UOU Report Vol. 16. No. 2. pp. 377~386. 1985 연구논문집 제16권 제 2 호 pp. 377~386. 1985

# Patterns of Capital Trade under Uncertainty

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(Received April 30, 1985)

〈**Abstract**〉

When country-specific technological uncertainty is introduced to production function, the international allocation of capital is influenced by the asset preferences of risk-averse consumer-investor. In this paper, we analysed the determinants of the direction of international capital movements in a model of trade in goods and real equities under the assumption that preferences over goods and real equities are identical and homethetic.

In a one-good variant of MacDougal model, it is found that physical capital flows in an uncertain world are subject to relative factor abundance, relative country riskiness. These determinants have separable but interrelated influences on the directon of equilibrium capital movements.

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# 不確實性下에서의 國際資本移動類型

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(1985. 4. 30 접수)

〈요 약〉

국제자본이동에 있어서 불확실성 혹은 위험의 문제는 실제적으로 매우 중요한 문제이나 이것이 이론적 모형에 도입되기 시작한 것은 오래지 않다.

본 논문에서는 생산함수에 기술적 불확실성을 도입한 경우, 국가간의 자본이동이 위험기피성향이 있는 개인들의 자산 선호에 의해 어느 정도 결정됨을 보인다.

국가간의 자본이동이 자본의 한계 생산력에 의해 결정된다고 보는 MacDougal 모형에 불확실성 또는 위험을 도입한 경우, 상대적인 요소부존도, 상대적인 노동력의 크기 및 상대적인 생산에서의 위험도가 국가간의 자본이동의 방향에 분리 가능하면서도 상호 연관된 영향을 미치는 것으로 나타난다.

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## I. Introduction

The main body of the pure theory of international trade is characterized by the assumption that goods are mobile between countries while factors of production are not. But today, international trade theory has been extended to incorporate uncertainty in trading environment. In this area, the introduction of randomness into the deterministic models violates many orthodox results, including those concerning the patterns of trade. (1)

(1) See Kemp and Liviatan(1973), Batra(1975), and Turnovsky(1974).

International capital movements, even more than the flow of goods, may be influenced by the existence of technological uncertainty. The worldwide allocation of capital takes place at large before the resolution of uncertainty and is motivated by the desire of risk-averse agents to hedge against risk. Capital flows into not only those sectors and countries where its marginal product is high, but also those which provide investors with a relatively stable pattern of income across states of nature.

Risk consideration have long been occupied an important position in studies and practices of the international flows of financial capital. Indeed, the hedging of uncertainty is often regarded as practically important motive for instances of direct foreign investment.

In this paper, we attempt to incorporate production risk explicitly into a model that determines the pattern of trade in capital. (2)

In order to do this, we study the interrelationships between international capital movements and international trade in securities under the condition of technological uncertainty. The problem takes on great interest under the assumption that random disturbances in an industry are not perfectly correlated across countries. The existence of such uncertainty introduces some new elements into the determination of the direction and level of capital movements. Essentially, the general equilibrium supply functions for real equities derive from the familiar supply relationships, but the demands for equities also have an important qualitative effect on the equilibrium allocation of resources, even when all individual in both countries have identical and homothetic preferences for goods and assets.

In the next section, we will show that, according to MacDougal model(3), if technologies are the same and nonrandom, capital flows to the country of relative labor abundance.

In section Ⅲ, by the simple variation of MacDougal model, it is showed that the relative sizes of the labor forces and the distribution of the random technology variables are of importance in the determination of the level and the direction of capital movement. In section Ⅳ, the model is extended to include an internationally traded bond. Under some restrictions on the utility function(4), the introduction of the bond market does not alter the conclusion of section Ⅲ.

Finally, results of this study are summarized in a concluding section.

## Ⅱ. The MacDougal Model

MacDougal dealt with the benefits and costs of private investment from aborad. He developed a model to explore the welfare implications of capital movements in a deterministic world under a variety of assumptions about technology, the behavior of labor, market structure and tax policy. (5) His model can be used to analyze capital movements in the situation with two countries, one good and two factors.

In this paper, our interests are focused only on the positive implications of the simplest variant of the MacDougal formulation (i.e. constant-returns-to-scale production functions, fixed labor

(2) Eaton and Gersovitz(1982) have developed a model of physical capital mobility incorporating the risk of expropriation.

(3) See MacDougal(1960).

(4) Preferences for goods and assets are internationally identical and homothetic, which is analogous to those needed to prove Heckscher-Ohlin theorem.

