



The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search

<http://ageconsearch.umn.edu>

aesearch@umn.edu

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

No endorsement of AgEcon Search or its fundraising activities by the author(s) of the following work or their employer(s) is intended or implied.



A Disequilibrium Model of International Capital Mobility

By

Ianchovichina, Elena

McDougall, Robert

Hertel, Thomas

GTAP Working Paper No. 10
2000

A Disequilibrium Model of International Capital Mobility

Elena Ianchovichina, Robert McDougall and Thomas Hertel*

Second Annual Conference on Global Economic Analysis
Denmark[†]

June 20-22, 1999

Abstract

The paper proposes a new disequilibrium approach to modeling international capital mobility for a dynamic multi-region general equilibrium model. Key to this approach are errors in investors' assessments of potential returns to capital – such as those recently observed in Asia. The investment theory, compatible with a simple recursive solution procedure, ensures the convergence of the model towards a stable equilibrium, brings realism into the analysis of international capital mobility and flexibility in tailoring to empirical data. The paper discusses two numerical examples, demonstrating the long-run convergence of the model and the dynamic adjustment to a deeper, longer crisis in Asia.

Key words: International capital mobility, adaptive expectations, East Asian crisis

*Ianchovichina: Assistant Professor, Department of Agricultural Economics, Kansas State University, 342 Waters Hall, Manhattan, KS 66506-4011, USA. McDougall: Deputy Director, Center for Global Trade Analysis, Department of Agricultural Economics, Purdue University, 1145 Krannert Building, IN 47907, USA. Hertel: Professor and Director, Center for Global Trade Analysis, Department of Agricultural Economics, Purdue University, 1145 Krannert Building, IN 47907, USA.

[†]Copyright 1999 by Ianchovichina, McDougall and Hertel. All rights reserved. Readers may make verbatim copies of this document for non-commercial purposes by any means, provided that this copyright notice appears on all such copies.

1 Introduction

The Asian financial crisis, which began in 1997 and which is still playing itself out, resulted in a heightened awareness of the need to understand global economic linkages. Virtually every country in the world has registered concern about the crisis' potential impact on their economy. The range of modeling tools available for the analysis of this economic phenomenon extend from multi-region partial equilibrium models to global macroeconomic models. Multi-region partial equilibrium and single-region general equilibrium trade models, while appropriate for some types of analyses, cannot adequately capture sectoral and regional linkages, respectively. This seriously undermines their capability to model endogenously the effect of economic phenomena on factor markets, and international trade and capital flows, respectively. Static, multi-region general equilibrium models (Hertel and Tsigas, 1997) overcome these limitations. The use of these models for economic analysis has become common practice over the years. More recently, these models have also been used for conducting comparative-static projections, based on shocks to endowments and technology (Arndt *et al.*, 1998). However, these comparative-static models offer little macroeconomic detail, do not produce time path results, and do not distinguish between short-run and longer term outcomes. Therefore, these models are of limited use in studying economic phenomena such as the East Asian crisis. Macroeconomic models, on the other hand, are designed to predict the impact of financial phenomena. These models, however, lack the sectoral and regional detail necessary to study the economy-wide implications of the crisis. Given that the effects of the East Asian crisis would be felt over the course of several years, and that these effects will differ across industries and economies, the study of this type of economic phenomena warrants a dynamic general equilibrium approach.

Despite the fact that a number of dynamic multi-region applied general equilibrium (AGE) models are in use today, only very few of these models incorporate international capital mobility adequately. The GREEN model of Burniaux *et al.* (1992) and Mercenier's intertemporal multi-country, multi-sector model (1995) do not permit international capital mobility. The G-Cubed model of McKibbin and Wilcoxen (1998) overcomes this limitation. Martin and McKibbin (1998) and McKibbin (1998) have recently used this model to study the implications of the East Asian crisis. The model offers both the dynamic macroeconomic features of the MSG2 model by McKibbin and Sachs (1991) and the disaggregated, econometrically-estimated general equilibrium model of the U.S. economy by Jorgenson and Wilcoxen (1990). The rational expectations assumption and the equilibrium nature of the G-Cubed model, however, are inconsistent with the disequilibrium nature of the East Asian crisis, which revealed errors in investors' expectations about the region's economic growth.

This study contributes to the existing literature by offering a new disequilibrium approach to modeling international capital mobility. With this approach instead of changing the data to fit the model, as required in models with rational expectations, the theory of the model accommodates empirical facts as observed in the current world economy. We show that the disequilibrium model developed in this study has good stability properties and converges to a long-run equilibrium. Key to our disequilibrium approach is a new investment theory of adaptive expectations that emphasizes international capital movements and errors in investors'

assessments of potential returns to investment. In addition, this practical approach to modeling international capital mobility permits a simple recursive-solution procedure. This greatly facilitates its use with highly disaggregated models of the world economy.

