Demand Changes and Real Exchange Rate Dynamics in a Finite-horizon Model with Sectoral Adjustment Costs

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ABSTRACT

In this paper, we use the Blanchard-type uncertain lifetime overlapping generations framework to develop a three-sector open economy to examine the effects of demand changes on the economic performance of small open economies with sectoral adjustment costs. Our simulation results reveal a discernible Harberger-Laursen-Metzler effect on both temporary and permanent terms-of-trade shocks. The inclusion of sectoral adjustment costs generates persistent deviations of the real exchange rate from its long-run equilibrium in response to terms-of-trade shocks, with the degree of sectoral adjustment costs having an effect on the subsequent dynamic transition of the economy. We also find that an increase in the mortality rate leads to a lowering of the trade balance.

Keywords: Terms of trade; Current account; Real exchange rate; Sectoral adjustment costs.

JEL Classification: F11, F32, F47.

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1. INTRODUCTION

Although the traditional macroeconomic models tend to explain economic fluctuations by focusing solely on supply shocks, given that equilibrium is determined by both demand and supply, it would seem obvious that changes in demand may also have important effects, in terms of their contribution to economic oscillations. Changes in demand can easily occur, particularly for those developing, small open economies. For example, small open economies can be easily disturbed by external shocks such as terms-of-trade shocks through international trade. Another example is the reduction in the mortality rate during the economic development. For export-orientated growth economies in particular, such as Hong Kong and Taiwan, changes in either the terms of trade or the mortality rate can significantly influence economic performance, impacting upon the real exchange rate, investment, output, savings and the current account.[1]

The extant literature contains a wealth of studies in which analysis has been undertaken of the impact on economic performance stemming from temporary and permanent terms-of-trade shocks, with economists having shown particular interest in the investigation of the consequences of such shocks on the current account. Indeed, the so-called Harberger-Laursen-Metzler (HLM) effect demonstrates that a reduction in current income arising from adverse terms-of-trade shocks lowers both the trade balance and private savings (Harberger, 1950; Laursen-Metzler, 1950).

The 1980s witnessed the early stages of the development of a number of economic models with inter-temporal optimization frameworks designed specifically to revisit this issue. Obstfeld (1982a, 1982b, 1983), for example, showed that with infinitely-lived households, permanent and temporary terms-of-trade shocks could have diverse effects

[1] Kose (2002), for example, found that about 95 per cent of fluctuations in the trade balance in developing countries were positively accounted for by terms-of-trade shocks.

on the current account.[2] Svesson and Razin (1983) went on to adopt a two-period, two-sector (importable and exportable goods) framework to reexamine Obstfeld's propositions and found deterioration in both the current account and savings as a result of a temporary deterioration in the terms of trade, but suggested that this could go either way as a result of any permanent deterioration.[3]

In most of the prior studies in which examinations of the HLM effect have been undertaken, there has been a general tendency for researchers to use two-sector open models with a fixed exchange rate regime and there is no real consideration of the role of non-traded goods. Although this can clearly simplify the analysis, such an approach essentially ignores the consequences of changes in the real exchange rate brought about by terms-of-trade shocks; however, it is clear that changes in both terms of trade and the real exchange rate play crucial roles in the behavior of firms and households alike.

Firms will invariably adjust their allocation of capital and labor between sectors based upon the changes in the terms of trade or the real exchange rate, while the consumption behavior and savings behavior of households will also be affected, given that, along with the changes in the relative prices of exportable, importable and non-traded goods, there are corresponding changes in permanent income.[4] It should be noted that there will inevitably be changes not only in the amount of consumer spending, but also in the composition of such spending (that is, the amount spent on importable, exportable and non-traded goods). When terms-of-trade shocks occur, both

2 Under the assumption that the rate of time preference could vary, Obstfeld (1982a) found that the HLM effect failed to hold when there was a permanent change in the terms of trade. However, Obstfeld (1982b, 1983) also showed that with a constant rate of time preference, a temporary worsening in the terms of trade led to a current account deficit, but that when the terms of trade reverted to their original level, the current account moved into surplus and ultimately back to its initial steady-state level.

3 There was a gradual shift towards the utilization of stochastic models in the subsequent studies on the HLM effect; see, for example, Backus (1993), Backus et al. (1994) and Mendoza (1995).

4 The study by Sen and Turnovsky (1989) indicated that the HLM effect depended on whether or not the income effect dominated the substitution effect during the deterioration in terms of trade.

consumption (savings) and investment behavior have important roles to play in determining the current account.[5]

In this paper, we develop a three-sector open economy comprising of exportable, importable and non-traded goods with sectoral adjustment costs and uncertain lifetime to study the effects of changes in demand under a flexible exchange rate regime.[6] The consideration of a model comprising of three goods enables us to study the dynamics of the real exchange rate when demand changes. Capital production and accumulation are also incorporated into the framework to facilitate an examination of the investment behavior of firms. We assume that capital is produced by the non-traded sector and that installation costs are incurred when capital is transported to the exportable sector.[7] As indicated by Morshed and Turnovsky (2004), the inclusion of sectoral adjustment costs of capital can generate persistent deviations from the long-run equilibrium by the real exchange rate in response to shocks.[8]

As opposed to the adoption of a representative agent model, an approach which is usually adopted for the real business cycle models, we use the 'overlapping generations' model, developed by Yaari (1965) and Blanchard (1985), to study household savings behavior. Within this model, agents live with finite lifetime, such

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5 See Persson and Svensson (1985), Brock (1988, 1996), Matsuyama (1987, 1988), Buiter (1989) and Sen and Turnovsky (1989a, 1989b).

6 The household structure of the model is based on Blanchard (1985) and the production structure is based on Morshed and Turnovsky (2004). However, the issue of this paper was different from theirs. The focus of Blanchard (1985) was the impact of fiscal policy while the focus of Morshed and Turnovsky (2004) was capital adjustment cost. The HLM effect was not studied in both papers. The HLM effect in an uncertain lifetime model with capital accumulation was studied by Chen and Hsu (2006). However, they did not consider the real exchange rate dynamics and capital adjustment costs and did not study the impact of the decline in mortality rate during the economic development.

7 Models with costly investment can be found in Brock (1988), Sen and Turnovsky (1989a, 1989b) and Morshed and Turnovsky (2004).

8 In the absence of any installation costs, capital stock adjustment occurs instantaneously. The real exchange rate responds totally and immediately to the supply shock, but does not respond to the demand shock when the tradable sector has greater capital intensity. When capital intensity is greater in the non-traded sector, the speed of adjustment is unrealistically high; see also Brock and Turnovsky (1994) and Brock (1996).

that different types of agents simultaneously live in the economy.[9] The advantage of the Blanchard-style model is that the rate of time preference need not equal the global real interest rate in order to guarantee the convergence of consumption and foreign asset holdings to the steady-state value in the inter-temporal optimization framework.

Furthermore, considering a model with finite lifetime allows us to study the impact of changes in the mortality rate on the economic performance in an open economy. There have been growing numbers of studies on the linkage between longevity and economic growth recently;[10] and indeed, it is already well understood that economic development is invariably accompanied by a reduction in the mortality rate as a result of higher health investment (both public and private) and better healthcare.[11] However, previous studies tend to analyze the impact of mortality decline in a closed economy. Among these studies, Kalemli-Ozcan et al. (2000) extended the Blanchard-type finite lifetime framework by including human capital accumulation into the model and found that increased life expectancy will increase both schooling and consumption.

