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Essays in Open Economy Macroeconomics

Kihyun Park
University of Tennessee - Knoxville

To the Graduate Council:

I am submitting herewith a dissertation written by Kihyun Park entitled "Essays in Open Economy Macroeconomics." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Economics.

Mohammed Mohsin, Major Professor

We have read this dissertation and recommend its acceptance:

Robert A. Bohm, Matthew N. Murray, Seong-Hoo Cho

Accepted for the Council:

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Essays in Open Economy Macroeconomics

A Dissertation
Presented for the
Doctor of Philosophy Degree
The University of Tennessee, Knoxville

Kihyun Park

May 2010

Dedication

To Mijung, Janie, Julia, and Jaden

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Abstract

This dissertation studies the dynamic effects of various economic shocks in a two-sector small open economy. It is divided into three essays. Essays 1 and 2 have a theoretical focus; they involve the developing of intertemporal optimizing models of a small open economy. In these essays, we use the representative-agent framework to derive dynamic macroeconomic effects. Specifically, in the first essay we examine the effects of monetary policy targeted at an inflation rate in a small open economy. We adopt a two-sector dependent economy where money is introduced through various cash-in-advance (CIA) constraints. Results are very significant and sensitive to various CIA constraints as well as relative capital intensities. Higher inflation will generate more investment in the economy leading to a higher level of capital stock and a lower level of net foreign assets in the long-run when the nontraded sector is more capital intensive and households need cash for purchasing tradable goods. However, the long-run effects are completely opposite if households need real balances for purchasing nontradable goods instead. In the second essay we examine the effects and the associated dynamics of an increase in international oil prices and domestic inflation. We show that an increase in oil prices or higher domestic inflation lowers the level of investment, production, and consumption in the long-run. The economy experiences a current account surplus along with a fall in capital stock by holding more foreign traded bonds. Transitional dynamics significantly depend on sectoral capital intensity as well. In essay 3 we investigate the explanatory power of yield spread in predicting economic activities in developing economies. We employ both the Markov regime switching model (MS) and the probit model to estimate the probability of recessions during the Asian financial crisis. We find that three-regime MS model is better predictor of recessions than two-regime MS model. The MS results are also compared with that of the standard probit model for comparison. The MS model does not significantly improve the forecasting ability of the yield spread in forecasting business cycles.

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Preface

The growing integration of economic activities across nations emphasizes the era of increasing globalization of the production process and financial markets. It is now difficult to design and implement economic policy in isolation, and even large countries cannot neglect the policies adopted by other countries. As a result, we observe tremendous growth in the macroeconomic literature dedicated to various open economy issues. On the theoretical front, however, the primary focus is the development of one-sector models where the effects of various policies are examined on aggregate macroeconomic variables such as output, consumption, employment, investment and the current account. In these one-good models, the nontraded sector does not play any role in the economy. But, we know that most of the developed and developing countries have a significant portion of nontraded sectors in their economies. For example, the consumption of nontradable goods accounts for 40 percent of GDP in the United States. The share of nontradable goods in GDP is more than 60 percent for the OECD countries (Cashin and McDermott, 2003 for details). This indicates that one must include both tradable and nontradable goods in a model to obtain a realistic evaluation while examining various policy implications.

The importance of the traded and nontraded sector is well acknowledged because a model with just one good is likely to overstate the linkages between economies. Nontradable goods are quantitatively important and can play a role in breaking the link between foreign and domestic consumption. The two-sector model can account for the role of the relative price between alternative consumption goods (tradable vs. nontradable) and therefore can address an economy's sectoral allocation of resources. In addition, the two-sector model could capture some other important issues such as output fluctuations across sectors, real wage movements, and trade patterns. Moreover, the two-sector model enables us to examine dynamic adjustments of a real exchange rate given an exogenous shock.

The main objective of this dissertation is to develop a small open economy two-sector general equilibrium macroeconomic model to address a few important macroeconomic issues. To be precise, the aim is to develop an *inter-temporal* optimizing growth model to study the effects of monetary policy aimed at targeting inflation. We also want to examine the effects of changing international oil prices in this two-sector dependent economy. While these issues are addressed at the theoretical and numerical levels, this dissertation also addresses an important empirical concern. Using macroeconomic data from two Asian economies (well known for their openness in terms of economic trade and commerce), we want to examine if one can predict economic recessions by exploiting the yield spread. To this end, we will employ both a Markov regime switching model and a probit model as an empirical framework.

In the context of an open economy, a central issue has been to understand how various sectors respond differently to many external and internal shocks. The literature dealing with Dutch disease is worth referring to. The discovery and exportation of resources cause an increase in income to the resource-exporting country. The positive wealth effect influences consumers' consumption and saving behavior in the country. Firms adjust their production according to the change in consumption, altering the sectoral allocation of resources such as capital and labor.

The change in the relative price (the real exchange rate between two consumption goods) through a rise in aggregate demand increases the return to capital in the nontraded sector at the expense of the traded sector since a booming sector takes resources away from other sectors. In particular, the impact of the discovery of resources on capital accumulation, output, terms of trade and the significantly different effects on both traded and nontraded sectors are well documented.

A two-sector model is capable of addressing some important concerns that are otherwise not possible in a standard one-sector model. Given economic shocks, one sector expands at the expense of the other sector through relative price changes. In the long-run, changes in the relative price cause changes in capital stock, output, and the current account given the predetermined structure of production and investment. Even though output fluctuations at the aggregate level are small, they can be significant in different sectors. Differentiating production between sectors generates their asymmetric responses to exogenous shocks and brings sector-specific features into the model. In reality, because of the different characteristics between the sectors, it is important to have a two-sector model to avoid aggregation bias. Such biases may mislead the central bank in their choice of optimal policies.

For our modeling purposes, we assumes that production factors such as capital and labor are perfectly mobile between sectors in order to investigate the long-run effects of a change in monetary policy and an increase in international oil prices. Following the asset pricing literature and recent advances in the monetary growth literature we introduce money through various cash-in-advance constraints. The dynamics of capital accumulation, the current account and sectoral reallocations are investigated following an inflationary shock. The first essay of this dissertation will capture these in detail. The dynamics involving the real exchange rate will also be addressed at length. In the second essay we investigate the effects of an increase in international oil prices (oil is an input in the production process) and domestic inflation on oil-importing countries. To do so, we extend the optimizing framework developed in essay 1. Oil is placed on both sectors as a production factor. We evaluate the effects and the associated dynamics of an increase in international oil prices and domestic inflation. In both essays we will conduct an extensive calibration exercise for numerical evaluations. In the third essay we address an empirical issue for open economies. Here, we investigate the usefulness of the yield spread in predicting economic recessions using a Markov regime switching model. We investigate the accurate turning point predictions of two Asian emerging countries and explore whether the economic recessions following the Asian crisis of 1997 could have been predicted.

The rest of this dissertation will be organized as follows. In chapter 1 we will discuss the first essay of this dissertation. A brief outline of the model and the methodology will be provided. Chapter 2 focuses on the second essay of this dissertation, which describes the effects of an increase in international oil prices and domestic inflation in a two-sector dependent economy. Chapter 3 outlines the final essay where we focus on the empirical evidence for predicting recessions using the yield spread by the Markov regime switching model.

Chapter 1

Monetary Policy in a Two-sector Dependent Economy

1.1 Introduction

The key objective of monetary policy for most central banks is to control inflation while achieving desirable long term economic growth. Price instability, such as inflation or hyperinflation, creates uncertainty in the economy which leads to lower economic growth. As a result, over the past few decades, inflation targeting has been adopted by many developed and developing countries as a framework for their own monetary policies. However, in modeling the effects of monetary policy in a small open economy setup, most researchers adopt a standard one-sector framework, and focus on the effects of changes in the aggregate level of economic variables. This precludes analysis of the full impacts of monetary policy shocks on various sectors and their effects on different parts of the economy. The main objective of this study is to fill this gap in the literature.

With increasing globalization, each country has become more open to, and integrated with, other countries. As the volume of international trade gradually increases among countries, so does the distinction between the traded and nontraded sector. The impact of monetary policy varies between the economic sectors because of production technology differences, market imperfections in each sector, and other structural differences. Monetary shocks alter the long-run allocations of sectoral resources such as labor and capital through changes in the relative price of goods. We will show in our model that the introduction of nontradable goods plays a very important role in the exchange rate behavior. Upon monetary shocks, the adjustment of the relative price plays a significant role in the sectoral reallocation. Monetary policy affects the price of goods, and consumers alter their consumption patterns accordingly. As a result, we observe the reallocation of consumption and inputs for the production of goods between sectors. Such important transmission mechanism can only be modeled if we introduce both traded and nontraded sectors.[1]

There exist a very limited number of studies in the literature that pay attention to the dynamics of capital accumulation in a two-sector open economy framework. Turnovsky and Sen (1995), Brock (1996), and Cardi and Restout (2007) discuss a real exchange rate behavior and capital accumulation in a two-sector general equilibrium framework, but they all focus on the fiscal side of the economy. For example, Turnovsky and Sen discuss in detail the effects of productivity shocks and an increase in domestic government expenditure in the traded and/or

[1] At the empirical level, Dedola and Lippi (2005) measure the effects of monetary policy on 21 industries from five industrialized countries using a structural VAR from 1975-1997. They find that monetary policy shocks have a different impact on sectoral outputs and are systematically related to the durability of the industry output, financing requirements, borrowing capacity and firm sizes. Similarly, Dotsey and Duarte (2008) study the relationship between nontraded sector and real exchange rates to find that nontradable goods play an important role in accounting for real exchange rate fluctuations compared to the model that abstracts from nontradable goods.

nontraded sectors. They find that an increase in government expenditure on the traded sector, for example, will raise the demand for tradable goods and labor moves from the nontraded sector to the traded sector to increase the production of tradable goods. As a result, the output of the nontraded sector declines. The others focus exclusively on the effects of an increase in international transfers and temporary fiscal shocks. None of these studies include money or monetary policies in their models. In this study we will focus exclusively on the monetary side of the economy and thereby fill a crucial gap in the literature.

The introduction of money in a monetary growth model is always an important issue. In the open economy macroeconomic literature, early studies by Obstfeld (1981 a, b) introduced money into the utility function. Though this approach is still popular, researchers often criticize it as a short cut method. Another approach that is very popular in the asset pricing literature is to introduce money through cash-in-advance (CIA) constraints. This approach relies on the transaction technology of demand for money. In the open economy literature important references include Helpman and Razin (1984), Calvo (1987), Calvo and Vegh (1995), Mansoorian and Mohsin (2006). We follow this line of literature in the construction of our model. However, since these studies deal with a one-good economy, they did not address the role of money and monetary policies in the sectoral adjustment process.

Further discussion on the modeling feature is warranted here. For the dependent economy the price of tradable goods is exogenously given by the world market, while the relative price of nontradable goods is endogenously determined by domestic market equilibrium. In our model, the representative household consumes both tradable and nontradable goods. The production factors, capital and labor, are perfectly mobile between two sectors and aggregate labor supply is perfectly inelastic. We assume that the economy faces a perfect world capital market. Both goods are produced with unique constant returns to scale production functions. It is important to note that the effects of an increase in inflation depend on the structure of demand for money in the economy. An increase in the long-run inflation rate could change the relative price between two consumption goods, as one could be “a cash good” and the other could be “a credit good” (e.g. Lucas and Stokey, 1987).

The existence of two sectors provokes non-uniform monetization between sectors. The use of cash varies across sectors because goods have a various degree of credit rationing. In this study, a few possible alternative specifications will be discussed. To do so, we generalize CIA constraints so that we have three possible polar cases. From our initial modeling results, we find that this has significant bearing on the effects of monetary policy in the economy as a whole.

First, we consider the case where households need real balances for consumption expenditure on tradable goods only. We may think about tradable goods as cash goods and the nontradable goods as credit goods. If the nontraded sector is more capital intensive, then a permanent increase in the inflation rate increases the relative demand for the nontradable goods (credit goods), and increases the relative price of the nontradable goods. It causes resources to shift from the traded to the nontraded sector and capital stock starts to rise. As the capital stock increases the current account deteriorates. Real wages of both sectors fall as the marginal product of labor falls and returns to capital rise. Capital owners are better off and laborers are worse off. The appreciation of real exchange rate will increase domestic costs of producing tradable goods and decrease the country’s international competitiveness. It will alter trade patterns as imports rise and exports fall. As a result, it shrinks exportable sectors. On the other hand, with the reversal in capital intensity, the economy experiences capital decumulation with a current account surplus which exhibits opposite results from the previous case. Consequently, investment falls and the capital stock decreases in the economy, but in the long-run the relative price remains intact.

Second, we consider another case where households need real balances for nontradable consumption only. Results are expected to be significantly different. The results are also expected to be sensitive to sectoral capital intensity. Third, CIA constraints are applied to both the tradable and nontradable goods jointly. In this case, the relative price will not be affected by a permanent increase in inflation. We expect the super-neutrality of monetary policy to hold. We show that a positive monetary shock does not necessarily increase output across different sectors. The interesting feature of this dynamic behavior comes from the nature of the production functions as well. The transitional dynamics of the economy depend on the distinction of two different production processes and the relative capital intensities of the two sectors as proposed by Turnovsky and Sen (1995).

Finally, the model is calibrated with standard parameter values for detailed quantitative analysis. When the sectoral capital intensity of the nontraded sector is greater than that of the traded sector, a permanent increase in the inflation rate from 4% to 8% will increase the steady state total capital stock and output by 0.42 percent and 0.13 percent, respectively. Under the same conditions, the steady state labor and output in the traded sector fall by 1.88 percent and the steady state labor and output in the nontraded sector increase by 1.7 percent. The steady state consumption of the tradable goods falls by 1.87 percent, while that of nontradable goods rises by 1.7 percent. So, the steady state total consumption rises by 0.0024 percent and the current account decreases by 1.78 percent. If we look at the overall changes in output and consumption, they are small relative to the sectoral changes. The effects of the change in consumption and output are more pronounced with a higher inflation rate. With the reversal in capital intensity, the steady state labor and output of the traded sector now fall by 2.45 percent, while those of the nontraded sector rise by 1.7 percent. The steady state total capital stock falls by 0.4 percent, and the steady state net foreign position increases by 2.3 percent, which is a current account surplus.

The rest of this essay is organized as follows; Section 2 presents the basic structure of the model, Section 3 describes the equilibrium dynamics, Section 4 presents the real effects of inflationary shocks, Section 5 summarizes the calibration results. The model with alternative CIA constraints is discussed in Section 6 and concluding remarks are given in section 7.

1.2 The Model

The model is that of a small open economy with an infinitely lived representative household that consumes both the tradable goods C_T and the nontradable goods C_N The household supplies one unit of labor ($L = 1$) in order to receive the wage bill w_t. The economy is small and takes the world interest rate, r, as given. The representative firm produces the tradable goods that can be consumed domestically and exported and the nontradable goods that can be either consumed or invested domestically. The basic framework follows closely to that of Turnovsky and Sen (1995). The domestic nominal price of the tradable goods is equal to the exchange rate times the foreign currency price of goods, that is, P=EP*. For convenience, we may set P*=1. With flexible prices, the change in the rate of inflation is equal to the rate of depreciation of the domestic currency.

1.2.1 The Representative Household

The representative household chooses consumption levels C_T and C_N to maximize the present value of lifetime utility:

$$\int_0^\infty U(C_{T_t}, C_{N_t})e^{-\rho t}dt, \tag{1.1}$$

where ρ is the fixed rate of time preference. The household derives positive but diminishing marginal utility from consumption, $U_{C_T} > 0, U_{C_N} > 0, U_{C_T C_T} < 0$, $U_{C_N C_N} < 0$ and $U_{C_T C_T}U_{C_N C_N} - U^2_{C_T C_N} \geq 0$.

Money is introduced in the model through various cash-in-advance constraints. The representative household requires real money balances (m_t) to finance his consumption expenditure:

$$m_t \geq \varphi_1 C_{T_t} + \varphi_2 e_t C_{N_t}, \tag{1.2}$$

where $0 \leq \varphi_1, \varphi_2 \leq 1$ and e_t is the relative price of the nontradable to the tradable goods (real exchange rate). For simplicity, we will consider three possible cases in this study: $(i)\ \varphi_1 = 1, \varphi_2 = 0, (ii)\ \varphi_1 = 0, \varphi_2 = 1$, and $(iii)\ \varphi_1 = 1, \varphi_2 = 1$. For our base line model, we will consider case (i) $(m_t \geq C_{T_t})$. This constraint requires the representative household to hold real money balances to finance tradable consumption purchases. The remaining cases will be discussed briefly thereafter.

The representative household owns all the domestic firms and gets the dividend D_t. He receives monetary transfer with real values τ_t from the government as well. The household also accumulates internationally traded bonds, b_t at the fixed interest rate, r. His flow budget constraint is

$$\dot{a}_t = D_t + w_t + rb_t + \tau_t - C_{T_t} - e_t C_{N_t} - \pi_t m_t, \tag{1.3}$$

where π_t is the inflation rate and $\pi_t m_t$ the inflation tax due to holding real balances. Note that a_t $(= m_t + b_t)$ represents the household's total real asset position at time t. As long as both inflation and the nominal interest rate remain positive, the return from money is dominated by the return from bonds, as money does not yield direct utility. The CIA constraint will, thus, hold with strict equality $(m_t = C_{T_t})$ and the dynamic budget constraint can be re-written as

$$\dot{a}_t = D_t + w_t + ra_t + \tau_t - C_{T_t} - e_t C_{N_t} - (\pi_t + r)m_t. \tag{1.4}$$

By solving the household's problem we obtain the following optimal conditions:

$$U_{C_T}\left(C_{T_t}, C_{N_t}\right) = \lambda_t(1 + r + \pi_t), \tag{1.5.1}$$

$$U_{C_N}\left(C_{T_t}, C_{N_t}\right) = \lambda_t e_t, \tag{1.5.2}$$

$$\dot{\lambda}_t = \lambda_t(\rho - r), \tag{1.5.3}$$

and the transversality condition: $\lim_{t\to\infty} \lambda_t a_t e^{-\rho t} = 0$. Without any ongoing growth in the long-run, in order for us to obtain a meaningful steady state, we require the rate of time preference to be equal to the world interest rate, $\rho = r$. This means that $\dot{\lambda}_t = 0$ for all t. It also implies that the marginal utility of wealth, λ_t, remains constant at its steady state level $(\bar{\lambda})$ all the time. If there is an external shock that affects the marginal utility of wealth, $\bar{\lambda}$ will jump to new steady state level immediately and stay there. See Turnovsky and Sen (1995) for details.

1.2.2 The Representative Firm

The representative firm produces both tradable (Y_T) and nontradable (Y_N) goods using capital and labor: $Y_T = F(K_T, L_T)$ and $Y_N = H(K_N, L_N)$. The variables involving the traded sector are indexed by subscript *T* and the nontraded sector by subscript *N*. The production functions exhibit standard neo-classical features - positive but diminishing marginal productivity of each input and constant returns to scale. Following Turnovsky and Sen, we assume that the tradable goods are used for consumption only and the nontradable goods can be used for both consumption and the accumulation of capital.[2] The objective of the representative firm is to maximize the present value of lifetime profits (the dividend). The dividend payment in time *t* (D_t) net of investment expenditure is defined as follows:

$$D_t = F\left(K_{T_t}, L_{T_t}\right) + e_t H\left(K_{N_t}, L_{N_t}\right) - w_t\left(L_{T_t} + L_{N_t}\right) - e_t I_t. \tag{1.6}$$

Hence, the representative firm maximizes:

$$\int_0^\infty D_t e^{-rt}\, dt = \int_0^\infty \left[F\left(K_{T_t}, L_{T_t}\right) + e_t H\left(K_{N_t}, L_{N_t}\right) - w_t\left(L_{T_t} + L_{N_t}\right) - e_t I_t\right] e^{-rt} dt.$$

[2] In another attempt, Brock and Turnovsky (1994) consider both tradable and nontradable goods for capital accumulation. They found that the latter plays an important role for determining equilibrium dynamics. If tradable goods are used for investment the capital stock adjusts instantaneously.

subject to the standard capital accumulation constraint, $\dot{K}_t = \dot{K}_{T_t} + \dot{K}_{N_t} = I_t$, and the initial K_0. In this optimizing problem the following two constraints involving capital and labor must also be satisfied:

$$K_{T_t} + K_{N_t} = K_t \quad \text{and} \quad L_{T_t} + L_{N_t} = 1.$$

The firm's problem yields the following optimal conditions:

$$F_{L_T}\left(K_{T_t}, L_{T_t}\right) = e_t H_{L_N}\left(K_{N_t}, L_{N_t}\right) = w_t, \tag{1.7.1}$$

$$e_t = q_t, \tag{1.7.2}$$

$$\dot{q}_t = q_t r - F_{K_T}\left(K_{T_t}, L_{T_t}\right), \tag{1.7.3}$$

$$\dot{q}_t = q_t r - e_t H_{K_N}\left(K_{N_t}, L_{N_t}\right), \tag{1.7.4}$$

and the transversality condition: $\lim_{t\to\infty} e_t K_t e^{-rt} = 0$. Here, q_t is the co-state variable associated with capital – also known as *Tobin's* q (the real price of equity in the sector). From (1.7.2) − (1.7.4) we also obtain:

$$F_{K_T}\left(K_{T_t}, L_{T_t}\right) = e_t H_{K_N}\left(K_{N_t}, L_{N_t}\right), \tag{1.7.5}$$

$$\dot{e}_t = e_t \left(r - H_{K_N}\left(K_{N_t}, L_{N_t}\right)\right). \tag{1.7.6}$$

Since labor and capital are perfectly mobile across sectors, the profit maximizing conditions show that the marginal products of capital and labor across sectors are equal in equilibrium. Equation (1.7.6) represents the rate of change of the real exchange rate. In equilibrium, the rate of return on the nontraded capital should equal the rate of return from the internationally traded bond. In other word, the domestic real interest rate is equal to the world fixed interest rate adjusted by the rate of appreciation of the real exchange rate. Since $e_t = q_t$ at each t, the evolution of e is identical to that of q.

1.2.3 The Government

We abstract from all fiscal tools and concentrate exclusively on the monetary side. To keep everything simple, we assume that the government (or the monetary authority) controls the inflation rate in the economy by choosing its real transfer τ_t in order to obtain the desired level of inflation rates π_t, and, thus, satisfy the following flow budget constraint:

$$\dot{m}_t + \pi_t m_t = \tau_t. \tag{1.8}$$

Equation (1.8) implies that total real monetary transfers τ_t should be equal to the government revenue from seigniorage $(\dot{m}_t + \pi_t m_t)$. It is assumed that the government is benevolent and seeks to undertake a policy that maximizes the intertemporal utility of the agent subject to the equilibrium constraints. It is assumed that the central bank targets the inflation rate by continuously adjusting the transfers. Such simplification is quite standard in the literature (see Calvo (1987), Calvo and Vegh (1995) or Mansoorian and Mohsin (2006) for example).

1.3 Equilibrium Dynamics

We now study the equilibrium dynamics of the economy. It is convenient to work with an intensive form. Let us denote $k_i\left(=\frac{K_i}{L_i}\right)$ the capital to labor ratio in sector $i = T, N$. The production functions can be rewritten as follows: $f(k_T) \equiv F(K_T, L_T)/L_T$ and $h(k_N) \equiv H(K_N, L_N)/L_N$. We obtain the following set of equations by combining all the constraints and optimality conditions of the representative household, firm, and the government (dropping time suffices):

$$U_{C_T}(C_T, C_N) = \bar{\lambda}(1 + r + \pi), \tag{1.9.1}$$

$$U_{C_N}(C_T, C_N) = \bar{\lambda}e, \tag{1.9.2}$$

$$f'(k_T) = eh'(k_N), \tag{1.9.3}$$

$$f(k_T) - k_T f'(k_T) = e[h(k_N) - k_N h'(k_N)] \equiv w, \tag{1.9.4}$$

$$L_T k_T + L_N k_N = K, \tag{1.9.5}$$

$$L_T + L_N = 1, \tag{1.9.6}$$

$$\dot{e} = e[r - h'(k_N)], \tag{1.9.7}$$

$$\dot{K} = L_N h(k_N) - C_N, \tag{1.9.8}$$

$$\dot{b} = L_T f(k_T) - C_T + rb. \tag{1.9.9}$$

These equations capture the equilibrium dynamics of the economy. To appreciate and understand the system we need to solve the dynamic system involving various state, co-state, and control variables. Equation (1.9.8) represents a market clearing condition for the nontradable goods' market. Any excess output will be accumulated as capital (nontradable goods are used for both consumption and capital accumulation). Equation (1.9.9) describes the economy's current account. The rate of accumulation of the traded bond (net foreign assets) is obtained by combining the budget constraints of the household and government along with incorporating the definition of profit (equations (1.4), (1.6) and (1.8)).

We will solve for the equilibrium dynamics above sequentially. Initially, we solve for the equilibrium C_T,C_N, k_T, k_N, L_T and L_N by using (1.9.1) − (1.9.6) and then incorporate them into the remaining differential equations to understand the transitional dynamics. Now it should be noted from (1.9.1) and (1.9.2) that the equilibrium levels of C_T and C_N can be represented by the following equations:

$$C_T = C_T(\bar{\lambda}, e, \pi), \tag{1.10.1}$$

$$C_N = C_N(\bar{\lambda}, e, \pi). \tag{1.10.2}$$

The partial derivatives of the tradable and nontradable consumption demand implicit in equations (1.10.1) and (1.10.2) are found by differentiating (1.9.1) and (1.9.2) with respect to $\bar{\lambda}, e,$ and π. This gives:

$$\frac{\partial C_T}{\partial \lambda} = \frac{\left(U_{C_N C_N}(1+r+\pi) - eU_{C_T C_N}\right)}{\Delta} < 0, \quad \frac{\partial C_N}{\partial \lambda} = \frac{\left(eU_{C_T C_T} - U_{C_N C_T}(1+r+\pi)\right)}{\Delta} < 0,$$

$$\frac{\partial C_T}{\partial e} = \frac{-\bar{\lambda} U_{C_T C_N}}{\Delta}, \quad \frac{\partial C_N}{\partial e} = \frac{\bar{\lambda} U_{C_T C_T}}{\Delta} < 0, \quad \frac{\partial C_T}{\partial \pi} = \frac{\bar{\lambda} U_{C_N C_N}}{\Delta} < 0, \text{and} \quad \frac{\partial C_N}{\partial \pi} = \frac{-\bar{\lambda} U_{C_T C_N}}{\Delta},$$

where $\Delta = U_{C_T C_T} U_{C_N C_N} - U^2_{C_T C_N} > 0$.

