sum_{a=0}^{\infty} (1 - \gamma)\, \gamma^a s^I.$$

On the basis of this relation (and assuming that labour productivity is the same across individuals) it can easily be shown that aggregate human wealth is equivalent to the expression found for individual human wealth. For financial wealth it can be shown that

$$W_{t+1} = (1 + r)\,(W_t + w_t^T N_t^T + p_t w_t^{NT} N_t^{NT} - C_t^T - p_t C_t^{NT}). \tag{21}$$

As is evident, the rate of interest applicable to the per-capita value of aggregate private-sector financial wealth is the risk-free market rate of interest. This should be contrasted with the formulation of the individual financial wealth in equation (10) in which the rate of interest applicable to the computation of individual financial wealth is the risk-adjusted effective rate. In the rest of the paper all variables are in aggregate form.

Substituting (19) and (21) into (20) the following expression for aggregate consumption is obtained:

$$E_t(C_{t+1}) = \frac{1+r}{1+\rho}\,(C_t) - (1 - \frac{\gamma}{1+\rho})(1 - \frac{1}{\gamma})E_t W_{t+1}. \tag{22}$$

Note that with infinite lifetime, $\gamma = 1$, the second term on the righthand side of the equality disappears. Equation (22) reduces to the dynamic equation that displays Robert Hall's (1978) result that the marginal utility of consumption follows a univariate first order Markov process.

The market for nontradable goods must clear during each period. The market clearing condition for domestic nontradable goods is

$$Y_t^{NT} = C_t^{NT} + \frac{\psi^{NT}}{2}\,(K_t^{NT} - K_{t-1}^{NT})^2/K_t^{NT} + I_t^{NT}. \tag{23}$$

This implies that the accumulation equation for the domestic claims on the rest of the world, B, is given by[2]

$$B_{t+1} = (1 + r)\,\{B_t + Y_t^T - C_t^T - \frac{\psi^T}{2}(K_t^T - K_{t-1}^T)^2/K_t^T - I_t^T\}. \tag{24}$$

The model simulated for the aggregate economy consists of equations (5), (6), (7), (11), (12), (13), (15), (18), (21), (22), (23) and (24). There are 15 equations but only 14 of them are independent. Equation (24) can be derived from equations (6), (7), (11) and (21). This ensures that the form of the individual's budget constraint and the firms' first order conditions are all part of a coherent economic environment. 14 independent equations would determine the dynamics of 14 endogenous variables: w^T, w^{NT}, K^T, K^{NT}, q^T, q^{NT}, N^T, N^{NT}, C^T, C^{NT}, C, B, W, and p.

II.4 Numerical Solution Procedure

We use King, Plosser and Rebelo's (1988) log linear modification of the procedure used by Kydland and Prescott (1982) to obtain an approximate solution. We solve for the nonstochastic steady state of the model and approximate the dynamics of the model in response to exogenous shocks by linearizing equations in terms of percentage deviations from the steady state. Conditions required for the steady state of the economy can be derived from the equations (5), (6), (7), (11), (12), (13), (15), (18), (21), (22), (23) and (24) by imposing the condition that $X_{t-1} = X_t = X_{t+1}$ for any variable X.

$$w^T = Y_N^T$$

$$w^{NT} = Y_N^{NT}$$

$$q^T = q^{NT} = 1$$

$$1 = (1 + r)\,(1 - Y_K^T + d^T)$$

$$1 = (1 + r)\,(1 - Y_K^{NT} + d^{NT})$$

[2] Since the domestic claims on the rest of the world, B, is measured in units of tradables, fluctuations in the relative price of nontradables, p, do not affect the law of motion for B.