We test the empirical performance of the model by simulating the dynamic adjustment to a marginally deeper, longer crisis in East Asia. For this purpose, we introduce the new disequilibrium theory of investment into an existing static global AGE model, GTAP (Hertel and Tsigas, 1997). The resulting, dynamic global AGE model uses the new investment theory, while preserving other features of GTAP, among which the sophisticated representation of consumer demands and a supply side that emphasizes the role of inter-sectoral factor mobility in the determination of sectoral output. This model can, therefore, be implemented by adding minimum additional data to the publicly available GTAP data base (McDougall, 1997)

2 The model

A serious limitation of forward-looking intertemporal models in the context of modeling the East Asian crisis, is the assumption of investors' perfect foresight of returns to capital. The developments in East Asia suggest that investors have not foreseen correctly returns to capital. The crisis-affected regions in Asia experienced a severe credit crunch as investors withdrew investment from the region, acknowledging errors in their expectations and adjusting their expectations in a downward direction. In deference to this empirical reality, this paper acknowledges the importance of errors in investors' expectations and introduces a novel investment theory of adaptive expectations.

The introduction of international capital mobility involves explicitly keeping track of regional capital stocks, which accumulate through time giving rise to medium-run growth effects referred to by Baldwin (1989) as accumulation effects. Since the reallocation of capital across regions affects aggregate regional welfare and wealth, to obtain valid welfare results the model keeps track of capital ownership.

Equity in domestic enterprises and equity in enterprises located in foreign regions comprise regional wealth. Over time regional savings, which are a fixed share of income, augment regional wealth. Due to an absence of data on bilateral investment flows, we do not model bilateral equity ownership, instead we assume that regional households invest abroad via a global investment trust. The global trust collects the savings that the regional households have chosen to invest in foreign regions and invests these funds on their behalf. The investment theory determines how the trust allocates funds across regions.

Since regional households earn income, not from the capital stock they harbor, but from the capital stock they own, the model takes into account separately of capital and wealth accumulation by region. The total equity of the domestic economy consists of equity in domestic enterprises owned by domestic investors and equity in domestic enterprises owned by foreign investors.

We assume that each region specializes in its own assets. The composition of regional wealth and domestic capital change as needed to be consistent with the level of regional savings and investment determined elsewhere in the model. We do not distinguish between debt and equity investment. All foreign funds are used for the purchase of physical investment goods, which are then added to the existing stock of physical capital.

2.1 Adjustment costs and regional demand for investment funds

In each region, there is an investment firm owned both by domestic and foreign residents. The firm provides capital to all industries in a region and earns rent on the capital services K it supplies. Domestic and foreign residents invest in the region through the investment firm; i.e., they buy capital goods, I . Following the adjustment cost models of Lucas (1967), Treadway (1969) and Uzawa (1969), we assume that the investment process is associated with waste of some of the purchased investment goods. This waste occurs either during or before installation.

We adopt Uzawa's approach by assuming that the per unit cost of installation is a linear function of investment and depends on the rate of investment I/K . Therefore, regional investment adjustment costs C are:

$$C = \pi^e \frac{\Phi}{2} \left(\frac{I}{K} \right) I, \quad (1)$$

where superscript e denotes expectations; π is the price of capital goods measured in dollars; capital stock K and investment goods I are measured in the same units; and the parameter Φ is a constant with respect to time.

The investment firm maximizes intertemporal profits:

$$\max \int_t^\infty [q^e(s)K(s) - P^e(s)I(s) - \pi^e(s) \frac{\Phi}{2} \left(\frac{I(s)}{K(s)} \right) I(s)] e^{-R_s(s-t)} ds \quad (2)$$

s.t.

$$\dot{K}(t) = I(t) - \delta K(t). \quad (3)$$

The variable q is the rental price of capital in dollar terms, P is the price of raw capital goods, and R is a discount factor. We assume that capital has the same productive characteristics whatever its age. Capital changes according to the rate of fixed capital formation and depreciates at a fixed geometric rate. The discount factor of the objective function is:

$$R_s = \frac{1}{(s-t)} \int_t^s r^e(\nu) d\nu, \quad (4)$$

where r determines the time rate of preference.

The present value Hamiltonian of this problem is:

$$H = [q^e(s)K(s) - P^e(s)I(s) - \pi^e(s) \frac{\Phi}{2} \left(\frac{I(s)}{K(s)} \right) I(s) + \lambda(I(s) - \delta K(s))] e^{R_s(s-t)}, \quad (5)$$

with first-order conditions given as:

$$\frac{\partial H}{\partial I} = \left(-P^e(s) - \pi(s)\Phi\left(\frac{I(s)}{K(s)}\right) + \lambda \right) e^{-R_s(s-t)} = 0, \quad (6)$$

$$-\frac{\partial H}{\partial K} = \frac{d\lambda e^{-R_s(s-t)}}{dt} = -\left(q^e(s) + \pi^e \frac{\Phi}{2} \left(\frac{I(s)}{K(s)} \right)^2 - \lambda \delta \right) e^{-R_s(s-t)}, \quad (7)$$

$$\frac{\partial H}{\partial \lambda} = I(s) - \delta K(s) = \dot{K}(s). \quad (8)$$

Using equation (6), omitting the superscript e and the time index s for convenience, we obtain the following expression for the investment-capital ratio:

$$\frac{I}{K} = \frac{\lambda - P}{\pi\Phi}. \quad (9)$$

When combined, equations (7) and (9) lead to the following equation of motion:

$$\dot{\lambda} - (r + \delta)\lambda = -\left(q + \pi \frac{\Phi}{2} \left(\frac{\lambda - P}{\pi\Phi} \right)^2 \right). \quad (10)$$

Using the first order condition (6), we have for the price of capital λ :

$$\lambda = P + \pi\Phi \frac{I}{K}. \quad (11)$$

Under myopic expectations of the investment firm about the price of capital (i.e., $\dot{\lambda} = 0$), equations (10) and (11) lead to the following expression for the gross rate of return:¹

$$r + \delta = \frac{q + .5\Phi\pi(I/K)^2}{P + \Phi\pi I/K}. \quad (12)$$

The numerator of (12) is capital earnings in the presence of adjustment costs. In addition to the rental rate earned by installed capital, there is a marginal benefit due to a decline in adjustment costs as a result of installing one more unit of capital. However, the rate of return expression excludes capital gains.