The equilibrium levels of k_T, k_N, L_T and L_N can be represented by the following equations:

$$k_T = k_T(e), \tag{1.11.3}$$

$$k_N = k_N(e), \tag{1.11.4}$$

$$L_T = L_T(e, K), \tag{1.11.5}$$

$$L_N = L_N(e, K). \tag{1.11.6}$$

The partial derivatives of capital and labor supply of tradable and nontradable goods implicit in Equations (1.11.3) – (1.11.6) are found by differentiating (1.9.3) – (1.9.6) with respect to e and K. This gives:

$$\frac{\partial k_T}{\partial e} = k'_T = \frac{h}{f''(k_N - k_T)}, \quad \frac{\partial k_N}{\partial e} = k'_N = \frac{f}{e^2 h''(k_N - k_T)}, \quad \frac{\partial L_T}{\partial K} = \frac{1}{(k_T - k_N)},$$

$$\frac{\partial L_N}{\partial K} = \frac{1}{(k_N - k_T)}, \quad \frac{\partial L_T}{\partial e} = \left[\frac{L_N f}{e^2 h''} + \frac{L_T h}{f''}\right]\frac{1}{(k_T - k_N)^2} < 0, \text{and}$$

$$\frac{\partial L_N}{\partial e} = -\left[\frac{L_N f}{e^2 h''} + \frac{L_T h}{f''}\right]\frac{1}{(k_T - k_N)^2} > 0.$$

Finally, substituting (1.11.3) – (1.11.6) into the production functions, the traded and nontraded output can be written as follows:

$$Y_T = Y_T(e, K), \tag{1.12.1}$$

$$Y_N = Y_N(e, K). \tag{1.12.2}$$

The partial derivatives of the output of tradable and nontradable goods are:

$$\frac{\partial Y_T}{\partial K} = \frac{f(k_T)}{(k_T - k_N)}, \quad \frac{\partial Y_N}{\partial K} = \frac{h(k_N)}{(k_N - k_T)}, \quad \frac{\partial Y_T}{\partial e} = \left[\frac{L_N f^2}{e^2 h''} + \frac{L_T e h^2}{f''}\right]\frac{1}{(k_T - k_N)^2} < 0,$$

and $\frac{\partial Y_N}{\partial e} = -\left[\frac{L_N f^2}{e^2 h^{"}} + \frac{L_T e h^2}{f^{"}}\right]\frac{1}{(k_T - k_N)^2} > 0.$

As explained earlier, the dynamics of the economy are controlled by

$$\dot{e} = e[r - h'(k_N(e))],$$

$$\dot{K} = L_N h(k_N(e)) - C_N(\bar{\lambda}, e, \pi),$$

$$\dot{b} = L_T f(k_T(e)) - C_T(\bar{\lambda}, e, \pi) + rb.$$

Moreover, the system is block recursive. We can utilize the first two differential equations and obtain the saddle path involving *K* and *e*, then use the solution to obtain the transitional path of *b*. As a result, it will be easier to draw the phase diagrams involving a system of three differential equations. First, following Turnovsky and Sen, linearize the equations involving *K* and *e* to get:

$$\begin{bmatrix}\dot{K}\\ \dot{e}\end{bmatrix} = \begin{bmatrix}a_{11} & a_{12}\\ 0 & a_{22}\end{bmatrix}\begin{bmatrix}K - \bar{K}\\ e - \bar{e}\end{bmatrix}, \tag{1.13}$$

where $a_{11} = \frac{h}{k_N - k_T}$, $\quad a_{12} = \frac{\partial Y_N}{\partial e} - \frac{\partial C_N}{\partial e} > 0$, and $\quad a_{22} = -\frac{f}{e(k_N - k_T)}$.

The determinant of the coefficient matrix is negative and the system, thus, has one negative and one positive eigenvalue. This yields a unique stable saddle-path regardless of the sectoral capital intensity. Let $\mu_1 < 0$ and $\mu_2 > 0$ be two eigenvalues and the optimal solution for *K* and *e* is:

$$K_t = \bar{K} + (K_0 - \bar{K})e^{\mu_1 t}, \tag{1.14.1}$$

$$e_t = \bar{e} + \left(\frac{\mu_1 - a_{11}}{a_{12}}\right)(K_0 - \overline{K})e^{\mu_1 t}. \quad (1.14.2)$$

Before we discuss the detailed saddle paths and obtain the solution for the current account balance we need to address two situations involving capital intensity of the two sectors − case (i) when $k_T > k_N$ and case (ii) when $k_T < k_N$. In case (i) when the traded sector is more capital intensive we will find that $\mu_1 = a_{11}$ and equation (1.13) will be reduced to:

$$K_t = \overline{K} + (K_0 - \overline{K})e^{\mu_1 t}\ , \quad (1.15.1)$$

$$e_t = \bar{e}. \quad (1.15.2)$$

This is the case when the relative price of the nontradable goods remains constant at its steady state level during dynamic evolution. After the permanent shock, the adjustment of the relative price of the nontradable goods occurs immediately and the current account exactly offsets the investment flow. So the change in capital stock takes place without any change in relative price. It can be seen by considering the arbitrage relationship $\dot{e}\ = e[r - h'(k_N(e))]$. Suppose that e increases. As e increases, k_N increases ($\frac{\partial k_N}{\partial e} = k'_N > 0, when\ k_T > k_N$). This requires that the marginal product $h'(k_N)$ declines. $\dot{e}$ must rise to ensure that the rate of return on capital equals the given return on bonds. That implies that a further increase in e and the economy is obviously an unstable path. For the stability the relative price remains unchanged. In this case the SS schedule in Figure B.2 is the saddle path. We will get back to this later. However, where $k_T < k_N$ we have $\mu_1 = a_{22}$ and the relationship between e and K along the saddle path is given by:

$$e_t = \bar{e} + \left(\frac{a_{22} - a_{11}}{a_{12}}\right)(K_t - \bar{K}), \tag{1.16}$$

which is a negatively sloping schedule. The SS schedule in Figure B.1 is drawn accordingly. In this case, a positive or negative demand shock, which leaves steady state $\bar{e}$ unchanged, changes e in the short-run. Due to the relative price change in the short-run, resources move from one sector to another and enable capital to accumulate or decumulate. As an example, higher demand in the nontraded sector will increase the real exchange rate (the relative price) and labor moves to the nontraded sector. Thus, the output of the nontraded sector rises and the capital stock starts to grow.

To obtain the optimal solution of the current account, first linearize equation (1.9.9) around the steady state and then use (1.14.1) and (1.14.2) to obtain

$$\dot{b} = \Omega(K_t - \bar{K}) + r\big(b_t - \bar{b}\big),$$

$$\text{where} \quad \Omega = \left[\frac{\partial Y_T}{\partial K} + \left(\frac{\partial Y_T}{\partial e} - \frac{\partial C_T}{\partial e}\right)\left(\frac{\mu_1 - a_{11}}{a_{12}}\right)\right].$$

Assuming that the economy starts from the initial stock of bonds b_0, we obtain the following solution:

$$b_t - \bar{b} = \frac{\Omega}{\mu_1 - r}(K_0 - \bar{K})e^{\mu_1 t} = \frac{\Omega}{\mu_1 - r}(K_t - \bar{K}). \tag{1.17}$$

It is extremely important to note that to obtain the above solution we imposed the following condition (to assure convergence):

$$b_0 - \bar{b} = \frac{\Omega}{\mu_1 - r}(K_0 - \bar{K}), \tag{1.18}$$

$$\text{where} \quad \frac{\Omega}{\mu_1 - r} = -\left\{\bar{e} + \left(\frac{1}{\mu_1 - r}\right)\left(\frac{\partial Y_T}{\partial e} - \frac{\partial C_T}{\partial e}\right)\left(\frac{\mu_1 - a_{11}}{a_{12}}\right)\right\}.$$

This is also known as "intertemporal solvency" condition (the ZZ schedule in Figure s B.1 and B.2). Equation (1.18) shows the relationship between the foreign bonds and the capital stock as linked through their initial and final levels. If $k_T > k_N$, we have an unambiguously negative relationship between the current account and the rate of the capital accumulation as obtained from $b_0 - \bar{b} = -\bar{e}(K_0 - \bar{K})$. On the other hand, with the reversal of capital intensity, such a negative relationship is not as clear (in equation (1.18)). If the savings do not respond significantly, the current account is negatively correlated with capital accumulation. This is commonly observed in empirical studies. Equation (1.18) has another significant implication. As the initial and final levels are tied, the model will exhibit hysteresis. In other words the initial condition matters and even a temporary shock will have permanent effects. With this basic description of our model, we will now examine the effects of inflationary shocks.

1.4 The Effects of Inflation

In this section, we discuss the steady state effects of an unanticipated and permanent increase in inflation rates. In the steady state we have $\dot{K} = \dot{e} = \dot{b} = 0$, which together with equation (1.17) yields:

$$Y_N(\bar{K}, \bar{e}) - C_N(\bar{\lambda}, \bar{\pi}, \bar{e}) = 0, \tag{1.19.1}$$

$$h'(k_N(\bar{e})) = r, \tag{1.19.2}$$

$$Y_T(\bar{K}, \bar{e}) + r\bar{b} - C_T(\bar{\lambda}, \bar{\pi}, \bar{e}) = 0, \tag{1.19.3}$$

$$b_0 - \bar{b} = \frac{\Omega}{\mu_1 - r}(K_0 - \bar{K}). \tag{1.19.4}$$

These equations jointly determine the steady state equilibrium. Equation (1.19.1) states that when there is no investment in the steady state, the total supply of nontraded output must equal the total demand for nontradable consumption. Since the nontradable goods are exclusively used for domestic investment, it is obvious that the marginal physical product of capital in this sector should equal world interest rate. Equation (1.19.2) states this profit maximizing condition. Equation (1.19.3) implies that the current account balance must be zero in the steady state. Equation (1.19.4) implies that the steady state depends on the initial condition (K_0, b_0). By totally differentiating these equations, the steady state effects of an increase in the inflation rate can be obtained for the case when nontraded sector is more capital intensive ($k_N > k_T$):

$$\frac{d\bar{K}}{d\pi} = \frac{1}{\Delta}\left(\frac{\partial C_N}{\partial \lambda}\frac{\partial C_T}{\partial \pi} - \frac{\partial C_T}{\partial \lambda}\frac{\partial C_N}{\partial \pi}\right) > 0,$$

$$\frac{d\bar{e}}{d\pi} = \frac{d\bar{q}}{d\pi} = 0\,, \tag{1.20}$$

$$\frac{d\bar{b}}{d\pi} = \left(\frac{\Omega}{\mu_1 - r}\right)\frac{d\bar{K}}{d\pi} < 0,$$

$$\text{where } \Delta = \left(-\frac{\partial Y_N}{\partial K}\frac{\partial C_T}{\partial \lambda} + \frac{\partial Y_T}{\partial K}\frac{\partial C_N}{\partial \lambda} + \frac{\partial C_N}{\partial \lambda}\left(\frac{\Omega}{\mu_1 - r}\right)\right) > 0.$$

Along with these steady state effects, consider the transitional process as well. In Figure B.1, points “A” and “J” jointly represent the initial equilibrium. With an unanticipated permanent increase in the inflation rate, the new equilibrium is represented jointly by “Q” and “G”. As explained earlier, ZZ schedule remain unchanged; however, the old saddle path SS is replaced by new saddle path S'S'. At time $t = 0$ when the new policy is announced and implemented, the economy immediately jumps from "A" to "B". This is because capital is a predetermined variable and we observe a sharp instant increase in e (equal to q). We will observe no instantaneous effect on the net asset position as it is also a predetermined variable. As a result, at time $t = 0$ when the policy is announced there is no short-run movement of the economy in terms of "J" on the ZZ schedule. However, immediately after that the economy moves to "Q" and "G" along the S'S' and ZZ schedules. During this period the capital stock slowly increases and the stock of foreign bond decreases to their new steady state levels. Therefore, we observe a current account deficit in this case. Before we provide some economic explanations, it is also worthwhile to show the effects on sectoral employment and output levels. Because the two sectors are affected differently, demand for employment in both traded and nontraded sectors responds differently. The level of output across sectors will respond differently as well. We could easily show analytically that:

$$\frac{\partial \bar{L}_T}{\partial \pi} = \frac{\partial L_T}{\partial K}\frac{\partial \bar{K}}{\partial \pi} + \frac{\partial L_T}{\partial e}\frac{\partial \bar{e}}{\partial \pi} < 0; \qquad \frac{\partial \bar{L}_N}{\partial \pi} = \frac{\partial L_N}{\partial K}\frac{\partial \bar{K}}{\partial \pi} + \frac{\partial L_N}{\partial e}\frac{\partial \bar{e}}{\partial \pi} > 0. \tag{1.21}$$

$$\frac{\partial \bar{Y}_T}{\partial \pi} = \frac{\partial Y_T}{\partial K}\frac{\partial \bar{K}}{\partial \pi} + \frac{\partial Y_T}{\partial e}\frac{\partial \bar{e}}{\partial \pi} < 0; \qquad \frac{\partial \bar{Y}_N}{\partial \pi} = \frac{\partial Y_N}{\partial K}\frac{\partial \bar{K}}{\partial \pi} + \frac{\partial Y_N}{\partial e}\frac{\partial \bar{e}}{\partial \pi} > 0. \tag{1.22}$$

In other words, higher inflation leads to labor re-allocation. Labor moves from the traded to the nontraded sector. We observe a lower output level in the traded sector but a higher level in the nontraded sector. Moreover, in the long-run, a higher inflation rate causes the capital stock to increase and the current account balance to deteriorate as we observe a negative relationship between the accumulation of capital and the holding of foreign traded bonds.

The economic intuition of this analysis is as follows. With the cash-in-advance constraint on tradable consumption, the increase in the inflation rate raises the opportunity cost of purchasing tradable goods (C_T) relative to the nontradable goods (C_N). As we mentioned earlier, we may think of C_T as the cash goods and C_N as the credit goods. As a consequence, the relative price will rise to clear both markets and we observe both price effects and substitution effects leading to lower demand for tradable goods and higher demand for nontradable goods.

As a result, we see a shift of labor supply from the traded sector to the nontraded sector. Producers move resources out of the traded sector into the nontraded sector in search of a higher return. As a result, labor in the traded sector falls and that of the nontraded sector rises. Since the nontraded sector is more capital intensive than the traded sector, the increase in the relative price of the nontradable goods will increase the marginal productivity of the capital. As the economy produces more nontradable goods and less tradable goods, the traded sector releases resources in a bundle involving a higher ratio of labor to capital. The nontraded sector absorbs most of the capital but only part of labor since it is the capital intensive sector. There would emerge excess demand for capital and excess supply of labor, causing a rise in the return from capital and a fall in the return from labor, which is wages. With the increased supply of labor, the output in the nontraded sector rises and investment starts to rise as the marginal product of capital rises.

During the transition, the capital stock rises steadily while the relative price gradually falls to the initial level. It is clearly seen from Figure B.1 that the capital stock and investment increase as marginal product of capital increases.[3] Since sectoral capital intensities are fixed, the aggregate capital stock relies on whether labor moves from the labor-intensive sector to the capital-intensive sector. Since labor moves from the traded sector, which is labor intensive, to the nontraded sector, which is capital intensive, over all capital stock $\overline{K}$ rises. The increase in investment will cause the current account to deteriorate, leading to a decline in net foreign assets. As capital moves from the traded to the nontraded sector, the capital stock will rise along the adjustment path to the new long-run equilibrium. Clearly, we can see the expansion of the nontraded output and the decline of the production in the traded sector. Now we will discuss the effects of higher inflation in the economy when the traded sector is more capital intensive ($k_T > k_N$). As it turns out, the effect will be ambiguous. However, if the determinant D (when evaluated at the steady state) is positive, that is[4]

$$D = \left(-\frac{\partial Y_N}{\partial K}\frac{\partial C_T}{\partial \lambda} + \frac{\partial Y_T}{\partial K}\frac{\partial C_N}{\partial \lambda} + r\bar{e}\frac{\partial C_N}{\partial \lambda}\right) > 0,$$

then we will get:

$$\frac{d\overline{K}}{d\pi} = \frac{1}{D}\left(\frac{\partial C_N}{\partial \lambda}\frac{\partial C_T}{\partial \pi} - \frac{\partial C_T}{\partial \lambda}\frac{\partial C_N}{\partial \pi}\right) < 0,$$

$$\frac{d\bar{b}}{d\pi} = -\bar{e}\frac{d\overline{K}}{d\pi} > 0. \tag{1.23}$$

[3] Note that q is the ratio of the market value of a firm's capital (as measured by the market value of its outstanding stock and debt) to the replacement cost of the firm's assets, so q will be affected by the marginal product of capital. If Tobin's q is above 1, the firm is earning a rate of return higher than that justified by the cost of its assets, so $\dot{K} > 0$. Similarly, if q falls below 1 then we will have $\dot{K} < 0$.

[4] This is the main reason why we concentrate on calibration exercise. Based on existing empirical and other rear business cycle literature we expect a negative relationship between capital stock and the stock of internationally traded bonds.

In terms of the phase diagram, the transition to the new steady state is simple. In Figure B.2, the economy directly moves from point "a" to point "b" along the saddle path SS. The capital stock falls and foreign bonds accumulate. This is the movement from point "d" to "e". Higher inflation causes the immediate shifting of labor away from the traded to the nontraded sector. The output of the traded sector immediately falls and the marginal product of capital begins to fall. The traded sector releases resources in a bundle involving a higher ratio of capital to labor. There would emerge excess demand for labor and excess supply of capital, causing a fall in the return from capital and a rise in the return from labor. Investment begins to decline. So, the capital stock decreases in order to increase the production of the labor-intensive nontradable goods, leading to the accumulation of foreign bonds.[5] In the long-run the relative price remains unchanged and there are no transitional dynamics, so the relative price remains fixed all along. Without any change in the relative price, labor adjusts gradually as the resources move to the nontraded sector. As labor moves from the capital-intensive to the labor-intensive sector, $\overline{K}$ will fall and the current account will have a surplus.

On the other hand, if the determinant is negative, we will get completely opposite results. In terms of Figure B.2, the economy directly moves from point "a" to point "c" along the saddle path SS. However, the magnitude will be greater since we have a smaller denominator. Interestingly, these results are similar to the earlier case in which the nontraded sector was more capital intensive.

[5] Here we have: $\frac{\partial Y_T}{\partial K} = \frac{f(k_T)}{k_T - k_N} > 0$ and $\frac{\partial Y_N}{\partial K} = \frac{h(k_N)}{k_N - k_T} < 0$.

1.5 Calibration

Now we will calibrate the model for quantitative analysis. Following the existing literature we use the instantaneous utility function:

$$U(C_T, C_N) = \frac{1}{\eta}\left({C_T}^{\theta}{C_N}^{1-\theta}\right)^{\eta},$$

and the production functions:

$$f(k_N) = {k_N}^{\alpha},$$

$$f(k_T) = {k_T}^{\beta}.$$

Here, $\frac{1}{1-\eta}$ measures the intertemporal elasticity of substitution, θ parameterizes the relative importance of the tradable and nontradable goods in the overall consumption bundle, and α and β indicate the degree of the capital intensity in the nontraded and traded sectors.

Table A.1 (A) shows base parameter values. We follow Morshed and Turnovsky (2004) very closely and set $\theta = 0.5$ and assume $\eta = -1.5$, so that the intertemporal elasticity of substitution is 0.4. These parameter values are also consistent with empirical literature. The world interest rate is fixed at 6%. The productivity parameters α and β are set to 0.35 and 0.25 when the nontraded sector is more capital intensive ($k_N > k_T$). For the other case where the traded sector is more capital intensive ($k_T > k_N$), α and β correspond to 0.25 and 0.35. The idea of the narrow range of the productivity parameters is that production technologies in a country are not totally different between sectors (e.g. Morshed and Turnovsky, 2004).

Table A.1 (B) summarizes the key steady state values and ratios corresponding to the base parameter values. When the nontraded sector is more capital intensive, the relative sectoral capital-labor ratio (k_N/k_T) is 1.62. The capital-output ratio in the traded and nontraded sectors is 5.34 and 5.83, respectively. The overall capital-output ratio is 6.53. Around 43% of total output is produced with approximately 48% of labor employed in the traded sector. When the traded sector is more capital intensive, the relative sectoral capital-labor ratio (k_N/k_T) is 0.62. The corresponding capital-output ratios in the traded and nontraded sectors are 4.70 and 4.17 respectively, resulting in an overall capital-output ratio of 4.41. In this case around 44% of total output is produced with 41% of labor employed in the traded sector.

1.5.1 When $k_N > k_T$

The steady state effects of a permanent increase in the inflation rate are summarized in Table A.2. We consider two different values of the intertemporal elasticity of substitution parameter, 0.4 (η = -1.5) and 0.7 (η = -0.4), two different inflation rates from the benchmark parameters, 8% and 12%, and lastly, two different world interest rates: 6% and 4%, respectively. When the sectoral capital intensity of the nontraded sector is greater than that of the traded sector, a permanent increase in the inflation rate from 4% to 8% will increase the steady state total capital stock and output by 0.42 percent and 0.13 percent, respectively, while the steady state labor and output in the traded sector falls by 1.88 percent and the steady state labor and output in the nontraded sector increases by 1.7 percent. Higher inflation attracts resources from the traded sector to the nontraded sector when the CIA constraint applies on the tradable goods only.

The steady state consumption of the tradable goods falls by 1.87 percent, while that of the nontradable goods rises by 1.7 percent. So the steady state total consumption rises by 0.0024 percent and the net foreign asset decreases by 1.78 percent. If we look at the overall changes on output and consumption, the changes are small relative to the sectoral changes. For example, the steady state total output rises by 0.13 percent but the output of the traded sector falls by 1.88 percent and that of the nontraded sector rises by 1.7 percent, respectively. This is the reason why policy makers should consider these sectoral fluctuations to design and implement any policies. This problem is closely connected to social welfare issues and welfare analysis. In the long-run the relative price, $\bar{e}$, and the capital-labor ratios, $\bar{k}_T$ and $\bar{k}_N$, remain unchanged. This implies that the demand shock does not affect the capital intensities of either sector or the relative price changes only in the short-run, but it comes back to the initial level in the long-run.

The labor employed in the nontraded sector increases by 1.7 percent with output and consumption changing in the same proportion. When the inflation rate increases from 4% to 12%, holding other parameters constant, the steady state total capital stock and output increase by 0.82 percent and 0.25 percent, respectively. While the output in the traded sector falls by 3.7 percent, the output in the nontraded sector rises by 3.34 percent. Overall, total output and total consumption increases, and the economy experiences a current account deficit of 3.5 percent. With higher inflation, the effects on aggregate consumption and output are pronounced. However, the quantitative results of the permanent change in the inflation rate are not sensitive to the change in intertemporal elasticity of substitution.

Lastly, we carry out a similar calibration exercise with world interest rate of 4% and compare the results with that of 6%. We observe that the change in the steady state total capital stock, the total consumption, and the total output are not very different except for the current account position. The current account falls by 3.1 percent (with a 4% world interest rate) which is greater than 1.78 percent (with 6% of world interest rate) when we increase the inflation rate from 4% to 8%. This implies that the change in the current account is sensitive to the change in the world interest rate.

We also calculate the short-run effects numerically and try to fully understand the transitional dynamics. As shown in Figure B.3 at $t = 0$, when the inflation rate is increased, there are no short-run effects on the level of the capital and the current account since both are predetermined variables. However, in the long-run, the stock of capital increases, leading to the decrease of foreign bonds. As a result, the economy experiences a current account deficit in the long-run. If we look at the time path of the real exchange rate, the response is different. It immediately jumps up at $t = 0$ along with the increase in the inflation rate. It gradually decreases as the economy accumulates more capital. The initial rise of the real exchange rate will be more pronounced for a large shock. In the long-run, the real exchange rate comes back to the initial value. The time path of two consumption goods is also shown in Figure B.3. Consumption of the tradable goods drops at time $t = 0$ and gradually converges to its new equilibrium which is lower than the initial value. On the other hand, consumption of the nontradable goods initially increases and converges to the new higher equilibrium level.

1.5.2 When $k_N < k_T$

The results of this case are summarized in the Table A.2 (B). As in previous case, the increase in the inflation rate attracts resources from the traded sector into the nontraded sector with the decrease in the output level in the traded sector and the increase in the output level in the nontraded sector. When the inflation rate increases from 4% to 8%, steady state labor and output of the traded sector fall by 2.46 percent, while those of the nontraded sector rise by 1.7 percent. The relative price and the capital-labor ratio remain unchanged in the long-run. The striking feature is that now the steady state total capital stock falls by 0.5 percent in order to increase the production of labor-intensive nontradable goods. Furthermore, steady state total output falls by 0.15 percent as the output of the traded sector decreases more than the output of nontraded sector. The change in the steady state total consumption is roughly zero in this case. However, as the steady state total capital stock falls, the steady state net foreign position increases by 2.3 percent.

We have worked out the short-run effects as well and summarized the results in Figure B.4. Like the previous case, there is no short-run effect on the level of capital accumulation or the current account balance since both are predetermined variables. However, the stock of capital decreases after the increase in the inflation rate leading to an accumulation of foreign bonds. As a result, the foreign asset position in the economy improves in the long-run. As argued earlier, there is no response by the real exchange rate at $t = 0$ since the long-run level is unaffected by the demand shock. The economy's capital stock gradually decreases to the new steady state level with the constant real exchange rate. The time path of the two consumption goods show that the tradable and nontradable consumption goods changes by their full amount to the new level of consumption. In other words, they adjust instantaneously and the magnitudes of short-run and long-run effects are identical. This is significant when we compare this to the previous case when the nontraded sector is more capital intensive.

1.6 Some Extensions

As discussed in the introduction, the effects of monetary policy depend on the role of money in the economy. So far we considered the case in which households need money for consumption of tradable goods only. We will consider other two possibilities briefly.

1.6.1 The Model with CIA Constraint on C_N only

This change only affects the consumer's problem keeping the firm's problem and the government's problem unchanged. When the cash-in-advance constraint is applied to the nontradable goods only:

$$m_t \geq e_t C_{N_t}. \qquad (1.24)$$

This is the opposite of the case in the previous section. Since the return of money is dominated by the return from bonds, the CIA constraint will hold with strict equality ($m_t = e_t C_{N_t}$) and the dynamic budget constraint can be written as

$$\dot{a}_t = D_t + w_t + ra_t + \tau_t - C_{T_t} - e_t(1 + r + \pi_t)C_{N_t}. \qquad (1.25)$$

The first two optimal conditions of the household will be:

$$U_{C_T}\left(C_{T_t}, C_{N_t}\right) = \lambda_t, \qquad (1.26.1)$$

$$U_{C_N}\left(C_{T_t}, C_{N_t}\right) = \lambda_t e_t(1 + r + \pi_t). \qquad (1.26.2)$$

From the equation (1.26.1) and (1.26.2) that the equilibrium levels of C_T and C_N can be represented by the following equations:

$$C_T = C_T(\bar{\lambda}, e, \pi), \tag{1.27.1}$$

$$C_N = C_N(\bar{\lambda}, e, \pi). \tag{1.27.2}$$

The partial derivatives of C_T and C_N with respect to their arguments are

$$\frac{\partial C_T}{\partial \lambda} = \frac{\left(U_{C_N C_N} - e(1+r+\pi)U_{C_T C_N}\right)}{\Delta} < 0, \qquad \frac{\partial C_N}{\partial \lambda} = \frac{\left(e(1+r+\pi)U_{C_T C_T} - U_{C_N C_T}\right)}{\Delta} < 0,$$

$$\frac{\partial C_T}{\partial e} = \frac{-\bar{\lambda}(1+r+\pi)U_{C_T C_N}}{\Delta}, \qquad \frac{\partial C_N}{\partial e} = \frac{\bar{\lambda}(1+r+\pi)U_{C_T C_T}}{\Delta} < 0, \qquad \frac{\partial C_T}{\partial \pi} = \frac{-\bar{\lambda} e U_{C_T C_N}}{\Delta}, \text{and}$$

$$\frac{\partial C_N}{\partial \pi} = \frac{\bar{\lambda} e U_{C_T C_T}}{\Delta}, \text{where } \Delta = U_{C_T C_T} U_{C_N C_N} - U^2_{C_T C_N} > 0.$$

Combining the optimality conditions of the household, the dynamics of the model can be analyzed as shown earlier. For the sake of brevity, it will be worthwhile to use phase diagrams for discussions. Interestingly, the outcome of this case mirrors that of the outcome of our initial setup where the CIA constraint was imposed on the tradable consumption only. The results are sensitive to sectoral capital intensity as well.

When the nontraded sector is more capital intensive, higher inflation lowers capital stock and the economy experiences a current account surplus since the inflation lowers the relative price and induces labor to move from the nontraded sector to the traded sector. In terms of Figure B.1, a new equilibrium will move to “P” from the initial equilibrium “A”. After the increase in the inflation rate, the economy drops to point “C”. Then it will gradually adjust from point “C” to point “P” along the new saddle path $S''S''$. During this period the economy also moves from “J” to “F” along the ZZ schedule with K falling and b rising. The increase in the inflation rate raises the opportunity cost of purchasing nontradable goods (C_N) relative to tradable goods (C_T). This induces people to demand more on the tradable goods.

If the traded sector is more capital intensive ($k_N < k_T$) and the determinant is positive, the results would be completely opposite. In terms of Figure B.2, the economy moves directly from point “a” to point “c” along the saddle path SS. The capital stock rises and the decumulation of bonds occurs as the economy moves from point “d” to “f”. The capital stock increases in order to increase the production of the capital intensive tradable goods, leading to the decumulation of foreign bonds. As we know, the long-run relative price remains unchanged and there are no transitional dynamics. Labor adjusts gradually as the resources move from the nontraded to the traded sector.