$$Y^{NT} = C^{NT} + d^{NT} K^{NT}$$

$$W = B + K^T + p\, K^{NT}$$

$$W = (1 + r)\,(W + w^T N^T + p\, w^{NT} N^{NT} - C)$$

$$C = C^T + p\, C^{NT}$$

$$C = \frac{1+r}{1+\rho} C - (1 - \frac{\gamma}{1+\rho})(1 - \frac{1}{\gamma})\, W$$

$$B = (1 + r)\,(B + Y^T - C^T - d^T K^T)$$

$$\frac{(C^{NT})^{-(\mu+1)}}{(C^T)^{-(\mu+1)}} = p$$

$$\frac{v\,(1-N^{NT}-N^T)^{-1}}{[(C^T)^{-\mu}+(C^{NT})^{-\mu}]^{-1}(C^T)^{-(\mu+1)}} = w^T$$

$$w^T = p w^{NT}$$

These 15 equations[3] determine the steady state values of the 14 variables w^T, w^{NT}, K^T, K^{NT}, q^T, q^{NT}, N^T, N^{NT}, C^T, C^{NT}, C, B, W, and p.

For any variable X, let $\hat{X}_t$ denote the percentage deviation of X_t from its nonstochastic steady state value, i.e., $\hat{X}_t = \ln(X_t/X)$. Then the equations (5), (6), (7), (11), (12), (13), (15), (18), (21), (22), (23) and (24) imply that the log-linear laws of motion are governed by[4]:

$$\hat{K}_t^T = \hat{K}_{t-1}^T + \frac{1}{\psi^T} \hat{q}_t^T \tag{25}$$

$$\hat{K}_t^{NT} = \hat{K}_{t-1}^{NT} + \frac{1}{\psi^{NT}} \hat{q}_t^{NT} \tag{26}$$

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[3] As previously pointed out, only 14 of them are independent. The redundant equation can be used to check the internal consistency of the model.

[4] Before equations (25) - (36) were derived, equation (5) was substituted into equations (13), (15) and (21) . Equation (11) was not used because it was redundant.

$$\hat{W}_{t+1} = (1+r)\,\hat{W}_t + \frac{(1+r)Y_N^T}{W}(N^T\,\hat{N}_t^T + N^{NT}\,\hat{N}_t^{NT}) + \frac{(1+r)(N^T+N^{NT})}{W}(Y_{NN}^T\,N^T\,\hat{N}_t^T + Y_{NK}^T\,K^T\,\hat{K}_t^T + Y_N^T\,\hat{A}_t^T) - \frac{(1+r)C}{W}\hat{C}_t \tag{27}$$

$$E_t\hat{q}_{t+1}^T = (1+r)\,\hat{q}_t^T - (1+r)\,(\phi^T - 1)\,Y_K^T\,\hat{K}_t^T - (1+r)\,(1-\phi^T)\,Y_K^T\,\hat{N}_t^T - (1+r)\,Y_K^T\,\hat{A}_t^T \tag{28}$$

$$E_t\hat{q}_{t+1}^{NT} = (1+r)\,\hat{q}_t^{NT} - (1+r)\,(\phi^{NT} - 1)\,Y_K^{NT}\,\hat{K}_t^{NT} - (1+r)\,(1-\phi^{NT})\,Y_K^{NT}\,\hat{N}_t^{NT} - (1+r)\,Y_K^{NT}\,\hat{A}_t^{NT} \tag{29}$$

$$E_t\hat{C}_{t+1} = \frac{1+r}{1+\rho}\,\hat{C}_t - \frac{(1-\frac{\gamma}{1+\rho})(1-\frac{1}{\gamma})W}{C}\,E_t\hat{W}_{t+1} \tag{30}$$

$$\hat{C}_t = \frac{C^T}{C}\,\hat{C}_t^T + \frac{pC^{NT}}{C}\,\hat{C}_t^{NT} + \frac{pC^{NT}}{C}\,\hat{p}_t \tag{31}$$