Equation (12) represents the demand for investment funds. The proportionate change (denoted with a “hat”: $\hat{\cdot}$) form of the demand for investment funds is:

$$\widehat{r + \delta} = A(\hat{q} - \hat{P}) - \alpha \hat{I}/K, \quad (13)$$

where $A = 1/(1 + .5\Phi\pi(I/K)^2) \leq 1$. In the special case where $A = 1$, there are no adjustment costs ($\Phi = 0$). More generally, A is a function of the investment-capital ratio and adjustment costs, and α is the elasticity of the rate of return with respect to the investment-capital ratio.

It can be shown that adjustment costs alone cannot satisfactorily determine capital allocation in a multi-region model (Ianchovichina, 1998). A theory specifying the supply of investment funds is required. Next, we propose such an investment theory of adaptive expectations.

¹The theory implies the equality between the time rate of preference and the net rate of return to capital.

2.2 Adaptive expectations and regional supply of investment funds

In each region there is a target (gross) rate of return R_t . We define the target rate of return as the global rate of return, which clears the market for global investment funds, adjusted by a region-specific risk premium.² Investment supplied to each region is such as to achieve some required rate of growth $\Gamma \stackrel{\text{def}}{=} \dot{R}/R$ in the rate of return:

$$d\Gamma = \Lambda(\hat{R}_t - \hat{R}_e), \quad (14)$$

where Λ is a parameter determining the speed of adjustment in the expected rate of return towards the target rate and R_e is the expected rate of return.³ Since investors typically expect to derive returns over some considerable period of time, they are concerned not only with the rate of return at the moment of investing funds, but also with the rate of return through the life of the asset. Therefore, it is the expected return in future periods, R_e , not the actual return to which investors respond.

The rate of return and capital stock in a region are related via the actual investment schedule (A) shown in Figure 1:

$$\frac{R_a}{R_f} = \left[\frac{K}{K_f} \right]^{-\phi}, \quad (15)$$

Differentiation of this equation with respect to time determines the actual rate of growth in the rate of return Γ_a ($\stackrel{\text{def}}{=} \dot{R}_a/R_a$). The pairs of reference capital and (gross) rate of return (K_f , R_f) and actual capital and rate of return (K , R_a) determine the position of and along the actual schedule (A), respectively. The elasticity of schedule (A), ϕ , determines the response of the actual rate of return to changes in the capital stock.

To determine the regional composition of investment, we impose equality between the actual and required rates of growth in the rate of return. Thus, Γ varies inversely with the actual rate of growth in the capital stock and directly with the normal rate of growth in the capital stock Ω :

$$d\Gamma = -\phi \left(\frac{I}{K} \left(\frac{\hat{I}}{\hat{K}} \right) - d\Omega \right), \quad (16)$$

The normal rate of growth in the capital stock is this rate of growth in the capital stock that allows the rate of return to remain constant through time. If there is a discrepancy between the estimated and the normal rate of growth in capital stock, Ω will change as specified by the following equation:

$$d\Omega = \eta \left(\hat{K} + \frac{\hat{R}_a}{\phi} - \Omega dt \right). \quad (17)$$

This relationship is such that the normal rate of return adjusts towards the estimated rate of growth in capital stock $\hat{K} + \hat{R}_a/\phi$ at a speed determined by the parameter η .

²In the absence of risk premia, the target rate is uniform across regions.

³The operators d and $\hat{\cdot}$ denote a change and a proportionate change, respectively.

Investors' expectations are "sticky" or "sluggish." When the observed rate of return changes, investors are unsure whether this change is transient or permanent. They adjust their expectations of future rates of return only with a lag. At first investors make a small adjustment, then if the change in the actual rate persists, they make further changes in expectations, until eventually the expected rate conforms to the observed rate:⁴

$$\hat{R}_e = -\phi(\hat{K} - \Omega dt) - \mu \log \frac{R_e}{R_a} dt. \quad (18)$$

We derive equation (18) by proportionately differentiating the expected investment schedule (E). This schedule, analogously to the actual one (A), described in mathematical form by (15), has the following form:

$$\frac{R_e}{R_f^e} = \left[\frac{K}{K_f^e} \right]^{-\phi} \quad (19)$$

Figure 1 shows that the actual and expected investment schedules differ reflecting the errors in investors' expectation. The pairs of expected reference capital stock and rate of return (K_f^e, R_f^e) , and capital stock and expected rate of return (K, R_e) determine the position of and along the expected schedule (E).⁵ To allow expectations to adjust and the expected schedule to move towards the actual one, changes in K_f^e depend on changes in Ω and the error in expectations measured by the deviation of R_e from R_a . Equivalently, the error in expectation reflects the deviation K_w , the capital stock consistent with the observed rate of return R_a , the capital stock K , and the expected rate of return R_e , from the observed capital stock K .