Table A.3 reports the effects of a permanent increase in the inflation rate using the same base parameters and functional forms. When the sectoral capital intensity of the nontraded sector is greater than that of the traded sector, a permanent increase in the inflation rate from 4% to 8% will reduce the steady state capital by 0.42 percent, steady state output by 0.13 percent, and steady state consumption by 0.002 percent. A fall in the steady state total capital stock and consumptions induces a current account surplus by 2.09 percent. If we look at the sectoral fluctuations of labor, output, and consumption, the effects of sectoral changes are more pronounced than the effects of overall changes. The long-run relative price and the capital-labor ratios remain intact as in the previous case. If the traded sector is more capital intensive, the capital stock increases by 0.49 percent and the economy experiences the current account deficit by 2.4 percent. Lastly, if we use a world interest rate of 4% and carry out the same exercise we find similar results except for the current account. This is consistent with the basic model.

Figure B.5 reports the short-run effects when the CIA constraint applies on the nontradable consumption goods and the nontraded sector is more capital intensive. At time $t = 0$ after the shock, the capital stock gradually decreases and the current account improves to the new steady state level. The real exchange rate immediately drops down at $t = 0$, along with an increase in the inflation rate, and gradually increases as the economy decumulates its capital stock. The consumption of the tradable goods jumps up at time $t = 0$ and it gradually moves to the new level. Nontradable consumption drops at time $t = 0$ and converges to its new level. Figure B.6 reports the case where the CIA constraint applies to the nontradable consumption goods and the traded sector is more capital intensive. The stock of capital increases after the increase in the inflation rate leading to the decumulation of foreign bonds. The real exchange rate remains unchanged. The responses of the two consumption goods are significant – they instantly adjust to their new long term levels.

1.6.2 The Model with CIA Constraint on both C_T and C_N

Again, the change only affects the consumer's problem, so the firm's problem and the government's problem remain intact. When the cash-in-advance constraint is applied to both the tradable and the nontradable goods together we obtain:

$$m_t \geq C_{T_t} + e_t C_{N_t}. \tag{1.28}$$

This is the case where the analysis basically same as a one consumption good model. In this case, the relative price will not be affected by a permanent increase in inflation and therefore the economy experiences neither capital accumulation nor current account surplus or deficit. All macro-variables such as outputs, consumptions, and labors remain same in the long-run. This produces the neutrality of money so the increase in the growth rate of money supply does not affect real variables. The dynamic budget constraint can be written as

$$\dot{a}_t = D_t + w_t + ra_t + \tau_t - (1 + r + \pi_t)C_{T_t} - e_t(1 + r + \pi_t)C_{N_t}. \qquad (1.29)$$

The optimality conditions with respect to tradable and nontradable consumption will be

$$U_{C_T}\left(C_{T_t}, C_{N_t}\right) = \lambda_t(1 + r + \pi_t), \qquad (1.30.1)$$

$$U_{N_T}\left(C_{T_t}, C_{N_t}\right) = \lambda_t e_t(1 + r + \pi_t). \qquad (1.30.2)$$

From the equation (1.30.1) and (1.30.2) that the equilibrium levels of C_T and C_N can be represented by the following equations:

$$C_T = C_T\left(\bar{\lambda}, e, \pi\right), \qquad (1.31.1)$$

$$C_N = C_N\left(\bar{\lambda}, e, \pi\right). \qquad (1.31.2)$$

The partial derivatives of C_T and C_N with respect to their arguments are

$$\frac{\partial C_T}{\partial \lambda} = \frac{\left(U_{C_N C_N} - eU_{C_T C_N}\right)}{\Delta}(1 + r + \pi) < 0, \qquad \frac{\partial C_N}{\partial \lambda} = \frac{\left(eU_{C_T C_T} - U_{C_N C_T}\right)}{\Delta}(1 + r + \pi) < 0,$$

$$\frac{\partial C_T}{\partial e} = \frac{-\bar{\lambda}(1 + r + \pi)U_{C_T C_N}}{\Delta}, \qquad \frac{\partial C_N}{\partial e} = \frac{\bar{\lambda}(1 + r + \pi)U_{C_T C_T}}{\Delta} < 0, \frac{\partial C_T}{\partial \pi} = \frac{\bar{\lambda}U_{C_N C_N} - e\bar{\lambda}U_{C_T C_N}}{\Delta},$$

and $\frac{\partial C_N}{\partial \pi} = \frac{\bar{\lambda} e U_{C_T C_T} - \bar{\lambda} U_{C_T C_N}}{\Delta}$, where $\Delta = U_{C_T C_T} U_{C_N C_N} - U_{C_T C_N}^2 > 0$.

Higher inflation will affect the prices of both goods equally keeping the relative price unchanged. The outcome will be very similar to the outcome of a one good model. With inelastic aggregate labor supply, higher inflation will have no steady state effects. Since consumption and investment are unaffected, the net foreign asset will also remain the same.

1.7 Conclusion

In this essay, we examine the real effects of inflation in a small open economy. Since we adopt a two-sector framework, our results provide overall effects as well as sectoral effects of monetary policy in the economy. We also draw attention to the detailed inter-sectoral adjustment process involving employment, investment, consumption etc. We also focus on current account dynamics.

We introduce money through various CIA constraints. In our model households consume both tradable and nontradable goods with inelastic aggregate labor supply. With intersectoral labor mobility, the economy produces both goods using labor and capital as inputs. We assume standard constant returns to scale production functions with no adjustment cost involving capital movement between sectors. Our results are very significant and sensitive to various CIA constraints, as well as relative capital intensities. For example, when the nontraded sector is more capital intensive and households need cash for purchasing tradable goods, higher inflation will generate more investment in the economy, leading to a higher level of capital stock and a lower level of net foreign assets in the long-run. However, the long-run effects are completely opposite if households need real balances for purchasing nontradable goods instead. Interestingly, when the household requires cash for all consumption, the super-neutrality of monetary policy prevails. We also calibrate the model with standard parameter values for quantitative analysis. The effects are significant. Often, sectoral effects are more pronounced than economy's wide aggregate effects. This explains why policy makers should pay more attention to various sectors of the economy.

Chapter 2

Domestic Inflation and International Oil Prices in a Two-Sector Small Open Economy

2.1 Introduction

The objective of this study is to examine the effects of international oil prices and domestic inflation in a small open economy. Needless to say, for the policymakers of any open economy these issues are of utmost interest due to their potential impacts in the domestic economy. In the literature, these issues are modeled independently and most importantly in a one good framework. As we know, increases in oil prices and domestic inflation are often integrated. Our objective is to offer a model employing a two-sector framework where we can address the effects of these important issues comprehensively.

An important limitation of a standard one good model is that it precludes the analysis of the full impacts of various policy shocks on different sectors. With increasing globalization, each country has become more open to, and integrated with, other countries. As the volume of international trade increases among countries, so does the distinction between the traded and the nontraded sector. The impact of economic shocks varies between the economic sectors because of production technology differences and other structural differences.

We show in our model that the introduction of nontradable goods plays an important role in exchange rate behavior. Different shocks affect the economy in different ways in terms of the real exchange rate or the relative price, and consumers alter their consumption patterns accordingly. As a result, we observe the reallocation of consumption and inputs for the production of goods between sectors. Such an important transmission mechanism can only be modeled if we introduce both traded and nontraded sectors.[6]

The effect of an increase in oil prices has been analyzed extensively in macroeconomics because it is considered one of the most important sources of economic recessions in many countries. Many studies have examined this issue since the first oil shocks in the 1970s. Hamilton (1983, 1996), for instance, found that oil price shocks were the major cause of U.S. recessions. However, Blanchard and Gali (2007) explain that today oil shocks seem to have different impacts on economic activities than before because labor markets are more flexible and central banks use anti-inflationary monetary policy to maintain low volatility of both prices and quantities. Although the power of oil shocks has declined, the negative consequences of higher oil price shocks may have a large impact on the macro economy. Despite the large body of literature, the focus has remained exclusively within a closed economy context. With increasing

[6] At the empirical level, Betts and Kehoe (2006) study the relationship between the United States' real exchange rate and relative price of nontradable goods. Similarly, Dotsey and Duarte (2008) study the relationship between a nontraded sector and real exchange rates. They find that nontradable goods play an important role in accounting for real exchange rate fluctuations compared to the model that abstracts from nontradable goods.

globalization, an open economy framework appears to be more appealing. Most importantly, as we are extremely interested in evaluating their effects on the current account balance, the open economy framework is an obvious choice.

Obstfeld (1980) and Sachs (1981) examine the response of the current account due to an increase in the oil price in a small open economy. They argue that a permanent increase in the oil price can actually improve the current account balance by reducing domestic investment. Sen (1991), on the other hand, demonstrates opposite results following an oil price shock. He shows that a higher oil price deteriorates a current account in an optimizing model without capital mobility. An unanticipated increase in the oil price, whether it is permanent or temporary, lowers real interest rates in the economy and leads to current account deficits. Svensson (1984) finds that a temporary oil shock worsens the current account by reducing savings without changes in investment, while the current account response is ambiguous for permanent oil price increases.[7] These early models adopt a one-sector framework and focus exclusively on an aggregate level. Unfortunately, these models are not able to capture the impacts of higher oil prices on different sectors of the economy. Our model will fill this gap in the literature.

An exception is Marion (1984) who incorporates two sectors to find that the structure of production technology in the traded and the nontraded sectors is a crucial determinant of the current account following oil shocks. The degree of substitutability between oil and capital in the nontraded sector will affect the level of investment and the current account. Marion also finds that a permanent oil price increase has an uncertain effect on investment. However, in this two-

[7] Some researchers have found that the current account responds ambiguously to a permanent oil price shock. In their empirical work, Kilian et al. (2009) differentiate between the oil and non-oil trade balance and show that the overall trade balance is determined by the relative magnitude of the responses of the oil and non-oil trade balance. They find that oil shocks, in most cases, tend to cause current account deficits in the long-run. Birol (2004), however, empirically supports the results of Sen (1991).

period model the complete dynamic adjustment behavior of an economy and the real exchange rate dynamics cannot be observed following exogenous oil shocks. Furthermore, the accumulation of capital stock along with changes in the current account is absent. Though a two-period setting is useful for examining the current account analysis, the framework is somewhat limited.

In our infinite horizon optimizing model, the household derives utility from both tradable and nontradable consumption. Oil is used as an input in the production process along with labor and capital in both sectors. Factors of production are perfectly mobile across two sectors and aggregate labor supply is perfectly inelastic. For simplicity, we assume that the tradable goods are used for consumption only and the nontradable goods are used for both consumption and investment as proposed by Turnovsky and Sen (1995).[8]

There is also important aspect of our model that merits attention. One of the objectives of this study is to evaluate the effects of domestic inflation. To do so, we need to introduce money into the model. The introduction of money in a growth model is always an important concern. Though the money in the utility (MIU) approach is still popular, researchers often criticize it as a short cut method. Cash-in-advance (CIA) approach, on the other hand, is relatively popular within the asset pricing literature. In the open economy literature important references include Helpman and Razin (1984), Calvo (1987), Calvo and Vegh (1995), and Mansoorian and Mohsin (2006). We follow this line of literature. However, instead of introducing CIA constraints on consumption, we assume that firms need real balances for the purchase of international oil. This is a significant departure from the existing literature. Moreover, by using a two-sector model our

[8] This is reasonable to assume as Burstein et al. (2004) point out that the share of nontraded investment expenditures for 15 OECD countries is about 60% on average (46% -71% range).

study contributes to the existing open economy monetary growth literature that mostly relies on a one good framework. This model allows us to examine the effects of inflation targeting in different sectors and also capture the inter-sectoral dynamics.

Within this framework, we examine the effects of a permanent increase in the oil price and domestic inflation. An oil price increase changes the relative price between two consumption goods through the changes in production. For example, in the short-run, an increase in the oil price decreases the use of oil in both sectors. As a complementary input, the use of labor in the traded sector falls immediately. We assume that the nontradable goods are only invested and converted into capital if they are not consumed. Thus, the relative production of the nontradable to tradable goods increases. As a consequence, the relative price of the nontradable goods immediately falls, and then rises once capital starts to decumulate. As the level of investment is largely determined by the nontraded sectors in many oil-importing countries, an increase in the price of oil affects the production of the nontraded sectors and hence an investment level.

Oil price changes induce sectoral resource reallocations as well. Labor moves from the traded to the nontraded sector after the increase in the oil price regardless of the capital intensity. Since the production of the nontradable goods is less affected by oil shocks, the nontraded sector attracts labor from the traded sector which alters the whole structure of the economy.[9] Furthermore, an oil price shock affects production of the tradable and nontradable goods through two effects associated with the relative price. Suppose that the nontraded sector is more capital intensive. First, the increase of the relative production of nontradable goods after the oil price

[9] Recently, some empirical studies have shown that allocative disturbances are a mechanism by which oil shocks affect economic activity (see e.g. Davis and Haltiwanger (2001) and Lee and Ni (2002)). Labor moves across sectors that are directly affected by oil shocks. Aggregate output decreases while resources shift to other sectors.

shock immediately decreases the relative price in the short-run. Second, once capital starts to decumulate, the marginal product of labor and the marginal product of oil decline. It further reduces the production of both the tradable and nontradable goods. So, the relative price starts to rise. Therefore, we clearly see that the relative price initially undershoots its long-run level and then appreciates over time after the initial shock as capital stock is decumulated. The effects of an increase in domestic inflation are also very interesting. We observe a decline in both capital and oil intensities in the long-run. We find consumption to increase due to significant savings in foreign bonds. Aggregate capital stock declines whereas the current account enjoys a surplus.

We observe that the dynamic behavior depends on the relative capital intensities of the two sectors as proposed by Turnovsky and Sen (1995). If the traded sector is more capital intensive, there are no dynamics of the relative price because the adjustment of the relative price occurs immediately. However, if the nontraded sector is more capital intensive, the adjustment now involves a transitional dynamic process.

Finally, the model is calibrated with standard parameter values for a detailed quantitative analysis. We report some steady state effects in the case when nontraded sector is more capital intensive. An increase in the oil price by 50% will decrease the use of oil in both the traded and the nontraded sector by 34.8 percent and the capital intensities of both sectors will fall to around 2.4 percent. As a consequence, the output of the both sectors declines and the steady state overall output falls by 2 percent. At the same time, labor in the traded sector falls by 1.9 percent, but labor in the nontraded sector rises by 2 percent. Overall capital stock decreases by 1.9 percent but, the current account improves by 18.4 percent. The effects of the increase in domestic inflation are significant as well. The increase of the inflation rate from 2% to 6% leads to a fall in oil intensity in both sectors by 3.76 percent and capital intensity by 0.22 percent. In the long-run, output in the traded sector declines by 0.47 percent. We observe significant labor mobility across sectors. The current account improves by 1.40 percent which leads to increase in consumption. In terms of steady state effects, the results above are somewhat similar when we assume a reversal of capital intensity.

It has been widely observed that as oil prices rise, inflation rises as well since oil is a major input in the economy. Blanchard and Gali (2007) show that the strong positive relationship between oil shocks and the U.S. CPI inflation over the period of 1970 to 2005. If we consider the case of a permanent increase in oil prices along with an increase in the inflation rate, the economy experiences capital ducumulation and a current account surplus. The effects get even stronger than the case that abstracts from higher inflation.

There is also strong evidence that there was a fall in world interest rates during the 1970s after the 1973-1974 oil shock, and the more recent period between 1999 and 2005. It is important to note, given our theoretical model, that one cannot address this issue at the analytical level. At the numerical level, however, we have tried to address this. An increase in oil prices along with a decrease in the world interest rate deteriorates the current account in oil-importing economies by decreasing saving and increasing investment. With the increased export demand, labor moves from the nontraded to the traded sector to increase the production of the tradable goods. With decreased labor and oil, the production of the nontraded sector falls, inducing an immediate increase of a relative price of the nontradable goods in the short-run. However, the production of the tradable goods increases with the higher level of employment and capital. Capital accumulates with increased investment, and the economy ends up with higher capital stock and a current account deficit.

The rest of this essay is organized as follows; Section 2 presents the basic structure of the model, Section 3 describes the equilibrium dynamics, Section 4 describes the steady state of the economy, Section 5 summarizes the calibration results followed by concluding remarks in Section 6.

2.2 The Model

The model is that of a small open economy with two sectors – traded and nontraded. The economy has an infinitely lived representative household that provides one unit of labor ($L = 1$) at a competitive wage (W) and consumes both tradable and nontradable goods. The representative firm produces both tradable and nontradable goods with inputs such as labor (L), capital (K), and imported oil (X). We will outline the structure of the economy by explaining the problems of the household, firm and government separately. For convenience, variables referring to the traded sector are indexed by subscript T, and the nontraded sector by N.

2.2.1 The Representative Household

The representative household chooses consumption levels C_T and C_N to maximize the present value of lifetime utility:

$$\int_0^\infty U(C_{T_t}, C_{N_t}) e^{-\rho t} dt \tag{2.1}$$

where ρ is the fixed rate of time preference. The household derives positive but diminishing marginal utility from consumption, $U_{C_T} > 0, U_{C_N} > 0, U_{C_T C_T} < 0$, $U_{C_N C_N} < 0$ and $U_{C_T C_T} U_{C_N C_N} - U^2_{C_T C_N} \geq 0$.

The representative household owns all the domestic firms and gets the dividend D_t. He receives real transfer τ_t from the government as well. The household also accumulates internationally traded bonds, b_t at the fixed interest rate, r. His flow budget constraint is

$$\dot{b}_t = D_t + W_t + r b_t + \tau_t - C_{T_t} - \sigma_t C_{N_t}, \tag{2.2}$$

where σ_t measures the relative price of nontradable to tradable goods (the real exchange rate). By solving the household's problem we obtain the following optimal conditions:

$$U_{C_T}(C_{T_t}, C_{N_t}) = \lambda_t \tag{2.3.1}$$

$$U_{C_N}(C_{T_t}, C_{N_t}) = \lambda_t \sigma_t \tag{2.3.2}$$

$$\dot{\lambda}_t = \lambda_t(\rho - r), \tag{2.3.3}$$

and the transversality condition: $\lim_{t\to\infty} \lambda_t a_t e^{-\rho t} = 0$. Here, λ represents the marginal utility of wealth. To assure a steady state, we require the rate of time preference to be equal to the world interest rate, $\rho = r$. This means that $\dot{\lambda}_t = 0 \ \forall t$, implying λ_t to remain constant at its steady state level ($\bar{\lambda}$) all the time. If there is an external shock affecting the marginal utility of wealth, $\bar{\lambda}$ will jump to a new steady state level immediately and stay there. See Turnovsky (1997) for details.

2.2.2 The Representative Firm

The representative firm produces both tradable goods (Y_T) and nontradable goods (Y_N): $Y_T = F(K_T, L_T, X_T)$ and $Y_N = F(K_N, L_N, X_N)$. We assume that all three factors are perfectly mobile across sectors. As a result, the labor market always clears. The production functions exhibit standard neo–classical features – positive but diminishing marginal productivity of each input and constant returns to scale. The aggregate labor supply is fixed at unity.

The nontraded sector can be either relatively capital intensive or labor intensive as we will consider both cases separately. The relative price of the nontradable goods, which is same as a real exchange rate, will be endogenously determined by the domestic market. But, the prices of both tradable goods and international oil are determined by the world market. A small economy is a price taker and pays a fixed unit price of ω for international oil. We assume that the tradable goods are used for consumption only and the nontradable goods can be used for both consumption and the accumulation of capital. We also assume that the representative firm needs cash in advance to finance the purchase of international oil: $m_t \geq \omega_t X_t$. Let M_t be the firm's nominal money holdings, and d_t the value of its debt.[10] Then total dividend payments at time *t* to the firm's equity-holders will be

$$D_t = F\left(K_{T_t}, L_{T_t}, X_{T_t}\right) + \sigma_t H\left(K_{N_t}, L_{N_t}, X_{N_t}\right) - W_t - \sigma_t I_t - \omega_t X_t - r d_t + \dot{d}_t - \frac{\dot{M}_t}{P_t} \qquad (2.4)$$

which is equal to profits $F\left(K_{T_t}, L_{T_t}, X_{T_t}\right) + \sigma_t H\left(K_{N_t}, L_{N_t}, X_{N_t}\right) - W_t - \omega_t X_t$, minus current investment expenditures $\sigma_t I_t$, minus interest on the firm's debt $r d_t$, plus revenue from the firm's

[10] When discussing money holdings by the firm some conceptual clarity is attained when the firm's debt is introduced into the model.

issues of new bonds (debt) $\dot{d}_t$, minus the real value of the money balances the firm is hoarding to finance its expenditures on international oil, $\frac{\dot{M}_t}{P_t}$.

Next, let a_t be the firm's net asset holdings; that is, its *real* money holdings m_t less the amount of bonds it has issued,

$$a_t = m_t - d_t. \qquad (2.5)$$

Differentiating this equation, and using it in equation (2.4), we can write the dividend payments by the firm as

$$D_t = F\left(K_{T_t}, L_{T_t}, X_{T_t}\right) + \sigma_t H\left(K_{N_t}, L_{N_t}, X_{N_t}\right) - W_t - \sigma_t I_t$$
$$-\omega_t X_t - \dot{a}_t + r a_t - (r + \pi_t) m_t. \qquad (2.6)$$

Now multiplying both sides of equation (2.6) by e^{-rt} and integrating over *t*, we can show that in order to maximize the present value of the dividend payment the firm should maximize

$$\int_0^\infty \left[F\left(K_{T_t}, L_{T_t}, X_{T_t}\right) + \sigma_t H\left(K_{N_t}, L_{N_t}, X_{N_t}\right) - W_t - \sigma_t I_t - \omega_t X_t - (r + \pi_t) m_t\right] e^{-rt} dt.$$

along the CIA constraint on financing the purchase of international oil: $m_t \geq \omega_t X_t$.[11] However, it should be noted that as long as the nominal interest rate is positive the CIA constraint will hold with equality and the firm maximizes:[12]

[11] In fact, the present value of the dividend payments will be:
$a_0 + \int_0^\infty \left[F\left(K_{T_t}, L_{T_t}, X_{T_t}\right) + \sigma_t H\left(K_{N_t}, L_{N_t}, X_{N_t}\right) - W_t - \sigma_t I_t - \omega_t X_t - (r + \pi_t) m_t\right] e^{-rt} dt.$
But, a_0 is predetermined. Hence, to maximize the present value of the dividend payment the firm must maximize (2.6).

[12] Notice $(r + \pi_t) m_t$ is the opportunity cost to the equity-holders of having the firm hold real balances in order to

$$\int_0^{\infty} \left[F\left(K_{T_t}, L_{T_t}, X_{T_t}\right) + \sigma_t H\left(K_{N_t}, L_{N_t}, X_{N_t}\right) - W_t(L_{T_t} + L_{N_t}) - \sigma_t I_t - (1 + r + \pi_t)\omega_t X_t\right] e^{-rt} dt$$

subject to the standard capital accumulation constraint, $\dot{K}_t = \dot{K}_{T_t} + \dot{K}_{N_t} = I_t$, and the initial condition K_0. In this optimizing problem the following three constraints involving capital, labor and oil must also be satisfied:

$$K_{T_t} + K_{N_t} = K_t\,,\; L_{T_t} + L_{N_t} = 1 \text{ and } X_{T_t} + X_{N_t} = X_t.$$

The firm's problem yields the following optimal conditions:

$$F_{L_T}\left(K_{T_t}, L_{T_t}, X_{T_t}\right) = \sigma_t H_{L_N}\left(K_{N_t}, L_{N_t}, X_{N_t}\right) = W_t, \tag{2.7.1}$$

$$F_{X_T}\left(K_{T_t}, L_{T_t}, X_{T_t}\right) = \sigma_t H_{X_N}\left(K_{N_t}, L_{N_t}, X_{N_t}\right) = \omega_t(1 + r + \pi_t), \tag{2.7.2}$$

$$\sigma_t = q_t, \tag{2.7.3}$$

$$\dot{q}_t = q_t r - F_{K_T}\left(K_{T_t}, L_{T_t}, X_{T_t}\right), \tag{2.7.4}$$

$$\dot{q}_t = q_t r - \sigma_t H_{K_N}\left(K_{N_t}, L_{N_t}, X_{N_t}\right), \tag{2.7.5}$$

and the transversality condition: $\lim_{t\to\infty} q_t K_t\, e^{-rt} = 0$. Here, q_t is the co-state variable associated with capital – also known as *Tobin's q* (the real price of equity). From (2.7.3) $-$ (2.7.5) we also obtain:

$$F_{K_T}\left(K_{T_t}, L_{T_t}, X_{T_t}\right) = \sigma_t H_{K_N}\left(K_{N_t}, L_{N_t}, X_{N_t}\right), \tag{2.7.6}$$

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finance its advance expenditure on imported oil.

$$\dot{\sigma}_t = \sigma_t \left(r - H_{K_N}\left(K_{N_t}, L_{N_t}, X_{N_t}\right)\right). \tag{2.7.7}$$

Since labor and capital are perfectly mobile across sectors, the profit maximizing conditions show that the marginal products of capital and labor across sectors are equal in equilibrium. Equation (2.7.7) represents the rate of change of the real exchange rate. In equilibrium, the rate of return on the nontraded capital should equal the rate of return from the internationally traded bond. In other words, the domestic real interest rate is equal to the world fixed interest rate adjusted by the rate of appreciation of the real exchange rate. Since $\sigma_t = q_t$ at each t, the evolution of σ is identical to that of q.

2.2.3 The Government

For simplicity, we assume that the government (or the monetary authority) controls the inflation rate in the economy by choosing its real transfer τ_t in order to obtain the desired level of inflation rates π_t, thus satisfying the following flow budget constraint:

$$\dot{m}_t + \pi_t m_t = \tau_t. \tag{2.8}$$

Equation (2.8) implies that the total transfer should be equal to the government revenue from seigniorage ($\dot{m}_t + \pi_t m_t$).

2.3 The Equilibrium Dynamics

We will now study the equilibrium dynamics of the economy. It is convenient to work with an intensive form for analytical purposes. Let $k_i \left(= \frac{K_i}{L_i}\right)$ be the capital and labor ratio and $x_i \left(= \frac{X_i}{L_i}\right)$ be the oil and labor ratio in sector $i = T, N$. The production functions can be expressed as: $f(k_T, x_T) \equiv F_K(K_T, L_T, X_T)/L_T$ and $h(k_N, x_N) \equiv H_K(K_N, L_N, X_N)/L_N$. We can rewrite the optimality conditions as follows (dropping time suffices):

$$U_{C_T}(C_T, C_N) = \bar{\lambda}, \quad (2.9.1)$$

$$U_{C_N}(C_T, C_N) = \bar{\lambda}\sigma, \quad (2.9.2)$$

$$f_k(k_T, x_T) = \sigma h_k(k_N, x_N) \equiv r^k, \quad (2.9.3)$$

$$f_X(k_T, x_T) = \sigma h_X(k_N, x_N) \equiv \omega(1 + r + \pi), \quad (2.9.4)$$

$$f(k_T, x_T) - k_T f_k(k_T, x_T) - x_T f_x(k_T, x_T) =$$

$$\sigma[h(k_N, x_N) - k_N h_k(k_N, x_N) - x_N h_x(k_N, x_N)] = W, \quad (2.9.5)$$

$$L_T k_T + L_N k_N = K, \quad (2.9.6)$$

$$L_T x_T + L_N x_N = X, \quad (2.9.7)$$

$$L_T + L_N = 1, \quad (2.9.8)$$

$$\dot{\sigma} = \sigma\big(r - h_K(k_N, x_N)\big), \quad (2.9.9)$$

$$\dot{K} = I = L_N h(k_N, x_N) - C_N, \quad (2.9.10)$$

$$\dot{b} = L_T f(k_T, x_T) - C_T + rb - \omega X. \quad (2.9.11)$$

These equations capture the equilibrium dynamics of the economy. Equation (2.9.10) represents a market clearing condition for the nontradable goods' market. Any excess output will be accumulated as capital (nontradable goods are used for both consumption and capital accumulation). Equation (2.9.11) describes the economy's current account. The rate of accumulation of the traded bond (net foreign assets) is obtained by combining the budget constraints of the household and government along with incorporating the definition of profit (equations (2.2), (2.5), (2.6) and (2.8)). From our first step we solve equations (2.9.1) and (2.9.2) for C_T and C_N to obtain:

$$C_T = C_T(\bar{\lambda}, \sigma), \tag{2.10.1}$$

$$C_N = C_N(\bar{\lambda}, \sigma). \tag{2.10.2}$$

The partial derivatives of the tradable and nontradable consumption demand implicit in Equations (2.10.1) and (2.10.2) are found by differentiating (2.9.1) and (2.9.2) with respect to $\bar{\lambda}$ and σ . This gives:

$$\frac{\partial C_T}{\partial \lambda} = \frac{(U_{NN} - \sigma U_{TN})}{\Delta} < 0, \frac{\partial C_N}{\partial \lambda} = \frac{(\sigma U_{TT} - U_{TN})}{\Delta} < 0, \frac{\partial C_T}{\partial \sigma} = \frac{(-\bar{\lambda} U_{TN})}{\Delta}, \frac{\partial C_N}{\partial \sigma} = \frac{(\bar{\lambda} U_{TT})}{\Delta} < 0.$$

where $\Delta = U_{TT}U_{NN} - U_{TN}^2 > 0$.