We demonstrate in this study, that the economic dynamics within a small open economy can be represented by a 'six-by-six' dynamic system; that is, a system containing six first-order differential equations comprising of: (i) capital used in the exportable sector; (ii) capital used in the non-traded sector; (iii) the real exchange rate; (iv) investment in the exportable sector; (v) consumption; and (vi) foreign asset holdings. Given the complexity of this dynamic system, we then simulate the model to study the effects on economic transition stemming from terms-of-trade shocks and the mortality rate.

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[9] An open economy with finite lifetime can be also found in Frenkel and Razin (1986, 1987), Buiter (1987, 1988, 1989), Eaton (1989), Klundert and Ploeg (1989) and Engel and Kletzer (1990).

[10] See Ehrlich and Lui (1991), de la Croix and Licandro (1999), Kalemli-Ozcan et al. (2000) and Cervellati and Sunde (2005).

[11] See Chakraborty (2004) and Das and Chakraborty (2005) for both empirical and theoretical studies of the relationship between mortality and growth through the channel of health investment.

We select 1990 data on Taiwan for use in calibrating the parameter values, essentially because Taiwan is a small open economy which is heavily reliant on international trade. Our computational results show that a steady-state solution does exist, and that it is a saddle point; however, the results also indicate that the speed of adjustment to the steady state is quite slow. We find that a temporary or permanent appreciation in terms of trade will increase foreign asset holdings; that is, we observe the presence of the HLM effect. However, the transitions in the current account differ markedly, in terms of their response to temporary and permanent terms-of-trade shocks. The numerical results indicate that a temporary appreciation in terms of trade will lead to an immediate sharp increase in both the real exchange rate and consumption, along with a temporary increase in foreign asset holdings.

With a permanent 5 per cent appreciation in terms of trade, there are corresponding increases of 5 per cent in the real exchange rate and 5.156 per cent in consumption, at the steady state. A temporary reduction in foreign assets holdings is then followed by a 5.228 per cent increase at the steady state. An explanation for foreign asset holdings reacting differently to temporary and permanent terms-of-trade shocks is that permanent shocks induce larger changes in permanent income, which, in turn, leads to larger changes in consumption and savings behavior.

Our computational results also show that the degree of sectoral adjustment costs does not affect the steady-state value; however, it does affect the speed of adjustment in response to terms-of-trade shocks, with the asymptotic speed of convergence increasing with the degree of sectoral adjustment costs. Furthermore, with an increase in the degree of sectoral adjustment costs, there is a reduction in deviations from the steady-state value by the transitional path of capital within the exportable sector; this, in turn, affects the wealth of households and, as a result, the dynamic transitions of both consumption and the current account.

With a permanent 5 per cent increase in the probability of instantaneous death, there is a 12.117 per cent reduction in consumption and a 26.316 per cent reduction in foreign asset holdings at the steady state. There are, essentially, two effects caused by the increase in the probability of instantaneous death. First of all, it raises the effective rate of return on non-human wealth which leads to an increase in household's foreign asset holdings. Secondly, however, since life expectancy is shorter, households will tend to reduce their foreign asset holdings, and instead, raise their consumption levels. Our simulation results show that at the steady state, the latter effect dominates the former and, as a result, foreign asset holdings are reduced. However, consumption is also reduced as a direct result of the lower wealth.

The remainder of this paper is organized as follows. In the next section, we develop a small open economy with sectoral adjustment costs (to facilitate our examination of the investment behavior of firms) and with finite lifetime (to facilitate our examination of the savings behavior of households). Section 3 presents the calibration of the parameter values and simulation of the model design used in our study of the impact of changes in demand on economic performance. The conclusions drawn from this study are presented in the final section.

2. THE PRODUCTION MODEL

We assume that the economy comprises of identical households with a constant life expectancy, and that there is no population growth. Let β be the constant probability of instantaneous death, and assume that the random variable 'time until death' has an exponential distribution; expected lifetime is then equal to the expected value of the random variable which is $1/\beta$; in other words, $1/\beta$ can be thought of as an index of the effective horizon of individuals. As β goes to zero, the horizon becomes infinite, and we have the Ramsey-Cass-Koopmans model. At each instant, a new cohort of size β is born, so that the size of the total population at any given time is normalized as one. The global real interest rate is denoted as r, which is constant for a small open economy.

2.1 Firms

We endogenize production and capital accumulation into a small open economy and, in contrast to the two-sector open economy model,[12] we also incorporate a non-traded goods sector to examine the additional effects of demand changes stemming from changes in the real exchange rate. Hence, goods are categorized into exportable, importable and non-traded goods.

Following Mendoza (1995), we use importable goods as the numeraire; the relative price of exportable goods, i.e. the terms of trade, is denoted by P_T;[13] and the relative price of non-traded goods is P_N, which is defined as the real exchange rate. The economy produces exportable goods (T) and non-traded goods (N) using both capital and labor, whilst importable goods (M) are imported from abroad. Households are endowed with one unit of time per period and use all of their time for work. They can choose to work in the exportable sector (L_T) or in the non-traded (L_N) sector for the real wage rate (w).

Capital is produced by the non-traded sector and can be used in both the exportable and non-traded sectors; however, it is costly for capital to move from the

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12 Such models were adopted by Sen and Turnovsky (1989a, 1989b) and Engel and Kletzer (1990).

13 The three-sector (exportable, importable and non-traded goods) model is also used by Ostry (1988); however, capital formation was not incorporated into his model. Ostry and Reinhart (1992) and Cashin and McDermott (2003) adopted a simple three-sector model to empirically test the effects of terms of trade shocks on economic performance for both developing and industrialized countries. Chen and Hsu (2006) also considered a three-sector open economy where capital was imported from abroad. However, without the production of capital, there is an immediate and total response by the real exchange rate to temporary and permanent terms-of-trade shocks.

non-traded sector to the exportable sector. We let K_T denote the capital used in the exportable sector and K_N denote the capital used in the non-traded sector, and assume that capital does not depreciate over time. The functions of $F(K_T, L_T)$ and $H(K_N, L_N)$ represent constant returns-to-scale production functions in the respective exportable and non-traded sectors. Both production functions satisfy neoclassical assumptions: the positive, but diminishing marginal product of labor and capital.

Investment in the non-traded sector is denoted by I, while investment in the exportable sector is represented by X. Given that capital is costly to move across sectors, following Morshed and Turnovsky (2004), the inter-sectoral adjustment costs are represented by a convex function $\dfrac{bX^2}{2K_N}$, where b is the parameter used to measure the degree of sectoral adjustment costs. Since no externality is generated by capital, the decentralized solutions for the representative firms in the exportable and non-traded sectors are the same as those chosen by a 'planner' in the economy. The optimal behavior of a representative firm in the economy can be described as:[14]

$$V_t = \max \int_t^{\infty} \left[p_T F(K_T, L_T) + p_N H(K_N, L_N) - w(L_T + L_N) - p_N I \right] e^{-r(v-t)} dv \tag{1}$$

s.t.

$$\dot{K}_T = X, \tag{2}$$

$$\dot{K}_N = I - X\left(1 + \frac{bX}{2K_N}\right), \tag{3}$$

$$L_T + L_N = 1. \tag{4}$$

A planner will optimize Equation (1) subject to Equations (2), (3) and (4) by selecting the way in which labor and investment will be allocated between the exportable and non-traded sectors. The conditions of optimality are:

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[14] The time notation is omitted without confusion.

$$p_T F_L(K_T, L_T) = p_N H_L(K_N, L_N), \tag{5}$$

$$p_N = q_2, \tag{6}$$

$$X = K_N \left(\frac{q_1 - q_2}{b q_2} \right), \tag{7}$$

$$\dot{q}_1 = r q_1 - p_T F_K(K_T, L_T), \tag{8}$$

$$\dot{q}_2 = r q_2 - p_N H_K(K_N, L_N) - q_2 \frac{bX^2}{2K_N^2}, \tag{9}$$

together with the conditions of transversality:

$$\lim_{t\to\infty} K_T e^{-rt} = 0, \qquad \lim_{t\to\infty} K_N e^{-rt} = 0. \tag{10}$$

Within the exportable sector, F_K represents the marginal product of capital and F_L represents the marginal product of labor, whilst within the non-traded sector, H_K represents the marginal product of capital and H_L represents the marginal product of labor. Variables q_1 and q_2 are the respective shadow prices of exportable and non-traded capital.

