

# INTERNATIONAL PORTFOLIO CHOICE AND THE EFFECT OF INFORMATION COSTS

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This paper presents a model of international asset pricing in the presence of shadow costs of incomplete information. The model shows that the exchange rate risk is priced in an international setting. The home bias equity is explained by the shadow costs of incomplete information. These costs are defined in the spirit of Merton (1987) model of capital market equilibrium with incomplete information. The model supports the empirical findings in Kang and Stulz (1997) and Dahlquist and Robertsson (2000).

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# 1 Introduction

Modern portfolio theory suggests that the international diversification does better than portfolio diversification in the national level. The benefits from international diversification have been emphasized over the past forty years by several authors including Levy and Sarnat (1970), Solnik (1974a), Harvey (1994) and De Santise and Gerard (1997).

Despite the gains from international diversification, most investors hold nearly all of their wealth in domestic assets. This is referred to in international finance as "home bias equity".

Many authors tend to explain this phenomena by market frictions such as transaction costs, taxes, restrictions on foreign ownership, asymmetric information, etc.

Black (1974) presents a model of international asset pricing in the case of market segmentation.

He develops a two country-model in the presence of explicit barriers to international investments in the form of a tax (on holdings of assets in one country by residents of the other country). The tax is intended to present various kinds of barriers to international investment, such as the possibility of expropriation of foreign holdings, or a transaction cost on trading assets. Black's (1974) model was extended by Stulz (1981b). In this paper, Stulz (1981b) considers the tax on the short and long positions. In these two models, the home bias equity is explained by the effect of this tax that prevents the domestic investors from investing in foreign countries. In recent studies, Cooper and Kaplanis (2000) extend Stulz's (1981 b) model to the case of  $n$  countries. They show that the deadweight cost has an impact on portfolio choice and capital budgeting decisions.

Cooper and Kaplanis (1994) extend the model developed by Adler and Dumas (1983) to account for deadweight costs or taxes.

The empirical test provided by Cooper and Kaplanis (1994) shows that the effect of inflation rate risk and the differences between the consumption baskets do not explain the home bias equity in international finance.

In recent studies Lewis (1999) uses a similar tax as Black (1974) in order to explain the home bias equity.

Errunza and Losq (1985) present a two-country-model to characterize the mild segmentation. The foreign investors called unrestricted can trade on both assets 'eligible' or restricted and 'ineligible' or unrestricted.

Domestic investors trade only on the 'eligible' or unrestricted assets. The domestic investors can not participate in the foreign market due to the restriction imposed by the foreign government.

Errunza and Losq (1985) show that the unrestricted assets are priced as if the international markets were integrated, and that the restricted assets are priced differently. The unrestricted investors recommend a super risk premium for the restricted assets which is proportional to the conditional market risk.

Errunza and Losq (1989) show that the removal of investment barriers generally leads to an increase in the aggregate market value. The authors suggested that the introduction of different types of index funds in the international market increase the world market integration and investor welfare.

Eun and Jankirmannan (1986) consider a two-country-model in the world, one domestic and one foreign. The proportion of the number of assets held by the domestic investors is assumed to be  $\delta$ .

The authors show that price of the same foreign asset is different for the domestic and foreign investors.

The difference between the price paid by the domestic and foreign for the same assets is explained by the constraint imposed on the domestic investors. These investors are willing to pay a premium over the price of foreign asset under no restriction, and the foreign investors demand a discount over the same price of the foreign under no restriction.

Hietala (1989) presents a two-country-model. The domestic country has two types of assets, restricted assets which are held by the domestic investors and unrestricted assets held by the foreign and domestic investors. Domestic investors can not trade in the foreign country.

Hietala (1989) shows that the unrestricted assets are traded at premium prices from the domestic investors' point of view.

He shows how the partial market segmentation affects the expected rate of return and the premium of the same assets. This segmentation explains the home bias equity observed in domestic portfolios.

Stulz and Wasserfallen (1995) develop a model where the demand function for domestic assets differs between domestic and foreign investors due to the deadweight costs. They show the existence of a price risk premium for the unrestricted assets.