The consumption of tradable and nontradable goods depends on the marginal utility of wealth and the real exchange rate determined by the relative price. An increase in the marginal utility of wealth, λ, causes the consumption of both tradable and nontradable goods to fall since it encourages savings. We can also say that a higher marginal utility of wealth is associated with lower income which tends to lower consumption, assuming everything else remains unchanged.

An increase (appreciation) of the real exchange rate increases the relative price of nontradable goods to tradable goods. Keeping everything else unchanged, it is obvious that higher σ leads to lower level of C_N. In other words, its own price effect is negative. However, the response of the tradable consumption depends on cross marginal utility. If we assume U_{TN} to be positive, then higher σ leads to lower C_T when we observe no changes in the economy. Now, the equilibrium levels of $k_T, k_N, x_T, and\ x_N$ can be represented by the following equations:

$$k_T = k_T(\sigma, \omega, \pi), \quad k_N = k_N(\sigma, \omega, \pi), \tag{2.11.1}$$

$$x_T = x_T(\sigma, \omega, \pi), \quad x_N = x_N(\sigma, \omega, \pi). \tag{2.11.2}$$

The partial derivatives of capital and oil of tradable and nontradable goods implicit in Equations (2.11.1) and (2.11.2) are found by differentiating (2.9.3), (2.9.4), and (2.9.5) with respect to $\sigma, \omega,$ and π. This gives:

$$\frac{\partial k_T}{\partial \sigma} = \left(\frac{hf_{xx}}{(k_N - k_T)S}\right), \quad \frac{\partial k_T}{\partial \omega} = \frac{-x_N f_{xx}}{(k_N - k_T)S}, \quad \frac{\partial k_T}{\partial \pi} = \frac{-\omega x_N f_{xx}}{(k_N - k_T)S},$$

$$\frac{\partial x_T}{\partial \sigma} = \left(\frac{-hf_{kx}}{(k_N - k_T)S}\right), \quad \frac{\partial x_T}{\partial \omega} = \frac{x_N f_{kx}}{(k_N - k_T)S}, \quad \frac{\partial x_T}{\partial \pi} = \frac{\omega x_N f_{kx}}{(k_N - k_T)S},$$

$$\frac{\partial k_N}{\partial \sigma} = \frac{\{h - (k_N - k_T)h_k\}h_{xx} + (k_N - k_T)h_x h_{kx}}{\sigma(k_N - k_T)T}, \quad \frac{\partial k_N}{\partial \omega} = \frac{-\{(k_N - k_T)h_{kx} + x_N h_{xx}\}}{\sigma(k_N - k_T)T},$$

$$\frac{\partial k_N}{\partial \pi} = \frac{-\omega\{(k_N - k_T)h_{kx} + x_N h_{xx}\}}{\sigma(k_N - k_T)T},$$

$$\frac{\partial x_N}{\partial \sigma} = \frac{[\{h - (k_N - k_T)h_k\}h_{kx} + (k_N - k_T)h_x h_{kk}]}{\sigma(k_N - k_T)T}, \quad \frac{\partial x_N}{\partial \omega} = \frac{\{(k_N - k_T)h_{kk} + x_N h_{kx}\}}{\sigma(k_N - k_T)T},$$

and $\dfrac{\partial x_N}{\partial \pi} = \dfrac{\omega\{(k_N - k_T)h_{kk} + x_N h_{kx}\}}{\sigma(k_N - k_T)T}$,

where $S = f_{kk}f_{xx} - f_{kx}^2 > 0, T = h_{kk}h_{xx} - h_{kx}^2 > 0$.

In this model of a two-sector economy with three factors of production, the signs in (2.11.1) and (2.11.2) depend on the relative sectoral capital intensities (i.e. $k_T > k_N$ or $k_T < k_N$). They also depend on the complementarity or substitutability of capital with oil in production. We can also solve for sectoral labor allocation (L_T and L_N) and aggregate oil consumption (X) by using the solutions obtained in (2.11.1) and (2.11.2) to get:

$$L_T = \frac{K - k_N(\sigma,\omega,\pi)}{k_T(\sigma,\omega,\pi) - k_N(\sigma,\omega,\pi)} \equiv L_T(\sigma,\omega,\pi,K), \tag{2.12.1}$$

$$L_N = 1 - L_T \equiv L_N(\sigma,\omega,\pi,K), \tag{2.12.2}$$

$$X = x_T(\sigma,\omega,\pi)L_T(K,\sigma,\omega,\pi) + x_N(\sigma,\omega,\pi)L_N(K,\sigma,\omega,\pi) \equiv X(K,\sigma,\omega,\pi). \tag{2.12.3}$$

The partial derivatives are as follows:

$$\frac{\partial L_T}{\partial K} = \frac{1}{(k_T - k_N)}, \qquad \frac{\partial L_T}{\partial \sigma} = -\frac{1}{k_T - k_N}\left(L_T\frac{\partial k_T}{\partial \sigma} + (1 - L_T)\frac{\partial k_N}{\partial \sigma}\right),$$

$$\frac{\partial L_T}{\partial \omega} = -\frac{1}{k_T - k_N}\left(L_T\frac{\partial k_T}{\partial \omega} + (1 - L_T)\frac{\partial k_N}{\partial \omega}\right), \qquad \frac{\partial L_T}{\partial \pi} = -\frac{1}{k_T - k_N}\left(L_T\frac{\partial k_T}{\partial \pi} + (1 - L_T)\frac{\partial k_N}{\partial \pi}\right),$$

$$\frac{\partial X}{\partial K} = \frac{(x_T - x_N)}{(k_T - k_N)}, \text{and } \frac{\partial X}{\partial \sigma} = (x_T - x_N)\frac{\partial L_T}{\partial \sigma} + \left(L_T\frac{\partial x_T}{\partial \sigma} + (1 - L_T)\frac{\partial x_N}{\partial \sigma}\right).$$

In addition, we can solve for the equilibrium levels of domestic output of two goods.

$$Y_T \equiv f\{(k_T(\sigma,\omega,\pi), x_T(\sigma,\omega,\pi))L_T(K,\sigma,\omega,\pi)\} \equiv Y_T(K,\sigma,\omega,\pi), \tag{2.13.1}$$

$$Y_N \equiv h\{(k_N(\sigma,\omega,\pi), x_N(\sigma,\omega,\pi))L_N(\sigma,\omega,\pi,K)\} \equiv Y_N(\,K,\sigma,\omega,\pi). \qquad (2.13.2)$$

The partial derivatives are as follows:

$$\frac{\partial Y_T}{\partial K} = \frac{-f}{(k_N - k_T)}, \qquad \frac{\partial Y_T}{\partial \sigma} = f\frac{\partial L_T}{\partial \sigma} + \left(f_k\frac{\partial k_T}{\partial \sigma} + f_x\frac{\partial x_T}{\partial \sigma}\right)L_T,$$

$$\frac{\partial Y_T}{\partial \omega} = f\frac{\partial L_T}{\partial \omega} + \left(f_k\frac{\partial k_T}{\partial \omega} + f_x\frac{\partial x_T}{\partial \omega}\right)L_T, \qquad \frac{\partial Y_T}{\partial \pi} = f\frac{\partial L_T}{\partial \pi} + \left(f_k\frac{\partial k_T}{\partial \pi} + f_x\frac{\partial x_T}{\partial \pi}\right)L_T,$$

$$\frac{\partial Y_N}{\partial K} = \frac{h}{(k_N - k_T)}, \qquad \frac{\partial Y_N}{\partial \sigma} = -h\frac{\partial L_T}{\partial \sigma} + \left(h_k\frac{\partial k_N}{\partial \sigma} + h_x\frac{\partial x_N}{\partial \sigma}\right)(1 - L_T),$$

$$\frac{\partial Y_N}{\partial \omega} = -h\frac{\partial L_T}{\partial \omega} + \left(h_k\frac{\partial k_N}{\partial \omega} + h_x\frac{\partial x_N}{\partial \omega}\right)(1 - L_T),$$

$$and\ \frac{\partial Y_N}{\partial \pi} = -h\frac{\partial L_T}{\partial \pi} + \left(h_k\frac{\partial k_N}{\partial \pi} + h_x\frac{\partial x_N}{\partial \pi}\right)(1 - L_T).$$

The partial derivatives of output of the traded and the nontraded sector show that both of them also depend on the relative sectoral intensities. Now, we are in a position to work out the equilibrium dynamics. Upon substituting the solutions for $C_T, C_N, k_T, k_N, x_T, x_N, L_T, L_N$ and X as obtained in (2.10.1) – (2.13.2) into (2.9.9) – (2.9.11), we can easily see that the dynamics of the entire economy are controlled by three differential equations and, interestingly, the system is block recursive and can be solved sequentially.

We now look at the equilibrium dynamics involving K and σ. The dynamics of the economy are controlled by $\dot{\sigma} = \sigma\bar{r} - r^k(\sigma,\omega,\pi)$ and $\dot{K} = L_N h\big(k_N(\sigma,\omega,\pi)\big) - C_N\big(\bar{\lambda},\sigma\big)$. First, linearizing the equations around the steady state following Turnovsky and Sen (1995), we get

$$\begin{bmatrix}\dot{K}\\ \dot{\sigma}\end{bmatrix} = \begin{bmatrix}a_{11} & a_{12}\\ 0 & a_{22}\end{bmatrix}\begin{bmatrix}K - \bar{K}\\ \sigma - \bar{\sigma}\end{bmatrix} \qquad (2.14)$$

where $a_{11} = \frac{h}{(k_N - k_T)}, \quad a_{12} = \frac{\partial Y_N}{\partial \sigma} - \frac{\partial C_N}{\partial \sigma} > 0, \quad a_{22} = \bar{r} + \frac{h}{(k_T - k_N)} = \frac{f}{\sigma(k_T - k_N)}.$

The system has one negative eigenvalue and one positive eigenvalue yielding a unique stable saddle-path. Let $\mu_1 < 0$ and $\mu_2 > 0$ be the two eigenvalues. The solution for K and σ is given by

$$K(t) = \bar{K} + (K_0 - \bar{K})e^{\mu_1 t}, \tag{2.15.1}$$

$$\sigma(t) = \bar{\sigma} + \left(\frac{\mu_1 - a_{11}}{a_{12}}\right)(K_0 - \bar{K})e^{\mu_1 t}. \tag{2.15.2}$$

Now, we need to discuss the role of capital intensities in this model. It is clear that when the traded sector is more capital intensive $(k_T > k_N)$ we find that the negative eigenvalue is equal to a_{11} and the optimal path for K and σ are represented respectively by:

$$K(t) = \bar{K} + (K_0 - \bar{K})e^{\mu_1 t} \tag{2.16.1}$$

$$\sigma(t) = \bar{\sigma}. \tag{2.16.2}$$

And the saddle path $\sigma(t) = \bar{\sigma}$ is basically represented by $\dot{\sigma} = 0$ locus whose slope equals to zero. The relative price of the nontradable goods jumps up or down to a new steady state level for a given shock. It remains constant throughout the transitional period. In other words, when the tradable good is more capital intensive, given any permanent shock, the adjustment of the relative price of the nontradable goods occurs immediately and the current account exactly offsets the investment flow. So the change in the capital stock takes place without any change in the relative price. However, when the nontraded sector is relatively more capital intensive $(k_T < k_N)$ we have $\mu_1 = a_{22}$ and the relationship between K and σ on the saddle path is given by:

$$\sigma(t) = \bar{\sigma} + \left(\frac{a_{22} - a_{11}}{a_{12}}\right)(K(t) - \bar{K}). \tag{2.17}$$

which is a negatively sloping schedule. Any shock will affect the value of σ both in the short-run and in the long-run. As a result, we observe transitional dynamics in the real exchange rate.

To obtain the optimal solution of the current account, first linearize equation (2.9.11) around the steady state and use (2.15.1 and 2.15.2) to obtain $\dot{b} = \Omega(K - \bar{K}) + r(b - \bar{b})$ where $\Omega = \left[\frac{\partial Y_T}{\partial K} - \omega\frac{\partial X}{\partial K} + \left(\frac{\partial Y_T}{\partial \sigma} - \frac{\partial C_T}{\partial \sigma} - \omega\frac{\partial X}{\partial \sigma}\right)\left(\frac{\mu_1 - a_{11}}{a_{12}}\right)\right]$. Assuming that the economy starts from the initial stock of bonds b_0, we obtain the following solution:

$$b(t) = \bar{b} + \frac{\Omega}{\mu_1 - r}(K_0 - \bar{K})e^{\mu_1 t} + \left[(b_0 - \bar{b}) - \frac{\Omega}{\mu_1 - r}(K_0 - \bar{K})\right] e^{rt}. \tag{2.18}$$

For equation (2.18) to converge, we must set the coefficient of e^{rt} to be zero. Hence, we obtain the following optimal solution for the accumulation of internationally traded bonds:

$$b(t) - \bar{b} = \frac{\Omega}{\mu_1 - r}(K_0 - \bar{K})e^{\mu_1 t} = \frac{\Omega}{\mu_1 - r}(K(t) - \bar{K}). \tag{2.19}$$

It is important to note that we impose the following condition to obtain the above solution (to assure convergence):

$$b_0 - \bar{b} = \frac{\Omega}{\mu_1 - r}(K_0 - \bar{K}). \tag{2.20}$$

This is very important in this kind of model. Such an imposed restriction which is also termed the "intertemporal solvency" condition explains how initial positions of capital stock and foreign bonds are linked to their long-run levels. Now, we study the effects of international oil prices and domestic inflation in this economy.

2.4 The Steady State

As noted earlier, we examine the long-run effects of international oil prices and domestic inflation. First, we define the steady state in this economy. In the steady state, we have $\dot{K} = \dot{\sigma} = \dot{b} = 0$ which together with equation (2.20) yields:

$$Y_N(\bar{K}, \bar{\sigma}, \pi, \omega) - C_N(\bar{\lambda}, \bar{\sigma}) = 0, \tag{2.21.1}$$

$$r = h'(k_N(\bar{\sigma}, \pi, \omega)) \tag{2.21.2}$$

$$Y_T(\bar{K}, \bar{\sigma}, \pi, \omega) + r\bar{b} - C_T(\bar{\lambda}, \bar{\sigma}) - \omega X(\bar{K}, \bar{\sigma}, \pi, \omega) = 0 \tag{2.21.3}$$

$$b_0 - \bar{b} = \frac{\Omega}{\mu_1 - r}(K_0 - \bar{K}). \tag{2.21.4}$$

These equations jointly determine the steady state equilibrium. Equation (2.21.1) implies that nontradable output must equal demand for zero investment. Equation (2.21.2) shows that the marginal physical product of capital in the nontraded sector equals the world interest rate in the steady state. Equation (2.21.3) implies that the current account must be zero in the steady state. Equation (2.21.4) implies that the steady state depends on the initial condition (K_0, b_0). By totally differentiating these equations, the steady state effects of an increase in the inflation rate or the international oil prices can be obtained. Unless we know the proper sign of Ω, it is not possible to obtain unambiguous analytical results. This is the main reason why we concentrate heavily on calibration exercise. Based on existing empirical and other real business cycle literature we will assume appropriate functional forms and parameter values. Within reasonable limits we can assume Ω to be positive. If this is the case, the intertemporal solvency condition (equation (2.20)) represents a negative relationship between capital stock and the stock of internationally traded bonds. This is economically meaningful as well. Higher inflation rates reduce the effective rate of return from investment. This, in turn, increases the relative return from foreign bonds. As a result, one will prefer more foreign bonds and less domestic capital to accumulate wealth. Also consider the following. It involves a portfolio decision. For a given level of savings, if the household decides to invest more in capital stock, it has to be at the cost of fewer foreign bonds and vice versa. Such relationship is also very evident in many models in Turnovsky (1997).

2.5 Calibration

We calibrate the model with standard functional forms and parameter values to gain a better understanding in terms of steady state effects and transitional dynamics. We use the following instantaneous utility function:

$$U(C_T, C_N) = \frac{1}{\eta}\left(C_T^{\theta} C_N^{1-\theta}\right)^{\eta}.$$

The production functions of the traded and nontraded sectors take the Cobb-Douglas form respectively:

$$f(k_N, x_N) = (k_N^{\alpha 1} x_N^{\alpha 2}),$$

$$f(k_T, x_T) = \left(k_T^{\beta 1} x_T^{\beta 2}\right).$$

Here, $\frac{1}{1-\eta}$ measures the intertemporal elasticity of substitution, and θ parameterizes the relative importance of tradable and nontradable goods in the overall consumption bundle. Also, note that α_1 and β_1 indicate the degree of capital intensity, and α_2 and β_2 indicate the degree of oil intensity in the nontraded and traded sector. Following the existing RBC literature we assume the parameter values as follows: $\omega = 1, \eta = -1.5,\ \theta = 0.5,\ \ r = 6\%,\ \alpha_1 = 0.3,\ \beta_1 = 0.2,\ \alpha_2 = 0.04, \beta_2 = 0.04,$ and $\pi = 2\%$. Note that these are the benchmark parameters when the nontraded sector is more capital intensive. We will switch the parameter values of α and β to get another benchmark equilibrium where the traded sector is more capital intensive.[13]

Table A.4 (A) shows the base parameter values of both cases. With benchmark parameters, labor employed in the traded sector is 51%, while labor employed in the nontraded sector is about 49% when the nontraded sector is more capital intensive. The share of oil, which is 4%, is the same in the traded and the nontraded sectors. The world interest rate is chosen to be 6%. The oil price (ω) is chosen to be 1 to get the initial (benchmark) equilibrium. The intertemporal elasticity of substitution is $\frac{1}{1-\eta} = 0.4$. We calculate key steady state values and ratios and we examine the effect of various shocks in the economy. First, we start by examining the effects of the increase in the international oil price which the small economy takes as given.

[13] Kakkar (2003) provides sectoral intensities for fourteen OECD countries. He finds that the traded sector is more capital intensive in seven countries, and the nontraded sector is more capital intensive in seven countries.

2.5.1 The effects of an Increase in International Oil Prices

The steady state effects of a permanent increase in the oil price are summarized in Table A.5. We report three cases where oil prices increase by 30%, 50%, and 100%. Here, we assume no other changes. The dynamic response of consumption of goods, aggregate capital accumulation, the real exchange rate, and the current account balance of the economy are shown in Figure B.7 − Figure B.10. From Figure B.7 where the nontraded sector is more capital intensive, the new steady state equilibrium will be point "C" from the initial equilibrium point "A" with a new stable path $S'S'$. After the increase in oil price at time $t=0$, relative price drops to point "*B*" on the stable path $S'S'$. Then it gradually increases to point "C" as capital stock slowly falls to its lower steady state level K_1. The current account improves as the equilibrium moves from the point "D" to "E" along the BB schedule with decumulation of capital. With the reversal of capital intensity from Figure B.8, the dynamic effects are similar since oil is a complementary input in both production processes. However, the relative price decreases immediately after the shock, and capital stock decreases without an adjustment process via the relative price.

Now we discuss the steady state effects of the increase in the oil price (50%) for the present purpose. As explained before, the results are very sensitive to the sector-specific capital intensities.

We will report the results separately and as carefully as possible. As reported in Table A.5, capital stocks of the traded and the nontraded sector decrease by 4.3 percent and 0.5 percent respectively when the nontraded sector is more capital intensive. Overall, the steady state level of capital stock ($\overline{K}$) decreases by 1.9 percent, but the current account position ($\overline{b}$) improves by 18.5 percent. Aggregate output, consumption, capital intensity, and oil intensity of both sectors decline. At the same time labor in the traded sector falls by 1.9 percent but labor in the nontraded sector rises by 2 percent. Oil intensities from both sectors clearly drop according to the size of the shocks. The larger the size of shock, the larger is the reduction in the use of oil. 50% increase in the oil price decrease the use of oil in both sectors by 34.8 percent and the capital intensities of both sectors fall to around 2.4 percent. As a consequence, output of both sectors declines and steady state overall output falls by 2 percent. Welfare and wealth fall as consumption falls because of the oil price increase. The dynamic path of the real exchange rate shows that it immediately drops from 0.8295 to 0.8284 with an increase in the oil price by 50%. And then it gradually moves to the new higher equilibrium level. Results involving steady state effects are qualitatively similar when the traded sector is more capital intensive. However, in terms of overall transition, we find significant differences. Figures B.9 and B.10 capture that.

We have also calculated the shout-run (or instantaneous) effects in our numerical exercise. It can be shown in Figure B.9 and B.10 that at $t = 0$ when the increase in oil prices is realized, there are no short-run effects on the level of capital stock and the net foreign asset position since both are predetermined variables. Capital stock decumulates after the oil price increase leading to an accumulation of foreign bonds. As a result, the economy experiences a current account surplus in the long-run. The real exchange rate, a jump variable, immediately drops at $t = 0$ after an increase in the oil price. And then it will gradually increase as capital decumulates to a new equilibrium as shown in Figure B.9. The initial drop of the real exchange rate will be more pronounced for a large shock. It is important to note that the new equilibrium value of the real exchange rate is higher than the initial one. Consumption paths are very similar in both sectors. They initially drop at time $t = 0$, and then gradually increase to the new steady state level of consumption.

However, the new equilibrium consumption level is lower than the initial consumption level. This implies that households actually overreact in the short-run to the economic news. This "overshooting" behavior is an interesting observation.

In Figure B.10 we report the adjustment and immediate reactions of all the major variables where the traded sector is more capital intensive. The qualitative response of capital stock and the current account is very similar to previous case. However, as shown by our numerical estimates, there are no transitional dynamics involving the real exchange rate. Given shocks, it adjusts immediately by the full amount. We observe no transitional dynamics in consumption either. Given a positive oil price shock, it immediately adjusts to its lower long-run levels. Of course, these results are due to the behavior of the real exchange rate and the shadow price of wealth.

The increase in the oil price changes the relative price between two consumption goods through the change in production. The increase in the oil price decreases the use of oil in both sectors since the own substitution effect is always negative. As a complementary input, the use of labor in the traded sector falls immediately. However, labor moves from the traded to the nontraded sector to find employment as the unconsumed nontradable goods are invested and converted into capital. The relative production of the nontradable to tradable goods increases with increased labor migration. As firms purchase less oil, the marginal products of capital and labor fall given the amount of capital and labor. As the marginal product of capital falls, the desired capital stock will decrease. As the level of investment is largely determined by nontraded sectors in many oil-importing countries, a rise in the price of oil affects the production of the nontraded sector and, hence, investment level.

Higher oil prices lead to a portfolio shift of capital into foreign assets, resulting in the current account surplus. We observe an inverse relation between capital stock and foreign traded bonds. The relative price falls initially as the relative production of the nontradable to tradable goods increases. Once capital begins to decumulate, the relative price begins to rise as the production of both the tradable and nontradable goods declines since the marginal product of labor and marginal product of oil declines. Consequently, outputs from both sectors fall so the economy experiences a recession. The economy ends up with lower capital stock and a current account surplus. The long-run level of the real exchange rate differs from its initial level and depends on the capital intensity. Furthermore, the dynamics are very different in both cases shown in Figures B.9 and B.10.

Now we will consider the case of increasing the international oil price along with a drop in the world interest rate. At the analytical level we could not pursue such analysis. As discussed earlier, it is very likely that we observe a current account surplus given a higher oil price shock holding the world interest rate constant. However, if we allow the world interest rate to decline along with the higher oil price, it is very likely that we would observe current account deterioration. Again, we perform a similar exercise where we increase the oil prices by 30%, 50%, and 100%. Now we decrease the world interest rate from 6% to 5.5% in all three cases. The steady state effects are summarized in Table A.6. The transitional dynamics and the dynamic response of capital accumulation, the real exchange rate, and the current account are shown in Figures B.13 and B.14.

Figure B.11 presents the transitional dynamics to the new steady state. The results show that the new steady state equilibrium will be point “C” from the initial equilibrium point “A” with a new stable path $S'S'$. After both the increase in oil price and the decrease in the world interest rate at time t=0, the relative price jumps to point “B”. Then it gradually decreases to point “C” as capital stock slowly rises to its higher steady state level K_1. The current account deteriorates as the equilibrium moves from the point “D” to “E” along the BB schedule with accumulation of capital. With the reversal of capital intensity from Figure B.12, the dynamic effects are similar since oil is a complementary input in both production processes. However, the relative price increases immediately after the shock and capital stock decreases without adjustment of the relative price.

Once again we will discuss the case where the oil price is increased by 50%. All the results are reported in Table A.6. Overall capital stock rises by 8.4 percent, but the net foreign asset position deteriorates by 82 percent when the nontraded sector is more capital intensive. Output and employment of the traded sector increase by 8 percent and 7.6 percent respectively, while those of the nontraded sector decrease by 6.5 percent and 7.8 percent respectively. However, there is only a 0.1 percent fall in the overall aggregate output level. The capital intensity of both sectors increase by 10.7 percent. The increase in the oil price by 50 percent along with the fall in the world interest rate decreases the use of oil in both the traded and the nontraded sector by 32.7 percent in per capita terms. As the wealth falls because of the oil price increase, tradable consumption falls by 7.4 percent and nontradable consumption falls by 6.5 percent, respectively. With the reversal of the capital intensity, the long-run results are qualitatively similar. However, there are significant differences in terms of transitional dynamics.

Consider Figures B.13 and B.14 to compare and contrast the differences in transitional dynamics. There is no short-run effect on the level of capital stock and the current account balance since both variables respond slowly. The stock of capital increases, leading to the decumulation of foreign bonds. As a result, the economy experiences a current account deficit in the long-run. As shown in Figure B.13, the real exchange rate responds by immediately jumping up at $t = 0$ and gradually decreasing as capital accumulates to a new equilibrium. The final level is lower than the initial level. The consumption paths are again similar in both sectors. They initially drop at time $t=0$ to a lower level and then gradually decrease further to the new steady state level of consumption. The new equilibrium consumption level is lower than the initial consumption level. As reported in Figure B.14, where the traded sector is more capital intensive, we find no transitional dynamics involving consumption of both tradable and nontradable goods and the real exchange rate. Given such dual shocks, they adjust immediately by the full amount. In other words, the short term and long term effects are identical in those variables. With the reversal of the capital intensity, the new equilibrium of the real exchange rate is higher than the initial value. Interestingly, this is completely opposite if and when the nontraded sector is more capital intensive. The steady state results involving other variables are qualitatively similar when the traded sector is more capital intensive.