Equations (14), (16), (17) and (18) comprise the investment theory of adaptive expectation and determine regional supply of investment funds. These equations, together with equation (13), determine regional investment in the dynamic multi-region model.

2.3 Stability conditions and dynamic properties

This section studies the dynamic properties of the proposed model and characterizes its equilibrium. We show that the model with adaptive expectations moves towards an equilibrium defined by the same conditions as those for the problem of the investment firm (equations (2) and (3) in section 2.1). We show also that, when achieved, this equilibrium is stable.

2.3.1 Stability conditions

Equation (10), which we derived from the first order conditions of the problem of the investment firm, can be rewritten also as:

$$\dot{\lambda} + \frac{\lambda^2}{2\pi\Phi} - \left(r + \delta + \frac{P}{\pi\Phi} \right) \lambda + q + \frac{P^2}{2\pi\Phi} = 0. \quad (20)$$

We rewrite this equation, known as a 'Riccati' equation, as:

$$\frac{d\lambda}{dt} + a\lambda^2 + b\lambda + c = 0, \quad (21)$$

where $a = 1/(2\pi\Phi)$, $b = -(r + \delta + P/(\pi\Phi))$ and $c = q + P^2/(2\pi\Phi)$. The 'Riccati' equation can be solved by reducing it to a second order homogeneous differential equation via the transformation $u = e^{\int \lambda dt}$ (Green, 1984):

$$\frac{d^2 u}{dt^2} + b \frac{du}{dt} + ac u = 0, \quad (22)$$

The following formula specifies the transformation that allows us to retrieve λ , once we obtain a solution to equation (22):

$$\lambda = \left(\frac{1}{au} \right) \frac{du}{dt}. \quad (23)$$

We find the solution to (22) by solving the following equation:

$$m^2 + b m + ac = 0. \quad (24)$$

Depending on the roots of this equation, different solutions to the 'Riccati' equation are obtained. We show that only the case of a zero discriminant leads to a feasible (sustainable) solution under the basic economic assumptions. In this case the price of capital λ depends only on prices, and under myopic expectations of the investment firm about prices, required by the iterative solution procedure, is constant through time.

Thus, in equilibrium, the following system of equations of motion is satisfied:

$$\dot{\lambda} = 0, \quad (25)$$

$$I/\dot{K} = 0. \quad (26)$$

Using the first order conditions (6), (7) and (8), we obtain the following equations of motion:

$$\dot{\lambda} = (r + \delta)\lambda - q - \pi \frac{\Phi}{2} \left(\frac{I}{K} \right)^2, \quad (27)$$

$$\dot{v} = \frac{1}{\pi\Phi} \left((r + \delta)\lambda - q - \pi \frac{\Phi}{2} v^2 \right), \quad (28)$$

where v denotes the investment-capital ratio I/K . To characterize the equilibrium, we linearize the system of equations (27) and (28) in the neighborhood of the steady-state equilibrium (λ^s, v^s) :

$$\dot{\lambda} = -\pi\Phi v^s(v - v^s) + (r + \delta)(\lambda - \lambda^s), \quad (29)$$

$$\dot{v} = -v^s(v - v^s) + \frac{r + \delta}{\pi\Phi}(\lambda - \lambda^s). \quad (30)$$

The characteristic equation associated with the system of equations (29) and (30) is:

$$\det \begin{vmatrix} -v^s - x & \frac{r + \delta}{\pi\Phi} \\ -\pi\Phi v^s & r + \delta - x \end{vmatrix} = 0,$$

or also

$$x(x + v^s - r - \delta) = 0. \quad (31)$$

⁴Ianchovichina (1998) provides complete derivations of these equations.

⁵We assume that investors are able to correctly predict capital stocks, but not rates of return.

The roots of this equation are $x_1 = 0$ and $x_2 = r + \delta - v^s$. In this case, the solution $(v(t), \lambda(t))$ moves away from the equilibrium unless $v(0) = v^s$ and $\lambda(0) = \lambda^s$.⁶ Thus, unless the initial state is the steady state, which typically is not the case in empirical situations, the problem of the investment firm leads to an unstable solution. The next section discusses how adaptive expectations help in resolving this problem.

2.3.2 Dynamic properties of the model

This section shows how adaptive expectations can gradually move the model from the disequilibrium in the initial year towards the steady-state equilibrium, defined by conditions (25) and (26). Once achieved, we show that this equilibrium is a stable one. We start with an illustration of the adjustment process. Next we discuss the equilibrium conditions in the model.

Suppose that in the initial period, in a given region, the actual rate of return R_a is above the target rate R_t and the expected rate R_e , as shown on Figure 1. When investors recognize the difference between expected and actual rates of return, the expected rate of return R_e will increase via equation (18). There is an upward movement along the expected investment schedule (E) and a decline in the level of capital stock. This movement is accompanied by a shift in the expected investment schedule (E) towards the actual one (A). The magnitude of the shift is determined by the normal rate of growth in the capital stock Ω and the discrepancy of the expected and actual rates of return. Simultaneously, equation (14) suggests that there will be a negative change in the required rate of growth in the rate of return Γ . Via equation (16), this implies an increase in investment in the region and a decline in R_a towards the target rate R_t . The normal rate of return to capital continues to be positive, but declines at a decreasing rate as the movement of the expected schedule (19) towards the actual one (15) slows down over time.