$$\hat{p}_t = (1+\mu)\,\hat{C}_t^T - (1+\mu)\,\hat{C}_t^{NT} \tag{32}$$

$$\left(\frac{Y_{NN}^T N^T}{Y_N^T} - \frac{N^T}{1-N^T-N^{NT}}\right)\hat{N}_t^T - \frac{N^{NT}}{1-N^T-N^{NT}}\,\hat{N}_t^{NT} = \left(\mu + 1 - \frac{\mu\,(C^T)^{-\mu}}{(C^T)^{-\mu}+(C^{NT})^{-\mu}}\right)\hat{C}_t^T - \frac{\mu\,(C^{NT})^{-\mu}}{(C^T)^{-\mu}+(C^{NT})^{-\mu}}\,\hat{C}_t^{NT} - \frac{Y_{NK}^T K^T}{Y_N^T}\,\hat{K}_t^T - \hat{A}_t^T \tag{33}$$

$$\frac{Y_{NN}^T N^T}{Y_N^T}\,\hat{N}_t^T - \frac{Y_{NN}^{NT} N^{NT}}{Y_N^{NT}}\,\hat{N}_t^{NT} = \hat{p}_t + \frac{Y_{NK}^{NT} K^{NT}}{Y_N^{NT}}\,\hat{K}_t^{NT} + \hat{A}_t^{NT} - \frac{Y_{NK}^T K^T}{Y_N^T}\,\hat{K}_t^T - \hat{A}_t^T \tag{34}$$

$$(Y_K^{NT} - d^{NT})\,K^{NT}\,\hat{K}_t^{NT} + Y_N^{NT}\,N^{NT}\,\hat{N}_t^{NT} + Y^{NT}\,\hat{A}_t^{NT} = C^{NT}\,\hat{C}_t^{NT} + \frac{K^{NT}}{\psi^{NT}}\,\hat{q}_t^{NT} \tag{35}$$

$$\hat{B}_t = \frac{W}{B}\,\hat{W}_t - \frac{K^T}{B}\,\hat{K}_{t-1}^T - \frac{K^T}{B}\,\hat{q}_t^T - \frac{pK^{NT}}{B}\,\hat{K}_t^{NT} - \frac{pK^{NT}}{B}\,\hat{q}_t^{NT} - \frac{pK^{NT}}{B}\,\hat{p}_t \tag{36}$$

There are 12 equations and 12 endogenous variables: $\hat{K}^T$, $\hat{K}^{NT}$, $\hat{W}$, $\hat{q}^T$, $\hat{q}^{NT}$, $\hat{C}$, $\hat{C}^T$, $\hat{C}^{NT}$, $\hat{p}$, $\hat{N}^T$, $\hat{N}^{NT}$, and $\hat{B}$. The forcing variables are the productivity shocks variables, $\hat{A}^T$ and $\hat{A}^{NT}$.

The last 6 equations can be solved to give $\hat{C}_t^T$, $\hat{C}_t^{NT}$, $\hat{N}_t^T$, $\hat{N}_t^{NT}$, $\hat{p}_t$ and $\hat{B}_t$ as functions of the variables $\hat{K}_{t-1}^T$, $\hat{K}_{t-1}^{NT}$, $\hat{W}_t$, $\hat{q}_t^T$, $\hat{q}_t^{NT}$ and $\hat{C}_t$. Given these, the first six equations imply a first-order dynamic system in $\hat{K}^T$, $\hat{K}^{NT}$, $\hat{W}$, $\hat{q}^T$, $\hat{q}^{NT}$ and $\hat{C}$.

$$E_t\, \mathbf{x}_{t+1} = \mathbf{A}\, \mathbf{x}_t + \mathbf{B}\, \hat{\mathbf{A}}_t \tag{37}$$

where $\mathbf{x}_t = (\hat{K}_{t-1}^T, \hat{K}_{t-1}^{NT}, \hat{W}_t, \hat{q}_t^T, \hat{q}_t^{NT}, \hat{C}_t)'$ and $\hat{\mathbf{A}}_t = (\hat{A}_t^T, \hat{A}_t^{NT})'$.