The results show that the increase in oil prices along with a decrease in the world interest rate deteriorates the current account in oil-importing economies by increasing investment. Capital accumulates with increased investment, and the economy ends up with a higher capital stock and a current account deficit. Our intuition is as follows. The reduction of the world interest rate lowers the effective return from foreign bonds. As a result, a larger share of domestic savings will go towards domestic capital (investment) instead of foreign bond purchases. A drop in the world interest rate is also likely to be associated with higher investment and increased consumption in the world economy. As a result, with increased export demand, labor moves from the nontraded to the traded sector to increase the production of the tradable goods in the domestic economy. With decreased labor and oil, the production of the nontraded sector falls, inducing an immediate increase in the relative price of the nontradable goods in the short-run. However, the production of the traded sector increases with higher levels of employment and capital. With increased investment, the economy has a higher capital stock and a current account deficit.[14]

2.5.2 The Effects of an Increase in Domestic Inflation

The steady state effects of a permanent increase in the inflation rate are summarized in Table A.7. We show results for a scenario when domestic inflation is increased from 2% to 4% and also when it is increased from 2% to 6%. We will discuss the first set of results. When the capital intensity of the nontraded sector is greater than that of the traded sector, a permanent increase in the inflation rate from 2% to 4% will decrease the steady state total capital stock and output by 0.07 percent and 0.09 percent, respectively. The steady state labor and output in the traded sector falls by 0.14% and 0.24% as well. However, the nontraded sector attracts labor from the other sector and increases output in that sector. Unlike the previous cases, capital stock in the traded sector falls and capital stock in the nontraded sector increases. Because the prices of the tradable

[14] It has been widely observed that OPEC's surpluses have forced the rest of the world to run current account deficits. Sachs (1981) and Svensson (1984) have explained the low world interest rate as evidence of this line of reasoning throughout most of the seventies. A fall in the world interest rate was observed after the 1973-1974 oil shock and more recently between 1999 and 2005. The reductions in the world interest rate are crucial to explaining a huge deficit of oil-importing economies since 1970s. Sachs (1981) states it is the investment response to determine the current account behavior from permanent oil shocks. Since investment is likely to fall, the economy experiences a current account surplus rather than deterioration. The world rate of interest must fall to create the current account deterioration.

goods are determined by the world market, the increased costs of production inputs resulting from inflation reduce the output of the tradable goods. We can see that the traded sector contracts while the nontraded sector expands their outputs. As total capital stock decreases, the current account ($\bar{b}$) improves by 0.70 percent. Higher inflation attracts resources from the traded sector to the nontraded sector.

Figures B.15 and B.16 show short-run effects as well as transitional dynamics. In both cases, capital stock decumulates with higher domestic inflation leading to an accumulation of foreign bonds. When the nontraded sector is more capital intensive (Figure B.15), our numerical results reveal that the relative price of the nontradable goods declines initially. However, it increases as the capital stock decumulates. The consumption of both goods jumps up at time t=0 and gradually converge to the new, higher, level of consumption. The economy experiences a current account surplus. As can be seen in Figure B.16, there are no transitional dynamics in consumption and real exchange rate behavior when the traded sector is more capital intensive. The steady state effect on the real exchange rate is completely opposite. Once again, though the steady state effect on consumption is qualitatively similar, the transitional dynamics depend on sectoral capital intensity.

Recall, the firm is subject to a cash-in-advance requirement for the purchase of foreign oil. Oil is an important input in the production of both tradable and nontradable goods. Higher inflation increases the relative price of oil in terms of other factors of production. As a result, we observe price and substitution effects playing significant roles here. It is natural that the oil intensity in both sectors goes down. Capital intensity in both sectors drops as well. This is mainly due to labor mobility across sectors. Labor moves from the traded to the nontraded sector. As a result, we observe a lower level of production in the traded sector. However, more labor increases the marginal product of capital in the nontraded sector, leading to additional investment there. In the steady state, the marginal product of capital must be equal to the world interest rate. As a result, despite the fall in oil intensity and capital intensity, the production level in the nontraded sector goes up in the long-run. This explains why we observe a steady state increase in nontradable consumption. However, the steady state consumption of tradable goods depends not only on output of tradable sector; it also depends on interest income from foreign bonds (savings) as well as a total expenditure on oil purchases. As we can clearly see, the last two factors help boost the consumption of the tradable goods despite a negative impact from the production side.

2.5.3 The Effects of an Increase in both Oil Prices and Domestic Inflation

Now we consider the case of increasing the oil price along with an increase in the inflation rate. It has been widely observed that as oil prices move up, inflation follows in the same direction. Blanchard and Gali (2007) show a strong positive relationship between oil shocks and the U.S. CPI inflation over the period of 1970 to 2005. Although the relationship between oil prices and inflation has been weakened in recent years compared to the 1970s, higher oil prices are still a major factor of domestic inflation in many oil-importing countries. The steady state effects are summarized in Table A.8.

We report the case where the oil price is increased by 50% and domestic inflation is increased from 2% to 4% and 2% to 6%. We discuss again the first set of results. The effects are significant when we compare them to those of Table A.7. Overall capital stock falls around 2 percent but the net foreign asset position improves by 19.1 percent when the nontraded sector is more capital intensive. The magnitude of changes is more significant in Table A.8. For example, the oil intensity of both sectors drops by 36 percent instead of 1.9 percent since firms use less oil for their production. Furthermore, the capital stock of the nontraded sector now decreases and the magnitude of the decrease in the tradable capital stock is more pronounced compared to the case of higher inflation alone. The transitional dynamics and the dynamic response of capital accumulation, the real exchange rate, and the current account are similar to Figures B.9 and B.10.

2.6 Conclusion

In this essay, we study the dynamic macroeconomic effects of a permanent increase in international oil prices and domestic inflation rates on the accumulation of capital stock, the real exchange rate, and the current account. We consider a small open economy with both traded and nontraded sectors. We show that the permanent increase in oil prices lowers the level of investment, production, and consumption. The current account improves by holding more foreign traded bonds. On the other hand, a permanent rise in oil prices along with a decrease in the world interest rate increases the level of investment and accumulates capital in the long-run, inducing current account deterioration. A permanent increase in the inflation rate will decrease the steady state total capital stock and investment level, inducing the current account surplus. However, sectoral responses are totally different; for example, capital stock in the nontraded sector actually rises to increase the production of the nontradable goods. Lastly, as expected, a permanent increase in oil prices along with higher inflation will also decrease the steady state output, capital stock, and investment level in the economy, inducing the current account surplus.

The effects are pronounced. The important advantage of using a two-sector model is that it enables us to see the sectoral and overall changes of capital, output, employment, and consumption. We also calibrate the model with standard parameter values for quantitative analysis. The effects are significant. Sectoral effects are more pronounced than economy's wide aggregate effects.

Chapter 3

Predicting Recessions Using Yield Spread in Developing Economies: Regime Switch vs. Probit Analysis

3.1 Introduction

It is fascinating that researchers often successfully predict economic activities by using limited available information. As a result, many empirical economists, policy makers, and various investors are always in search for better business cycle indicators. One common predictor of economic activity is the slope of the yield curve. Central bankers and policy makers pay serious attention to the slope of the yield curve, as it may contain useful information to aid in designing economic policy. In this essay, we test whether we can predict economic activity (recessions) using the yield spread in two Asian countries – South Korea and Thailand. These countries are known for their participation in global trade and commerce. In addition, they are highly linked with the rest of the world financially. Both are members of a group of countries known as the 'Asian Tigers' and experienced economic crises in the late 1990s. To analyze the predictive power of the yield spread, we employ a Markov regime switching autoregressive time series model for empirical analysis. We also compare and contrast our results to that of a standard probit analysis.

The yield spread measures the difference between long and short-term interest rates. It is assumed that the yield spread contains agent's expectations regarding the change in future government policies. Usually, the yield curve is upward sloping because long-term bonds have higher yields than short-term bonds. A higher yield spread tends to precede faster output growth. An inverted yield curve, on the other hand, raises concerns because it may indicate the approach of an economic downturn.[15] There is no clear-cut explanation as to why the yield spread predicts economic recession. However, there are two possible theoretical explanations. The first is the expectation hypothesis of the term structure of interest rates. It states that long-term interest rates are the average of current and expected future short-term interest rates. So, the anticipation of recession results in a decline in the expectation of future interest rates which is translated into the decrease of the long-term interest rates.[16] The second is a consumption based asset pricing model. Consumers prefer a stable level of income (and consumption) across business cycles. When consumers expect a recession in the near future, they prefer long-term bonds. As households sell their short-term bonds to finance the purchase of long-term bonds, the demand

[15] Before each of the last seven recessions in the United States, yield curves were inverted.
[16] Due to low levels of inflation, we expect to observe lower rates of returns during recessions. The expected declines in short-term interest rates tend to reduce current long-term rates and flatten the yield curve. This is consistent with the observed correlation between the yield curves and recessions.

for long-term bonds rises (the yield on long-term bonds decreases) and the demand for short-term bonds falls (the yield on short-term bond rises). As a result, the yield spread becomes flatter or even inverted.[17]

Many researchers have demonstrated empirically that the slope of the yield spread is a good predictor of recessions. Examples include Stock and Watson (1989), Estrella and Hardouvelis (1991), Plossor and Rouwenhorst (1994), Estrella (2005), Estrella and Mishkin (1998), Bernard and Gerlach (1998), and Ang, Piazzesi, and Wei (2006). Interestingly, all of these studies focus heavily on developed economies such as the United States, Canada, and European countries, and these results may not be generalized across economies.

It is useful to investigate such a relationship in developing economies for various reasons. For example, the relation between the yield spread and economic behavior might be different among emerging and developed economies. Compared to many developed countries, our sample countries (South Korea and Thailand) have experienced sharp economic growth over the past decades with a high degree of government intervention. Needless to say, significant government intervention in financial markets restricts the expectation of market participants. This may keep interest rates from reflecting the future path of the economy. Moreover, emerging countries often counter market imperfections by pegging their currencies to the currency of larger economies. Such behavior may establish weak relationships between the yield spread and economic activities. Plossor and Rouwenhorst (1994) point out that the variation of the predictive power of the yield spread among countries may be due to different inflation rates. It is expected that the yield spread is more useful to predict economic activities in the presence of low and stable

[17] Harvey (1988) applies this approach to examine the relationship between the term structure and consumption growth.

inflation rates. Temporary movements of the inflation rate affect the shape of the yield spread, but are not necessarily linked to the future state of the economy.[18] The high degree of volatility in the inflation rates of emerging economies provides another explanation as to why the domestic yield spread has a limited ability to explain future economic conditions. Due to all these inbuilt features of our sample countries, our empirical investigation is worth pursuing and hopefully will significantly contribute to the existing literature.

The empirical methodology is an important aspect of this kind of study. A quick survey of recent literature indicates that a standard probit analysis is most often used to predict economic recessions. Recently, authors such as Simpson et al. (2001) have argued that linear models are not efficient in capturing business cycle asymmetries with accuracy. As a result, the Markov regime switching model (due to Hamilton, 1989), which can distinguish between recession and expansion phases in a non-linear fashion, has been gaining momentum in forecasting economic turning points. Ahrens (2002) mentions the important reasons behind the model's popularity.

First, the most prominent difference between the regime switching model and the standard probit model is that the regime-switching model can estimate regime probabilities for any time t from the derived data. It provides and predicts different states (low and high for two-regimes) automatically at time t. Therefore the optimal forecast horizon is free compared to the conventional probit regression method.

Second, the regime switching procedure to estimate turning points in the economy does not depend on ex-post observed knowledge of recession dates, in other words, we do not need prior information relating to the recession dates. The regime switching method endogenously

[18] The standard deviations of inflation rates, for example, of Korea and Thailand are 0.70 and 0.72 respectively, whereas the average standard deviation of G-7 counties, except Japan, ranges from 0.29 to 0.39. The standard deviation of the Japanese inflation rate is 0.69.

determines lead or lag times of recession predictors. The probit model, on the contrary, relies fully on ex-post realized recession dates to examine the probability of recessions using the yield spread.

Third, the existence of two (or more) states enables us to better capture serial correlations. Therefore, it is not necessary to incorporate autoregressive terms in the mean as part of the regime switching model. For all these reasons, the regime switching model is preferred to the probit model to predict recessions. Moreover, in our context, it should be noted that the movement of interest rates is stochastic in nature and varies over time since there is a correlation between interest rates, government policies, and business cycles.[19] The regime switching model captures both the stochastic behavior of interest rates and structural changes of the economy.

The purpose of this essay is as follows. First, we want to show the accurate turning point predictions using the regime switching model to investigate the forecasting ability of the yield spread. Given the strong predictive power of the yield spread in developed countries, it is of interest to examine the predictive power of the yield spread in these developing economies. For our analysis, we employ macroeconomic data from South Korea and Thailand where market imperfections are prominent.[20] For comparison, we also investigate using a standard probit framework. In addition, we focus on discovering whether the recessions in these two countries (following the Asian crisis of 1997) could have been anticipated.

Second, we intend to study the duration of economic expansions and recessions. Business cycles represent a steady increase of output during expansions and a sharp drop in output during

[19] It is natural and also standard (due to the Lucas' critique) to assume that model parameters change over time due to various policy shocks.

[20] It is important to note that interest rates in Thailand have been relatively freely determined by the financial markets, but interest rates in South Korea had been somewhat restricted by the government.

recessions. We will test the hypothesis of asymmetric movements of business cycles. In addition, we will test whether the probability of expansion is greater than the probability of recession or vice versa.

The rest of this essay is organized as follows; Section 2 outlines the basic econometric model, Section 3 describes the data and explains the empirical results from regime switching models, Section 4 outlines a standard probit model with empirical results, followed by concluding remarks in Section 5.

3.2 Econometric Model

To forecast the probability of a recession using a country's yield spread, we extend the conventional Hamilton's model (1989) by allowing the mean and the variance to shift simultaneously across the regime. The Markov regime switching model captures the characteristics of nonlinearities and asymmetries to forecast business cycles and economic turning points using many economic variables. In our context, the Markov switching model assumes that deviations of the term spread from its mean follow a *p*-th order autoregressive process. The yield spread is represented as an AR (p) process:

$$y_t - \mu_{s_t} = \left[\sum_{i=1}^{p} \alpha_i \left(y_{t-i} - \mu_{s_{t-i}}\right)\right] + u_t, \qquad (3.1)$$

$$u_t \sim i.i.d\left(0, \sigma_{s_t}^2\right)$$

where the yield spread (y_t) depends on (y_{t-i}) which includes lags of the dependent variable. S_t, a regime indicator which cannot be observed, represents the state of the economy. It is a first-order

Markov process which means that the current regime S_t is dependent on the preceding regime (S_{t-1}). It takes the values of 1 or 2 and can be set $S_t = 1(S_t = 2)$ for the low (high) growth regime. The error, u_t is an *iid* random variable with a normal distribution, mean zero, and state (S_t) dependent variance. Since the states of the economy are not observable, a complete description of the probability law of the time series process requires a model of the regime generating process. The regime generating process is the *ergodic* Markov (EM) algorithm with a finite number of states.[21] In a two-state Markov-chain, we assume that the probability that a state at time *t* depends on the past only through the most recent past (S_{t-1}). The two regime transition probabilities are expressed by a first order Markov process as follows:

$$P(S_t = 1|S_{t-1} = 1) = P_{11}$$

$$P(S_t = 2|S_{t-1} = 1) = P_{12} = 1 - P_{11}$$

$$P(S_t = 2|S_{t-1} = 2) = P_{22} \tag{3.2}$$

$$P(S_t = 1|S_{t-1} = 2) = P_{21} = 1 - P_{22}$$

where $P_{11} + P_{12} = P_{21} + P_{22} = 1$. Equation (3.2) represents the transition probability specified as a constant coefficient. If the economy was in expansion in the last period, the probability of a regime switching is independent of the persistence of the expansion. The current regime S_t is determined by S_{t-1}. P_{11} is the probability of being in state 1 at time *t* given that the economy is

[21] A Markov chain is called an *ergodic* chain if it is possible to go from every state to every state (not necessarily in one move).

in state 1 at time $t-1$. P_{22} is the probability of being in state 2 at time t given that the economy is in state 2 at time $t-1$. P_{12} and P_{21} are the transition probability of one regime to another regime.

Here, the unobserved regime S_t is assumed to be generated by a probability distribution. The probability density function of y_t with the past information Y_{t-1}, where Y_{t-1} = {y_{t-1}, y_{t-2} ….} is:

$$f(y_t|s_t, Y_{t-1}) = \frac{1}{\sqrt{2\pi\sigma_{S_t}^2}} exp\left[\frac{(u_t)^2}{2\sigma_{S_t}^2}\right] \tag{3.3}$$

$$where \quad u_t = (y_t - \mu_{S_t}) - \sum_{i=1}^{p} \alpha_i (y_{t-i} - \mu_{S_{t-i}}).$$

In order to obtain parameter estimates, the log likelihood for the observed data $\ln L\,(Y_T|\theta)$ is maximized with respect to $\theta = (\mu_1, \mu_2, \sigma_1^2, \sigma_2^2, P_{11}, P_{22})$:[22]

$$= ln \sum_{t=1}^{T} f(y_t|s_t, Y_{t-1}; \theta) \tag{3.4}$$

$$= \sum_{t=1}^{T} ln \left\{ \sum_{s_t=1}^{2} f(y_t|s_t, Y_{t-1})\, P(s_t|\, Y_{t-1}) \right\}$$

The maximum likelihood estimates for θ can be obtained by maximizing the likelihood function. From equation (3.2), the expected duration of both regimes can be calculated from the transition probabilities. It gives us the expected length of staying in a certain regime. Then the expected duration of the regime i can be defined by

22 For the derivation of likelihood function, see Hamilton (1989).

$$E(d) = \frac{1}{1 - P_{ii}}, i = 1,2 \tag{3.5}$$

Even though the regime variable (S_t) is not observable in the MS-AR model, the specific regime probability can be obtained from the data. Since we have overall sample period information, we look at the *smoothing probability* to determine economic turning points (Hamiltion 1989).[23]

3.3 Data and Empirical Results

We construct a database from a monthly data set of interest rates which are taken from the IMF International Financial Statistics (IFS) Database. We target two newly-industrialized Asian countries, South Korea and Thailand, which have experienced liberalization in policies over the last decade. These countries are also known to be very open in terms of exports and imports. Sample periods for the long-term rate (government bond yield) and short-term rate (3 month money market rate) range from January 1982 to February 2007 for South Korea and January 1991 to June 2004 for Thailand. In Figures B.17 and B.18, big inverted yield curves are plotted between 1997 and 1998 for South Korea and Thailand.

3.3.1 Two-Regime Switching Model

[23] If we include the information set which is dated up to the time *t* and we can filter out the unobserved state of world, this is called the *filtering probability*. Once we estimate the parameters, filtering and smoothing probabilities can be computed. Generally, filtering probabilities and smoothing probabilities do not vary and give us similar results. The procedure for estimating the parameters is to maximizing the log likelihood function. And then we can use these parameters to get the filtering and smoothing probabilities for a certain regime S_t.

We estimate the model using a two regime-univariate MS−AR model. The estimation was made by a code developed by the authors in Matlab R2009a. Since it is a first order Markov process we denote MS (2)−AR (1). Figures B. 17 and 18 present the shape of the yield spread and the smoothed probabilities of a recession regime of two countries. The results support the notion that the MS model is effective in depicting a recession regime of Thailand. In contrast, the MS model fails to identify the post-2000 business cycles for South Korea. Specially, the MS model indicates that South Korea has persistently been in a recession regime since 2001 from Figure B.18 (B). The shaded areas indicate the actual recession periods. For Thailand, there is one 'noisy' signal where the estimated probability is higher than 50% and the recession did not occur. We do not consider the growth rate of GDP prior to 1993 for Thailand since data are not available at IFS. We assume that there are two regimes, expansion and recession. The estimation results of two countries are presented in Table A.10.

The first regime for each yield spread captures an economic expansion phase and the second regime captures a recession phase. It can be shown that the volatility of regime 2, σ_2^2 , for Thailand is higher than the volatility of regime 1, σ_1^2, where the monthly values are 5.84% and 1.89% respectively. They are statistically significant at 1%.[24] The first regime clearly represents a period with an upward-sloping yield curve and an average percentage spread of 2.82%. Besides that, the negative sign of regime 2 , μ_2, is associated with a period with a downward-sloping yield curve. The probability of staying regime 2 , P_{22}, is smaller than that of regime 1 which is P_{11}. The value of P_{11}, which is the probability of staying at regime 1 from regime 1, is 0.974 (97.4%) and the value of P_{22} , which is the probability of staying at regime 2 from regime 2, is 0.912

[24] We used the Newey West method to calculate the standard errors and covariance matrix. The results are robust to heteroskedasticity and serial correlation.

(91.2%). Table A.10 also provides the expected duration of each regime. The expected duration of being in regime 1, $E(d, S_t = 1)$, is longer than regime 2, $E(d, S_t = 2)$. The expected duration of state one $(1 - P_{11})^{-1}$ is 39 months and the expected duration of the regime two $(1 - P_{22})^{-1}$ is 11 months. So the differences between the two regimes reflect both term spread behavior and the asymmetric characteristics of the business cycles.

One advantage of using the regime switching model is that it provides the conditional regime probabilities of each regime. It is very useful to understand whether identified regimes are related to the business cycles. To see the economic recession phase, regime 2 provides the compounding probability of recession phases. Figures B.17 and B.18 show the smoothed probability plots for the regime 2 which is a recession phase. Recessions are defined as two consecutive quarters of declining of GDP. The National Bureau of Economic Research (NBER) type of identifying business cycles is not available for these countries. The identification of the business cycle has its own problem. We rely on recession dates published by the ECRI (Economic Cycle Research Institute) in South Korea. For Thailand, the recession dates are calculated from the IFS database using real GDP which is only available from January 1993.[25] In Thailand, the start of the recession is indicated well in advance. In particular, it is indicated 18 months in advance. The MS model appears to be effective in predicting the recession. But, it falsely signals a recession in 1995. The probability of a recession is very high but there was none.[26] When we consider the performance of the MS model in South Korea, the MS model fails to depict business cycles after the year 2000. The model gives many false signals and missed

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[25] Recession dates and business cycles are available in table A.9.

[26] Ahren (2002) finds that the falsely indicated peaks from eight developed countries range from 1 to 4, and the falsely indicated troughs from those countries are zero to one. In addition, missed signals range from 0 to 2.

signals for South Korea and we conclude that the Korean yield spread does not have power to forecast economic recessions prior to 2000 and the two regime MS model does not perform well.

3.3.2 Three-Regime Switching Model

Since we have failed to describe the business cycle of South Korea with the two-regime MS model, it is natural to examine the three-regime MS model. The main difference between the two-regime and the three-regime models is that in the case of three regimes, the expansion phase is separated in two regimes, moderate recovery (medium growth) and strong growth. In this sense, it is more applicable for most developing countries since they have large deviations in macro economic variables such as GDP and Inflation. Goodwin (1993) shows that the conventional two-regime MS model fails to capture several outliers; i.e.the two-regime model identifies them as separate states. As Ocal and Osborn (2000, p. 27) mention, there is growing evidence that at least three regimes are needed to adequately characterize business cycle movements. Clements and Krolzig (1998) have shown that a three-regime MS model captures the business cycle in a way that corresponds closely to NBER turning points.

Table A.11 shows parameter estimates and estimated transition probabilities of the MS(3)−AR(1). Figure B.19 depicts the smoothed probabilities of the recessions from both countries. From Table A.11, μ_1, μ_2, and μ_3 correspond to high growth, moderate growth, and the recession phase, respectively. In other words, there is an ‘H’ regime, an ‘M’ regime, and an ‘R’ regime. The third regime is obviously characterized as a period with a downward sloping yield curve, which is associated with the economic recession with an average percentage spread of −10.18% and −8.26%. Table A.11, with estimated variances, suggests that the volatility of regime 3, σ_3^2 , for both countries is higher than the volatility of regime 1 or regime 2. This finding is consistent with the previous two-regime case.

For Thailand, the three-regime MS model is more reliable than the two-regime MS model. It signals the recession of 1998 around 12 months ahead and does not have any false signals. The probability of staying at regime 3 from regime 3 is 0.92 (92%) and the duration of regime 3 is 12.9 months.

For South Korea, the model successfully captures the recession of 1998. As we know, the two-regime model has failed to capture this recession. The three-regime model is able to capture the probability of the recession with the inverted yield curve in 1991 and 1994, as seen in Figure B.19. Even though the yield curve was inverted from June 1991 to December 1991 which led to a dramatic economic decline in 1991-2, the Korean economy did not have an economic recession. Moreover, the yield curve was inverted from June 1994 to February 1995. However, South Korea experienced high economic growth in 1995.[27] One potential explanation is that the Korean bond markets, especially the long-term bond market, are not developed well enough to reflect the expectation of market participants. Furthermore, the Korean government put a direct restriction on the term spreads. Nevertheless, there are a few 'noisy' signals during 1980's and 1990's where the estimated probability is high but the recession did not occur. However, the model fails to capture the short recession of 2003. We conclude that the yield spread is confirmed to be a reliable recession predictor for Thailand but not for South Korea.

The estimated transition probabilities are given by Table A.11. The transition probability from H regime to H regime and M regime to M regime is 0.84 and 0.95. The transition

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[27] The growth rate of GDP between 1995 and 1996 was 8.1% and the inflation rate was 4.7%. We may conclude that the yield spread was not affected by business cycles but affected by the fluctuations of a financial market itself.

probability from R regime to R regime is 0.14, which is low. The persistence of each regime is relatively high, except for the R regime. However, the duration of the regimes is 6.26, 21.36, and 1.16 months for H, M, and R regimes, respectively. As can be seen from the table, the duration of regime R is less than two months. This indicates that the Korean economy has had a high growth rate of GDP over the last few decades.

3.4 The standard probit model

Briefly, a probit model is a limited dependent variable model which has two values: one if recession occurs, zero otherwise. Over the last few decades, the probit model method has been used widely to predict recession probabilities in macroeconomic activity. Important references include Estrella and Hardouvelis (1991), Estrella and Mishkin (1998) and Estrella, Rodrigues and Schich (2000). A set of probit models, using forecast horizons (denoted "j") which differ from 1 to 24 months, are estimated:

$$Prob(R = 1) = F\left(\alpha + \beta Spread_{t-j}\right) \quad (3.6)$$

where $j=1,3,6, \ldots,24$ is the forecasting horizon, R is a dummy variable denoting recessions in the country ($R=1$ if recession, 0 otherwise), β is the coefficient on the interest rate yield spread variable and α is a constant.[28] Another useful criterion is a goodness-of-fit measure. In the classical regression model, the coefficient of determination R^2 is used as a measure of the explanatory power of the regression model. It can range in value from 0 to 1, with a value close

[28] $Spread_{t-j}$ measures the slope of yield curve which is the difference between long-term and short-term interest rates. $F(.)$ denotes the standard normal cumulative distribution function.

to 1 indicating a good fit. In this kind of model it is no more likely to yield an R^2 close to 1.[29] To avoid this problem we use the measure of fit proposed by Estrella (1998). It is a *pseudo*-R^2 in which the log-likelihood of an unconstrained model, L_u, is compared with the log-likelihood of a nested model, L_c:[30]

$$pseudo\text{-}R^2 = 1 - \left(\frac{L_u}{L_c}\right)^{\frac{1}{(2/n)}L_c} \quad (3.7)$$

3.4.1 Results of probit model

The yield spread data (period *t*) can be used to predict future recessions (in period *t+j*). The explanatory power of the yield spread, as measured by *pseudo*-R^2, varies with the forecast horizon (number of months ahead on the prediction) and the specific character of the country's economy used in the analysis. Table A.12 provides the results for the estimated equation using the domestic term spread as a regressor. Using forecast horizons from one to twenty four months, Table A.12 reports the *z*-test statistics for the yield spread parameter, the associated probability level of significance (denoted *p-value*), and the *pseudo*-R^2 used in Estrella and Mishkin (1998). A probability level of 5 percent or smaller indicates that the yield spread contributes significantly to predicting recessions at that forecast horizon. The negative *z*-statistics, reflecting the underlying negative yield spread coefficients, are consistent with expectations.

First, the spreads are useful for predicting future recessions in both South Korea and Thailand. Although the optimal forecast horizon is twelve months (only one month for South Korea) or less, the yield spread parameter is significant across multiple forecast horizons for both

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29 See, for example, Pindyck and Rubinfeld (1991).

30 The constrained model comes from a model with β, in equation (3.6), equal to zero. The log-likelihood in the case of the probit model is given by $L = \sum_t R_t lnPr\left(R_t = 1|X_{t-j}\right) + (1 - R_t) lnPr\left(R_t|X_{t-j}\right)$.

countries. The best fit, in Thailand, is twelve months with the highest *pseudo*-R^2 of 0.5313 and *z*-statistics of −5.60, which is statistically significant at 1%. Second, the South Korea yield spread can predict recessions from j=1 to j=6 only. It loses predictive power after j=6 with a very low *pseudo*-R^2. Third, the explanatory power measured by *pseudo*-R^2 varies with the forecast horizon. The explanatory power rises from $j = 1$, peaks at 12 months, and then falls gradually as increasingly higher j's are considered in Thailand. Since interest rates are forward-looking variables, it is expected that the *pseudo*-R^2 initially rises. On the other hand, the explanatory power is at its highest at the first month and falls gradually for South Korea. We may conclude that the Korean yield spread does not have predictive power for future recessions or the Korean yield spread is not closely related to the Korean business cycle. There are large differences between countries in the predictive power of the spread. The predictive power, as measured by the *pseudo*-R^2, is high in Thailand but low in South Korea.