As R_e converges onto R_a and R_a converges onto R_t , the expected investment schedule (E) overlaps with the actual schedule (A). This requires not only R_a to equal R_e , but also the normal rate of growth in capital stock Ω to equal the actual rate of growth in capital \dot{K} . If this is not the case, schedule (E) will overshoot (A), and only after some time it will start moving back. This type of oscillating behavior will extend the process of convergence.

The equilibrium in our model is characterized by equality between the constant in equilibrium expected, actual and target rates of return and constant normal rate of growth in the capital stock:

$$R_e = R_t = R_a, \quad (32)$$

$$\dot{\Omega} = 0, \Omega = 0 \quad (33)$$

$$\dot{R}_e = \dot{R}_t = \dot{R}_a = 0. \quad (34)$$

These conditions in turn imply:

$$d\Gamma = 0, \quad (35)$$

$$w = 0, \quad (36)$$

⁶Kamien and Schwartz (1981) provide further detail on this topic.

Using equations (35), (36) and (16), we obtain the following equilibrium condition:

$$\frac{\dot{I}}{K} = 0. \quad (37)$$

Assuming myopic expectations of the investment firm about the price of capital, we obtain:

$$\dot{\lambda} = 0. \quad (38)$$

It can be shown that these conditions in turn imply constant investment-capital ratio: $(I/K)^s = \delta + \Omega^s$, where $\Omega^s = 0$. To determine whether Ω^s is zero in the steady-state, we consider equations (34) and (17). These equations imply that $\dot{K}/K = \Omega$ or that the normal rate of growth in the capital stock equals the actual rate of growth in the capital stock. Let us assume for a moment that Ω^s is constant and positive in value. This implies that in the steady state all factors except capital are fixed. This, in turn, implies that capital is growing at a higher rate than income and the depreciation-to-income ratio is rising. Since we have assumed a fixed propensity to save, the savings-to-income ratio is fixed. Net investment, which is determined by savings, is therefore also a fixed share of income. This suggests that the net investment-to-income ratio is declining, or in other words that the normal rate of growth in capital stock is declining over time. This, however, contradicts our assumption of constant and non-zero normal rate of growth in the steady-state. Thus, Ω^s must equal 0.

Conditions (37) and (38), characterizing the equilibrium of the model are exactly the same as conditions (25) and (26), characterizing the equilibrium solution to the problem of the investment firm. The mechanism of adaptive expectations ensures that the model moves towards this equilibrium. Section 2.3.1 shows that this equilibrium is stable only when the model happens to be already in equilibrium. This implies that once the model reaches this equilibrium, it will remain there. Typically the initial data do not represent the equilibrium state of the model. Therefore, the mechanism of adaptive expectations introduces not only realism in investors' behavior, but also ensures the transition to a steady-state equilibrium ($\Omega^s = 0$ and $(I/K)^s = \delta$) in the long-run.

We test the long run properties of the model over a hundred year period. We use a three-region aggregation of version 3 GTAP data base (McDougall, 1997) featuring the United States (USA), the European Union (E.U) and all other regions aggregated into a rest-of-world region (ROW). Using the GEMPACK suite of programs (Pearson, 1991), we solve the model in an iterative fashion. The solution consists of a sequence of results representing yearly percentage changes in variables. We use these to construct time profiles of variables. The simulation represents the changes in the three economies occurring solely due to the passage of time. It depicts the movement from the initial disequilibrium data (1992) towards a long-run equilibrium (2091). For simplicity, we assume zero regional risk premia and zero adjustment costs.

Figures 2 and 3 show the convergence of the regional rates of return R_a towards the target rate R_t , and the elimination of errors in expectations $\log(R_e/R_a)$ over time, respectively. Figure 4 displays the normal rate of growth in the capital stock Ω in its movement towards 0 over the long-run, while figure 5 demonstrates the process of adjustment towards constant

investment-capital ratios. The three figures suggest that stability conditions (32), (33), and (34) are satisfied over time.

The initial data (1992) reveal regional differences in rates of return, R_a (Figure 2), normal rates of growth in capital Ω (Figure 4), investment-capital ratios I/K (Figure 5), as well as sizable errors in expectations $\log(R_e/R_a)$ (Figure 3). In short, the benchmark data base depicts a world in disequilibrium.

Figure 3 suggests that in 1992 investors underestimated returns to capital in the United States and the rest of the world and overestimated returns to capital in the European Union. As investors realize their errors in predicting these returns, they adjust their expectations in an upward direction in the case of the United States and the rest-of-world region, and in a downward direction in the case of the European Union (via equation (18)). As a result, investment in the United States and the rest of the world increases, while investment in the European Union declines (via equations (14) and (16)). It takes approximately 12 years for the model to eliminate errors in expectations and inter-regional differences in rates of return (equilibrium condition (32)). However, since the remaining two equilibrium conditions (33) and (34) are not satisfied in 2004, this is only a temporary equilibrium. Positive and nonconstant Ω (Figure 4) implies that the expected investment schedule (E) will overshoot the actual one (A), and over time will start moving back. We observe this type of oscillating behavior on Figures 2, 3, 4, and 5 around 2004. Only after further reduction in Ω via equation (17), leading to a reduction in the investment-capital ratio I/K via equation (16), the model will permanently eliminate errors in expectations and inter-regional differences in rates of return.