(5) See MacDougal(1960).

supplies, perfect competition and laisses-faire).[6] In this case, equilibrium is characterized by equalization of marginal products of capital in two countries. Such an equilibrium is illustrated in figure 1, where the horizontal dimension of the box represents the fixed world endowment of capital and the marginal product of capital (MPK) as a function of the capital allocated to the home(foreign) country is plotted with respect to origin at the left(right) of the figure.

The equilibrium is at $E$, where $A_1$ and $A_2$ are two possible autarky allocations. At $A_1$, the marginal product of capital at home exceeds that of the foreign country, whereas the opposite is true at $A_2$.

Suppose production functions are the same in the two countries. Then $A_1$ must be characterized by a higher capital-labor ratio in the foreign country than that of at home and vice versa at $A_2$. It is clear that, if technologies are the same and nonorandom, capital flows into the country that, in autarky, has a greater relative abundance of labor.

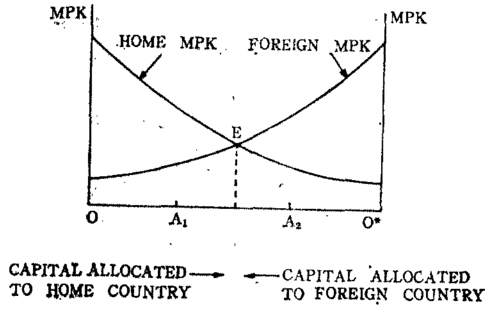


**Fig. 1.**

## Ⅲ. Variation of MacDougal Model

We begin this analysis of the pattern of capital trade under uncertainty by introducing multiplicative technological randomness into each of the countries of the MacDougal Model and allowing for international trade in equities.[7]

Let the $S$ possible states of nature be indexed by $\alpha$, $\alpha=1,\cdots,S$. Each state of nature is defined by the realization of the two country-specific random variables, $\theta(\alpha)$ and $\theta^*(\alpha)$, corresponding to the state of technology in the home and foreign industries, respectively.[8] The output of the $j$th home country firm in the state $\alpha$ is,

$$X_j(\alpha)=\theta(\alpha)F(L_j, K_j) \qquad (1)$$

for $\alpha=1,2,\cdots,S$ and $j=1,2,\cdots,J$, where $F$ is a standard, quasi-concave, constant-return-to-scale production function (the same for all firms), $L_j$ is the firm's labor input, and $K_j$ is its input of physial capital. Similarly, the output of $j$th foreign firm in state $\alpha$ is given by

$$X_j^*(\alpha)=\theta^*(\alpha)F(L_j^*,\ K_j^*) \qquad (2)$$

for $\alpha=1,2,\cdots,S$, and $j=1,2,\cdots,J^*$.

The production function for foreign firms is identical to that for home firms, but the multiplicative uncertainty term, which is the same for all firms within each country, is not necessarily the same for firms located in different countries. With these assumptions, firms in each country can be aggrgated to the industry level, so that we omit the $j$ subscript from now on.

Firms in each country choose their inputs prior to the resolution of uncertainty. It is a well-known result that when technologial uncertainty enters multiplicatively, as assumed in this

(6) The other assumptions of MacDougal are not required in this paper.
(7) Helpman and Razin(1978) introduced this manner for the first time.
(8) Asterisks are used to refer to the variables for the foreign country.

paper, stockholders are unanimous in their desire that firms act so as to maximize their net stock market value (i.e. gross values less factor payments). Let $q$ and $q^*$ be the prices of a unit of real equity in a representative home and foreign firm respectively, with $q=1$ as numeraire. A unit of real equity in a home firm pays $\theta(\alpha)$ units of the consumption good if state $\alpha$ is realized. Similarly, $\theta^*(\alpha)$ is the return to a unit of the foreign equity. Home and foreign firms produce $Z=F(L,K)$ and $Z^*=F(L^*,K^*)$ units of real equities respectively, which have gross stock market values of $F(L,K)$ and $q^*\ F(L^*,K^*)$. Thus the home-country industry chooses $L$ and $K$ to maximize $F(L,K)-wL-rK$, where $w$ is the home wage rate and $r$ the home rentel rate for capital, both expressed in terms of equities. The first order conditions for maximization are

$$F_L(L,K)=w \tag{3}$$

$$F_K(L,K)=r \tag{4}$$

The foreign industry desires to maximize $q^*\ F(L^*,K^*)-w^*L^*-r^*\ K^*$ and thus chooses $L^*$ and $K^*$ to satisfy

$$q^*F_L(L^*,K^*)=w^* \tag{5}$$

$$q^*F_K(L^*,K^*)=r^* \tag{6}$$

Capital and labor endowments in the home and foreign countries are $\bar{K}$ and $\bar{K}^*$ respectively, and labor endowments are $\bar{L}$ and $\bar{L}^*$. Labor is internationally immobile, so that the labor markets must clear seperately in each country.