These findings lead to a question of how the estimated recession probabilities depend on the spread. To answer this question the probability of the recession can be calculated at each forecast horizon as a function of the current spread. Using the probit model results, the probability of the recession can be calculated at each forecast horizon. Using each country's optimal forecast horizon (as indicated in Table A.12 with underlines), Figures B.20 and 21 show the predicted probability of recession for each country. Figure B.20 illustrates the estimation results shown in Table A.12. It plots the fitted value from estimation of model (3.6). For both countries, the probability of recession during the Asian crisis is significantly high which implies the yield spread is a good predictor of economic recession. These results are very similar to those of the MS model. For Thailand from Figure B.20, the probit model gives a probability of recession at

45% in 1995. However, the start of the recession is indicated in the middle of 1997 which implies that the recession is predicted 6 months ahead. As can be seen from the previous MS results, the recession was predicted 18 months ahead. Figure B.21 (A) shows the probability of recession with the optimal forecast horizon of one in South Korea. It captures the recession of the Asian financial crisis with the probability of 92%. It is shown that *pseudo*-R^2 is significantly lower for South Korea, compared to the *pseudo*-R^2 of Thailand. It is hard to expect the predictive power of the Korean yield spread. Figure B.20 (B) shows the probability of recession in South Korea six months ahead (j=6). So, the optimal forecast horizon is 6 months. As we can see, the predictive power drops significantly and the probability of having a recession is around 60%. The standard probit model of South Korea misses the 2003 recession as well.

3.5 Conclusion

In this essay we studied the ability of the yield spread to predict economic recessions in two developing Asian economies – South Korea and Thailand. We used both the regime switching model as well as the standard probit model for our empirical investigation. The empirical findings support the following claims. First, the regime-switching model serves well to depict economic turning points and business cycles for South Korea and Thailand. The MS model is more effective at depicting the economic turning points than the probit model.

Second, we find that three-regime MS model is better predictor of recessions than two-regime MS model. The three-regime MS model effectively measures the business cycles of South Korea and accurately predicts turning points. Specifically, the two-regime MS model fails to capture and depict the post-2000 period business cycle of South Korea which may have experienced structural changes.

Third, the yield spread is confirmed to be a reliable recession predictor in Thailand. Nevertheless, the Korean yield spread fails to capture Korean business cycles. The inverted yield spreads are not closely related to economic recessions in South Korea before the Asian financial crisis in particular.

Finally, the usefulness of the regime switching model compared to the standard probit model to predict recessions is in question. Forecasters should apply the MS method for unambiguous signals which could imply larger errors. However, the transition probability of the regime switching model to estimate turning points improves over the standard probit model.

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Appendices

Appendix A

Tables

Table A.1

Base parameter values (A) and key steady state equilibrium ratios (B)

(A) Base parameter values

Preferences η = -1.5, θ = 0.5

World Interest Rate r = 6%

Inflation rate π = 4%

$k_T < k_N$: α = 0.35, β = 0.25

$k_T > k_N$: α = 0.25, β = 0.35

(B) Key Steady-State Values and Ratios.

Nontraded Sector is more capital intensive: α=0.35, β=0.25

K_T/L_T	K_N/L_N	K_T/Y_T	K_N/Y_N	K/Y	L_T	Y_T/Y	e	C_T/Y_T	C_N/Y_N	C/Y	μ_1
9.334	15.077	5.34	5.834	6.53	0.475	0.43	0.781	1.159	1	1.069	-0.39, 0.45

Traded Sector is more capital intensive: α=0.25, β=0.35

K_T/L_T	K_N/L_N	K_T/Y_T	K_N/Y_N	K/Y	L_T	Y_T/Y	e	C_T/Y_T	C_N/Y_N	C/Y	μ_1
10.83	6.705	4.704	4.167	4.405	0.408	0.443	1.24	1.140	1	1.034	-0.389, 0.449

Table A.2

The effects of a permanent increase in π (% change) when CIA constraint on C_T

	$\bar{K}$	$\bar{L}_T$	$\bar{L}_N$	$\bar{Y}_T$	$\bar{Y}_N$	$\bar{Y}$	$\bar{k}_T$	$\bar{k}_N$	$\bar{C}_T$	$\bar{C}_N$	$\bar{C}$	$\bar{b}$	$\bar{e}$
(A) Nontraded sector is more capital intensive													
When r = 6%													
4% to 8%, η=-1.5	0.415	-1.880	1.702	-1.880	1.702	0.127	0	0	-1.867	1.702	0.0024	-1.782	0
When r = 4%													
4% to 8%, η=-1.5	0.414	-1.779	1.749	-1.779	1.749	0.126	0	0	-1.884	1.749	0.0024	-3.088	0
When r = 6%													
4% to 8%, η=-0.4	0.416	-1.882	1.704	-1.882	1.704	0.127	0	0	-1.865	1.704	0.0042	-1.757	0
4% to 12%, η=-1.5	0.816	-3.692	3.341	-3.692	3.341	0.249	0	0	-3.665	3.341	0.0048	-3.498	0
(B) Traded sector is more capital intensive													
When r = 6%													
4% to 8%, η=-1.5	-0.494	-2.459	1.699	-2.459	1.699	-0.145	0	0	-1.870	1.699	0	2.337	0
When r = 4%													
4% to 8%, η=-1.5	-0.487	-2.338	1.747	-2.338	1.747	-0.144	0	0	-1.887	1.747	0	4.214	0
When r = 6%													
4% to 8%, η=-0.4	-0.494	-2.459	1.699	-2.459	1.699	-0.145	0	0	-1.870	1.699	0	2.337	0
4% to 12%, η=-1.5	-0.970	-4.828	3.336	-4.828	3.336	-0.286	0	0	-3.669	3.336	0	4.588	0

Table A.3

The effects of a permanent increase in π (% change) when CIA constraint on C_N

	$\bar{K}$	$\bar{L}_T$	$\bar{L}_N$	$\bar{Y}_T$	$\bar{Y}_N$	$\bar{Y}$	$\bar{k}_T$	$\bar{k}_N$	$\bar{C}_T$	$\bar{C}_N$	$\bar{C}$	$\bar{b}$	$\bar{e}$
(A) Nontraded sector is more capital intensive													
When r = 6%													
4% to 8%, η=-1.5	-0.422	1.68	-1.87	1.68	-1.87	-0.13	0	0	1.70	-1.87	-0.002	2.09	0
When r = 4%													
4% to 8%, η=-1.5	-0.419	1.63	-1.89	1.63	-1.89	-0.12	0	0	1.74	-1.89	-0.002	3.10	0
(B) Traded sector is more capital intensive													
When r = 6%													
4% to 8%, η=-1.5	0.486	2.20	-1.87	2.20	-1.87	0.15	0	0	1.67	-1.87	0	-2.42	0
When r = 4													
4% to 8%, η=-1.5	0.480	2.15	-1.89	2.15	-1.89	0.14	0	0	1.74	-1.89	0	-3.60	0

Table A.4

Base parameter values (A) and key steady-state equilibrium ratios (B)

(A) Base parameter values

Preferences η = -1.5, θ = 0.5, World Interest Rate r = 6%, Price of oil ω = 1, Inflation Rate π = 2%

$k_T < k_N$: $\alpha 1$ = 0.3, $\beta 1$ = 0.2, and $\alpha 2$,=0.04 $\beta 2$ = 0.04

$k_T > k_N$: $\alpha 1$ = 0.2, $\beta 1$ = 0.3, and $\alpha 2$,=0.04 $\beta 2$ = 0.04

(B) Key Steady-State Values and Ratios.

Nontraded Sector is more capital intensive: $\alpha 1$=0.3, $\beta 1$=0.2

K_T/L_T	K_N/L_N	X_T/L_T	X_N/L_N	K	X	K/Y	L_T	σ	C_T/Y_T	C_N/Y_N	μ_1	λ
4.871	8.414	0.045	0.051	6.62	0.048	5.08	0.507	0.8295	1.12	1	0.475, -0.415	1.109

Traded Sector is more capital intensive: α1=0.2, β1=0.3

K_T/L_T	K_N/L_N	X_T/L_T	X_N/L_N	K	X	K/Y	L_T	σ	C_T/Y_T	C_N/Y_N	μ_1	λ
6.702	3.88	0.059	0.050	5.13	0.054	3.50	0.44	1.178	1.09	1	-0.412, 0.472	1.105

Table A.5

The effects of a permanent increase in oil prices (% change)

	$\bar{K}$	$\bar{K}_T$	$\bar{K}_N$	$\bar{L}_T$	$\bar{L}_N$	$\bar{Y}_T$	$\bar{Y}_N$	$\bar{Y}$	$\bar{k}_T$	$\bar{k}_N$	$\bar{x}_T$	$\bar{x}_N$	$\bar{C}_T$	$\bar{C}_N$	$\bar{b}$	$\bar{\sigma}$	RER (t=0)
(A) Nontraded sector is more capital intensive																	
ω (30%)	-1.24	-2.78	-0.32	-1.23	1.27	-2.62	-0.32	-1.33	-1.57	-1.57	-24.16	-24.16	-0.16	-0.32	11.99	0.16	0.8288
ω (50%)	-1.91	-4.27	-0.49	-1.90	1.96	-4.03	-0.49	-2.04	-2.41	-2.41	-34.78	-34.78	-0.25	-0.49	18.46	0.24	0.8284
ω (100%)	-3.23	-7.24	-0.84	-3.28	3.38	-6.85	-0.84	-3.46	-4.09	-4.09	-51.84	-51.84	-0.43	-0.84	31.30	0.42	0.8276
(B) Traded sector is more capital intensive																	
ω (30%)	-1.75	-2.89	-0.18	-1.54	1.22	-3.03	-0.18	-1.61	-1.37	-1.37	-24.24	-24.24	-0.31	-0.18	14.91	-0.14	1.1767
ω (50%)	-2.69	-4.46	-0.27	-2.38	1.89	-4.66	-0.27	-2.48	-2.12	-2.12	-34.88	-34.88	-0.48	-0.27	22.96	-0.21	1.1758
ω (100%)	-4.57	-7.57	-0.45	-4.12	3.27	-7.91	-0.45	-4.20	-3.60	-3.60	-51.97	-51.97	-0.81	-0.45	38.97	-0.37	1.1730

Table A.6

The effects of a permanent increase in oil prices and a decrease in a world interest rate from 6% to 5.5% (% change)

	$\bar{K}$	$\bar{K}_T$	$\bar{K}_N$	$\bar{L}_T$	$\bar{L}_N$	$\bar{Y}_T$	$\bar{Y}_N$	$\bar{Y}$	$\bar{k}_T$	$\bar{k}_N$	$\bar{x}_T$	$\bar{x}_N$	$\bar{C}_T$	$\bar{C}_N$	$\bar{b}$	$\bar{\sigma}$	RER (t=0)
(A) Nontraded sector is more capital intensive																	
ω (30%)	9.16	20.8	2.20	8.21	-8.47	9.54	-6.31	0.64	11.6	11.6	-21.7	-21.7	-7.34	-6.31	-89.6	-1.09	0.8355
ω (50%)	8.41	19.1	2.03	7.60	-7.84	8.08	-6.47	-0.10	10.7	10.7	-32.7	-32.7	-7.42	-6.47	-82.3	-1.01	0.8350
ω (100%)	6.92	15.7	1.67	6.35	-6.55	5.17	-6.79	-1.55	8.80	8.80	-50.3	-50.3	-7.58	-6.79	-67.7	-0.84	0.8340
(B) Traded sector is more capital intensive																	
ω (30%)	12.9	21.4	1.29	10.2	-8.06	12.3	-7.15	2.62	10.2	10.2	-21.2	-21.2	-6.25	-7.15	-111.2	0.97	1.1900
ω (50%)	11.8	19.6	1.17	9.41	-7.46	10.6	-7.25	1.72	9.34	9.34	-32.2	-32.2	-6.43	-7.25	-102.1	0.89	1.1889
ω (100%)	9.75	16.2	0.95	7.88	-6.26	7.29	-7.46	-0.06	7.68	7.69	-50.0	-50.0	-6.77	-7.46	-84.12	0.74	1.1871

Table A.7

The effects of a permanent increase in inflation (% change)

	$\bar{K}$	$\bar{K}_T$	$\bar{K}_N$	$\bar{L}_T$	$\bar{L}_N$	$\bar{Y}_T$	$\bar{Y}_N$	$\bar{Y}$	$\bar{k}_T$	$\bar{k}_N$	$\bar{x}_T$	$\bar{x}_N$	$\bar{C}_T$	$\bar{C}_N$	$\bar{b}$	$\bar{\sigma}$	RER (t=0)
(A) Nontraded sector is more capital intensive (*r* = 6%)																	
2% to 4%	-0.07	-0.25	0.03	-0.14	0.14	-0.24	0.03	-0.09	-0.11	-0.11	-1.91	-1.91	0.04	0.03	0.70	0.01	0.8295
2% to 6%	-0.14	-0.49	0.06	-0.27	0.28	-0.47	0.06	-0.17	-0.22	-0.22	-3.76	-3.76	0.08	0.06	1.40	0.02	0.8295
(B) Traded sector is more capital intensive (*r* = 6%)																	
2% to 4%	-0.14	-0.30	0.06	-0.20	0.16	-0.30	0.06	-0.11	-0.09	-0.09	-1.92	-1.92	0.05	0.06	1.24	-0.01	1.1782
2% to 6%	-0.29	-0.59	0.12	-0.39	0.31	-0.61	0.12	-0.23	-0.19	-0.19	-3.77	-3.77	0.10	0.12	2.46	-0.02	1.1781

Table A.8

The effects of a permanent increase in both oil prices (50%) and inflation (% change)

	$\bar{K}$	$\bar{K}_T$	$\bar{K}_N$	$\bar{L}_T$	$\bar{L}_N$	$\bar{Y}_T$	$\bar{Y}_N$	$\bar{Y}$	$\bar{k}_T$	$\bar{k}_N$	$\bar{x}_T$	$\bar{x}_N$	$\bar{C}_T$	$\bar{C}_N$	$\bar{b}$	$\bar{\sigma}$	RER(t=0)
(A) Nontraded sector is more capital intensive (*r* = 6%)																	
2% to 4%	-1.98	-4.51	-0.46	-2.05	2.11	-4.27	-0.46	-2.12	-2.52	-2.52	-36.0	-36.0	-0.20	-0.46	19.15	0.25	0.8285
2% to 6%	-2.04	-4.75	-0.43	-2.18	2.25	-4.50	-0.43	-2.21	-2.62	-2.62	-37.2	-37.2	-0.17	-0.43	19.83	0.27	0.8285
(B) Traded sector is more capital intensive (r = 6%)																	
2% to 4%	-2.83	-4.75	-0.21	-2.59	2.05	-4.96	-0.21	-2.59	-2.21	-2.21	-36.1	-36.1	-0.43	-0.21	24.17	-0.22	1.1757
2% to 6%	-2.97	-5.03	-0.15	-2.78	2.21	-5.25	-0.15	-2.70	-2.31	-2.31	-37.3	-37.3	-0.38	-0.15	25.37	-0.23	0.1756

Table A.9

Business cycle chronologies

ECRI business cycle chronologies for South Korea, 1982-2007

Peak	Trough
March 1979	October 1980
August 1997	July 1998
December 2002	September 2003

Source: www.businesscycle.com.

Business cycle chronologies for Thailand, 1993-2004

Peak	Trough
N/A	January 1993
January 1998	June 1999

Source: IFS database

Table A.10

Parameter estimates of a univariate two-regime switching model

Coefficient value (standard error, *p*-value)

	Thailand	South Korea
μ_1	0.0282 (0.0048, 0.00)	0.0114 (0.0050, 0.02)
μ_2	-0.0210 (0.0212, 0.00)	0.0095 (0.0020, 0.00)
σ_1^2	0.0189 (0.0050, 0.00)	0.1114 (0.0364, 0.00)
σ_2^2	0.584 (0.0067, 0.00)	0.0264 (0.0098, 0.01)
P_{11}	0.974	0.950
P_{22}	0.912	0.972
$E(d, S_t = 1)$	39.12	35.65
$E(d, S_t = 2)$	11.38	19.98

Table A.11

Parameter estimates of a univariate three-regime switching model
Coefficient value (standard error, *p*-value)

	Thailand	South Korea
μ_1	0.0201 (0.0140, 0.15)	0.0223 (0.0140, 0.11)
μ_2	0.0084 (0.0017, 0.00)	0.0059 (0.0016, 0.00)
μ_3	−0.1018 (0.1390, 0.46)	-0.0826 (0.0101, 0.00)
σ_1^2	0.0483 (0.0101, 0.00)	0.0580 (0.0541, 0.28)
σ_2^2	0.0112 (0.0006, 0.00)	0.0162 (0.0088, 0.07)
σ_3^2	0.1106 (0.0141, 0.00)	0.0617 (0.0142, 0.00)
P_{11}	0.97	0.84
P_{22}	0.99	0.95
P_{33}	0.92	0.14
$E(d, S_t = 1)$	37.64	6.26
$E(d, S_t = 2)$	100	21.36
$E(d, S_t = 3)$	12.91	1.16

Table A.12

Measures of fit for the probit model

$P(R = 1) = F(\alpha + \beta Spread_{t-j})$ *j*=months ahead in forecast

$Spread_{t-j}$	1	3	6	9	12	15	18	21	24
Thailand[1]									
Pseudo-R^2	0.054	0.136	0.327	0.4827	<u>0.5313</u>	0.3686	0.2139	0.105	0.016
z-stat[a]	-2.49	-3.82	-5.31	-5.64	-5.60	-5.42	-4.59	-3.35	-1.34
p-value[b]	0.013	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.181
South Korea[2]									
Pseudo-R^2	<u>0.240</u>	0.2052	0.0912	0.0281	0.0282	0.0341	0.0299	0.0337	0.0207
z-stat[a]	-5.19	-4.94	-3.69	-2.13	-2.13	-2.33	-2.18	-2.31	-1.81
p-value[b]	0.000	0.000	0.000	0.033	0.033	0.020	0.029	0.021	0.070

[a] *z*-stat denotes the *z*-statistics for the spread coefficient.
[b] *p*-value denotes the significance level for the *z*-test on the spread coefficient.
[1] Sample period: 1991:1-2004:6
[2] Sample period: 1982:1-2007:2

Appendix B

Figures

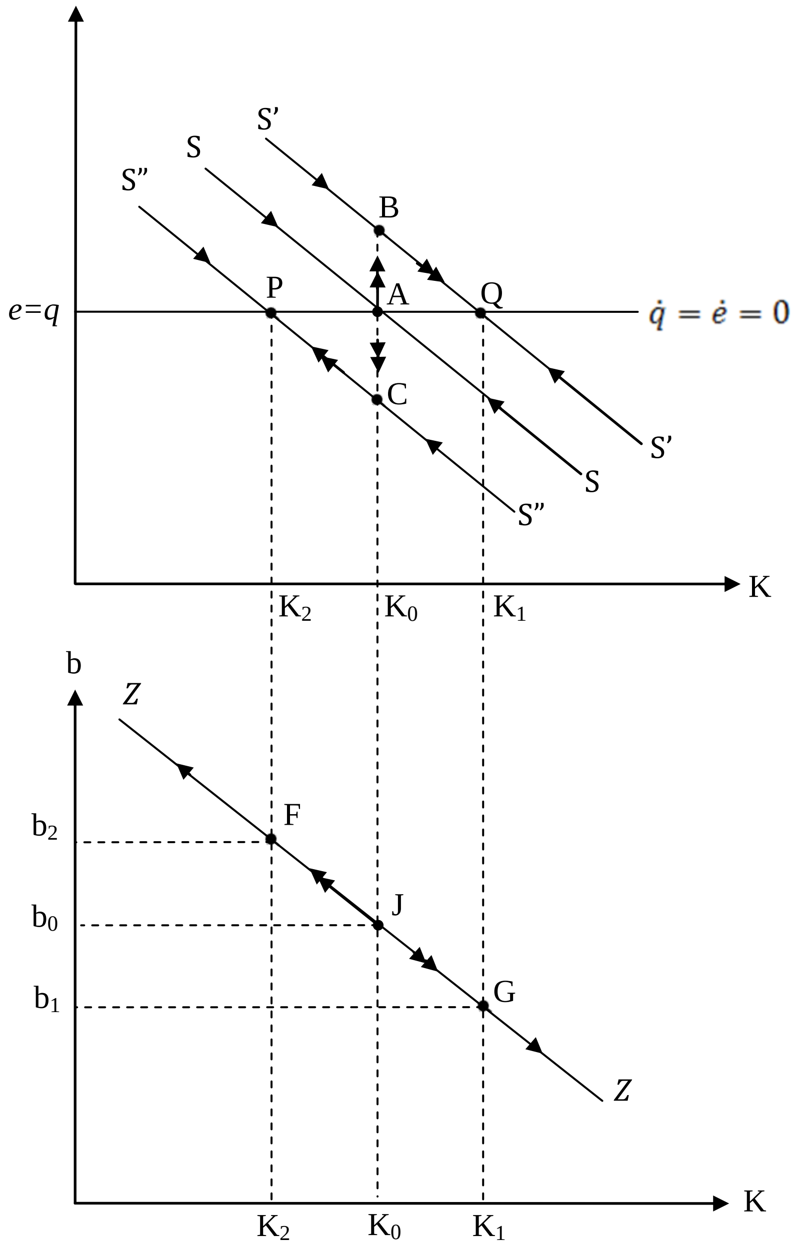


Figure B.1: The phase diagram ($K_N > K_T$)

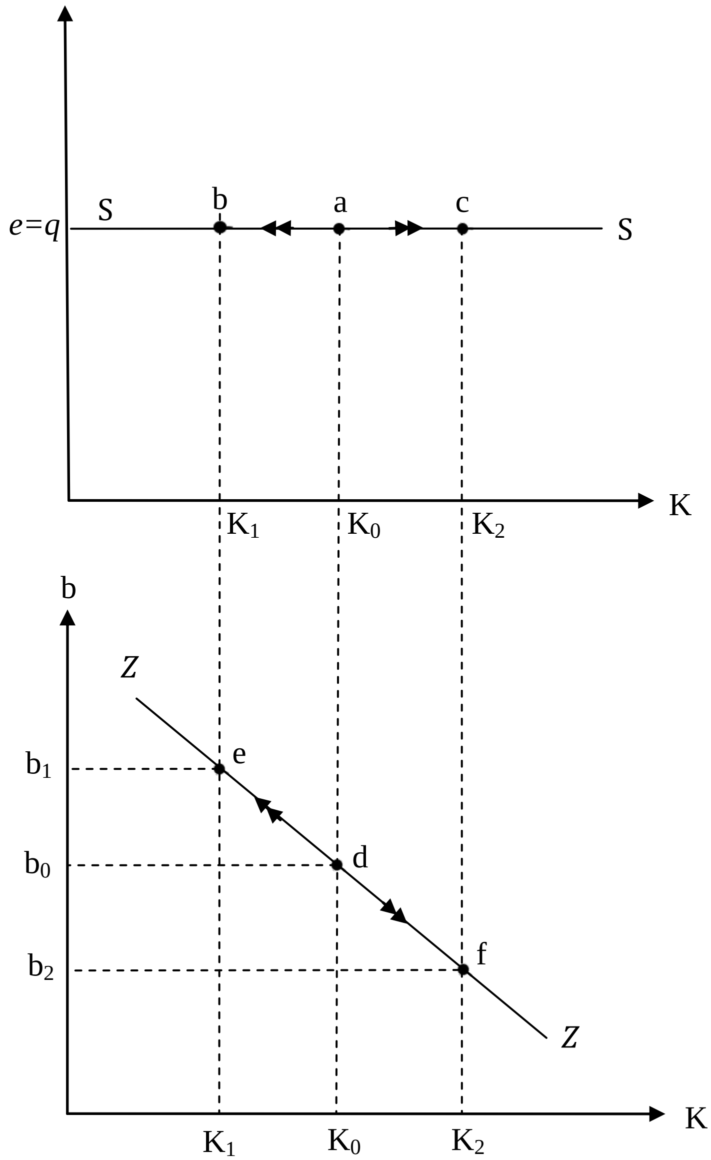
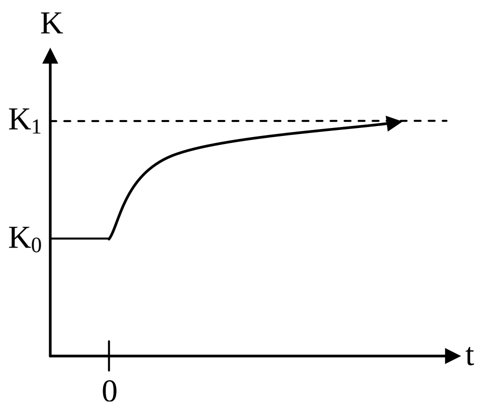
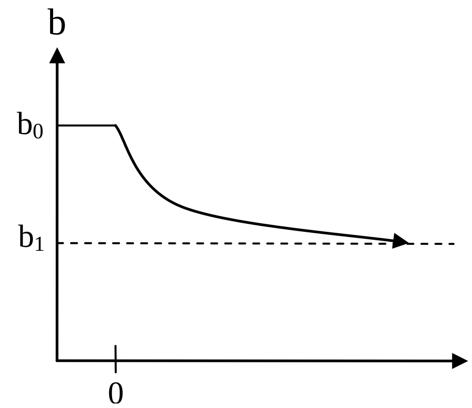


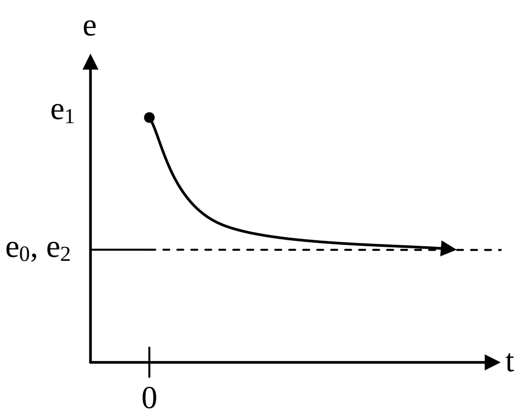
Figure B.2: The phase diagram ($K_T > K_N$)



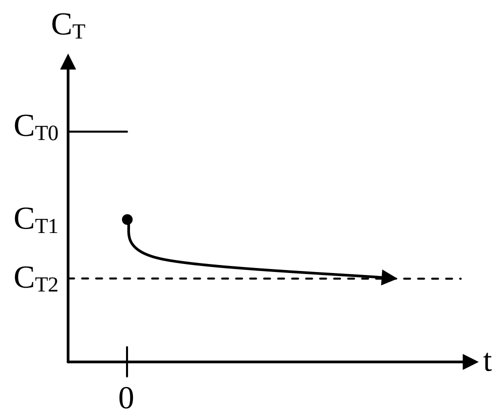
Time path of the level of capital



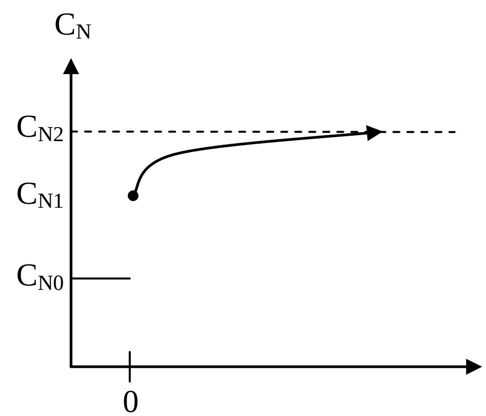
Time path of the current account



Time path of the real exchange rate



Time path of tradable consumption



Time path of nontradable consumption

Figure B.3: The effects of higher inflation (CIA on C_T and $K_N > K_T$)