From the resource constraint (Equation (4)), and the labor market efficiency condition (Equation (5)), we can obtain:[15]

$$L_T = L_T(K_T, K_N, p_N), \quad \partial L_T / \partial K_T > 0, \quad \partial L_T / \partial K_N < 0, \quad \partial L_T / \partial p_N < 0; \tag{11}$$

$$L_N = L_N(K_T, K_N, p_N), \quad \partial L_N / \partial K_T < 0, \quad \partial L_N / \partial K_N > 0, \quad \partial L_N / \partial p_N > 0. \tag{12}$$

2.2 Households

Assuming the existence of perfect annuity markets, with the absence of bequest

15 See Appendix 1.

motives and with negative bequests prohibited, individuals will contract to pay insurance companies non-human wealth Ω, contingent upon their death to receive $\beta\Omega$ per unit of time. Thus the effective rate of return on non-human wealth is $r+\beta$. As a result of the uncertain nature of life expectancy, the effective subjective discount rate of each household is $\rho+\beta$, where $\rho>0$ is the rate of time preference.

We assume that households consume exportable goods (c_T), importable goods (c_M) and non-traded goods (c_N). For agents born at time s, we define total household expenditure at time t as $c(s,t) = p_T c_T(s,t) + c_M(s,t) + p_N c_N(s,t)$. Starting from time t, households born at time s will maximize their expected utility, given by:

$$E_t[\int_t^{\infty} U(c_T(s,v), c_M(s,v), c_N(s,v)) e^{-\rho(v-t)} dv]. \tag{13}$$

Conditional on being alive at the earlier time t, the probability of being alive at time v is $e^{-\beta(v-t)}$; hence, the expected lifetime utility becomes:

$$\int_t^{\infty} U(c_T(s,v), c_M(s,v), c_N(s,v)) e^{-(\rho+\beta)(v-t)} dv. \tag{13'}$$

Labor income is denoted by $y(s,t)$; that is:

$$y(s,t) = w(t)[L_T(s,t) + L_N(s,t)] = w(t).$$

We use $a(s,t)$ to denote household wealth; households are required to pay a lump-sum tax $\tau(t)$ to the government; and we use the notation $\dot{z}(t)$ to denote the differential of a variable $z(t)$ with respect to time t. The instantaneous budget constraint for a household is therefore:

$$\dot{a}(s,t) = (r+\beta)a(s,t) + y^{\tau}(s,t) - c(s,t), \tag{14}$$

where $y^{\tau}(s,t) = y(s,t) - \tau(t)$ is the post-tax income of an individual.

By integrating Equation (14), the budget constraint can be rewritten as:

$$\int_t^{\infty} c(s,v) e^{-(r+\beta)(v-t)} dv = a(s,t) + h^{\tau}(s,t), \tag{15}$$

where $h^{\tau}(s,t) = \int_t^{\infty} y^{\tau}(s,v)\, e^{-(r+\beta)(v-t)} dv$ and $h(s,t) = \int_t^{\infty} y(s,v)\, e^{-(r+\beta)(v-t)} dv$.

Assume that the instantaneous utility function $U(c_T, c_M, c_N)$ has logarithmic form and is additively separable for consumption and leisure; that is:

$$U(c_T, c_M, c_N) = \sum_i \mu_i \log c_i \;,\; i = T, M, N, \tag{16}$$

where μ_i is the contribution of good i to utility, and $\sum_i \mu_i = 1$.

Solving the optimization problem for a household by maximizing Equation (13) subject to the instantaneous budget constraint (Equation (14)), we have:

$$\frac{\mu_T}{c_T(s,t)} = \lambda p_T(t), \tag{17}$$

$$\frac{\mu_M}{c_M(s,t)} = \lambda, \tag{18}$$

$$\frac{\mu_N}{c_N(s,t)} = \lambda p_N(t), \tag{19}$$

$$\dot{\lambda} = (\rho - r)\lambda, \tag{20}$$

where λ is the Lagrangian multiplier associated with Equation (14). The transversality condition of wealth is:

$$\lim_{v \to \infty} a(s,v) e^{-(r+\beta)(v-t)} = 0 .$$

With the logarithmic utility function, individual optimal consumption is:

$$c(s,t) = (\rho + \beta)[a(s,t) + h^{\tau}(s,t)]. \tag{21}$$

2.3 Aggregate Variables

We use $C(t)$, $A(t)$, $Y(t)$, $Y^{\tau}(t)$, $H(t)$ and $H^{\tau}(t)$ to respectively represent aggregate consumption, non-human wealth, labor income, post-tax labor income, human wealth and post-tax human wealth. Note that an aggregate variable $Z(t)$ is derived from an individual variable $z(t)$ by using the following equation:

$$Z(t) = \int_{-\infty}^{t} z(s,t)\beta e^{\beta(s-t)} ds. \tag{22}$$

Hence, from Equation (21), aggregate consumption is:

$$C(t) = (\rho + \beta)\left[A(t) + H^{\tau}(t)\right], \tag{23}$$

and post-tax human wealth is:

$$H^{\tau}(t) = \int_{-\infty}^{t} h^{\tau}(s,t)\beta e^{\beta(s-t)} ds$$

$$= \int_{-\infty}^{t} [\int_{t}^{\infty} y^{\tau}(s,v) e^{-(r+\beta)(v-t)} dv] \beta e^{\beta(s-t)} ds. \tag{24}$$

It should be noted that labor income is equally distributed between agents at any time t; that is, $y^{\tau}(s,t) = y^{\tau}(t) = w(t) - \tau(t)$; hence, differentiating Equation (24) with respect to t, we can derive the dynamics of post-tax human wealth as:

$$\dot{H}^{\tau} = (r + \beta)H^{\tau} - Y^{\tau}, \tag{25}$$

with the transversality condition of post-tax human wealth being:

$$\lim_{v \to \infty} H^{\tau}(t) e^{-(r+\beta)(v-t)} = 0.$$

Non-human wealth is:

$$A(t) = \int_{-\infty}^{t} a(s,t)\beta e^{\beta(s-t)} ds\,. \tag{26}$$

Taking the derivatives of Equation (26) with respect to t, and then substituting $\dot{a}(s,t)$ into our calculation, we obtain the dynamics of non-human wealth:

$$\dot{A} = rA + Y^{\tau} - C\,. \tag{27}$$

Differentiating Equation (23) with respect to t, and using Equations (25) and (27) to substitute $\dot{H}^{\tau}(t)$ and $\dot{A}(t)$, we get the dynamics of aggregate consumption:

$$\dot{C} = (r-\rho)C - \beta(\rho+\beta)A\,. \tag{28}$$

Non-human wealth comprises of foreign assets (B) and equity (K_T+K_N); that is:

