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A Portfolio Diversification Index Analysis of the Home Bias

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Abstract

This paper implements a parsimonious and practical methodology to examine the diversification potential of international equity portfolios. The analysis shows that the *Portfolio Diversification Index* (Rudin, A.M., and Morgan, J.S., Journal of Portfolio Management [2006]) efficiently replicates a number of stylized facts associated to home bias and local investors' preference for geographically proximate destinations over a sample of 8 developed countries.

Key words: Portfolio diversification index; Home bias; Diversification

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1. INTRODUCTION

Diversification is central to portfolio analysis. Since the development of the modern portfolio theory, it is well known that the diversification potential represented by a particular portfolio pool depends closely on the correlation structure: The weaker are the correlations between the portfolio's various constituents, the higher is the diversification potential provided by the considered investment set.

Another well-known result is that investors worldwide typically hold poorly diversified portfolios as they consider a practically limited scope among the set of all investable assets, an observation that particularly holds at an international scale. This so-called *home bias* in international portfolio investments is well documented by French and Poterba [1991], Lewis [1999], and Karolyi and Stulz [2003], among others. Indeed, as long as international portfolio diversification provides potentially profitable risk-return tradeoffs for stock market investors compared to domestic strategies (see, among others, Baele and Inghelbrecht [2009], Driessen and Laeven [2007]), limiting one's portfolio within locally traded stocks is perceived as an irrational behavior and likely to involve more or less important opportunity costs due to overlooking foreign markets. This paper's main objective is to reveal out these opportunity costs due to the global under-diversification of equity portfolios.

Doing so, I implement an alternative technique, the *portfolio diversification index* (PDI), recently proposed by Rudin and Morgan [2006]. Briefly, the PDI provides a methodology that resumes the diversification potential of a given investment set via a single statistic by only making use of the information inherent to the correlation matrix of returns through a principal components analysis (PCA). Indeed, as noted by Rudin and Morgan [2006], the direct exploitation of the correlations between stock returns could be highly inefficient for portfolio analysis purposes even when the investor has to deal with a medium-sized portfolio of, say, 30 stocks, which requires the analysis of 435 different correlation coefficients. In contrast, the PDI technique constitutes a relatively parsimonious framework that can be easily implemented by practitioners.

In particular, I implement the PDI analysis to highlight the effects of home bias on the diversification potential of international stock portfolios from the perspective of investors in major developed countries (G7 countries and Australia). Based on prior research, I assume that investors exhibit equity home bias using two different portfolio selection schemes. First, investors can hold disproportionately high proportions in local stocks, thereby altering the underlying diversification scheme of their aggregate investment portfolio. Second, even though investors consider foreign markets, they are doing so in such a way that they prefer geographically close markets to their home market (see, for example, Lane and Milesi-Ferretti [2008], Portes and Rey [2005]), a practice that ultimately mitigate the diversification potential of the international portfolio. The results show that the PDI technique can effectively take into account the effects of these investment practices, as well as the opportunity costs involved by holding poorly diversified international portfolios.

The organization of the paper is as follows. The next section is a brief overview of the PDI methodology. Section 3 shows how the PDI can be efficiently used to reveal out the diversification costs due to the home bias in international equity portfolios. Sections 4 and 5 provide two further examples regarding the implementation of the PDI technique. Specifically, I analyze the effects of local investors' preference for geographic proximity on international portfolio investments and the marginal declining value of international portfolio diversification. Section 6 concludes.

2. THE PORTFOLIO DIVERSIFICATION INDEX

Let \mathbf{X} be a matrix consisting of T independent observations on a $1 \times N$ dimensional vector $\mathbf{x}_{1\cdot} = [x_{11} \ x_{12} \ \dots \ x_{1N}]$ such that $\mathbf{X}' = [\mathbf{x}_1 \ \mathbf{x}_2 \ \dots \ \mathbf{x}_T]$. Let $\mathbf{X}'\mathbf{X}$ denote the minor-product moment and \mathbf{A} a transformation matrix consisting of the eigenvectors of $\mathbf{X}'\mathbf{X}$. Statistically, the *principal components* of the matrix \mathbf{X} are linear transformations of the form $\mathbf{Y} = \mathbf{A}\mathbf{X}$, designed to reduce the dimensionality of the original matrix \mathbf{X} while retaining a maximal portion of the variation described by the minor-product moment matrix of the raw data. Mathematically, the eigenvalues and eigenvectors of the matrix $\mathbf{X}'\mathbf{X}$ satisfy the following system of linear equations,

$$\mathbf{X}'\mathbf{X}\mathbf{v}_j = \lambda_j\mathbf{v}_j \quad \text{for } j = 1, \dots, N \quad (1)$$