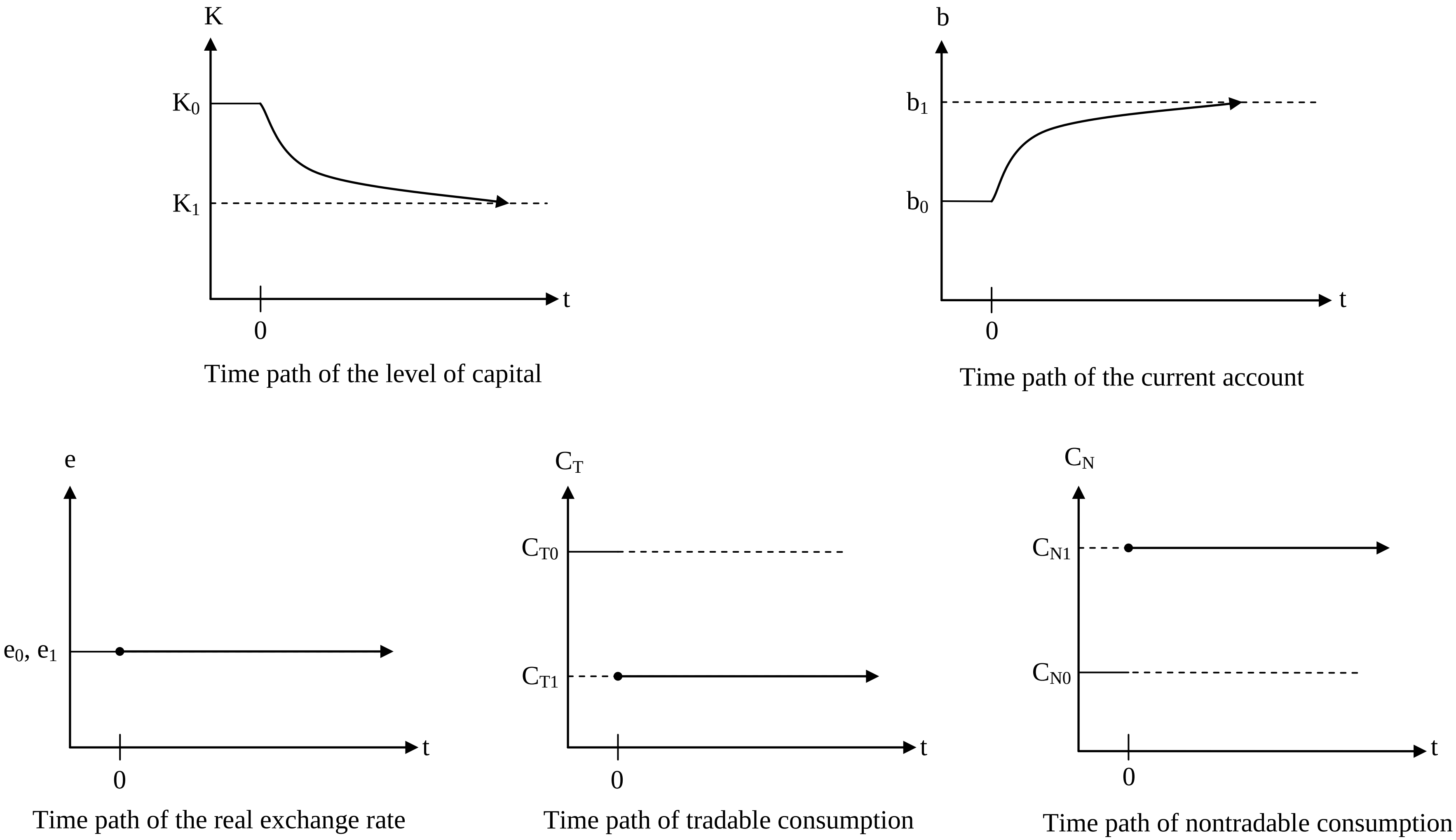


Figure B.4: The effects of higher inflation (CIA on C_T and $K_T > K_N$)

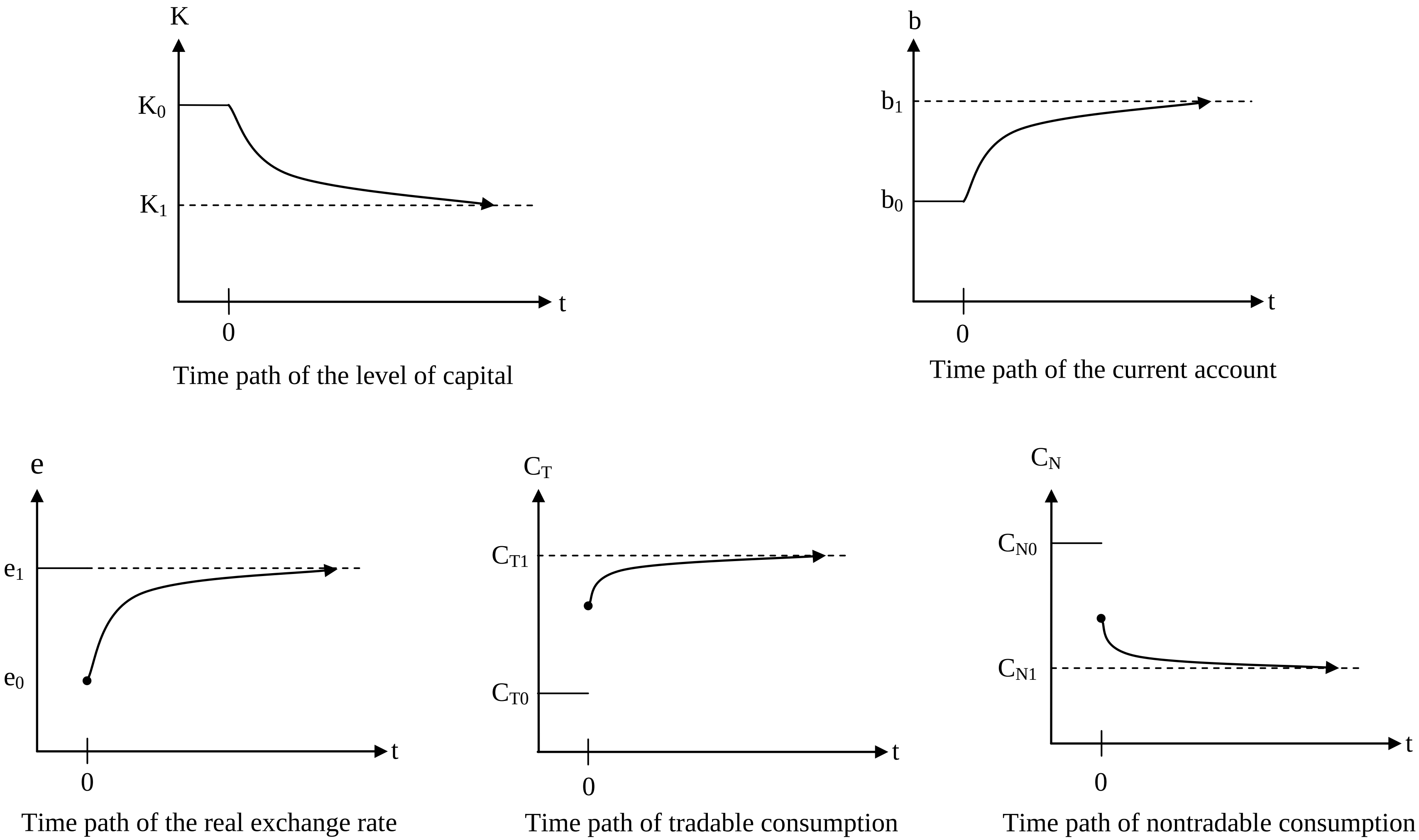


Figure B.5: The effects of higher inflation (CIA on C_N and $K_N > K_T$)

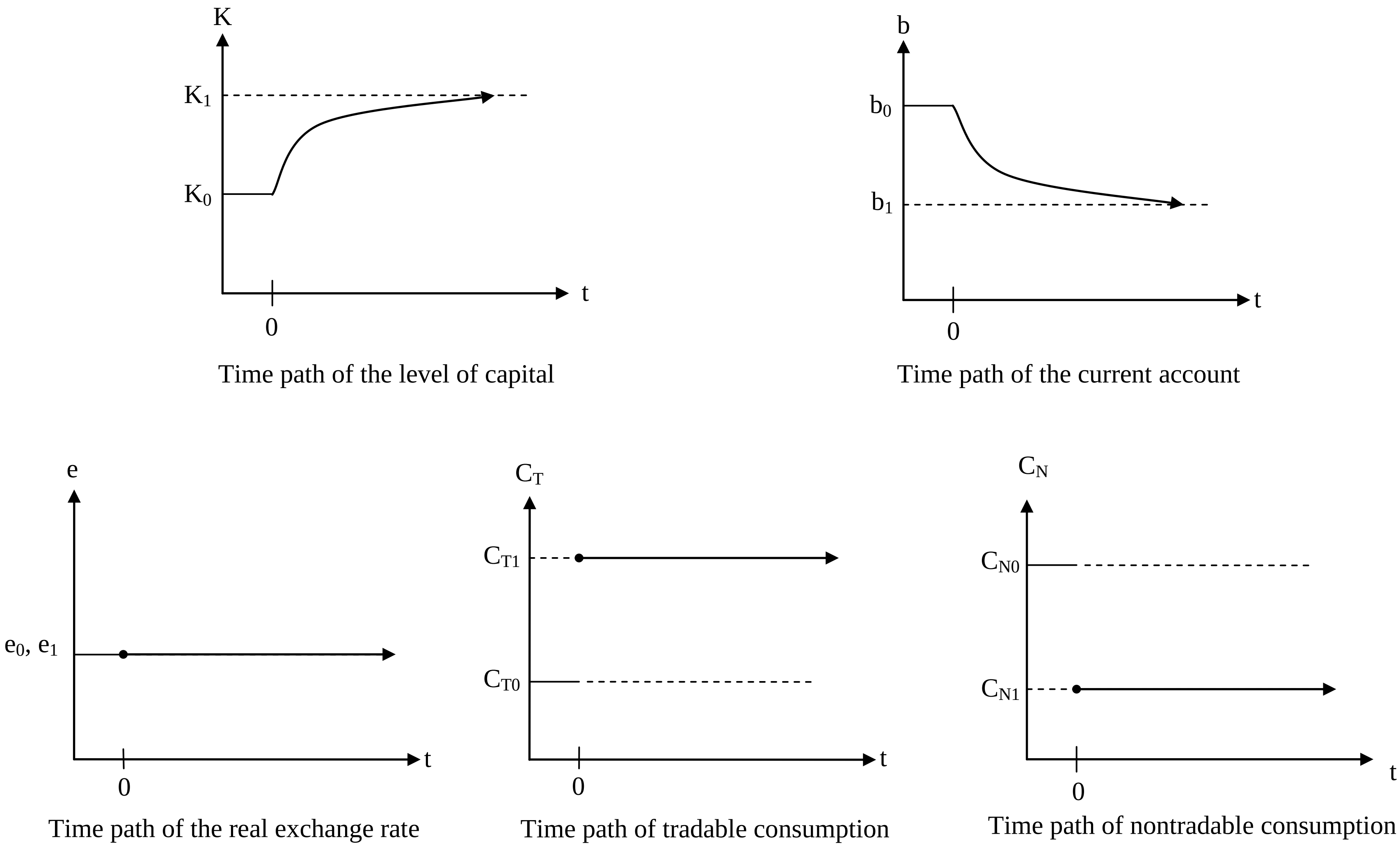


Figure B.6: The effects of higher inflation (CIA on C_N and $K_T > K_N$)

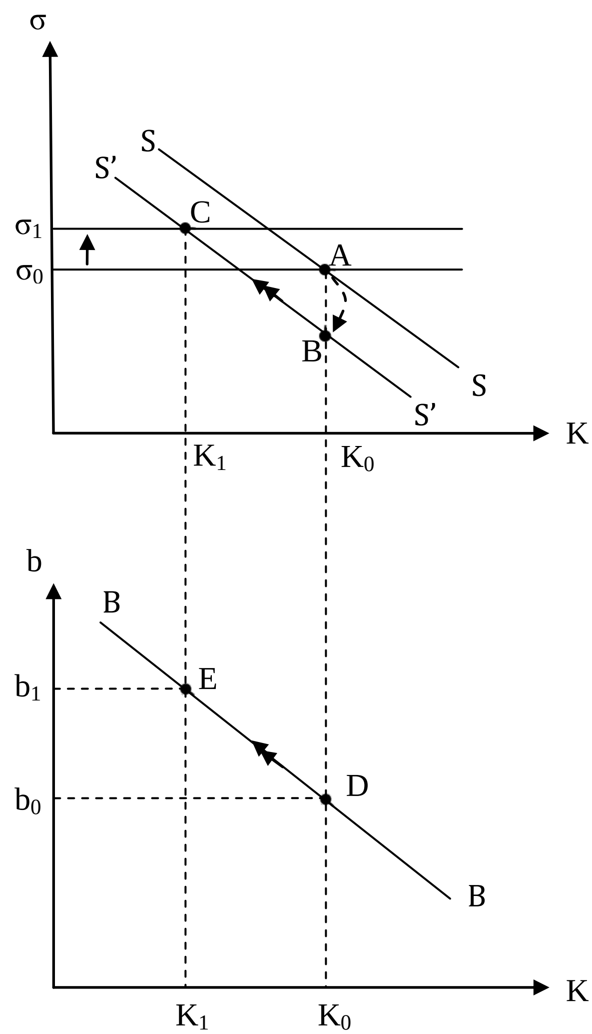


Figure B.7: The phase diagram ($K_N > K_T$)

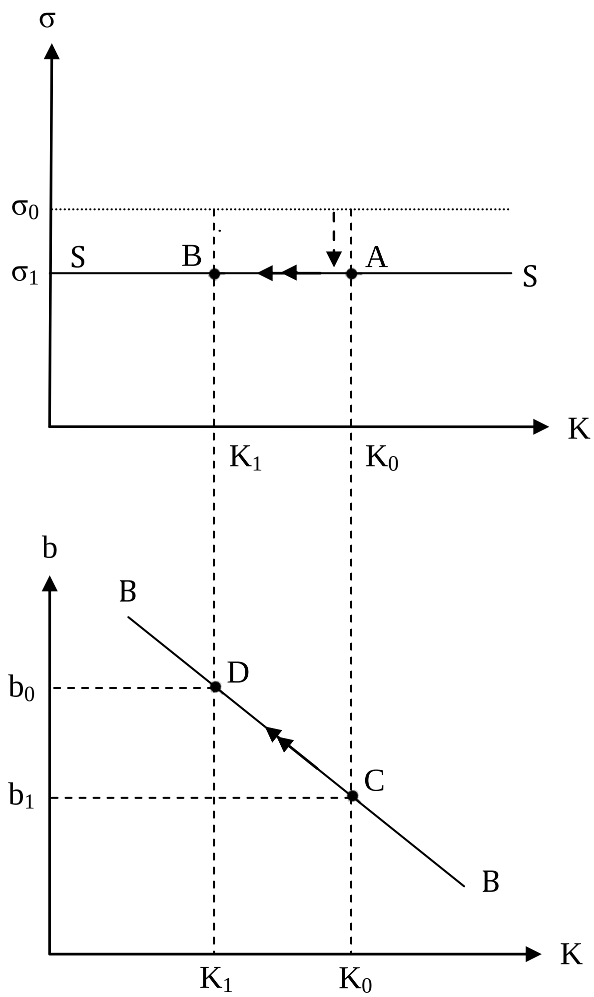
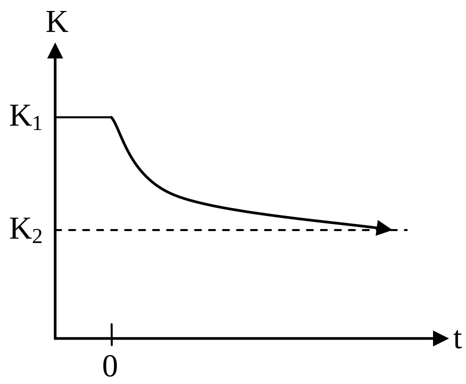
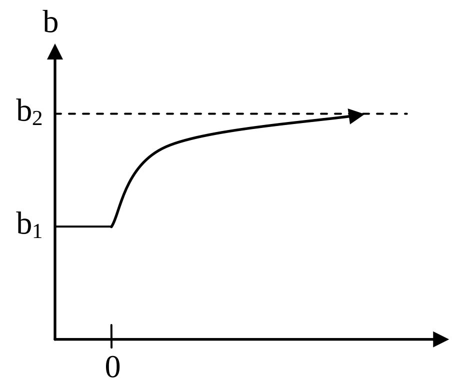


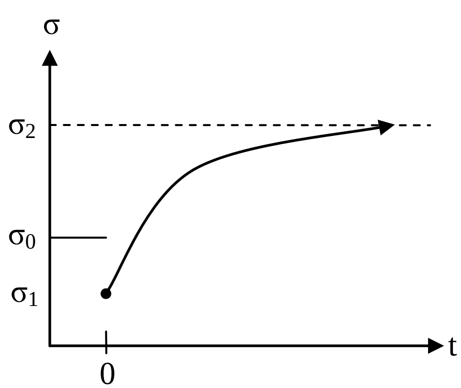
Figure B.8: The phase diagram ($K_T > K_N$)



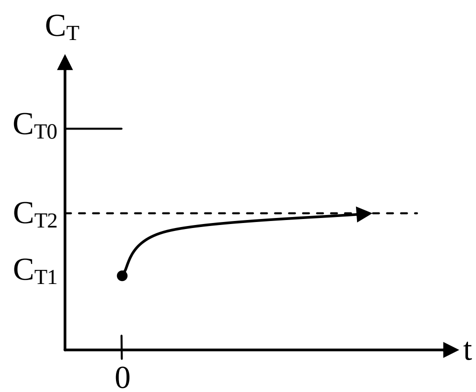
Time path of the level of capital



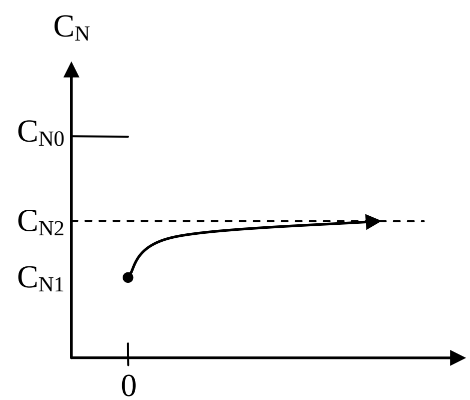
Time path of the current account



Time path of the real exchange rate

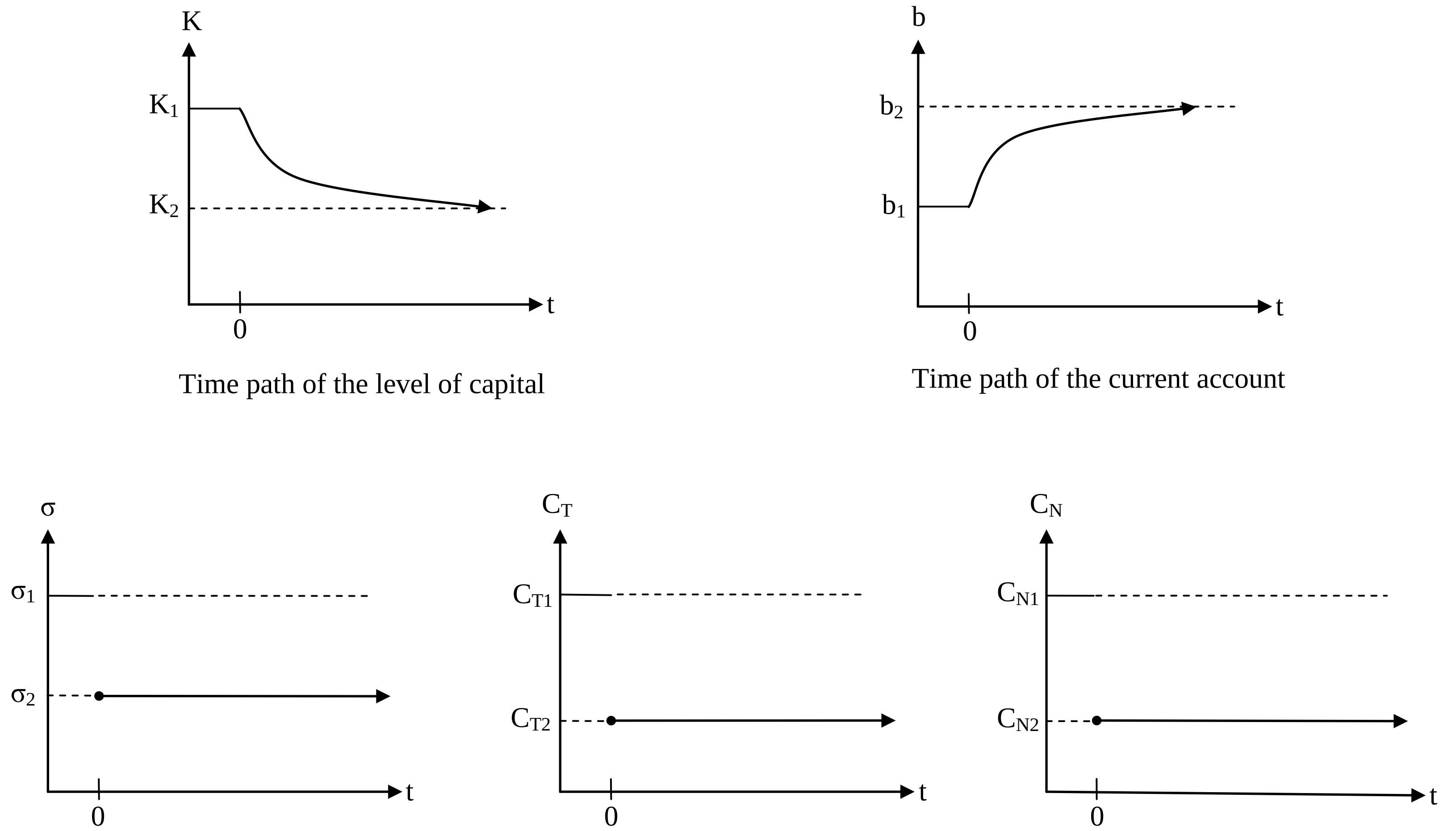


Time path of tradable consumption



Time path of nontradable consumption

Figure B.9: The effects of an increase in oil prices ($K_N > K_T$)



Time path of the level of capital

Time path of the current account

Time path of the real exchange rate

Time path of tradable consumption

Time path of nontradable consumption

Figure B.10: The effects of an increase in oil prices ($K_T > K_N$)

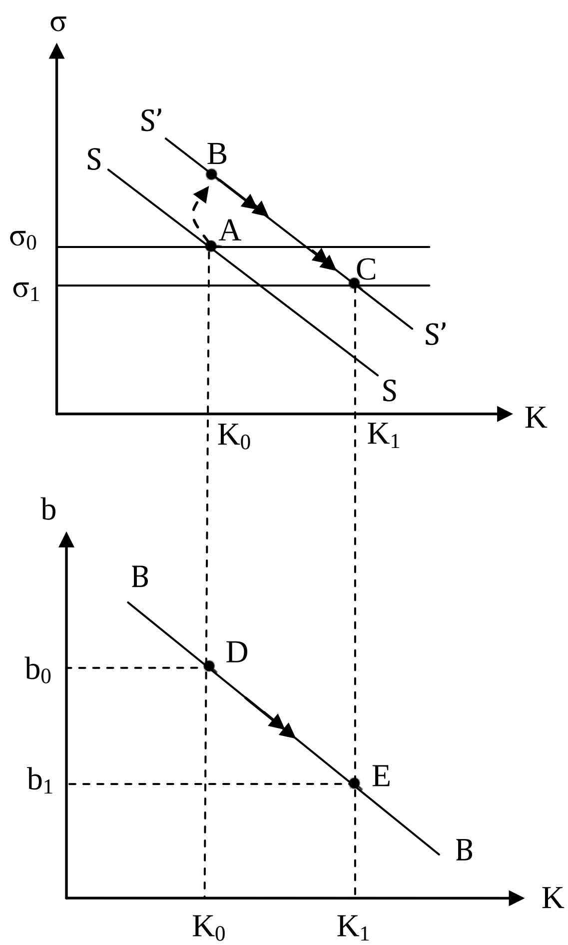


Figure B.11: The phase diagram ($K_N > K_T$)

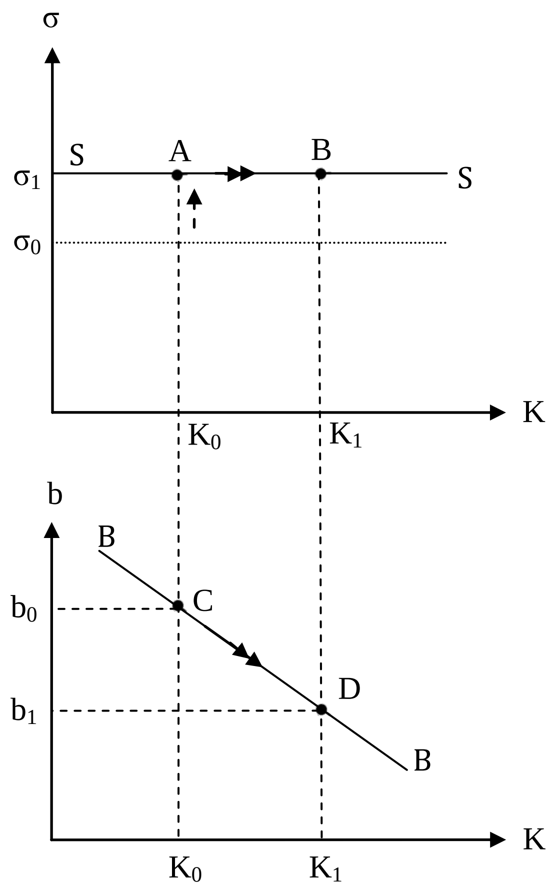


Figure B.12: The phase diagram ($K_T > K_N$)

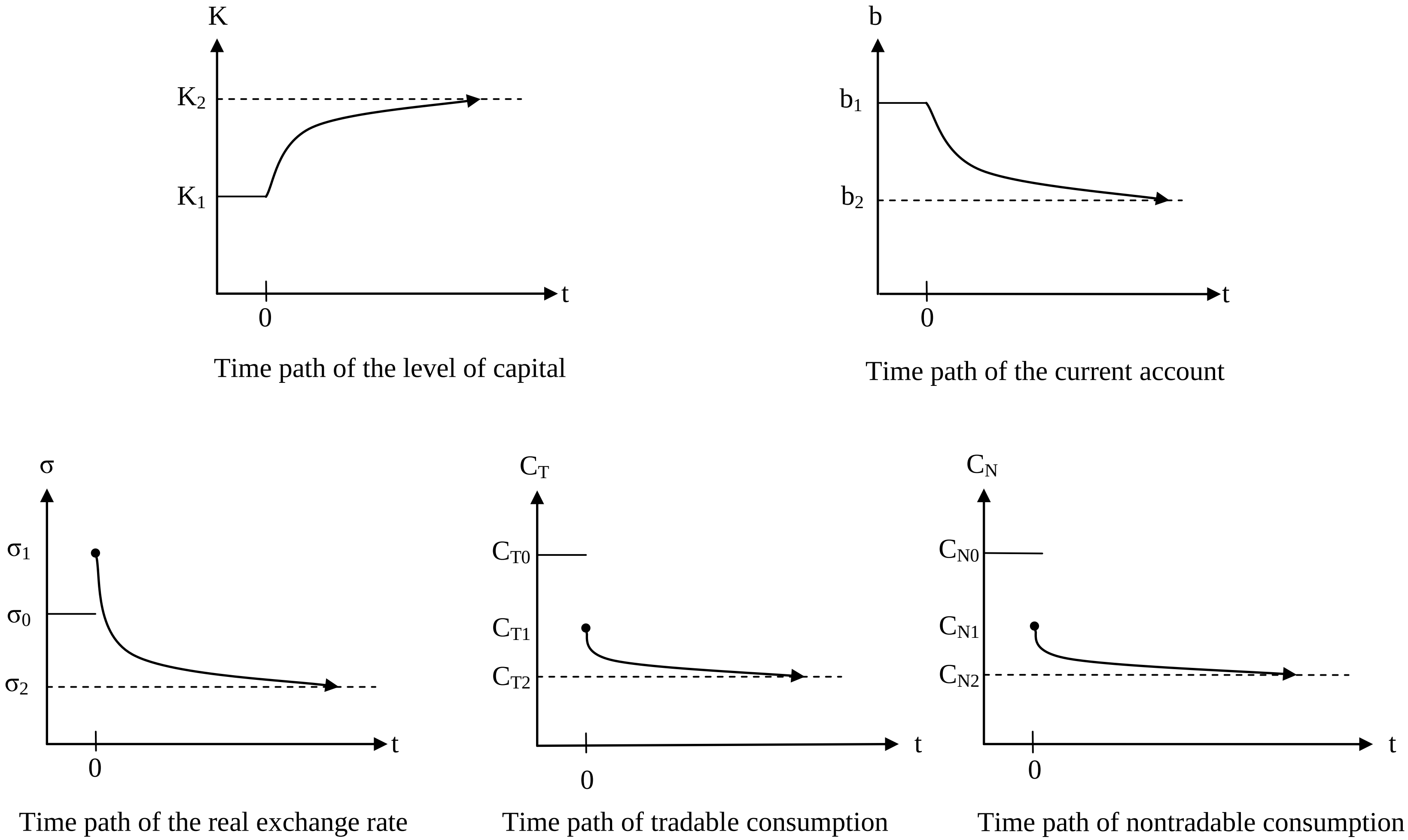


Figure B.13: The effects of an increase in oil prices with a decrease in a world interest rate ($K_N > K_T$)