Consistent with Hietala (1989), Stulz and Wasserfallen (1995) show that the ownership restrictions explain the higher price paid by the foreign investors

for the domestic assets than the domestic investors.

Domowitz and Madhavan (1997) examine the relationship between stock prices and market segmentation induced by the ownership restrictions in Mexico. They document a significant stock price premia for the unrestricted shares. This gives support to the model developed by Stulz and Wasserfallen (1995).

The restrictions imposed by governments explain the segmentation observed on the international market. Gulteken, Gultiken and Penati (1989) show that the price of risk is different before the liberalization of the Japanese market but not after.

Basak (1996) extends the previous work of Black (1974), Stulz (1981b), Er-runza and Losq (1985, 1989), Eun and Jankirmannan (1986) and Hietala (1989) to incorporate intertemporel consumption behavior and an endogenously determinated international borrowing. This extension allows Basak (1996) to reexamine the price and the welfare implications of segmentation in a richer model.

The next section presents an international asset pricing model in the presence of the shadow costs of incomplete information. This model can be seen as an international version of Merton (1987). The third section presents the empirical evidence of the model and explain that the home bias equity is based on the shadow of incomplete information. Finally, we present some concluding remarks.

## 2 International asset pricing in the case of the shadow costs of incomplete information

Following the analysis in Adler and Dumas (1983), we use the following assumptions.

$A_1$ . There  $K$  countries and currencies. All returns are stated in nominal terms of the  $K$ th currency ( $k_p$ ). There are  $K$  equity index assets and  $K - 1$  risky currency assets.

The price of the  $i$ th asset has the following dynamics :

$$\frac{dY_i}{Y_i} = \mu_i dt + \sigma_i dZ_i \text{ for } i = 1, 2, \dots, 2K - 1 \quad (1)$$

where:

$Y_i$  : is the market value of index asset  $i$  in terms of the reference currency of country  $K$  denoted by  $k_p$ ;

$\mu_i$  : the expected rate of return of asset  $i$ , which can denoted by  $E(R_i)$ ;

$\sigma_i$  the standard deviation of asset  $i$ ;

$dZ_i$  the increment to a standard Wiener process.

$A_2$ . Following the notations in Merton (1987) and Bellalah (2001), we assume that investors support an information cost for holding an asset  $i$ .

The shadow cost of incomplete information per investor is denoted by  $\lambda_i^k$  in the period  $dt$ .

Based on this assumption, relation (1) can be written as :

$$\frac{dY_i}{Y_i} = (\mu_i - \lambda_i^k)dt + \sigma_i dZ_i \text{ for } i = 1, 2, \dots, 2K - 1 \quad (2)$$

Relation (2) is similar to Cooper and Kaplanis (1994) who extended the model of Adler and Dumas (1983) to account for deadweight costs as in Black (1974) <sup>1</sup>.

$A_3$ . There are  $K$  investor types, each with a homothetic utility function. The price index  $P^k$  of an investor of type  $k$  expressed in the measurement currency follows the process:

$$\frac{dP^k}{P^k} = \Pi^k dt + \sigma_{\Pi^k} dZ_{\Pi^k} \text{ for } k = 1, 2, \dots, K \quad (3)$$

where:

$P^k$  : the price index;

$\Pi^k$  : the expected value of the instantaneous rate of inflation;

$\sigma_{\Pi^k}$  : the standard deviation of the instantaneous rate of inflation;

$dZ_{\Pi^k}$  : the increment to a standard Wiener process.

Using the same method as in Adler and Dumas (1983) and the Bellman principal, we obtain :

$$\mu_i = r + \lambda_i^k + \left(1 - \frac{1}{\alpha^k}\right)\sigma_{i\Pi^k} + \frac{1}{\alpha^k} \sum_i x_i^k \sigma_{ij} \quad (4)$$

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<sup>1</sup>The asset pricing model proposed by Black (1974) in the case of two countries has the same structure as the capital asset pricing model with incomplete information of Merton (1987). The tax effect in Black (1974) is the same as the shadow cost of Merton (1987)

where:

$x_i^k$  : the optimal holding allocated to asset  $i$  by investor  $k$ ;

$\frac{1}{\alpha^k} = \theta^k$  : the investor's risk aversion;

$\sigma_{ij} = cov(R_i, R_j)$ : the covariance of the nominal rate of return of asset  $i$  and  $j$ ;

$\sigma_{i\Pi^k} = cov(R_i, \Pi^k)$  : the covariance of the rate or return of asset  $i$  and investor's rate inflation.