We specify the technology shock process for the two industries as a bivariate autoregression,

$$\hat{\mathbf{A}}_{t+1} = \begin{bmatrix} \hat{A}_{t+1}^T \\ \hat{A}_{t+1}^{NT} \end{bmatrix} = \begin{bmatrix} \eta^T & 0 \\ 0 & \eta^{NT} \end{bmatrix} \begin{bmatrix} \hat{A}_t^T \\ \hat{A}_t^{NT} \end{bmatrix} + \begin{bmatrix} \varepsilon_{t+1}^T \\ \varepsilon_{t+1}^{NT} \end{bmatrix} = \eta \hat{\mathbf{A}}_t + \varepsilon_{A,t+1}. \tag{38}$$

The parameters η^T and η^{NT} are the serial correlation coefficients for the technology shocks on the tradable and nontradable goods sectors respectively. The innovations ε_t^T and ε_t^{NT} are serially independent, multivariate, normal random variables with contemporaneous covariance matrix **V**.

To compute the solution to the difference equation (37), we first decompose the matrix **A** so that

$$\mathbf{A} = \mathbf{P}\lambda\mathbf{P}^{-1} = \mathbf{P}\begin{bmatrix} \lambda_1 & 0 \\ 0 & \lambda_2 \end{bmatrix}\mathbf{P}^{-1},$$

where **P** is the matrix of characteristic vectors of **A** and λ is a diagonal matrix with the characteristic roots on the diagonal. λ_1 consists of all stable roots of **A** and λ_2 consists of all roots greater than 1 in absolute value. Let $\mathbf{x}_t = (\mathbf{x}_t^P, \mathbf{x}_t^J)'$ where $\mathbf{x}_t^P = (\hat{K}_{t-1}^T, \hat{K}_{t-1}^{NT}, \hat{W}_t)'$ is the vector of predetermined variables and $\mathbf{x}_t^J = (\hat{q}_t^T, \hat{q}_t^{NT}, \hat{C}_t)'$ is the vector of jump variables. Then by applying the solution procedure in Blanchard and Kahn (1980), we get the solution:

$$\mathbf{x}_{t+1}^P = \mathbf{P}_{11}\lambda_1\mathbf{P}_{11}^{-1}\, \mathbf{x}_t^P - \mathbf{A}_{12}\mathbf{C}_{22}^{-1} \sum_{j=0}^{\infty} \lambda_2^{-j-1} (\mathbf{C}_{21}\mathbf{B}_1 + \mathbf{C}_{22}\mathbf{B}_2)\eta^j\, \hat{\mathbf{A}}_t + \mathbf{B}_1\hat{\mathbf{A}}_t$$

$$x_t^J = - C_{22}^{-1} C_{21}\, x_t^P - C_{22}^{-1} \sum_{j=0}^{\infty} \lambda_2^{-j-1} (C_{21}B_1 + C_{22}B_2)\eta^j \hat{A}_t$$

where $A = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix}$, $B = \begin{bmatrix} B_1 \\ B_2 \end{bmatrix}$, $P = \begin{bmatrix} P_{11} & P_{12} \\ P_{21} & P_{22} \end{bmatrix}$, and $C = P^{-1} = \begin{bmatrix} C_{11} & C_{12} \\ C_{21} & C_{22} \end{bmatrix}$.

State dynamics are given by the system

$$s_{t+1} = \begin{bmatrix} x_{t+1}^P \\ \hat{A}_{t+1} \end{bmatrix} = \begin{bmatrix} P_{11}\lambda_1 P_{11}^{-1} & -A_{12}C_{22}^{-1} \sum_{j=0}^{\infty} \lambda_2^{-j-1} (C_{21}B_1 + C_{22}B_2)\eta^j + B_1 \\ 0 & \eta \end{bmatrix} \begin{bmatrix} x_t^P \\ \hat{A}_t \end{bmatrix}$$

$$+ \begin{bmatrix} 0 \\ \varepsilon_{A,t+1} \end{bmatrix} = Ms_t + \varepsilon_{t+1}.$$

Let the vector z_t be a vector of controls and other flow variables of interest. The linear equations relating flows to states,

$$z_t = \Pi\, s_t,$$

are derived from equations (31) - (36) and the definitions of variables.