$$A(t) = B(t) + p_N(t)(K_T(t) + K_N(t))\,. \tag{29}$$

Substituting Equation (29) into Equation (28), the dynamics of aggregate consumption can be rewritten as:

$$\dot{C} = (r-\rho)C - \beta(\rho+\beta)[B + p_N(K_T + K_N)]\,. \tag{28'}$$

2.4 The Government and Current Account Dynamics

We assume that the government consumes exportable (G_T), importable (G_M) and non-traded goods (G_N), and that it runs a balanced budget, financing government consumption by means of taxation. Total government expenditure is:

$$G = p_T G_T + G_M + p_N G_N\,.$$

From the definition of the current account, the dynamics of foreign assets are:

$$\dot{B} = p_T F(K_T, L_T(K_T, K_N, p_N)) + p_N H(K_N, L_N(K_T, K_N, p_N)) + rB - C - p_N I - G$$

$$= p_T F(K_T, L_T(K_T, K_N, p_N)) + rB - (\mu_T + \mu_M)C - (p_T G_T + G_M), \tag{30}$$

with the transversality condition of foreign asset holdings being:

$$\lim_{t \to \infty} Be^{-rt} = 0 .$$

2.5 The Dynamics

From Equations (17)-(19) and (22), we can obtain the relationship between consumption in non-traded goods and aggregate consumption:

$$C_N(t) = \frac{\mu_N C(t)}{p_N(t)} \tag{31}$$

Substituting Equation (31) into Equation (3), the dynamics of K_N can be expressed as:

$$\dot{K}_N = H(K_N, L_N(K_T, K_N, p_N)) - C_N - G_N - X\left(1 + \frac{bX}{2K_N}\right)$$

$$= H(K_N, L_N(K_T, K_N, p_N)) - \frac{\mu_N C}{p_N} - G_N - X\left(1 + \frac{bX}{2K_N}\right). \tag{32}$$

Differentiating Equation (6) with respect to t, and utilizing Equation (9), we can obtain the dynamics of p_N:

$$\dot{p}_N = \left(r - \frac{bX^2}{2K_N^2}\right)p_N - H_K(K_N, L_N(K_T, K_N, p_N))p_N . \tag{33}$$

Differentiating Equation (7) with respect to t, the dynamics of X are:

$$\dot{X} = \frac{X}{K_N}\dot{K}_N + \frac{K_N}{bq_2}(\dot{q}_1 - \dot{q}_2) - X\frac{\dot{q}_2}{q_2}. \tag{34}$$

Using Equations (6), (8), (9) and (34) to substitute q_2, $\dot{q}_1$, $\dot{q}_2$ and $\dot{K}_N$ in Equation (34), the dynamics of X are:

$$\dot{X} = \left(\frac{H(K_N, L_N(K_T, K_N, p_N)) - c_N - G_N}{K_N} + H_K(K_N, L_N(K_T, K_N, p_N))\right)X - \frac{X^2}{2K_N}$$

$$- \frac{K_N}{bp_N}(p_T F_K(K_T, L_T(K_T, K_N, p_N)) - p_N H_K(K_N, L_N(K_T, K_N, p_N)). \tag{34'}$$

Equations (2), (28'), (30), (32), (33) and (34') show that the entire dynamic system can be represented by K_T, K_N, p_N, X, C and B. Thus, there are six equations in our system determining the transitions of the six variables. We use the asterisked variables to denote the steady-state values. Note that by setting $\dot{K}_T = 0$ (Equation (2)), we can determine that $X^* = 0$.

Linearizing the system around the steady state ($K_T^*, K_N^*, p_N^*, X^*, C^*, B^*$), we get:

$$\begin{bmatrix} \dot{K}_T \\ \dot{K}_N \\ \dot{p}_N \\ \dot{X} \\ \dot{C} \\ \dot{B} \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & 1 & 0 & 0 \\ a_{21} & a_{22} & a_{23} & -1 & -\frac{\mu_N}{p_N} & 0 \\ a_{31} & a_{32} & a_{33} & 0 & 0 & 0 \\ a_{41} & a_{42} & a_{43} & H_K & 0 & 0 \\ a_{51} & a_{52} & a_{53} & 0 & r - \rho & a_{56} \\ a_{61} & a_{62} & a_{63} & 0 & -(\mu_T + \mu_M) & r \end{bmatrix} \begin{bmatrix} K_T - K_T^* \\ K_N - K_N^* \\ p_N - p_N^* \\ X - X^* \\ C - C^* \\ B - B^* \end{bmatrix}, \tag{35}$$

where

$$a_{21} = H_L \frac{\partial L_N}{\partial K_T}, \quad a_{22} = H_K + H_L \frac{\partial L_N}{\partial K_N}, \quad a_{23} = H_L \frac{\partial L_N}{\partial p_N} + \frac{\mu_N c^*}{p_N^2};$$

$$a_{31} = -p_N H_{KL} \frac{\partial L_N}{\partial K_T}, \quad a_{32} = -p_N \left(H_{KK} + H_{KL} \frac{\partial L_N}{\partial K_N} \right), \quad a_{33} - p_N H_{KL} \frac{\partial L_N}{\partial p_N};$$

$$a_{41} = -\frac{K_N}{bp_N} \left[p_T \left(F_{KK} + F_{KL} \frac{\partial L_T}{\partial K_T} \right) - p_N H_{KL} \frac{\partial L_N}{\partial K_T} \right];$$

$$a_{42} = -\frac{K_N}{bp_N} \left[p_T F_{KL} \frac{\partial L_T}{\partial K_N} - p_N H_{KK} - p_N H_{KL} \frac{\partial L_N}{\partial K_N} \right];$$

$$a_{43} = \frac{K_N}{b} \left(\frac{p_T F_K}{p_N^2} - \frac{p_T F_{KL}}{p_N} \frac{\partial L_T}{\partial p_N} + H_{KL} \frac{\partial L_N}{\partial p_N} \right);$$

$$a_{51} = a_{52} = -\beta(\rho + \beta) p_N^*, \quad a_{53} = -\beta(\rho + \beta)(K_T^* + K_N^*), \quad a_{56} = -\beta(\rho + \beta);$$

$$a_{61} = p_T F_K + p_T F_L \frac{\partial L_T}{\partial K_T}, \quad a_{62} = p_T F_L \frac{\partial L_T}{\partial K_N}, \quad a_{63} = p_T F_L \frac{\partial L_T}{\partial p_N}.$$

In order to study the dynamic system presented in Equation (35), it should first of all be noted that there are three predetermined variables, K_T, K_N and B, and three jumping variables, p_N, X and C. Therefore, given the initial conditions of K_T, K_N and B, we need to have three negative eigenvalues so that the number of predetermined variables is equal to the number of negative eigenvalues; this will result in a unique stable path to the steady state.