Relation (4) is similar to equation (8) of Adler and Dumas (1983) in which appears the effect of the shadow costs of incomplete information.

Based on these definitions, relation (4) can be written as follows :

$$E(R_i) = (r + \lambda_i^k) + (1 - \theta^k)cov(R_i, \Pi^k) + \theta^k \sum_i x_i^k cov(R_i, R_j) \quad (5)$$

Let us derive the expression of asset pricing model in an international setting in the presence of shadow costs of incomplete information. This can be done by multiplying expression (5) by  $\frac{W^k}{\theta^k}$  to obtain

$$E(R_i) \frac{W^k}{\theta^k} = r \frac{W^k}{\theta^k} + \lambda_i^k \frac{W^k}{\theta^k} + W^k \left( \frac{1}{\theta^k} - 1 \right) cov(R_i, \Pi^k) + W^k \sum_i x_i^k cov(R_i, R_j) \quad (6)$$

where  $W^k$  denotes the wealth of investor  $k$ .

Relation (6) can be written as follows:

$$E(R_i) = (r + \lambda_i^k) + \frac{W^k}{\theta^k} \left( \frac{1}{\theta^k} - 1 \right) cov(R_i, \Pi^k) + \frac{W^k}{\theta^k} \sum_i x_i^k cov(R_i, R_j) \quad (7)$$

Let us denote by  $x_i^m$  the proportion of asset  $i$  in the world market portfolio as :

$$x_i^m = \frac{\sum_k W^k x_i^k}{\sum_k W^k} \quad (8)$$

Aggregating expression (7) over all investors gives<sup>2</sup>:

$$E(R_i) = (r + \lambda_i) + \theta \sum_k \left( \frac{1}{\theta^k} - 1 \right) cov(R_i, \Pi^k) \frac{W^k}{W} + \theta cov(R_m, R_i) \quad (9)$$

where:

$\theta = \frac{\sum_k W^k}{\sum_k \frac{W^k}{\theta^k}}$ : the global harmonic mean degree of risk aversion;

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<sup>2</sup>The derivation of this relation is provided in the appendix 1.

$W = \sum_k W^k$ : the global wealth;

$R_m = \sum_j x_j^m R_j$ : the rate of return of the global market portfolio;

$\sum_k \lambda_i^k = \lambda_i$  the global shadow cost of incomplete information.

Relation (9) shows that the expected rate of return of security  $i$  depends on the shadow costs of incomplete information, the effect of the inflation rate and the global market portfolio.

Up to now we have considered that the purchasing power parity does not hold, in this case the international asset pricing model includes  $K + 1$  risk premia, one for the global market portfolio, one for the valuation currency's own inflation and  $K - 1$  additional risk that reflect the other country's uncertain inflation.

The effect of foreign inflation rates denominated in the reference currency  $k_p$  have two components. The first reflects the inflation in the foreign currency. The second shows the changes in the exchange rate between the foreign currency and the reference one  $k_p$ .

Assume as Solnik (1974) and Sercu (1980) that the inflation rate in each country's is not random when measured in its own currency. This case is referred to in Stulz (1994) as the special case of Solnik-Sercu. In this situation there is no inflation risk premium for the reference currency and the  $K - 1$  risk premia are attributed to nominal foreign exchange risks. In this context, relation (9) can be written as follows :

$$E(R_i) = (r + \lambda_i) + \theta \sum_{k \neq k_p} \left( \frac{1}{\theta^k} - 1 \right) cov(R_i, e_k) \frac{W^k}{W} + \theta cov(R_m, R_i) \quad (10)$$

where  $e_k$  refers to the percentage change of currency  $k$  relative to currency  $k_p$ .

A careful examination of relation (10) shows that the coefficients of the  $K$  covariance terms sum to one and that the choice of the reference currency is irrelevant. This result is consistent with Sercu (1980), who shows that the common fund is independent of the choice of the measurement currency.