The above formulation facilitates computation of impulse response functions for the system and population moments of the joint (z_t, s_t) process. The response of the system in period t+k to a technology impulse at date t is

$$s_{t+k} - E_t\, s_{t+k} = M^k\, \varepsilon_t,$$

$$z_{t+k} - E_t\, z_{t+k} = \Pi M^k\, \varepsilon_t.$$

Let Q be a matrix whose columns are the right characteristic vectors of **M**, and let **v** be a diagonal matrix consisting of the characteristic roots v_i of **M**. We have $M = QvQ^{-1}$. Given that $E(\varepsilon_{A,t}\varepsilon_{A,t}') = V$ and therefore $E(\varepsilon_t\varepsilon_t') = \begin{bmatrix} 0 & 0 \\ 0 & V \end{bmatrix}$, the variance-covariance matrix of the states Σ_{ss} is given by,

$$\Sigma_{ss} = E(s_t\, s_t') = Q\left[\frac{\Omega_{ij}}{1-v_i v_j}\right]Q',$$

where Ω_{ij} is the ij-th element of the matrix $\Omega = Q^{-1} E(\varepsilon_t \varepsilon_t') Q'^{-1}$. Then the autocovariance of z at lag j is

$$E(z_t z_{t-j}') = \Pi M^j \Sigma_{ss} \Pi'.$$

II.5 Illustrative Parameterization of the Model

To solve the model, values must be chosen for the parameters r, ρ, μ, v, γ, ψ^T, ψ^{NT}, ϕ^T, ϕ^{NT}, d^T, d^{NT}, η^T, η^{NT}, σ^T, σ^{NT} that characterise the preferences, technology and stochastic disturbances. Most of the parameters are chosen in conformity with earlier studies. The parameter values are given in Table 1.

Table 1

Parameter Values

$r = 0.04$		
Preference	Tradables Production	Nontradables Production
$\rho = 0.039$	$\psi^T = 0.5$	$\psi^{NT} = 0.5$
$\mu = 0.21$	$\phi^T = 0.6$	$\phi^{NT} = 0.6$
$v = 3.81$	$d^T = 0.1$	$d^{NT} = 0.1$
$\gamma = 0.885$	$\eta^T = 0.95$	$\eta^{NT} = 0.95$

The values of r, ρ and γ are those specified in Cardia (1991) for the US and Germany, with the value of $\gamma = 0.885$ implying that the life expectancy at birth is roughly 67 years. Consistent with Kravis and Lipsey (1987, p.101), we have chosen a value of μ so that the elasticity of substitution between tradables and nontradables consumption is less than one.[5] Our value of $\mu = 0.21$ implies that the elasticity is equal to 0.83. Parameters pertaining to the production side are more likely to vary by country than the parameters pertaining to preference. Here we assume that the parameters of the tradables production and the nontradables production are identical in order to capture the difference in dynamics that is solely due to the general

[5] In Kravis and Lipsey's (1987) cross country study on national price levels, one of their regression results "implies that given real GDP per capita and openness, high nontradables shares in final expenditures are associated with high nontradables prices." (p.101) They argue that "such a relationship may be attributable to elasticities of substitution between tradables and nontradables in final demand that are below 1." (p.101)

distinction between the tradables and the nontradables. The rates of depreciation (d^x, $x = T, NT$) are set to 10 % per annum, and the cost-of-adjustment parameters (ψ^x, $x = T, NT$) were chosen to be 0.5. These are the values chosen in Cardia (1991) for the single industry. The value $v = 3.81$, together with the values of other parameters, implies that the stationary value for total hours ($N^T + N^{NT}$) is 0.2. $\sigma^x = 1$ or 0 depending on which productivity shocks we are considering.