The three negative eigenvalues are represented by λ_1, λ_2 and λ_3, with $\lambda_1 < \lambda_2 < \lambda_3$. The unique stable path to the steady state can be represented by:

$$K_T(t) - K_T^* = D_1 e^{\lambda_1 t} + D_2 e^{\lambda_2 t} + D_3 e^{\lambda_3 t}, \tag{36}$$

$$K_N(t) - K_N^* = D_1 v_2^1 e^{\lambda_1 t} + D_2 v_2^2 e^{\lambda_2 t} + D_3 v_2^3 e^{\lambda_3 t}, \tag{37}$$

$$p_N(t) - p_N^* = D_1 v_3^1 e^{\lambda_1 t} + D_2 v_3^2 e^{\lambda_2 t} + D_3 v_3^3 e^{\lambda_3 t}, \tag{38}$$

$$X(t) - X^* = D_1 v_4^1 e^{\lambda_1 t} + D_2 v_4^2 e^{\lambda_2 t} + D_3 v_4^3 e^{\lambda_3 t}, \tag{39}$$

$$C(t) - C^* = D_1 v_5^1 e^{\lambda_1 t} + D_2 v_5^2 e^{\lambda_2 t} + D_3 v_5^3 e^{\lambda_3 t}, \tag{40}$$

$$B(t) - B^* = D_1 v_6^1 e^{\lambda_1 t} + D_2 v_6^2 e^{\lambda_2 t} + D_3 v_6^3 e^{\lambda_3 t}, \tag{41}$$

where a transpose matrix $\left(1\ v_2^i\ v_3^i\ v_4^i\ v_5^i\ v_6^i\right)'$, i = 1, 2, 3 is the normalized eigenvector which respectively corresponds to λ_1, λ_2 and λ_3. The constants D_1, D_2 and D_3 can be solved from Equations (36), (37) and (41) by utilizing the initial conditions of K_T, K_N and B.

3. SIMULATIONS

Given the complexity of the model, in this section we simulate the model to numerically examine demand changes on economic performance. Prior to simulating the model, we need to calibrate the parameter values for use in the model.

3.1 Calibration

We begin by describing the processes involved in the calibration of the parameter values used in our simulations, referring to the parameter values calibrated in this section as the 'baseline model'. We select Taiwan as a representative small open economy in our model, and calibrate the remainder of the parameter values to the data for the year 1990.[16] The birth rate in Taiwan in 1990 was 1.66 per cent; thus, in our model setting, wherein each individual can give birth to one child with no population growth, β is set at 3.32 per cent.

[16] Data source: Taiwan Statistical Data Book (2000).

The real interest rate is set at 0.06, and the rate of time preference is set at 0.035.

Cobb-Douglas production functions are assumed for both the exportable and non-traded goods sectors; that is, $F(K_T, L_T) = AK_T^{\xi_1} L_T^{1-\xi_1}$ and $H(K_N, L_N) = DK_N^{\xi_2} L_N^{1-\xi_2}$, where A>0 and D>0 represent the respective total factor productivity levels of the exportable and non-traded production functions, while ξ_1 and ξ_2 represent the respective capital shares in the exportable and non-traded sectors. Given that the major exports from Taiwan in 1990 were high-tech products, we assume that the exportable goods sector is more capital intensive than the non-traded goods sector; thus we set ξ_1= 0.35 and ξ_2= 0.3.[17] The total factor productivity levels, A and D, are respectively assigned values of 1 and 1.5.

We now turn to the calibration of the sectoral adjustment cost function. In their measurement of the costs of the adoption of new output into capital, Auerbach and Kotlikoff (1987) showed that b was between 10 and 15; however, in our model, since the adjustment costs represent the costs of converting existing capital in the non-traded sector into capital to be used in the exportable sector, the value of parameter b may well be far greater than that estimated by Auerbach ad Kotlikoff (1987). We therefore follow Morshed and Turnovsky (2004) and set $b = 30$. It should be noted that the value of b affects only the dynamic transition to the steady state and the speed of convergence, and does not affect the steady-state value.[18]

Government consumption comprises of exportable goods, importable goods and non-traded goods. Morshed and Turnovsky (2004) examined data on 30 countries and reported that the ratio of government consumption of tradable goods to tradable output was between 0.006 and 0.146. We assign G_T = 0.04 and G_M = 0.06 so that in our

[17] In 1990, the major exports from Taiwan were electronics products and information and communication products

[18] See Appendix 2 for details.

baseline model, $(G_T + G_M)/F$ is equal to 0.1228. The ratio of government consumption of non-traded goods to non-traded output reported by Morshed and Turnovsky (2004) was between 0.128 and 0.751; we therefore set $G_N = 0.2$ so that in our baseline model G_N/H is equal to 0.1293.

We assume that the weight of preference towards exportable and importable goods is roughly the same amongst all consumers, and therefore assign $\mu_T = 0.3$ and $\mu_M = 0.3$ (this implies that $\mu_N = 1 - \mu_T - \mu_M = 0.4$). Since the purpose of this paper is to study the impacts of P_T on economic performance, we initially set $P_T = 1$ and then allow it to vary. Based on these parameter values, the steady-state equilibrium is characterized by $K_T^* = 2.8065$, $K_N^* = 7.7324$, $p_N^* = 1.6925$, $X^* = 0$, $C^* = 5.6973$ and $B^* = 45.068$. Note that these numerical results show that in a finite-horizon model, there is no need to assume that $r = \rho$ for the existence of the steady-state value of C. Besides, our numerical results show that a finite-horizon model is suitable for characterizing a small open economy with a positive trade balance, such as that which prevails in the Taiwanese economy.

From Equations (4) and (5), the steady-state inputs of labor are $L_T^* = 0.2241$ and $L_N^* = 0.7759$, with the capital-labor ratios being 12.5216 for the exportable goods sector and 9.9662 for the non-tradable goods sector. The three negative eigenvalues determining the dynamic behavior of the economy are –0.0607, –0.0393 and –0.0088. The benchmark parameters and the calibrated values are summarized in Table 1.

<Table 1 is inserted about here>

3.2 Numerical Results

The simulation results of the effects of terms-of-trade shocks on the economy are illustrated in Figures 1 and 2. Figure 1 indicates that there is an unanticipated temporary appreciation in terms of trade (that is, an increase in the relative price of exportable goods) which lasts for one period, while Figure 2 reveals a permanent appreciation in terms of trade, with the changes in the real exchange rate (p_N), labor in the exportable sector (L_T), capital (K_T and K_N), aggregate consumption (C) and foreign assets (B) reacting differently in either case.[19]

The case of a temporary increase of 5 per cent in the relative price of exportable goods is illustrated in Figure 1, from which an immediate upward jump in L_T is discernible, along with a gradual increase in K_T . A reduction in non-traded goods output as a result of the reduced inputs (labor and capital) used in the non-traded sector leads to an increase in the relative price of the non-traded goods (the real exchange rate). Alongside any appreciation in terms of trade, there will also be increases in both real income and consumption.

<Figure 1 is inserted about here>

The change in consumption will be dependent on the 'revised' level of permanent income. If the terms-of-trade shock is temporary, there will be a small increase in permanent income and an even smaller increase in consumption, which will lead to an increase in foreign asset holdings in the aftermath of the shock. With a subsequent increase in the real exchange rate and the eventual subsidence of the terms-of-trade shock, there will be an increase in L_N and K_N along with a gradual reduction over time in L_T and K_T.

It should be noted once again that the terms-of-trade shock lasts for only one period, whereas it takes time for the real exchange rate to converge to its original

[19] The graph of L_N is not included in the Figures; this is because, since $L_N = 1 - L_T$, it simply moves in the opposite direction to L_T.

steady-state value; therefore, K_T will be lower than the steady-state value during the dynamic transition period, but will then rise and eventually converge at the steady-state value. Over time, consumption and foreign asset holdings will fall, ultimately converging at the original steady-state equilibrium.