In order to derive our currency index capital asset pricing model in the presence of the shadow costs of incomplete information we add these assumptions:  $A_4$  : Assume as in Cooper and Kaplanis (1994) and O'Brien and Dolde (2000) that the aggregate risk tolerances are equal across border, which means that  $\theta^k = \theta$ . This assumption was used by French and Poterba (1991) in their

empirical analysis of the home bias equity.

$A_5$  : We consider that the  $K - 1$  currency risk factors can be aggregated into a portfolio. The exact weights of this portfolio are unobservable as suggested by Adler and Dumas (1983) and O'Brien and Dolde (2000). This assumption is not critical for the practitioners , who are able to use a proxy currency index.

Based on these assumptions, relation (10) becomes:

$$E(R_i) = r + \lambda_i + (1 - \theta)cov(R_i, X) + \theta cov(R_m, R_i) \quad (11)$$

where:

$X = \frac{\sum_{k \neq k_p} W^k e_k}{W}$  : the wealth-weighted index of the percent changes in all other currencies in terms of the reference currency  $k_p$ .

$A_6$  : To get our currency index asset pricing model with shadow costs of incomplete information, we assume that relation (11) applies also to  $R_m$  (the global market portfolio) and to  $R_e$  that reflects the variation in  $X$ .

Using assumption  $A_6$  and relation (11), we obtain :

$$E(R_m) = r + \lambda_m + (1 - \theta)cov(R_m, R_e) + \theta var(R_m) \quad (12)$$

where the term  $\lambda_m$  corresponds to the information cost about the market. It can be interpreted as the weighted average of  $\lambda_i$ .

Applying relation (11) to  $R_e$  we get:

$$E(R_e) = r + (1 - \theta)var(R_e) + \theta cov(R_m, R_e) \quad (13)$$

Relation (13) does not contain the shadow costs of incomplete information about the exchange rate. In reality this consideration is logic due to the fact that the investor look for the information about assets that mean about a country and their firms or political stability. The information cost can be interpreted as a cost paid by the investor to be informed about the other country in order to trade in foreign markets.

The international investors are willing to pay this cost in order to get more informations about the other markets and assets.

In the case of symmetric information the foreign investors trade in other market and try to get a profit from international diversification.

Solving equations (12) and (13) simultaneously for  $\theta$  and  $(1 - \theta)$  and rearranging gives <sup>3</sup>:

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<sup>3</sup>The derivation of expression (13) is provided in the appendix 2.

$$E(R_i) = r + \lambda_i + \beta_{im}(E(R_m) - r - \lambda_m) + \beta_{ie}(E(R_e) - r) \quad (14)$$

where:

$$\beta_{im} = \frac{\text{var}(R_e)\text{cov}(R_i, R_m) - \text{cov}(R_m, R_e)\text{cov}(R_i, R_e)}{\text{var}(R_m)\text{var}(R_e) - \text{cov}(R_m, R_e)^2}$$

$$\beta_{ie} = \frac{\text{var}(R_m)\text{cov}(R_i, R_e) - \text{cov}(R_m, R_e)\text{cov}(R_i, R_m)}{\text{var}(R_m)\text{var}(R_e) - \text{cov}(R_m, R_e)^2}$$

Relation (14) characterizes the currency index international asset pricing model within information uncertainty.

This model shows how investors are exposed to the effects of exchange rate risk and incomplete information between the domestic and foreign investors. This model supports the empirical evidence in Kang and Stulz (1997), and Dahlquist and Robertsson (2000) where the home bias equity is explained by asymmetric information.

This model can be seen as an international version of Merton's (1987) model. The model provides an evidence for the pricing of the exchange risk in an international setting. It confirms the results in Dumas and Solnik (1995) and uses information costs as an explanation of market segmentation as suggested by Kadalec and Mcconnel (1994) and Foester and Karolyi (1999).

Relation (14) shows that the investor is willing to diversify his portfolio in an international context if the gains from international diversification exceed the information cost.

This model gives an explanation of the home bias by asymmetric information.