III. ILLUSTRATIVE SIMULATION RESULTS

Simulation results are reported in Tables 2, 3, 4 and 5. Tables 2 and 3 report the standard deviations of variables relative to aggregate output and the correlations of variables with relevant sectoral output. In Table 2 the productivity shock is to the tradable sector only ($\sigma^T = 1$, $\sigma^{NT} = 0$), whereas in Table 3 the shock is to the nontradable sector only ($\sigma^T = 0$, $\sigma^{NT} = 1$). Three features of the results are worth noting. First, in both tables and as is a well known key features of business cycles, the volatility of aggregate output is greater than the volatility of aggregate consumption and smaller than the volatility of aggregate investment. Both consumption and investment are positively correlated with aggregate output. Second, when there is a productivity shock to nontradable production only, aggregate consumption displays both very small relative volatility and very little correlation with aggregate output. If the productivity shock happens to both sectors, behaviour of aggregate consumption can be quite reasonable.[6] Third, the most interesting difference between the results in Table 2 and 3 lies in the correlation between aggregate output and the trade balance - aggregate output ratio (tb/Y). In Table 2 where there is productivity shock to the tradables sector only, the trade balance - aggregate output ratio is positively correlated with aggregate output. However, in Table 3 where there is productivity shock to the nontradables sector only, the trade balance - aggregate output ratio is negatively correlated with aggregate output. This conforms with the argument made in the Introduction. In our simulation, the temporal elasticity of substitution (0.83) is smaller than the intertemporal elasticity of substitution (1.0). Thus, abstracting from investment, a positive productivity shock on the nontradable good sector would unfavourably affect the trade balance.

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[6] Mendoza (1991) concludes that there is excessive consumption-output correlation in the model analysed in his paper and suggests that the addition of nontradable commodities could help reduce the excessive correlation. Our result seems to confirm the suggestion. Since the parameters of our model have not been calibrated in light of actual data, firmer conclusions should be postponed until further work is done.

Impulse responses following a one time, positive, one percent productivity shocks are reported in Table 4 and 5. Table 4 shows responses to a productivity disturbance in the traded-good producing sector and Table 5 shows responses to a productivity disturbance in the nontraded-good producing sector. Numbers represent percentage deviations from steady state values. From the tables, it can be seen that: (1) in the early periods labour moves toward the sector where productivity improvement happens, and (2) there are large increases in investments in the sector with positive productivity disturbances.

IV. CONCLUDING REMARKS

In this paper we have developed a real business cycle model of a small open economy that produces both traded goods and nontraded goods. We have simulated the model and compared the dynamics implied by the productivity shocks on the tradable goods sector and the productivity shocks on the nontradable goods sector. In the simulations, we basically adopted the parameter values used in the existing real business cycle literature, and were able to achieve credible empirical outcomes. A number of further research projects can now be considered. For example, to examine the extent to which the model might explain New Zealand macroeconomic fluctuations, the model parameters should next be calibrated more specifically to suit the New Zealand economy. In this respect, Philpott's (1990, 1991, 1992) sectoral databases provide capital stock, employment, and output series for tradable and nontradable sectors, and would therefore allow for production parameter values to differ between the two sectors.[7] Then, in order to analyse the relative importance of terms of trade shocks, the model could be further extended so that exportables and importables can be distinguished.

[7] I would like to thank Bryan Philpott for providing the information on his database to me.

References

Backus, D. K. and P. J. Kehoe (1991), "International Evidence on the Historical Properties of Business Cycles", Research Department Staff Report 145, Federal Reserve Bank of Minneapolis.

Backus, D. K., P. J. Kehoe and F. E. Kydland (1991), "International Real Business Cycles", Research Department Staff Report 146, Federal Reserve Bank of Minneapolis.