From Equations (36)-(41), we can calculate the speed of convergence of the key endogenous variables, at time t, as the absolute values of $\phi_j(t)$ ($j = K_T$, K_N , p_N , X, C, B):

where $$\phi_j(t) = \frac{\dot{j}(t)}{j_N(t) - j_N^*} = \frac{D_1 v_i^1 e^{\lambda_1 t}\lambda_1 + D_2 v_i^2 e^{\lambda_2 t}\lambda_2 + D_3 v_i^3 e^{\lambda_3 t}\lambda_3}{D_1 v_i^1 e^{\lambda_1 t} + D_2 v_i^2 e^{\lambda_2 t} + D_3 v_i^3 e^{\lambda_3 t}}, \tag{42}$$

$i = 1,..,6$ with $v_1^1 = v_1^2 = v_1^3 = 1$.

Thus, the absolute values of the three negative eigenvalues are critical determinants of the speed of convergence of our key endogenous variables. Note that asymptotically, $|\phi_j(t)| \to |\lambda_3|$; this represents the speed of convergence for the six key variables in the extreme long run. As Figure 1 shows, the speed of convergence is quite slow because the absolute values of the eigenvalues are quite small.

Figure 2 describes the dynamic effects of a permanent 5 per cent increase in the relative price of exportable goods. The new steady state is L_T^*= 0.2231, K_T^*= 2.794, K_N^*= 7.7324, p_N^*= 1.7771, C^* = 5.9911 and B^* = 47.4241, with the three negative eigenvalues being –0.0604, –0.0395 and –0.0088. As Figure 2 shows, there will be an initial increase in L_T and K_T due to the increase in the relative price of exportable goods.

The attraction of resources into the exportable sector reduces non-traded sector output, thereby raising the real exchange rate, with the real exchange rate continuing to rise until it reaches the new steady state. The continuing increase in the relative price of non-traded goods will attract labor and capital into the non-traded sector.[20] However, an increase in the real exchange rate implies that capital becomes more costly; thus, there will be little change in the overall capital stock ($K_T + K_N$) at the new steady state as exportable goods become more expensive.[21]

<Figure 2 is inserted about here>

Following the appreciation in terms of trade, the resultant sudden rise in consumption will continue unabated over time until it eventually converges at the new steady state value. With a permanent terms-of-trade shock, the increase in permanent income will be greater, which will, in turn, induce a more significant increase in consumption. Hence, unlike the impact on foreign asset holdings from a temporary appreciation in the terms-of-trade shock, there will be a discernible fall in foreign assets in the immediate aftermath of the shock. Foreign asset holdings will subsequently undergo a gradual rise, and will eventually converge at the higher steady-state value. Note that when the shock is permanent, a portfolio substitution effect is discernible, in the long run, between capital and foreign asset holdings.

Using the steady-state condition, Equation (4), and Equations (A2.4) (A2.5) from Appendix 2, we can derive:

$$k_N = \left(\frac{D\xi_2}{r}\right)^{\frac{1}{1-\xi_2}}, \qquad k_T = \frac{\xi_1(1-\xi_2)}{\xi_2(1-\xi_1)} k_N, \tag{43}$$

$$p_N^* = \frac{Ap_{T\xi_1}}{D\xi_2}\left(\frac{k_N^{1-\xi_2}}{k_T^{1-\xi_1}}\right), \tag{44}$$

[20] Note that there is an initial increase in L_T which subsequently starts to decline (and vice versa for L_N). As Figure 2 shows, similar to the transition of L_T, there is also an initial increase and subsequent decline in K_T and vice versa for K_N.

[21] The overall capital stock ($K_T + K_N$) is equal to 10.5389 at the old steady state, and 10.5374 at the new steady state.

where $k_T = \dfrac{K_T}{L_T}$ and $k_N = \dfrac{K_N}{L_N}$ are the respective capital-labor ratios within the exportable and non-traded sectors.

Equation (43) indicates that a permanent terms-of-trade shock will not affect the capital-labor ratios, k_T and k_N; therefore, at the steady state, there will be a decrease (increase) in L_T (L_N) in the same proportions as K_T (K_N). Furthermore, as Equation (44) shows, with the occurrence of a permanent terms-of-trade shock, and with constant k_T and k_N, the percentage rate of increase for p_N at the steady state will be the same as that for p_T.

From the simulation results presented in Figures 1 and 2, we find that a temporary appreciation in terms of trade will lead to an immediate rise in the current account, whilst a permanent increase in terms of trade will lead to an increase in the current account in the long run. This indicates the presence of an HLM effect with regard to terms of trade, for both temporary and permanent shocks, although the immediate reactions of the current account differ between temporary and permanent terms-of-trade shocks. Our theoretical results are consistent with the empirical findings of Otto (2003) which provided strong support for the existence of an HLM effect in developing countries.

We now focus on analysis of the ways in which the degree of sectoral adjustment costs affect economic performance, and demonstrate that the introduction of sectoral adjustment costs allows persistent deviations in the real exchange rate from the steady-state value for a considerable period of time after the occurrence of terms-of-trade shocks (Figures 1 and 2);[22] indeed, a number of empirical studies have provided evidence to show that deviations in the real exchange rate from the long-run equilibrium (PPP) may persist for several years.[23]

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22 See Morshed and Turnovsky (2004).

23 See Cheung and Lai (2000) for an empirical study of developing countries.

Although Appendix 2 shows that changes in b will not affect the steady state, they will nevertheless affect the dynamic transition of the economy from the old steady state to the new steady state. We first of all conduct a sensitivity analysis to determine how dependent the speed of convergence is on the degree of sectoral adjustment costs with a permanent 5 per cent appreciation in the terms of trade; the results are provided in Table 2.

<Table 2 is inserted about here>

As the figures in Table 2 show, the eigenvalues are sensitive to the degree of sectoral adjustment costs; with a rise in the value of b, there is a corresponding increase in the absolute value of λ_3. Thus, when investment in the exportable sector becomes more costly, there will be acceleration in the asymptotic rate of convergence for the key endogenous variables.[24]

Next, in order to examine the ways in which the degree of sectoral adjustment costs influence the dynamic transition of the economy, we present the transitional path for b = 30, 40 and 65, as a result of temporary terms-of-trade shocks (Figure 1) and permanent terms-of-trade shocks (Figure 2). Both Figures show that the greater the value of b, the greater the distance between the transitional path of p_N and the steady-state value to which it converges. With an increase in b, there will be a corresponding increase in the cost of investment in the exportable sector, alongside a decrease in the deviation of the transitional path of K_T from the steady-state value to which it converges. Since the capital devoted to the exportable sector will affect the exportable goods output, which will, in turn, affect household wealth, the transitional

[24] This result differs from that of Morshed and Turnovsky (2004) where an increase in the degree of investment costs in the exportable sector was found to be accompanied by a decrease in the asymptotic speed of convergence. The main reason for this is that the dynamic system in this paper includes the dynamics of two additional variables (consumption and the holdings of foreign assets). As a result, there will be one additional negative eigenvalue affecting the dynamic transition, with the asymptotic speed of convergence being determined by this eigenvalue.

path of consumption under different degrees of sectoral adjustment costs is crucially dependent on the transitional path of K_T.

Since the consideration of finite lifetime is important in our model, an additional channel to change the demand side is the probability of instantaneous death. In order to facilitate an examination of how susceptible economic performance is to the arrival rate of death, Figure 3 illustrates the impact on the dynamic transition from a permanent 5 per cent increase in the arrival rate of death.[25]

<Figure 3 is inserted about here>

The new steady state is $L_T^* = 0.306$, $K_T^* = 3.8315$, $K_N^* = 6.9166$, $p_N^* = 1.6925$, $C^* = 5.0069$ and $B^* = 33.208$ which implies that L_T^* and K_T^* will be higher at the new steady state, whereas K_N^*, C^* and B^* will be lower.[26] The three negative eigenvalues are -0.0748, -0.0289 and -0.0106.