In equilibrium, next equations are satisfied.

$$L=\bar{L} \tag{7}$$

$$L^*=\bar{L}^* \tag{8}$$

Capital movements are costless and unrestricted and this implies the existence of a unified world physical capital market. The conditions for equilibrium in this market are

$$K+K^*=\bar{K}+\bar{K}^*, \tag{9}$$

$$r=r^* \tag{10}$$

We turn finally to consumer behavior. Consumer-investers in each country are endowed with physical capital, labor and shares of ownership in firms. Prior to the resolution of uncertainty, each individual sells his factor endowmenst, bears his fraction of each firms factor costs in accordance with his initial ownership, and buys and sells shares of stock in the varicus firms.

Let $V^i[I^i(\alpha)]$ be the concave, von Neumann-Morgenstern indirect utility function for individual $i$, where $I^i(\alpha)$ is the individual's income in state $\alpha$.(9) Suppose the individual were to hold in his ultimate portfolio $z^i$ shares of stock in his home firms and $z^{*i}$ shares in foreign firms. Then his income in state $\alpha$ would be

$$I^i(\alpha)=\theta(\alpha)z^i+\theta^*(\alpha)z^{*i} \tag{11}$$

The portfolio choice problem of this individual is to maximize expected utility, given common subjective beliefs about the probability distribution for the states of nature and subject to the budget constraint that the cost of his portfolio can not exceed the value of his initial endowment. That is, the individual solves

$$\text{Max}_{z^i,z^{*i}}\ EV^i[\theta(\alpha)z^i+\theta^*(\alpha)z^{*i}]$$

$$\text{s.t.}\ z^i+q^*z^{*i}=wL^i+rK^i,$$

where $L^i$ and $K^i$ are the individual's initial endowments of labor and capital respectively. By

(9) See Neumann and Morgenstern(1944), Herstein and Milnor(1953).

the way, under the condition of constant return to scale, the equilibrium value of any initial share-holdings by this individual is, after factor payments are made, equal to zero. The portfolio allocation that the solves this proplem[10] must satisfy

$$\frac{E\theta^*(\alpha)V_I^{i}[\theta(\alpha)z^i+\theta^*(\alpha)z^{*i}]}{E\theta(\alpha)V_I^{i}[\theta(\alpha)z^i+\theta^*(\alpha)z^{*i}]}=q^* \tag{12}$$

where $V_I^i(.)$ is the marginal utility of income.

The model is closed by the world market-clearing conditions for the real equities of firms located in each of the countries; that is

$$\sum_i z^i = Z \tag{13}$$

$$\sum_i z^{*i} = Z^*, \tag{14}$$

where the summation is over all individuals in the world.

Before proceeding to an investigation of the properties of the cum-factor-movements-equilibrium, we need to place a restriction on the form of ulitity functions that is analogous to the one often invoked in nonstochastic trade models for proofs of theorems on the determinants of commodity trade.

In the present context, the assumption is that all consumers, worldwide, have identical and homothetic preferences over equities. The purpose of this assumption is to neutralize any bias in the pattern of trade in securities or in the direction of capital movements introduced on the demand side by differences in tastes or by income distributional considerations.[11]

For consumers' preferences over securities to be identical and homothetic, it is sufficient that they all have utility functions that show identical and constant relative aversion to income risk; that is, that their utility functions be of the form $V(\cdot)=(I^i)^{1-r}/(1-r)$, for some $r\neq 1$, or of the form $V(\cdot)=\ln(I^i)$. If the utility function takes one of these forms, (12) can be rewritten as

$$\frac{E\theta^*(\alpha)V_I[\theta(\alpha)+\theta^*(\alpha)\tilde{z}^i]}{E\theta(\alpha)V_I[\theta(\alpha)+\theta^*(\alpha)\tilde{z}^i]}=q^* \tag{12'}$$

where $\tilde{z}^i=z^{*i}/z^i$. From this, it is clear that the relative holdings of the stocks in any investor's portfolio are independent of his nationality or level of wealth.