3 Empirical performance: economic crisis in East Asia

The model developed in section 2.2 is also an ideal framework allowing us to study the dynamics of adjustment, sectoral and welfare implications of the East Asian crisis. This section discusses an illustrative numerical example depicting the dynamics of adjustment with this model to a marginally deeper, longer crisis in East Asia. Sectoral and welfare results are available for this application in Ianchovichina *et al.* (1999). However, we do not present these here as they do not pertain to the main focus of the paper, the investment theory of the model.

Our baseline simulation, based on a macroeconomic scenario of the World Bank (1998), portrays the recent Asian crisis and captures the rise in unemployment; the impairment of regional capital markets; the sharp increase in trade balances in East Asia 5 (Korea, Indonesia, Malaysia, Philippines, and Thailand) and Japan accompanying the crisis; the high expectations of potential returns in East Asia before 1997, and the subsequent drop in expectation as investors realign their expectations with the actual returns in the region (*e.g.*, Figure 6). We then compare this baseline to an alternative simulation of a longer, deeper Asian crisis resulting in a percentage point lower annual GDP growth rates in East Asia 5 than the baseline. The crisis is deeper due to further impairment of regional capital markets, a larger decline in employment, and a continued decline in investment in the East Asia 5 relative to the baseline over the near term (1999). The crisis is longer due to slower employment recovery and subsequent lower

factor productivity in the five East Asian economies relative to the baseline over the longer term (2010).

The deepening of the crisis translates into an immediate decline in the region's actual rate of return R_a in 1998 (Table 1). This signals a slowdown in the economy captured by a negative change in the estimated rate of growth in capital $\widehat{K} + \widehat{R}_a/\phi$, leading to a drop in the normal rate of growth in capital Ω via equation (17), and thereby a decline in investment I via equation (16). Since investors' expectations are sticky and adjust only slowly to changes in the economy, the expected rate of return R_e does not decline in this first period of the deeper, longer crisis. By 2001, investors have realized that the crisis is deeper and longer. They have adjusted their expectations in a downward direction via equation (18). The lower expected rate of return and the further decline in the estimated rate of growth in capital, result in a sharp annual decline in investment of 6.67 percentage points from their baseline levels via equations (18), (17), (14) and (16). Consequently, equation (3) translates this decline into an annual decline of 0.66 percentage points in the capital stock K . The decline in investment and capital is deep enough to result in an increasing rate of return between 2001 and 2004 (Figure 7). This, in turn, implies slower decline in investment. Thus, after the initial sharp cumulative decline over the period 1998-2002, investment in East Asia 5 resumes in 2002 resulting in a smaller cumulative decline in investment after 2003. Lower productivity for the period 2001-2010, however, implies that gross investment in the region is going to remain below its the baseline levels throughout the simulation period. Indeed, after 2004, we observe larger cumulative decline in investment in Thailand.

By 2010, the normal rate of growth in the capital stock has reduced substantially and the expected rate of return has adjusted towards the actual one. The deeper, longer crisis affects negatively rates of return to capital in Korea in the longer term (2010). Figure 7 suggests that the crisis leads to a cumulative decline in actual rates of return in Thailand and the other four East Asian economies of slightly less than one percentage point relative to the baseline by 2010. Consequently, investment in Thailand slows down, and by 2010 it is 17% lower relative to the base case. Via the capital accumulation equation (3), the decline in investment has a significant impact on capital stocks in East Asia. By 2010, figure 7 shows a cumulative reduction of capital in Thailand of around 9 percentage points relative to the baseline.

Over the course of the simulation period ending in 2010, capital inflows in East Asia and Japan are around US\$188 billion (in 1992 prices) lower than the base case. This leaves more capital to accumulate in other regions⁷ driving down the world rate of return and rates of return in all regions other than East Asia 5 and Japan by about .2 percentage points from their baseline levels in 2010.

⁷Business Week (1999) reports that despite the decline of portfolio investments in Latin America due to the spillover effects of the crisis and the perception of high risks in these markets, large inflows of direct investment have been observed coming into Latin America (Katz, 1999). This direct investment is an outcome of mergers and acquisitions as the large multinational companies are looking to strengthen their positions in foreign markets other than East Asia.

4 Concluding remarks

The feature that distinguishes the dynamic multi-region multi-sector model, proposed in this paper, from other dynamic global AGE models is its disequilibrium approach to modeling capital mobility. Central to this new approach is the assumption about the adaptive expectations of investors supplying capital to the regions. This assumption, compatible with a simple recursive solution procedure, ensures the stability of the model over the long-run. In addition, the investment theory of adaptive expectations brings realism into the analysis of economic phenomena such as the East Asian crisis. The model observes errors in investors' expectations about potential returns to investment, while offering flexibility in accommodating to empirical data. Despite some limitations of this model, such as the lack of equity-for-debt substitution, bilateral detail and short-run dynamics in employment, the model offers a unique treatment to modeling international capital mobility in a dynamic context. It captures the economy-wide effects of capital and wealth accumulation, and the income effects of foreign property ownership.