This can affect consumption and foreign assets in two distinct ways. On the one hand, an increase in β implies that there will be an increase in the effective rate of return on non-human wealth, which will induce households to increase their foreign asset holdings. On the other hand, with an increase in β, consumers would also tend to reduce their foreign asset holdings as a result of their reduced life expectancy, which, in turn, would tend to raise their immediate consumption levels. Our simulation results show that in the immediate after the change in life expectancy, the latter effect

[25] In this case, we consider only a permanent change because changes in the probability of instantaneous death tend to be permanent. Furthermore, similar to the terms-of-trade shocks, the higher the degree of sectoral adjustment costs in the exportable sector, the lower the deviation of the transitional path of K_T from its steady-state values. However, since changes in b do not directly affect the dynamics of consumption (and thereby, the holdings of foreign assets), there is very little difference in the dynamic transitions of consumption (and holdings of foreign assets) under different values of b. Hence, in Figure 3, we focus only on those cases where $b = 30$.

[26] Equation (44) shows that the probability of instantaneous death does not affect the steady-state value of the real exchange rate.

dominates the former, with the jump in consumption leading to an increase in consumption, and a resultant immediate increase in the real exchange rate, thereby attracting more labor into the non-traded sector.

However, with reduced foreign asset holdings, there will be a gradual decline over time for both consumption and the real exchange rate, with ultimate convergence at a lower steady state. Following the immediate upward jump in L_N, it then begins to fall over time, as does K_N. For the exportable sector, there is a downward jump in L_T immediately after the change in the life expectancy, but this subsequently increases to converge at the new steady state, whilst the decrease in K_T for a few periods is followed by an increase, and eventual convergence at the new steady state.

4. CONCLUSIONS

In this paper, we have utilized the Blanchard-type finite lifetime overlapping generations framework to develop a three-sector open economy in order to examine the effects of changes in demand on the economic performance of a small open economy with sectoral adjustment costs. The adoption of a three-good model allows us to analyze the impact of terms-of-trade shocks on the real exchange rate.

The allocation of inputs (labor and capital) between exportable and non-traded sectors, investment, consumption and the real exchange rate, will change accordingly, with the changes in investment and consumption behavior being crucial to the understanding of the impact of different demand changes on the current account. The simulation results indicate that an HLM effect is present for both temporary and permanent terms-of-trade shocks. We also find that the probability of instantaneous death is an important determinant of economic performance.

We make some assumptions in this paper in order to simplify the model; hence, in future studies, the model can be extended in several directions simply by relaxing these assumptions. Firstly, although we consider importable goods within the model, we assume that the economy does not itself produce importable goods; hence, the model can be extended by including the production of importable goods in order to examine the allocation of inputs among exportable, importable and non-traded sectors.

Secondly, we do not include leisure in our model and consider only the time allocation between the exportable and non-traded sectors with the occurrence of demand changes. The inclusion of leisure within the utility function would allow us to study the trade-off between working and leisure time and to carry out a welfare analysis when changes in demand occur.

Finally, in this paper we have focused on a small open economy; we nevertheless feel that it might be very interesting to make adjustments to the model such that an examination may be undertaken of the impact of changes in demand on a large open economy.

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Appendix 1

Labor Supply Functions L_T and L_N

Equations (4) and (5) imply that $L_T = L_T\,(K_T, K_N, p_N)$ and $L_N = L_N\,(K_T, K_N, p_N)$. From these two equations, we can further derive:

$$\frac{\partial L_T}{\partial K_T} = -\frac{p_T F_{LK}}{p_N H_{LL} + p_T F_{LL}} > 0, \qquad \frac{\partial L_T}{\partial K_N} = \frac{p_N H_{LK}}{p_N H_{LL} + p_T F_{LL}} < 0,$$

$$\frac{\partial L_T}{\partial p_N} = \frac{H_L}{p_N H_{LL} + p_T F_{LL}} < 0;$$

$$\frac{\partial L_N}{\partial K_T} = \frac{p_T F_{LK}}{p_N H_{LL} + p_T F_{LL}} < 0, \qquad \frac{\partial L_N}{\partial K_N} = -\frac{p_N H_{LK}}{p_N H_{LL} + p_T F_{LL}} > 0,$$

$$\frac{\partial L_T}{\partial p_N} = -\frac{H_L}{p_N H_{LL} + p_T F_{LL}} > 0.$$

Appendix 2

Calculation of the Steady State

In this appendix, we demonstrate how the steady state is calculated. Equation (2) implies that at the steady state, $X^* = 0$. Equations (28'), (30), (32), (33) and (34') indicate that at the steady state:

$$(r-\rho)C = \beta(\rho+\beta)[B + p_N(K_T + K_N)], \tag{A2.1}$$

$$p_T F(K_T, L_T(K_T, K_N, p_N)) + rB = (\mu_T + \mu_M)C + (p_T G_T + G_M), \tag{A2.2}$$

$$H(K_N, L_N(K_T, K_N, p_N)) = \frac{\mu_N C}{p_N} + G_N, \tag{A2.3}$$

$$H_K(K_N, L_N(K_T, K_N, p_N)) = r, \tag{A2.4}$$

$$p_T F(K_T, L_T(K_T, K_N, p_N)) = p_N H_K(K_N, L_N(K_T, K_N, p_N)). \tag{A2.5}$$

Equations (A2.1) - (A2.5) are used, together with Equations (4) and (5), to solve for ($L_T^*, L_N^*, K_T^*, K_N^*, p_N^*, C^*, B^*$).

Note that b does not appear in Equations (A2.1) - (A2.5); hence, its value does not affect the steady state.

Table 1 Benchmark parameters and calibrated values

Benchmark Parameters		
Probability of instantaneous death	β	0.0332
Real interest rate	r	0.0600
Time preference rate	ρ	0.0350
TFP of exportable goods	A	1.5000
TFP of non-tradable goods	D	1.0000
Capital share of exportable production	ξ_1	0.3500
Capital share of non-tradable production	ξ_2	0.3000
Degree of the sectoral adjustment costs	b	30.0000
Weight of consumption of importable goods	μ_M	0.3000
Weight of consumption of exportable goods	μ_T	0.3000
Weight of consumption of non-tradable goods	μ_N	0.4000
Government consumption of importable goods	G_M	0.0600
Government consumption of exportable goods	G_T	0.0400
Government consumption of non-tradable goods	G_N	0.2000
Terms of trade	p_T	1.0000
Calibrated Values		
Capital-labor ratio in the exportable good sector	K_T / L_T	12.5216
Capital-labor ratio in the non-traded good sector	K_N / L_N	9.9662
Government consumption-output ratio of tradable goods	$(G_T + G_M) / F$	0.1228
Government consumption-output ratio of non-traded goods	G_N / H	0.1293

Table 2 The effects of the degree of the sectoral adjustment costs on the eigenvalues

b	30	35	40	45	50	55	60	65
λ_1	-0.0604	-0.0658	-0.0686	-0.0705	-0.0718	-0.0729	-0.0737	-0.0743
λ_2	-0.0395	-0.0317	-0.0268	-0.0233	-0.0204	-0.0180	-0.0157	-0.0127
λ_3	-0.0088	-0.0090	-0.0091	-0.0093	-0.0096	-0.0100	-0.0105	-0.0120