Identical, homothetic preferences have the property of being aggregable. That is, world demand for assets can be consistently represented by a set of community asset indifference curves of the form

$$EV[\theta(\alpha)z+\theta^*(\alpha)z^*]=\bar{V}.$$

These also represent demand in each country taken separately. Utility is a quasi-concave function of asset holdings, and is strictly so, if individuals are risk averse (i.e., $V_{II}<0$) and if $\theta(\alpha)$ and $\theta^*(\alpha)$ are less than perfectly correlated.

The nature of the world equilibrium with free capital movement is best understood with the aid

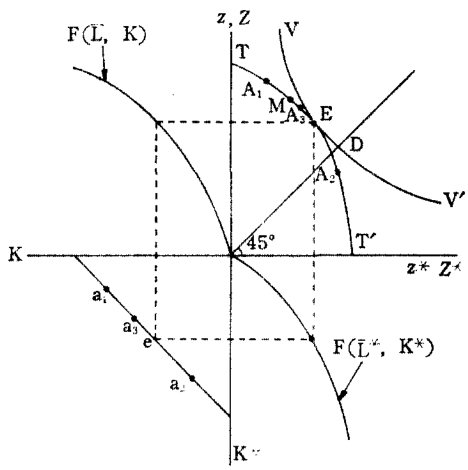


**Fig. 2**

(10) In this case, the possibility of corner solution is excluded.
(11) Anderson(1981) was the first to reorganize the relevance of this assumption in the context of the Helpman-Razin model of trade in goods and trade.

of Figure 2.

For illustrative purposes, we depict a situation in which $\theta(\alpha)$ and $\theta^*(\alpha)$ have identical distribution. (12)

In quadrants Ⅱ and Ⅳ, we draw the production function for real equities in each country as a function of the amount of capital located there. The sum of the allocations of capital to the two countries is constrained by equation (9) to be equal to the exogeneous world supply. This constraint is represented by a straight line with a slope of $-1$ in quadrant Ⅲ. Simultaneously, these constraints trace out, in quadrant $I$, a world transformation locus $TT'$, relating the feasible supplies of the two real equities. Each point on the frontier corresponds to a particular division of capital between the two countries. The slope of the transformation curve at any point is given by

$$-F_K(\bar{L}, K)/F_K(\bar{L}^*, K^*),$$

$A$ representative of the family of homothetic asset indifference curves is depicted in a quadrant $I$ by $VV'$. The slope of $VV'$ is given by (the negative of) the marginal rate of substitution of assets, that is, by the left hand side of equation (12). Under the assumption that $\theta(\alpha)$ and $\theta^*(\alpha)$ are symmetrically distributed, the slope of $VV'$ must be $-1$ where $z=z^*$.

World equilibrium occurs at $E$, the point of tangency of an asset indifference curve and the world transformation locus. This is because consumers set (the negative of) the marginal rate of substitution between assets(MRSA) equal to the relative price of securities, (13) while competetion in the world market for physical capital leads to equality between (the negative of) the marginal rate of transformation (MRTA) and the relative price of securities. (14)

In the diagram, the deterministic equilibrium, or "MacDougull point", is labeled $M$. As we have noted, the deterministic equilibrium is characterized by $F_K(\bar{L}, K)=F_K(\bar{L}^*, K^*)$, so the marginal rate of transformation at $M$ is $-1$.

By the concavity of the asset indifference curve and the fact that the latter has a slope of $-1$ at point $D$, it follows that equilibrium with uncertainty must lie(weakly) between the Mac Dougall point and 45° line; that is, it must exhibit more diversification. If agents are risk neutral, or if $\theta(\alpha)$ and $\theta^*(\alpha)$ are perfectly correlated, then the asset indifference curves are straight line with slopes of $-1$, and the two equilibria coincide at $M$.

Alternatively, if $\bar{L}=\bar{L}^*$, the MRTA is $-1$ at the 45° line, and again the equilibria coincide. In all other cases, the equilibrium under uncertainty differs from that for the case of no uncertainty by an amount that depends on the degree of relative risk aversion and the correlation between disturbances in the two countries. A higher degree of relative risk aversion and a less positive (or more negative) correlation between $\theta(\alpha)$ and $\theta^*(\alpha)$ tend to render the asset indifference curves more concave and thus contribute to a larger distance between points $M$ and $E$ in the diagram.