### 3 Empirical Evidence and the home bias equity

Tesar and Werner (1995) document the available evidence of international portfolio investment in five OCDE countries. They show that despite the gains from international diversification, there is a strong bias in domestic national portfolios. They conclude that although there has been some increase in international investment positions since the 1970s, the share of foreign as-

sets in domestic portfolios is smaller than standard theories would predict. In their analysis, they consider that the home bias in international data may be a reflection of a more basic investment behavior than the transaction costs. Tesar and Werner (1995) suggest that a richer model incorporating asymmetric information and institutional constraints can give a good explanation of the home bias.

Our model gives an explanation of the home bias equity by the effect of the shadow costs of incomplete information as suggested by Tesar and Werner (1995).

Forester and Karolyi (1999) show that the abnormal returns can be explained by the asymmetric information. In this model the empirical tests provide support for market segmentation hypothesis and Merton's (1987) investor recognition hypothesis. In the two last models the authors use a sample from US exchanges for an investor who trade in local market by constructing a diversified portfolio from securities of foreign firms listed in US exchange .

The empirical test provided by Kang and Stulz (1997) shows that the investor portfolio is biased against small firm and that the investors overinvesting in large firms in Japan due to the availability of information about these large firms. The authors find that holdings are relatively large in firms with large export sales, this evidence is consistent with the conjecture that foreign investors invest in firms that they are better informed about. From this fact the authors suggest that the home bias is derived by informational asymmetries.

Brennan and Cao (1997) develop a model of international equity portfolio investment flows based in informational endowments between foreign and domestic investors. In this model they show that when domestic investor possesses information advantage over foreign investors about their domestic market, investors tend to purchase foreign assets in periods when the return in foreign asset is high.

Falkenstein (1996) show that the preference of some assets is explained by the low transaction costs and low volatility. He shows that the investors tend to trade on the assets about which they are informed. In his model the information is detected by the investors through the publication of the new stories and the age of these assets.

Differences in information are important in financial and real markets. They are used in several contexts to explain some puzzling phenomena like the

'home equity bias', the 'weekend effect', "the smile effect"<sup>4</sup>, etc. Kadlec and McConnell (1994) document the effect on share value on the NYSE and report the results of a joint test of Merton's (1987) investor recognition factor and Amihud and Mendelson's (1986) liquidity factor as explanations of the listing effect. Amihud and Mendelson (1989) note that several studies predict a relationship between Merton's asset pricing factors and the size of the bid-ask spread. The Merton's  $\lambda$  can be seen as a proxy for changes in the bid-ask spread.<sup>5</sup> Kadlec and McConnell (1994) conclude that Merton's  $\lambda$  reflect also the elasticity of demand and that it may proxy for the adverse price movement aspect of liquidity.(footnote 19, page 629). Foerster and Karolyi (1999) construct an empirical proxy for the shadow cost of incomplete information for each firm, using the methodology in Kadlec and McConnell (1994). Their results are supportive of the Merton (1987) hypothesis and consistent with Kadlec and McConnell (1994). Beneish and Gardner (1995) study the Their evidence is consistent with the information cost/liquidity explanation, which holds that investors demand a premium for higher trading costs and for holding securities that have relatively less available information. Coval and Moskowitz (1999) document the economic significance of geography and attempt to uncover the effect of distance on portfolio choice. Their results suggest an information-based explanation for local equity. This is consistent with the findings in Kang and Stulz (1997) who find that foreign investors underweight small, highly levered firms, and firms that do not have significant exports. Amihud and Mendelson (1989) associate Merton's (1987) model with asset liquidity.<sup>6</sup> Since the transmission of information is costly as in Merton's model, Amihud and Mendelson (1988) show how managers can balance the costs against the added value from the higher liquidity of the claims of the firm.

Shapiro examines equilibrium in a dynamic pure-exchange economy under a generalization of Merton's (1987) investor recognition hypothesis (IRH).

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<sup>4</sup>See the models in Bellalah and Jacquillat (1995) and Bellalah (1999 a, b)

<sup>5</sup>Merton's  $\lambda$  may proxy for some aspects of liquidity that is not captured by the bid-ask spread.