Since by construction $\mathbf{X}'\mathbf{X}$ is positive definite and symmetric, the eigenvectors \mathbf{v}_j are all mutually orthogonal and ordered by declining variance $\lambda_1 \geq \dots \geq \lambda_N$. The resulting matrix of principal components are complex linear combinations of the original matrix $\mathbf{X}'\mathbf{X}$, weighted by the mutually orthogonal eigenvectors \mathbf{v}_j . Due to the declining order of the eigenvalues, the first component captures the largest part of the variance in the data, the second one captures the largest part of the remaining variance component and so on for the remaining components. Formally, we can express the fraction of the total variance due to the j th component by,

$$w_j = \lambda_j / \sum_{i=1}^N \lambda_i \quad (2)$$

such that the sum of component weights is always equal to 1.

Since eigenstructures play a central role in reorienting an original data space with correlated dimensions to uncorrelated axes, principal components analysis can also be of practical interest in portfolio selection because it technically allows to replace a large number of correlated variables by a smaller number of uncorrelated ones with negligible loss of information. Indeed, correlation or covariance matrices, both central to portfolio analysis, can be considered as special cases of the minor-product moment matrix given above with the desirable properties of being both positive definite and symmetric.

Making use of this dimension-reduction method, Rudin and Morgan [2006] have recently proposed the *portfolio diversification index* (PDI), a formula resuming within one single statistic the diversification potential likely to be provided by a given investment set. Specifically, for a set of N securities for which historical return data is available, the PDI is defined as follows,

$$\text{Portfolio Diversification Index} = 2 \cdot \sum_{j=1}^N j \cdot w_j - 1 \quad (3)$$

with w_j defined as above. According to this formulation the PDI is defined as the center of mass of the component weights vector. Thus, it resumes the extent to which the vector \mathbf{w} is front-loaded,

providing a concise measure of the potential diversification scheme likely to be obtained using the portfolio pool of interest. As underlined by Rudin and Morgan [2006], the PDI formula has a number of useful interpretations. First, it is numerically bounded within the continuous interval $[1, N]$. If the PDI is equal to 1, then the entire variation is attributed to only one component and the portfolio is completely non-diversified.¹ Second, if the PDI is equal to N , i.e. if $w_i \approx 1/N$, then portfolio provides the ideal diversification scheme since it implies that the elements of the vector of component weights are all equal to each other, suggesting a powerful orthogonal structure across different portfolio constituents. In practice, the decision rule is simply to prefer the portfolio yielding to the highest PDI score.

3. PDI APPROACH TO THE EQUITY HOME BIAS

In this section, I show how the PDI technique can be implemented to replicate the opportunity costs associated to home bias in international equity portfolios from the viewpoint of local investors in different countries. I use a dataset consisting of monthly returns from 48 investable market indices in USD terms with dividends reinvested, from January 1998 to December 2007. This also constitutes the international portfolio pool through which local investors in developed countries (i.e. G7 countries and Australia) can choose to diversify their equity portfolios. Exhibit 1 provides the sample means, standard deviations and correlations.

[Insert Exhibit 1 about here]

The last three columns show the average correlations between the returns on these eight sample countries and other countries included into the international portfolio pool. For example, the average correlation of the United States with the remaining 47 countries is 51.9%. Also, we observe that, on average, correlations with emerging countries are lower than those with other

¹ It can be checked that for the PDI formula to be equal to 1, the first element of the component weight vector must be close to unity, i.e. $w_1 \approx 1$, while the remaining elements automatically tend to have values close to zero, i.e. $w_{2 \leq i \leq N} \approx 0$.

developed countries. These high-to-moderate correlations generally stand on the basis of most of the gains from international portfolio diversification.