We illustrated the new disequilibrium theory of investment with two numerical examples. The first one demonstrated the long-run convergence of the model. The second example depicted the dynamics of adjustment to a marginally deeper, longer crisis in East Asia. We showed that the crisis affects negatively the productivity of the East Asian economies in the near term (1999) causing a decline in the rate of return to capital in East Asia 5, followed by a slowdown in these economies, and thereby a decline in investment in East Asia 5. Realizing that the economies of East Asia 5 have slowed down, investors lower their expectations about potential returns in the region, and thereby lead to further decline in investment in these regions. World cost of capital declines in the rest of the world, as capital accumulates at higher rates than the base case in regions other than East Asia 5.

5 References

- Arndt, C., T. Hertel, B. Dimaranan, K. Huff, and R. McDougall (1998), "China in 2005: Implications for the Rest of the World," *Journal of Economic Integration*.
- Baldwin, R. (1989), "The Growth Effects of 1992," *Economic Policy*, 4(9), pp. 247-283.
- Burniaux, J., G. Nicoletti and J. Olivera-Marins (1992), "GREEN: A Global Model for Quantifying the Costs of Policies to Curb CO_2 Emissions," *OECD Economic Studies* 19, OECD.
- Green, D. W. (ed.) (1984) *Perry's Chemical Engineering Handbook*, Section 2, McGraw-Hill Book Company, Sixth Edition.
- Hertel, T. W. and M. E. Tsigas (1997), "Structure of GTAP," In Hertel, T.W., (editor), *Global Trade Analysis Modeling and Applications*, Cambridge University Press, Chapter 2, pp. 13-73.
- Ianchovichina, E. I. (1998), "International Capital Linkages: Theory and Application in a Dynamic Computable General Equilibrium Model," Ph.D. Dissertation, Purdue University.

Ianchovichina, E. I., T. W. Hertel and R. A. McDougall (1999), "The East Asian Economic Crisis: It's Not All Bad News," *Choices*, June, forthcoming.

Jorgenson, D. W. and P. J. Wilcoxon (1990), "Environmental Regulations and U.S. Economic Growth," *The Rand Journal*, 21(2), pp. 314-340.

Katz, I. (1999), "Snapping Up South America," *Business Week* January 18.

Lucas, R. E. (1967), "Optimal Investment Policy and the Flexible Accelerator," *International Economic Review*, 8(1), pp. 78-85.

McDougall, R. A. (ed.) (1997), *Global Trade, Assistance, and Protection: The GTAP 3 Data Base*, Chapter 3, Purdue University.

Martin W. and W. McKibbin (1998), "The East Asian Crisis: Investigating Causes and Policy Responses," World Bank (mimeo).

McKibbin, W. (1998), "The Economic Crisis in Asia: An Empirical Assessment," Brookings Discussion Paper in International Economics No. 136, The Brookings Institution, Washington DC.

McKibbin, W. and P. Wilcoxon (1998), "The Theoretical and Empirical Structure of the G-CUBED Model," *Economic Modelling* (forthcoming).

McKibbin, W. and J. Sachs (1991), *Global Linkages: Macroeconomic Interdependence and Cooperation in the World Economy*, Brookings Institution, June.

Mercenier, J. (1995), An Applied Intertemporal General Equilibrium Model of Trade and Production With Scale Economies, Product Differentiation and Imperfect Competition," C.R.D.E. and University of Montreal.

Pearson, K. R. (1991), "Solving Nonlinear Economic Models Accurately via a Linear Representation," Impact Project Working Paper No. IP-55.

Shannon, C. E. (1948), "A Mathematical Theory of Communication," *Bell System Technical Journal*, 27, pp. 379-423, 623-659.

Treadway, A. (1969), "On Rational Entrepreneurial Behavior and the Demand for Investment," *Review of Economic Studies*, 3(2), pp. 227-39.

World Bank (1998), "Global Economic Prospects and the Developing Countries," The International Bank of Reconstruction and Development/ The World Bank, 1818 H Street, N.W., Washington, D.C. 20433 U.S.A.

World Bank (1992), *World Tables*, The World Bank Group.

Uzawa, H. (1969), "Time Preference and the Penrose Effect in a Two Class Model of Economic Growth," *Journal of Political Economy*, 77, pp. 628-652.