<sup>6</sup>Following the result in Amihud and Mendelson (1986) that asset returns increase with their illiquidity, they jointly estimate the effects of these factors on stock returns. Amihud and Mendelson (1988) consider several observed corporate policies that can be viewed as increasing the liquidity of investments.

In his model, a class of investors is assumed to have incomplete information which suffices to implement only a particular strategy because of information costs. His empirical analysis reveals that a consumption-based capital asset pricing model (CCAPM) augmented by the IRH is a more realistic model than the traditional CCAPM in explaining the cross-sectional variation in unconditional expected returns. All these theoretical models and empirical tests are consistent with our international asset pricing model with information costs, which explain the the home bias equity in international finance.

## 4 Conclusion

This paper presents a currency index capital asset pricing model in the presence of the shadow costs of incomplete information. This model shows that the asymmetric information explains some market frictions and in particular the home bias equity.

The model provides a theoretical evidence for some empirical tests on the international market such as Kang and Stulz (1997), Tesar and Werner (1995) and French and Poterba (1991). Our model represents a generalization of Merton's (1987) simple model of capital market equilibrium with incomplete information to an international context. The model can be used for the valuation of assets, the cost of equity and firms in an international context within incomplete information.

Appendix 1:

Aggregating relation (7) over all investors we get:

$$E(R_i) = r + \sum_k \lambda_i^k + \frac{\sum_k W^k}{\sum_k \frac{W^k}{\theta^k}} \sum_k \left( \frac{1}{\theta^k} - 1 \right) \text{cov}(R_i, \Pi^k) \frac{W^k}{\sum_k W^k} + \frac{\sum_k W^k}{\sum_k \frac{W^k}{\theta^k}} \text{cov} \left( \frac{\sum_k \sum_j W^k x_j^k R_j}{\sum_k W^k}, R_i \right)$$

(A1)

Rearranging (A1) and using the definition of  $x_j^m$  we obtain :

$$E(R_i) = r + \lambda_i + \frac{\sum_k W^k}{\sum_k \frac{W^k}{\theta^k}} \sum_k \left( \frac{1}{\theta^k} - 1 \right) \text{cov}(R_i, \Pi^k) \frac{W^k}{\sum_k W^k} + \frac{\sum_k W^k}{\sum_k \frac{W^k}{\theta^k}} \text{cov} \left( \sum_j x_j^m R_j, R_i \right)$$

which yields relation (9) .

Appendix 2:

We have expressions (12) and (13):

$$E(R_m) - r - \lambda_m - \theta \text{var}(R_m) = (1 - \theta) \text{cov}(R_m, R_e) \quad (12)$$

$$E(R_e) - r - \theta \text{cov}(R_m, R_e) = (1 - \theta) \text{var}(R_e) \quad (13)$$

Let us look to  $\frac{(12)}{(13)}$  :

$$\frac{E(R_m) - r - \lambda_m - \theta \text{var}(R_m)}{E(R_e) - r - \theta \text{cov}(R_m, R_e)} = \frac{(1 - \theta) \text{cov}(R_m, R_e)}{(1 - \theta) \text{var}(R_e)} \quad (A_2)$$

From  $A_2$  we obtain:

$$E(R_m) - r - \lambda_m - \theta \text{var}(R_m) = (E(R_e) - r) \frac{\text{cov}(R_m, R_e)}{\text{var}(R_e)} - \theta \frac{\text{cov}(R_m, R_e)^2}{\text{var}(R_e)} \quad (A_3)$$

Rearranging expression (A3) gives :

$$\frac{(E(R_m) - r - \lambda_m) \text{var}(R_e) - (E(R_e) - r) \text{cov}(R_m, R_e)}{\text{var}(R_e)} = \theta \frac{\text{var}(R_m) \text{var}(R_e) - \text{cov}(R_m, R_e)^2}{\text{var}(R_e)} \quad (A_4)$$

From (A4) we have:

$$\theta = \frac{E(R_m) - r - \lambda_m \text{var}(R_e) - (E(R_e) - r) \text{cov}(R_m, R_e)}{\text{var}(R_m) \text{var}(R_e) - \text{cov}(R_m, R_e)^2} \quad (A_5)$$