The introduction of uncertainty may alter the nature of the capital movements equilibrium either quantitatively or qualitatively. Consider the three potential autarky points at $A_1$, $A_2$ and $A_3$. (15) If autarky production is at $A_1$, then in both the deterministic model and the model with

(12) In other words, for the sake of diagram, it is supposed that the joint density function for the two random variables $\phi(\cdot, \cdot)$, satisfies $\phi(\theta, \theta^*)=\phi(\theta^*, \theta)$.
(13) This fact is proved by equation (12).
(14) By equation (4) (6) (10)
(15) Autarky production is represented by the point along $TT'$ that corresponds to the exogeneously given initial endowment at $a_1$, $a_2$, $a_3$.

uncertainty the home country exports capital, but more capital movement takes place in the latter case. With antarky at $A_2$, capital flows to the home country in both situations, but the introduction of uncertainty lessens of capital movement. Finally, if autarky is at $A_3$, the introduction of uncertainty reverses the direction of capital movement relative to the outcome in a deterministic model.

What can be said generally about the direction of capital movement in a one-good model with uncertainty and international trade in securities? In order to isolate the separate influences of the relative size of the labor forces, the relative factor abundances, and relative riskiness of two countries, we consider, in turn, initial situations that deviate from complete symmetry along only one of these dimensions. Our findings are summarized as follows.

(1) If $\theta(\alpha)$ and $\theta^*(\alpha)$ have identical distributions and $\bar{L}=\bar{L}^*$ then physical capital moves toward the country with the smaller autarky endowment of capital.

Proof: The fact that $\theta^*(\alpha)$ have identical distributions implies that the MRSA is $-1$ for $z=z^*$. The equality of labor forces implies that the MRTA is $-1$ for $Z=Z^*$. Thus, an equal division of the world's capital stock across countries ($K=K^*$) satisfies all the conditions for equilibrium. Also, equilibrium is unique, so capital must flow from the country in which it is initially abundant into the less endowed country.

(2) If $\theta(\alpha)$ and $\theta^*(\alpha)$ have identical distributions and $\bar{K}/\bar{L}=\bar{K}^*/\bar{L}^*$, then physical capital moves toward country with smaller labor force.

Proof: If $\bar{L}$ is greater(less) than $\bar{L}^*$, the autarky point lies along $TT'$ above(below) the point $Z=Z^*$. The MRTA is $-1$ at the autarky point[16] and decreases monotonically for movements downward along $TT'$. The slope of the asset indifference curve that intersects $TT'$ is $-1$ at the point where $Z=Z^*$ and increases monotonically for movements downward along the transformation locus. It follows that equilibrium must lie on $TT'$ between the autarky point and the point where $Z=Z^*$. In equilibrium, there is more production of the real equity of the initially smaller country than there is in autarky; that is, capital moves toward the country with smaller labor force.

(3) If $\bar{K}=\bar{K}^*$ and $\bar{L}=\bar{L}^*$, and the distribution of the random variable in the foreign country is riskier than that of the home country—in the sense that $\theta^*(\alpha)=\theta^*(\alpha)+\in(\alpha)$, where $\theta(\alpha)$ and $\theta^*(\alpha)$ have identical distributions, $\in(\alpha)$ is independent of both $\theta(\alpha)$ and $\theta^*(\alpha)$, and $E[\in(\alpha)]=0$[17] then capital moves toward the home country.

Proof: The asset indifference curve that intersects $TT'$ at the point where $Z=Z^*$ has a slope[18]

$$-\frac{E[\theta^*(\alpha)+\in(\alpha)]V_I[\theta(\alpha)+\theta^*(\alpha)+\in(\alpha)]}{E\theta(\alpha)V_I[\theta(\alpha)+\theta^*(\alpha)+\in(\alpha)]}$$

$$=-\left\{1+\frac{E\in(\alpha)V_I[\theta(\alpha)+\theta^*(\alpha)+\in(\alpha)]}{E\theta(\alpha)V_I[\theta(\alpha)+\theta^*(\alpha)+\in(\alpha)]}\right\},$$

where this equality follows from the fact that $\theta(\alpha)$ and $\theta^*(\alpha)$ are identically distributed each is independent of $\in(\alpha)$. The second term in the brackets is negative, since $\in(\alpha)$ and $V_I(\cdot)$ have negative covariance. Thus, the asset indifference curve has a slope greater than $-1$ at $Z=Z^*$, while the slope of $TT'$ is equal to $-1$ there. It follows that equilibrium is a point above

(16) Recall that MRTA$=-F_K(\bar{L},K)/F_K(\bar{L}^*,K^*)$ and $F$ is homogeneous of degree one.
(17) This definition of "riskier" is more restrictive than the notion of a mean-preserving spread, as developed by Rothschild and Stiglitz(1970).
(18) It is given in (12′)

the 45° line, that is, capital moves to the less risky country.