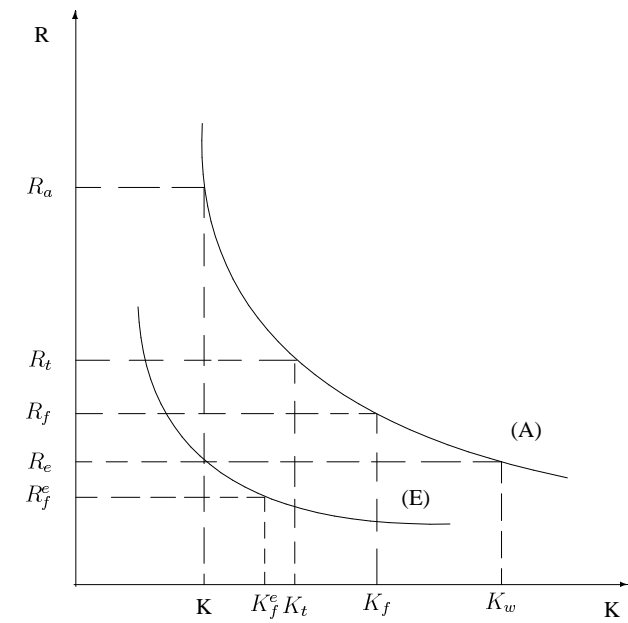


Figure 1: Actual and Expected Investment Schedules

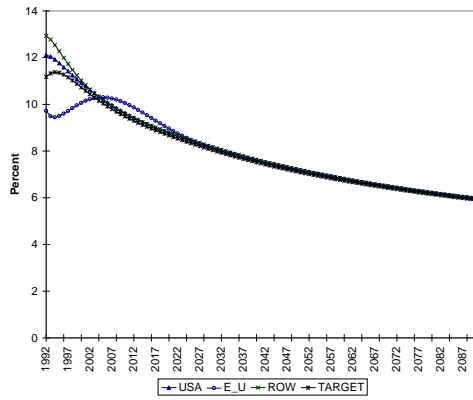


Figure 2: Actual and Target Rates of Return

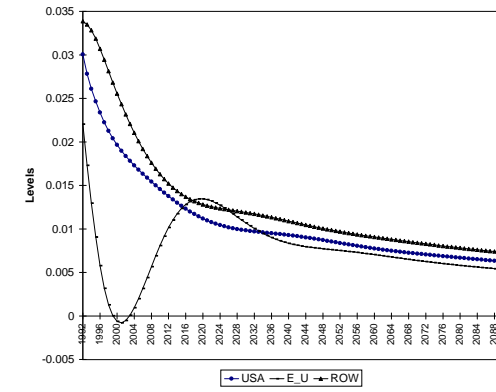


Figure 4: Normal Rate of Growth in Capital Stock, Ω

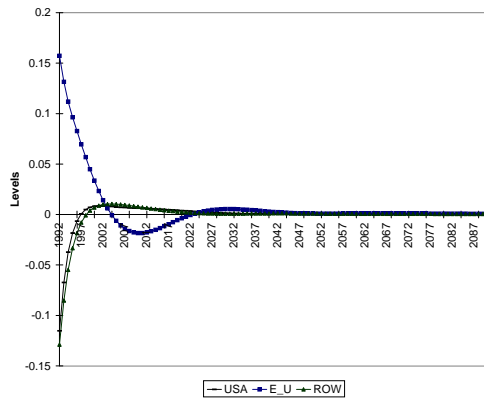


Figure 3: Errors in Expectations

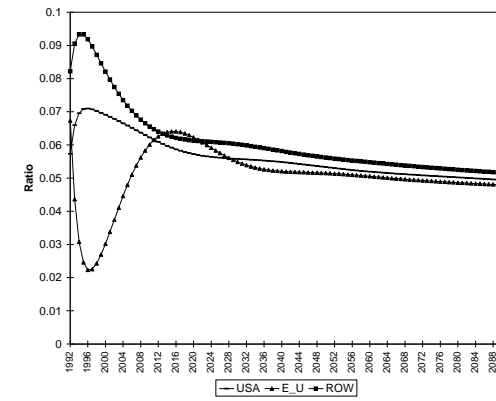


Figure 5: Investment-capital ratio, I/K

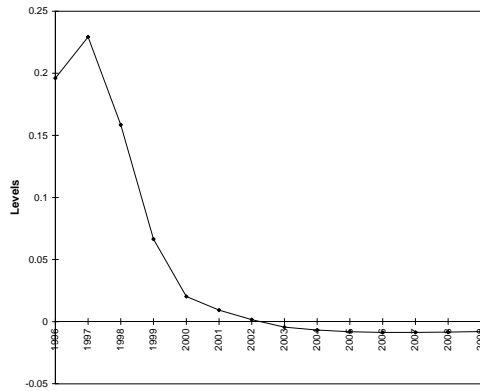


Figure 6: Errors in Expectations: Thailand

Table 1: Yearly Changes in Selected Variables Due to a Marginally Deeper Crisis in Thailand

Year	\widehat{R}_t	\widehat{R}_a	\widehat{R}_e	\hat{I}	\hat{K}	ω
1998	0	-0.62	0.30	-0.04	0	-0.19
2000	0	0.54	-1.13	-6.67	-0.66	0.25
2008	-0.01	-0.03	-0.05	-1.19	-0.72	-0.02

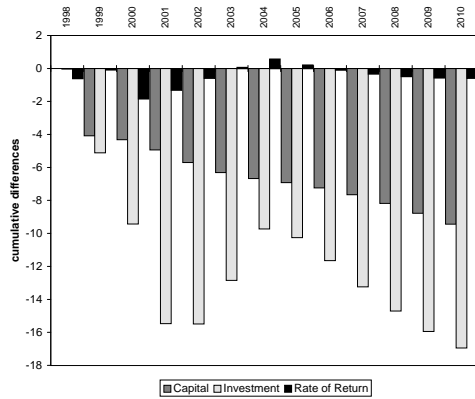


Figure 7: Selected Variables for Thailand: Alternative - Base Case