Baxter, M. and M. J. Crucini (June 1989), "Explaining Savings/Investment Correlations", Working Paper, Rochester Center for Economic Research.

Blanchard, O. J. (1985), "Debts, Deficits, and Finite Horizons", *Journal of Political Economy* 93, 223-247.

Cardia, E. (1991), "The Dynamics of a Small Open Economy in Response to Monetary, Fiscal, and Productivity Shocks", *Journal of Monetary Economics* 28, 411-434.

Feldstein, M. and C. Horioka (1980), "Domestic Saving and International Capital Flows", *Economic Journal* 90, 314-329.

Frenkel, J. A. and A. Razin (1987), *Fiscal Policies and the World Economy*, Cambridge: MIT Press.

Hall, R. E. (1978), "Stochastic Implications of the Life-Cycle-Permanent-Income Hypothesis: Theory and Evidence", *Journal of Political Economy* 86, 971-987.

Kim, I. and P. Loungani (1992), "The Role of Energy in Real Business Cycle Models", *Journal of Monetary Economics* 29, 173-189.

Kim, K. (1990), "Real Business Cycles in a Small Open Economy", in: L. Evans, J. Poot and N Quigley, ed., *Long-Run Perspectives on the New Zealand Economy*, Wellington, pp. 325-337.

King, R. G., C. I. Plosser and S. T. Rebelo (1988), "Production, Growth and Business Cycles: I. The Basic Neoclassical Model", *Journal of Monetary Economics* 21, 195-232.

King, R. G. and C. I. Plosser (1984), "Money, Credit and Prices in a Real Business Cycle", *American Economic Review* 74, 363-380.

Kravis, I. B. and R. E. Lipsey (1987), "The Assessment of National Price Levels", in: S. W. Arndt and J. D. Richardson, ed., *Real - Financial Linkages Among Open Economies*, Cambridge: MIT Press, pp. 97-134.

Kydland, F. E. and E. C. Prescott (1982), "Time to Build and Aggregate Fluctuations", *Econometrica* 50 1345-1370.

Long, J. B. and C. I. Plosser (1983), "Real Business Cycles", *Journal of Political Economy* 91, 39-69.

McCallum, B. T. (1989), "Real Business Cycle Models" in: R. J. Barro, ed., *Modern Business Cycle Theory*, Cambridge: Harvard University Press.

Mendoza, E. G. (1991), "Real Business Cycles in a Small Open Economy", *American Economic Review*, September 81, 797 - 818.

Philpott, B. (1990), "A Consistent Data Base of Sectoral Employment: 1950-1990", Internal Paper 223, Research Project on Economic Planning, Wellington.

Philpott, B. (1991), "Economic Growth in New Zealand: Models and Experience", in: L. Evans, J. Poot and N Quigley, ed., *Long-Run Perspectives on the New Zealand Economy*, Wellington, pp. 290-305.

Philpott, B. (1992), "Provisional Estimates of New Zealand Real Capital Stock by SNA Production Groups: 1950-1990", Internal Paper 233a, Research Project on Economic Planning, Wellington.

Tesar, L. (1991), "Savings, Investment, and International Capital Flows", *Journal of International Economics* 31, 55-78.

Table 2

Population Moments:

Technology Shock in Tradable Sector Only ($\sigma^T = 1.0, \sigma^{NT} = 0.0$)

Variable	Stan. Dev. Relative to Agg. Output	Correlation with Output
Aggregate		
C	0.633	0.441
I	1.373	0.765
N	0.762	0.783
w	0.621	0.689
tb/Y	7.000	0.722
Traded good sector		
Y	1.609	1.000
C	0.584	0.117
I	2.559	0.721
N	1.453	0.923
Nontraded good sector		
Y	0.188	1.000
C	0.192	0.962
I	0.224	0.873
N	0.192	0.998

Table 3

Population Moments:

Technology Shock in Nontradable Sector Only ($\sigma^T = 0.0, \sigma^{NT} = 1.0$)