In general situations, the direction of capital movement is determined by the interaction of the separate influences of relative country size, relative factor abundance, and relative country riskiness. However, the nature of this interation can be quite complex. For example, it is not true that an increase in the riskiness of one country(19) will always cause capital to flow out of that country. If the country that becomes riskier also has a smaller labor force and if the disturbances in the two countries are negatively correlated, then the increase in riskiness makes the real equity of that country a more attractive asset. Intuitively, the extra income the asset provides when the marginal utility of income is high outweighs the utility cost of the income forgone when marginal utility is low. One general statement that can be made is that, ceteris paribus, more capital will flow into a country the smaller is its labor force. On the part of consumer-investors, the desire for diversification implies a tendency for real equity supplies to be equalized.

## Ⅳ. MacDougal Model with Traded Bond.

In the previous section, capital movements in a one-good model with uncertainty are studied, where the only assets available to consumer-investor were risky real equities. In the present section, we extend the analysis to incorporate a market for a safe asset (i.e., an internationally traded bond), while maintaining all of earlier assumptions, including especially the one which is restricting agents' asset preferences to be identical and homothetic. We will show that this extension does not alter any of the previous conclusions.

Let $b^i$ be the holding of an internationally traded bond, with price $q_b$, by the ith individual. This asset pays a return of one unit of the consumption good in all states of nature. The consumer-investor must allocate his ex-ante wealth over three assets, the two real quities and the bond. The first-order conditions for expected utility maximization imply, in place of equation(12), the following equations:

$$\frac{E\{\theta^*(\alpha)V_{\mathrm{I}}[\theta(\alpha)z^i+\theta^*(\alpha)z^{*i}+b^i]\}}{E\{\theta(\alpha)V_{\mathrm{I}}[\theta(\alpha)z^i+\theta^*(\alpha)z^{*i}+b^i]\}}=q^* \tag{15}$$

$$\frac{E\{V_{\mathrm{I}}[\theta(\alpha)z^i+\theta^*(\alpha)z^{*i}+b^i]\}}{E\{\theta(\alpha)V_{\mathrm{I}}[\theta(\alpha)z^i+\theta^*(\alpha)z^{*i}+b^i]\}}=q_b \tag{16}$$

The bond-market-clearing condition is

$$\Sigma b^i=0 \tag{17}$$

All of the remaining equilibrium conditions of the earlier setup continue to hold.

The fact that all individuals have identical and homolhetic demands for assets implies that, in equilibrium, each will allocate the same fraction of his wealth to any given asset. If the equilibrium bond holding of one individual is either strictly positive or negative, such would also be true for every other individual. In either case, equation (17) could not be satisfird. It follows that, in equilibrium, $b^i=0$ for all $i$. By this fact, it is clear that the asset holdings that satisfy equation(12) will also satisfy equation(15). Indeed, all the conditions of the capital-movements equilibrium in the absence of bond trading are also consistent with equilibrium when a bond market is assumed to exist. Equation(16), then, serves to determine the price of bonds such that

(19) It implies risk increase in a mean-preserving spread sense.

in equilibrium all agents choose to take a net position of zero in the market for this safe asset. We summarize this finding as follows.

(4) When all agents have identical, homothetic asset utility functions, the equilibrium allocation of resources with free capital movements and free trade in equities and a traded bond are identical to the equilibrium allocation when the bond market does not exist.

## V. Conclusion

When production is characterized by technological uncertainty that is, at least to some extent country-specific, the international allocation of capital is influenced by the asset preferences of risk-averse consumer-investor. In this paper, we analyzed the determinants of the direction of international capital movements in a model of trade in commodities and real equities under the assumption that preferences over commodities and real equities are identical and homothetic.

In MacDougal model, capital flows to the country that has a greater relative abundance of labor under the assumption that technologies are the same and nonrandom.

But in a one-good variant of MacDougal model, we found that physical capital flows in an uncertain world are subject to the combined influences of relative factor abundance, relative size of labor force and relative country riskiness. When deviation from complete symmetry is along only one of these dimensions, capital moves toward the relatively labor-abundant country, the smaller country and the less risky country, respectively. However, in more general situations, the interaction between these effects can be quite campex.

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