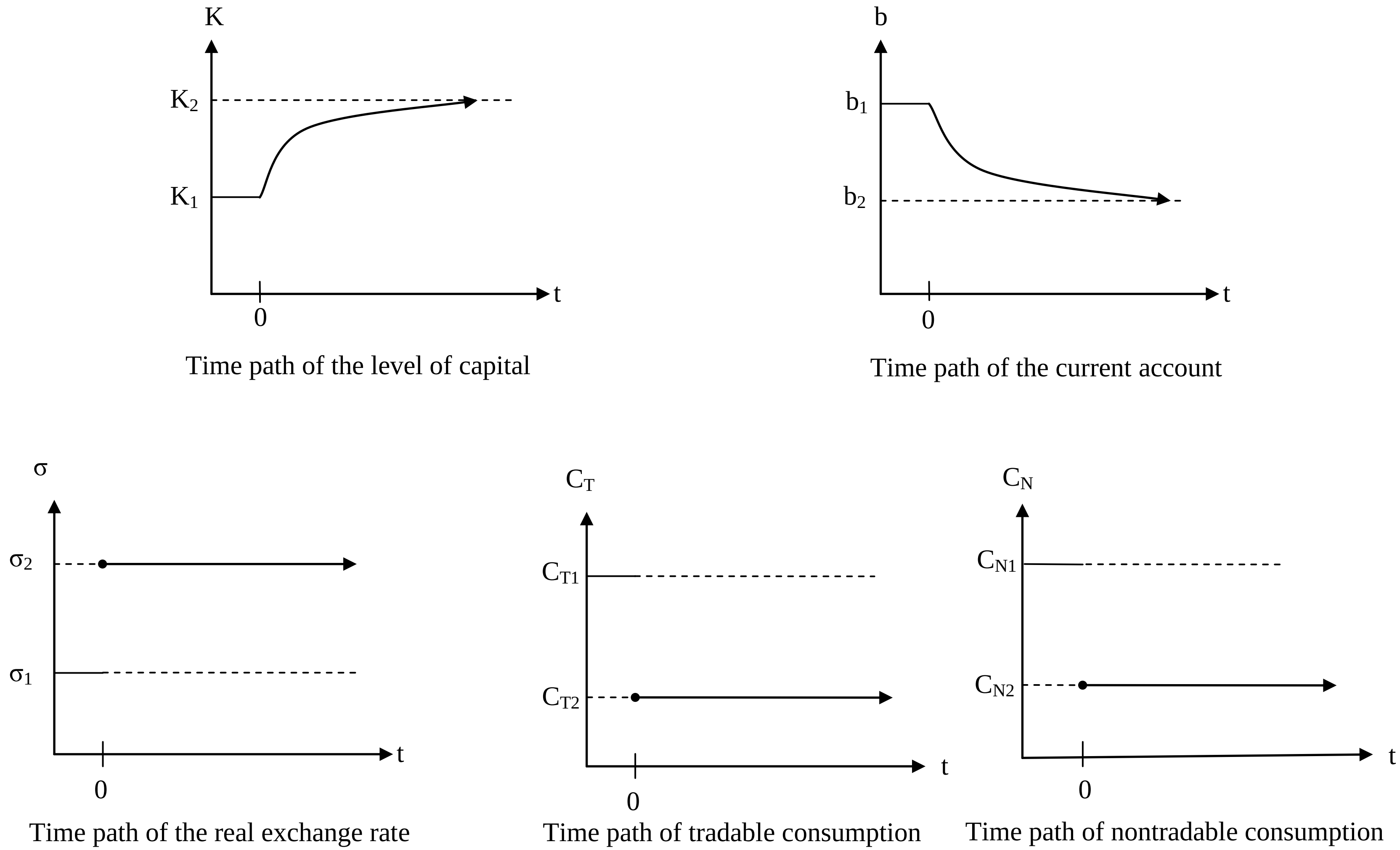


Figure B.14: The effects of an increase in oil prices with a decrease in a world interest rate ($K_T > K_N$)

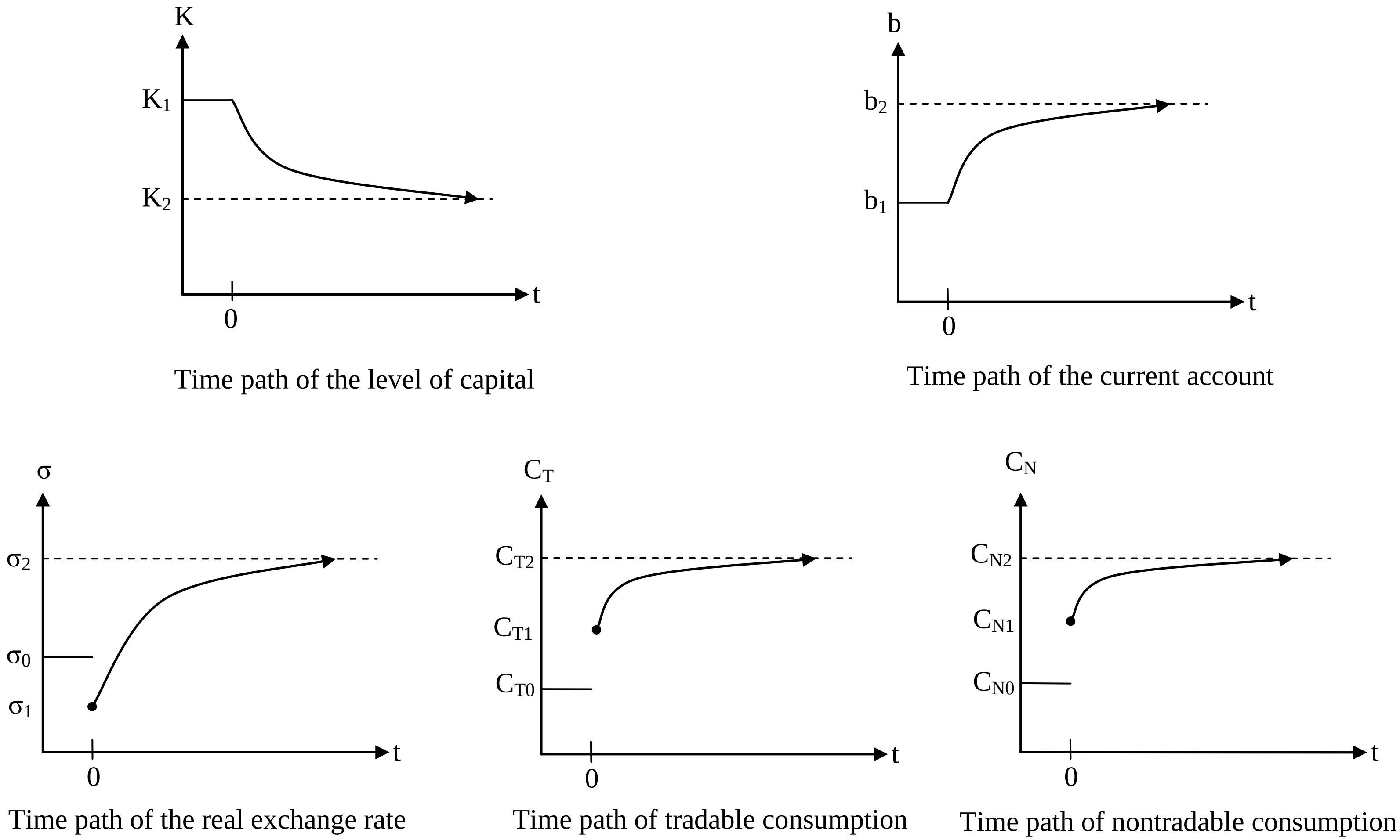


Figure B.15: The effects of a permanent increase in domestic inflation ($K_N > K_T$)

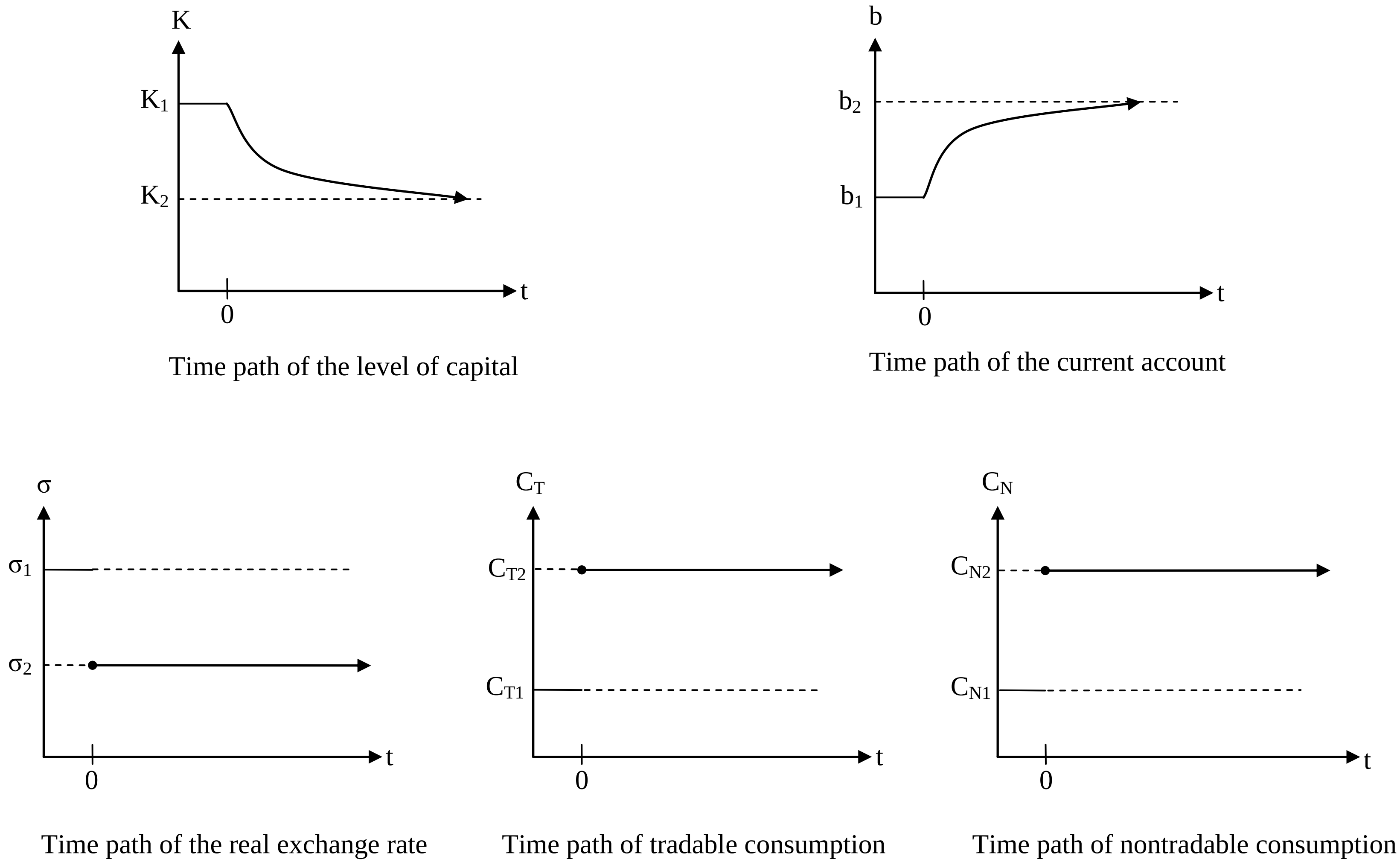
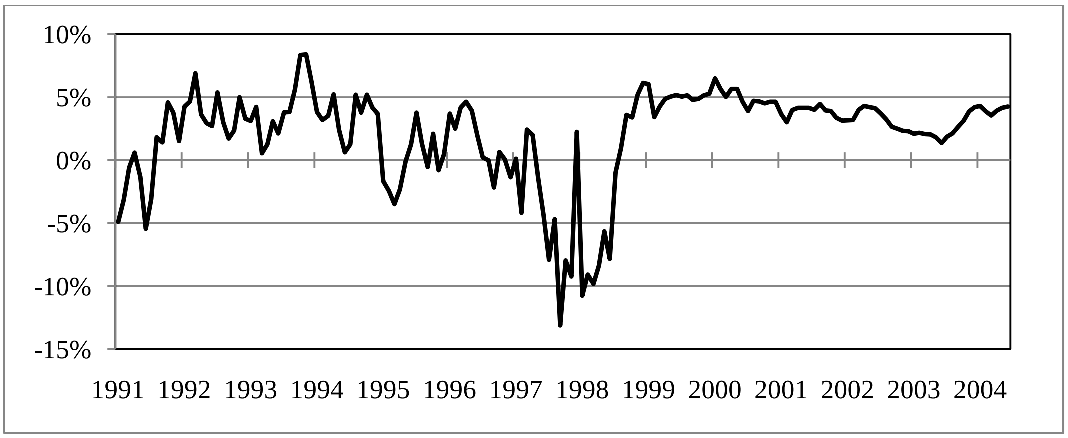


Figure B.16: The effects of a permanent increase in domestic inflation ($K_T > K_N$)

(A) Yield Spread



(B) Probability of Recession (Two-regimes)

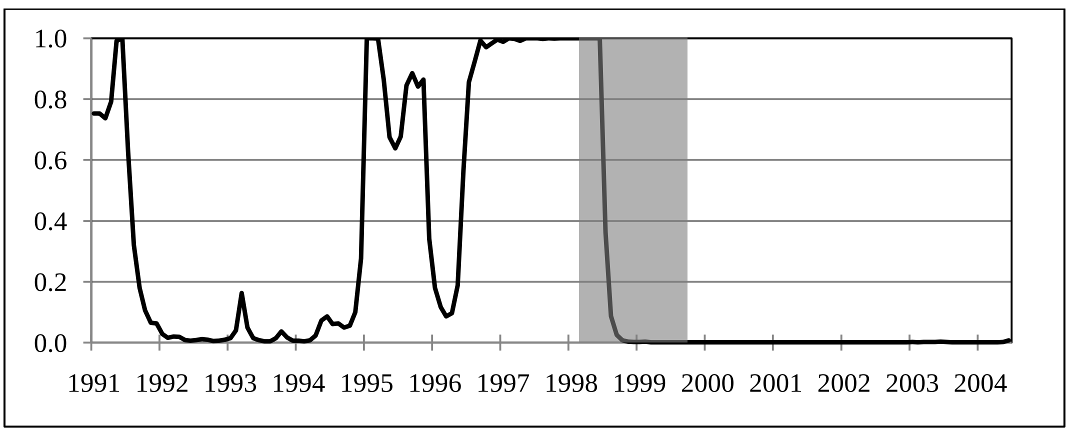
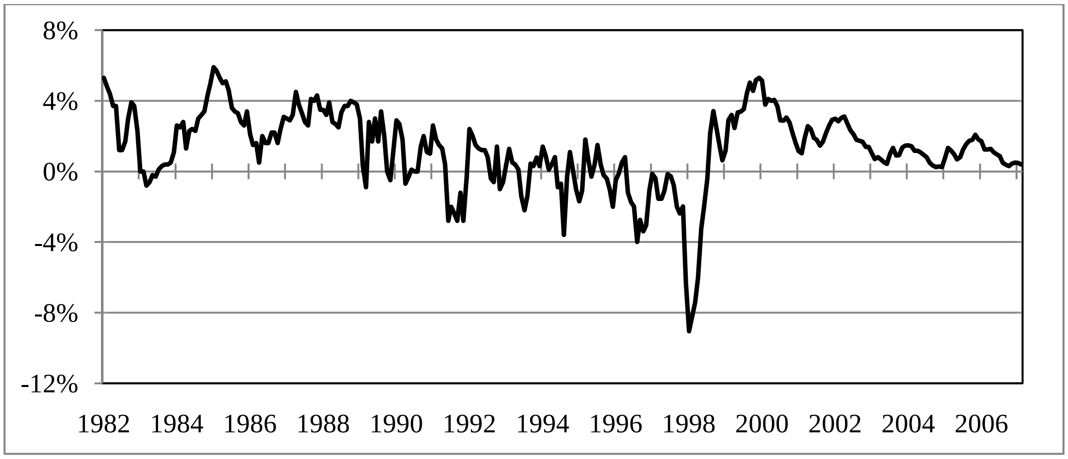


Figure B.17: Yield spread and smoothed probability of recessions (Thailand)

(A) Yield Spread



(B) Probability of Recession (Two-regimes)

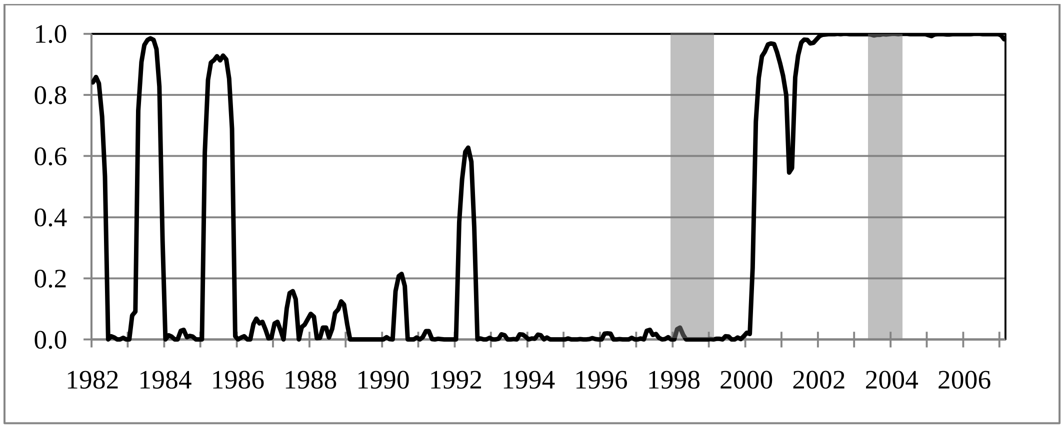
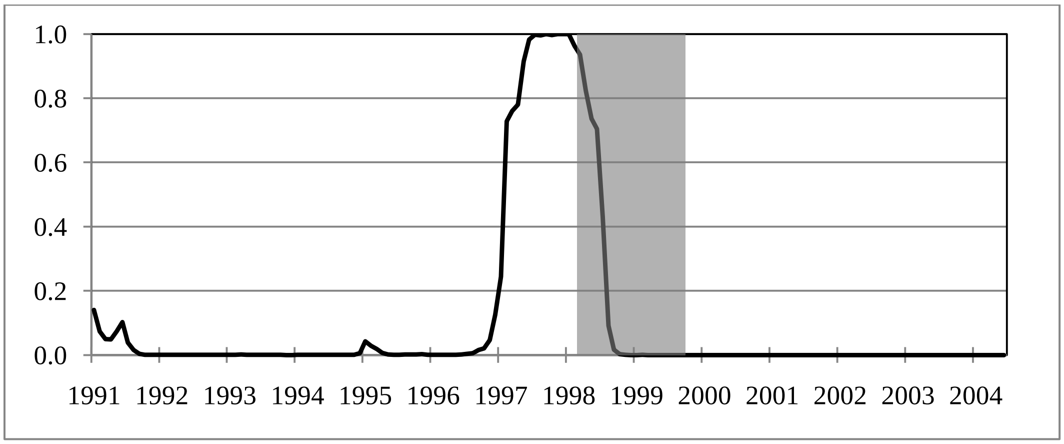


Figure B.18: Yield spread and smoothed probability of recessions (South Korea)

(A) Thailand



(B) South Korea

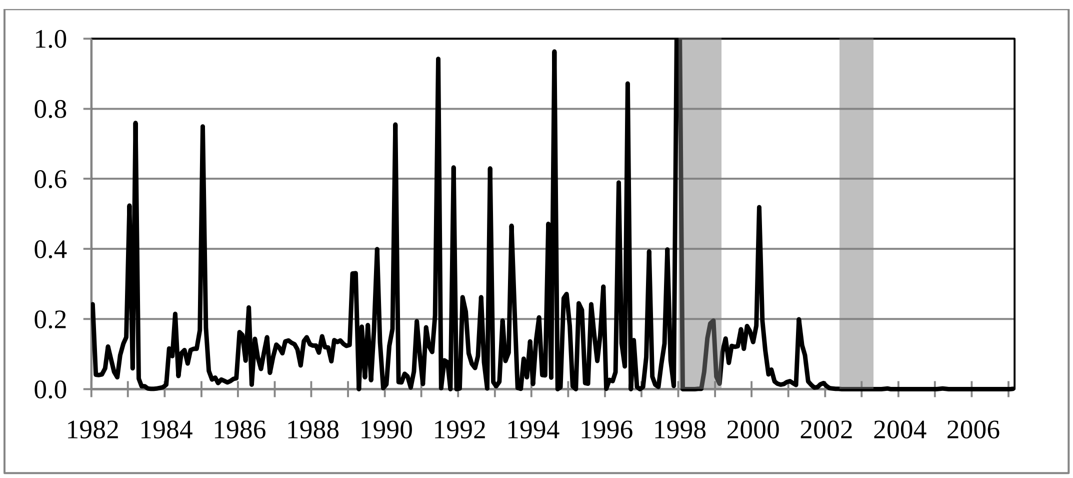


Figure B.19: Smoothed recession probability of three-regimes

$P(R = 1) = F(\alpha + \beta Spread_{t-12})$, 12 months ahead

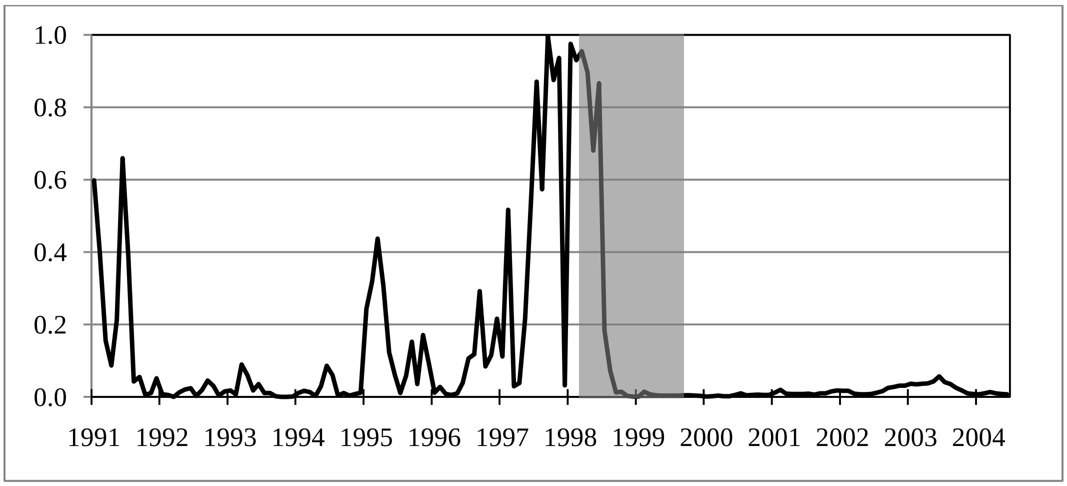
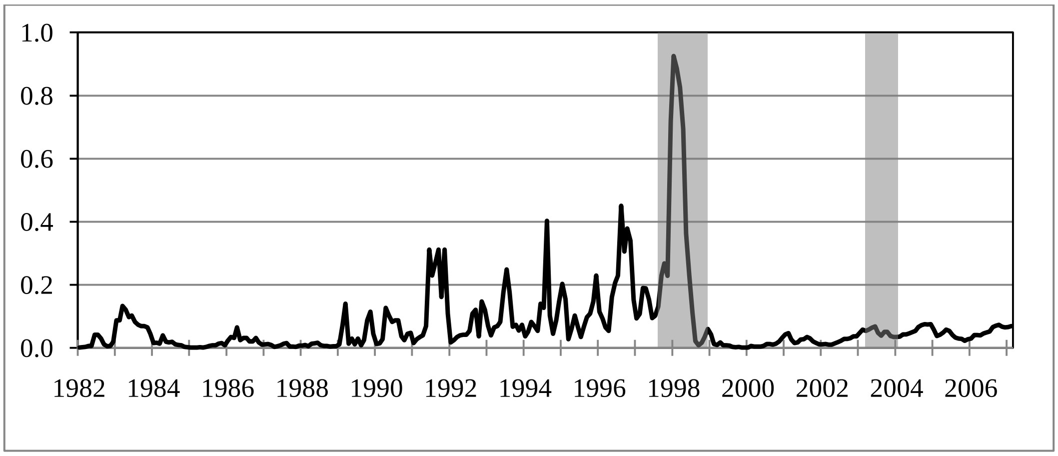


Figure B.20: Probability of recessions from the standard probit model (Thailand)

(A) $P(R = 1) = F(\alpha + \beta Spread_{t-1})$, 1 month ahead



(B) $P(R = 1) = F(\alpha + \beta Spread_{t-6})$, 6 months ahead

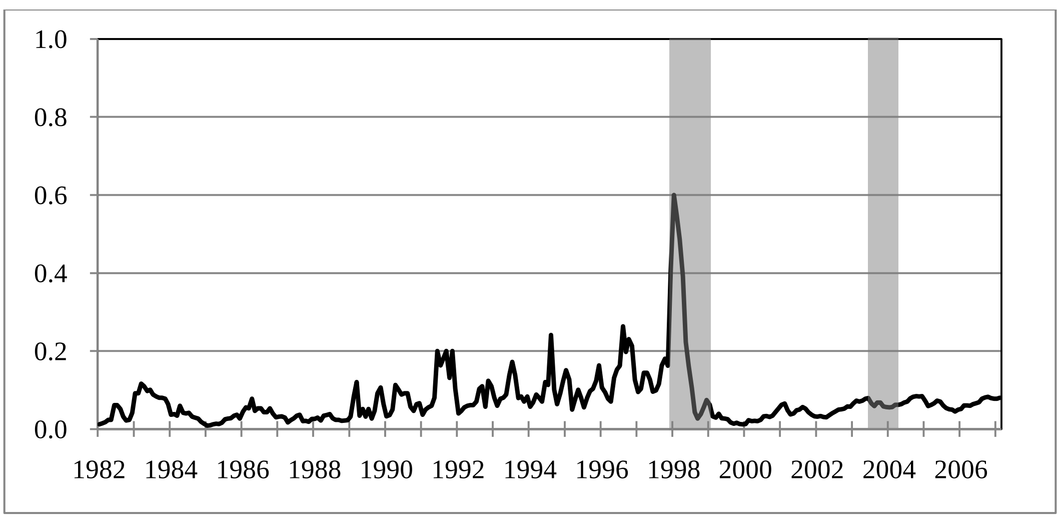


Figure B.21: Probability of recessions from the standard probit model (South Korea)

Vita

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