Variable	Stan. Dev. Relative to Agg. Output	Correlation with Output
Aggregate		
C	0.048	0.013
I	3.402	0.975
N	0.698	0.999
w	0.183	0.957
tb/Y	2.826	-0.569
Traded good sector		
Y	0.504	1.000
C	0.405	0.392
I	1.030	0.782
N	0.656	0.985
Nontraded good sector		
Y	4.163	1.000
C	3.908	0.780
I	8.318	0.829
N	2.485	0.351

Table 4

Impulse Response

to Technology Shock in Tradable Sector

Period	C^T	C^{NT}	I^T	I^{NT}	N^T	N^{NT}	tb/Y
1	0.783	0.041	10.111	-0.566	0.980	-0.231	-10.095
2	0.776	-0.045	8.148	-0.322	1.356	-0.177	-3.929
3	0.771	-0.094	6.512	-0.177	1.589	-0.148	0.666
4	0.768	-0.121	5.142	-0.079	1.709	-0.125	3.997
5	0.765	-0.133	3.992	-0.006	1.740	-0.104	6.317
6	0.762	-0.134	3.026	0.051	1.703	-0.083	7.832
7	0.759	-0.128	2.214	0.098	1.613	-0.060	8.711
8	0.755	-0.116	1.532	0.135	1.486	-0.038	9.091
9	0.751	-0.100	0.959	0.166	1.332	-0.015	9.087
10	0.746	-0.082	0.477	0.192	1.160	0.007	8.789
11	0.741	-0.061	0.073	0.212	0.977	0.028	8.271
12	0.735	-0.040	-0.265	0.228	0.788	0.049	7.595
13	0.728	-0.018	-0.548	0.241	0.598	0.068	6.808
14	0.721	0.003	-0.785	0.251	0.411	0.086	5.949
15	0.713	0.024	-0.981	0.259	0.228	0.103	5.048
16	0.704	0.045	-1.144	0.264	0.052	0.119	4.130
17	0.694	0.064	-1.277	0.268	-0.115	0.134	3.214
18	0.685	0.083	-1.387	0.270	-0.273	0.147	2.315
19	0.674	0.100	-1.475	0.271	-0.422	0.159	1.442

Table 5

Impulse Response

to Technology Shock in Nontradable Sector

Period	C^T	C^{NT}	I^T	I^{NT}	N^T	N^{NT}	tb/Y
1	0.014	-0.024	-1.032	9.145	-0.644	2.721	-2.071
2	0.105	0.959	-0.103	3.822	-0.256	0.774	-1.713
3	0.134	1.281	0.208	1.788	-0.089	0.048	-1.355
4	0.140	1.355	0.290	1.001	-0.011	-0.216	-1.039
5	0.138	1.338	0.292	0.688	0.030	-0.305	-0.772
6	0.133	1.289	0.268	0.555	0.054	-0.328	-0.553
7	0.126	1.230	0.238	0.490	0.070	-0.327	-0.375
8	0.120	1.170	0.209	0.452	0.080	-0.317	-0.232
9	0.114	1.111	0.183	0.425	0.087	-0.303	-0.117
10	0.108	1.055	0.160	0.403	0.092	-0.289	-0.027
11	0.103	1.001	0.141	0.383	0.094	-0.276	0.045
12	0.098	0.950	0.124	0.364	0.095	-0.262	0.100
13	0.093	0.902	0.110	0.346	0.095	-0.249	0.142
14	0.088	0.856	0.097	0.329	0.094	-0.237	0.173
15	0.084	0.813	0.087	0.313	0.093	-0.225	0.196
16	0.080	0.772	0.078	0.298	0.090	-0.214	0.211
17	0.076	0.733	0.070	0.283	0.088	-0.204	0.221
18	0.072	0.697	0.063	0.269	0.085	-0.193	0.227
18	0.068	0.662	0.057	0.256	0.082	-0.184	0.229

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