From (13) and (A5), we get:

$$1 - \theta = \frac{1}{\text{var}(R_e)} \left( E(R_e) - r - \frac{(E(R_m) - r - \lambda_m) \text{var}(R_e) - (E(R_e) - r) \text{cov}(R_m, R_e)}{\text{var}(R_m) \text{var}(R_e) - \text{cov}(R_m, R_e)^2} \text{cov}(R_m, R_e) \right) \quad (A_6)$$

We can write (A6) as follows:

$$1 - \theta = \frac{(E(R_e) - r)(\text{var}(R_m)\text{var}(R_e) - \text{cov}(R_m, R_e)^2)}{\text{var}(R_m)\text{var}(R_e)^2 - \text{cov}(R_m, R_e)^2\text{var}(R_e)} - \frac{(E(R_m) - r - \lambda_m)\text{var}(R_e)\text{cov}(R_m, R_e) - (E(R_e) - r)\text{cov}(R_m, R_e)^2}{\text{var}(R_m)\text{var}(R_e)^2 - \text{cov}(R_m, R_e)^2\text{var}(R_e)}$$

(A7)

Substituting (A5) and (A7) in (11) we get:

$$E(R_i) = r + \lambda_i + \frac{(E(R_m) - r - \lambda_m)\text{var}(R_e) - (E(R_e) - r)\text{cov}(R_m, R_e)}{\text{var}(R_m)\text{var}(R_e) - \text{cov}(R_m, R_e)^2} \text{cov}(R_i, R_m) + \left( \frac{(E(R_e) - r)(\text{var}(R_m)\text{var}(R_e) - \text{cov}(R_m, R_e)^2)}{\text{var}(R_m)\text{var}(R_e)^2 - \text{cov}(R_m, R_e)^2\text{var}(R_e)} - \frac{(E(R_m) - r - \lambda_m)\text{var}(R_e)\text{cov}(R_m, R_e) - (E(R_e) - r)\text{cov}(R_m, R_e)^2}{\text{var}(R_m)\text{var}(R_e)^2 - \text{cov}(R_m, R_e)^2\text{var}(R_e)} \right) \text{cov}(R_i, R_e)$$

(A8)

Relation (A8) can be written as follows:

$$E(R_i) = r + \lambda_i + (E(R_m) - r - \lambda_m) \left[ \frac{\text{var}(R_e)\text{cov}(R_i, R_m)}{\text{var}(R_m)\text{var}(R_e) - \text{cov}(R_m, R_e)^2} - \frac{\text{var}(R_e)\text{cov}(R_e, R_m)\text{cov}(R_i, R_e)}{\text{var}(R_m)\text{var}(R_e)^2 - \text{cov}(R_e, R_m)^2\text{var}(R_e)} \right] + (E(R_e) - r) \left[ \frac{\text{var}(R_m)\text{var}(R_e)\text{cov}(R_i, R_e) - \text{cov}(R_m, R_e)^2\text{cov}(R_i, R_e)}{\text{var}(R_m)\text{var}(R_e)^2 - \text{cov}(R_m, R_e)^2\text{var}(R_e)} - \frac{\text{cov}(R_m, R_e)\text{cov}(R_i, R_m)}{\text{var}(R_m)\text{var}(R_e) - \text{cov}(R_m, R_e)^2} + \frac{\text{cov}(R_m, R_e)^2\text{cov}(R_i, R_e)}{\text{var}(R_m)\text{var}(R_e)^2 - \text{cov}(R_e, R_m)^2\text{var}(R_e)} \right]$$

A9

Relation A9 can be written as follows :

$$E(R_i) = r + \lambda_i + \frac{\text{var}(R_e)\text{cov}(R_i, R_m) - \text{cov}(R_m, R_e)\text{cov}(R_i, R_e)}{\text{var}(R_m)\text{var}(R_e) - \text{cov}(R_m, R_e)^2} (E(R_m) - r - \lambda_m) +$$

$$\frac{\text{var}(R_m)\text{cov}(R_i, R_e) - \text{cov}(R_m, R_e)\text{cov}(R_i, R_m)}{\text{var}(R_m)\text{var}(R_e) - \text{cov}(R_m, R_e)^2}(E(R_e) - r)$$

This relation is equation (14).

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