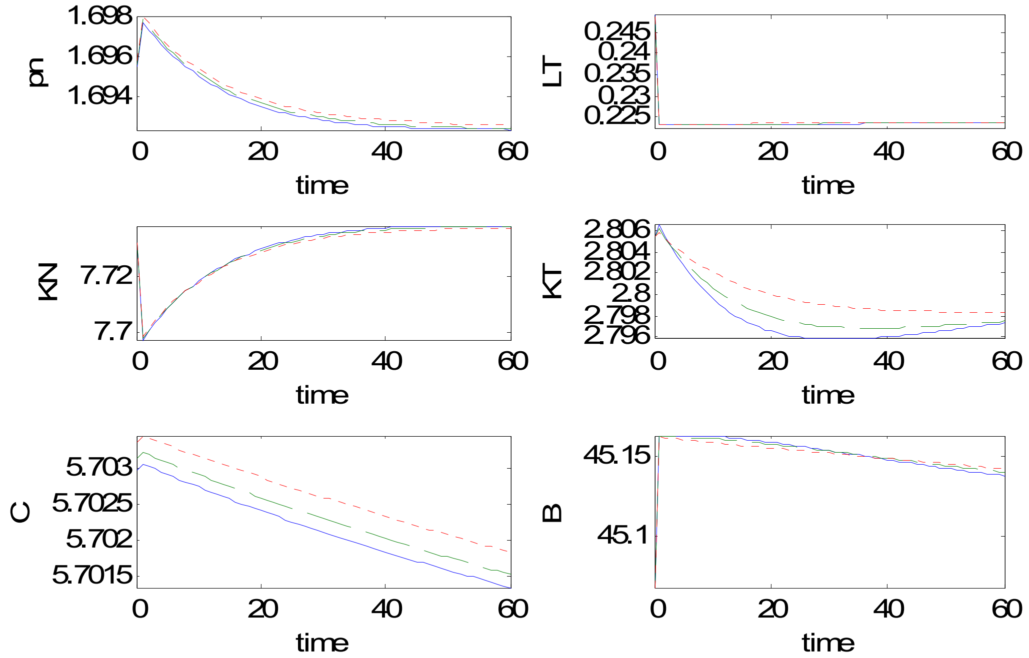

Figure 1 The effects on the economy from a temporary appreciation in terms of trade

Note: * The solid line indicates $b = 30$; the dashed line indicates $b = 40$; and the dotted line indicates $b = 65$.

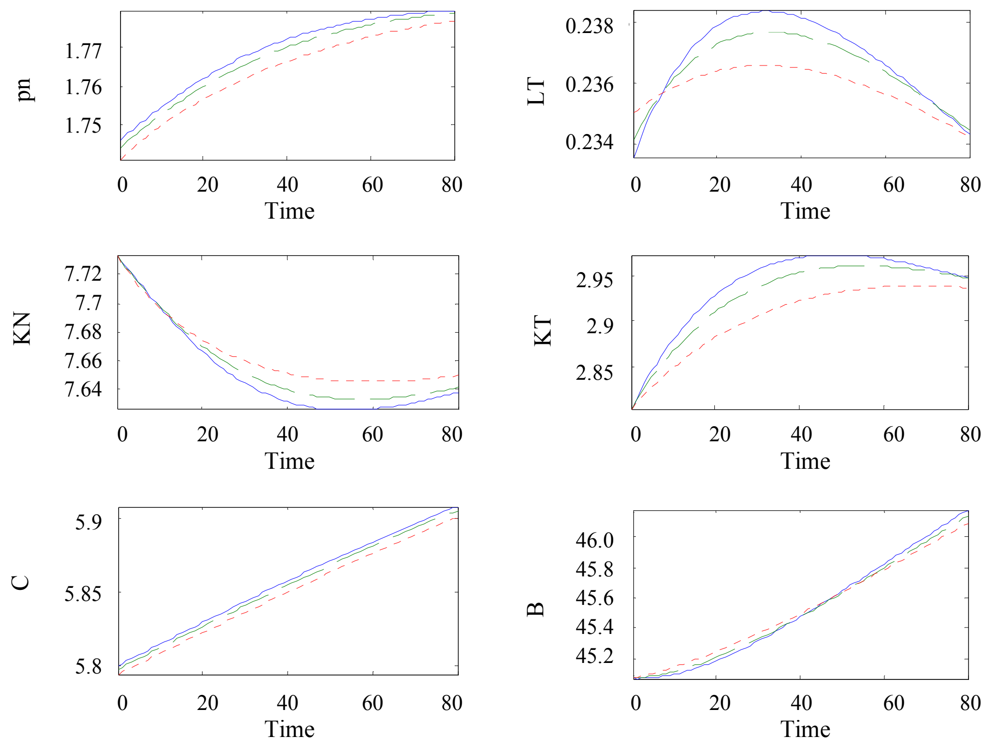

Figure 2 The effects on the economy from a permanent appreciation in terms of trade

Note: * The solid line indicates $b = 30$; the dashed line indicates $b = 40$; and the dotted line indicates $b = 65$.

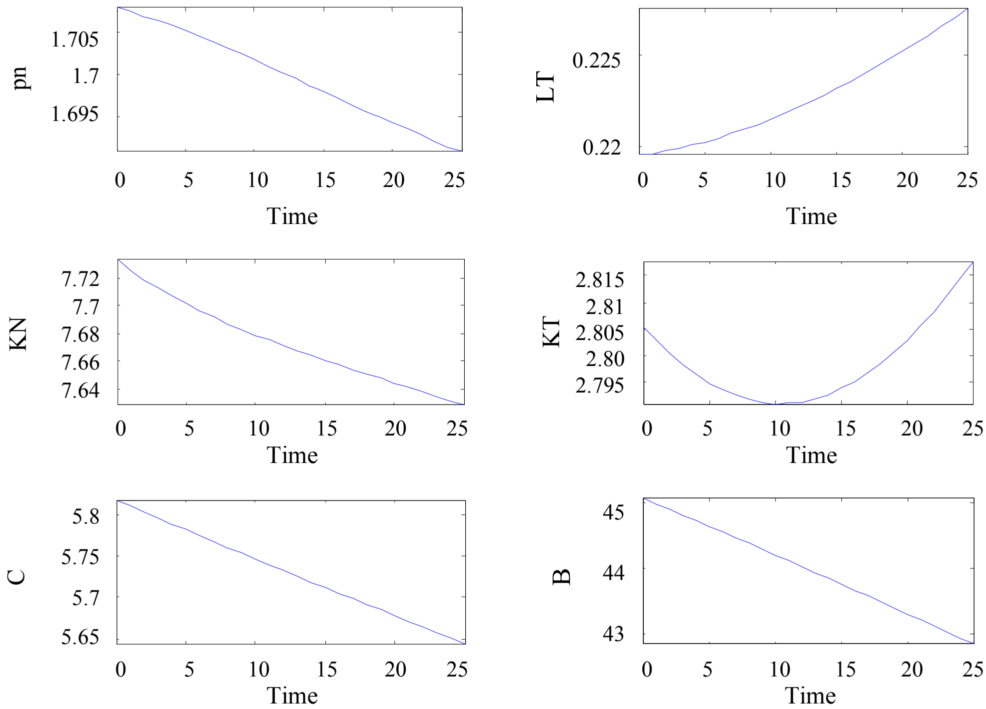

Figure 3 The effects on the economy from a permanent increase in the probability of instantaneous death