To illustrate the implications of home bias on the diversification potential of international portfolios by means of the PDI technique, it is necessary and sufficient to weight the index returns by the actual portfolio weights. For ease of calculations, I assume that local investors allocate a constant portion of their equity investments into their home market, and that they follow an equally-weighted portfolio strategy concerning their foreign holdings. Thus, if the domestic market weight is $d\%$, the respective portfolio weights of the remaining markets in the international portfolio pool are $(100 - d\%)/47$. Then, I compute different PDI scores as a function of increasing values of the domestic market share to replicate a home-biased investment scheme. The PDI analysis of home bias in international equity portfolios for local investors in G7 countries and Australia is shown in Exhibit 2.

[Insert Exhibit 2 about here]

The graph points out to one common observation: The diversification potential of an international portfolio decreases sharply as the domestic investment share increases. For example, when French investors allocate 20% of their equity assets within their domestic stock market, the PDI score associated to an equally-weighted international diversification strategy is about 1.13. This score very close to unity suggests that the resulting international portfolio consists of a unique truly independent component. Indeed, when the domestic portfolio weight exceeds 20%, the resulting international portfolio of local investors in developed markets exhibits, on average, an almost non-diversified pattern as shown by the PDI scores.

4. PDI ANALYSIS OF THE PREFERENCE FOR GEOGRAPHIC PROXIMITY

Academics have so far established a convincing case that investors prefer geographically close investment vehicles, both domestically (Huberman [2001], Coval and Moskowitz [1999]) and internationally (Lane and Milesi-Ferretti [2008], Portes and Rey [2005]). For example, Portes and Rey [2005] report that when geographic distance is divided by two, foreign investment almost doubles. In this section, I employ the PDI technique to analyze the effects of this preference for geographic proximity on the diversification potential of international equity portfolios.

Doing so, I first compute the PDI score associated to an international portfolio pool of K markets, $PDI(K)$, which always includes local investors' home market. Then, it is possible to check whether the addition of one more foreign market into the existing portfolio pool improves the international diversification potential by computing the marginal PDI score defined as,

$$\text{Marginal } PDI(K + 1) = PDI(K + 1) - PDI(K) \quad (4)$$

As noted by Rudin and Morgan [2006], at the limit of large pool sizes, the expression above is the first derivative of the PDI with respect to the portfolio pool size.

To replicate investors' preference for geographic proximity in international portfolio investments, I proceed as follows: Starting by local investors' home country, I gradually enlarge the international portfolio pool by including the first geographically close foreign country and compute the resulting PDI score. Then, I repeat this process till the most distant foreign country in the sample is included into the international portfolio pool, which ultimately consists of 47 foreign countries plus investors' home country.² For example, for French investors, according to flight distances between capital cities, the first three foreign markets to be included are Belgium, the U.K. and the Netherlands. While working with the same dataset on monthly index returns for 48 countries, I standardize those returns prior to the computations and bring them to the same volatility level in order to guarantee comparability across countries. Exhibit 3 shows the marginal

² I compute the flight distance between the capital or the main cities of countries using the Great Circle Distance formula. More details can be found in Coval and Moskowitz [1999].

PDI scores calculated for local investors in G7 countries and Australia.

[Insert Exhibit 3 about here]

The plots clearly highlight the negative impact of investors' preference toward geographical proximity on international portfolio diversification. First, we observe that a great deal of the diversification potential result from the first 10 to 15 foreign markets: On average, adding the first 10 destinations in a ascending order of the physical distance from the source provides 70% of the total international portfolio diversification potential as measured by the PDI score. Second, the impact of adding one more foreign country into the initial international portfolio pool drops sharply as the pool size K increases: Including the last 10 foreign countries into an existing international portfolio pool generates, on average, only 6% of the total diversification potential over the sample. Third, the preference for geographic proximity has an important negative impact on the diversification potential as shown by negative marginal PDI scores in 75 out of a total of 368 observations. For example, for German investors, adding Czech and Hungarian markets reduces the resulting PDI score of the international portfolio pool respectively by 23% and 8%.

5. IS MORE IS BETTER?

I provide a final illustration related to the PDI technique in international portfolio choice. I show that the PDI can also be used to emphasize the marginal declining value of diversification, a well-known result since the early stages of modern portfolio analysis. The example provided here follows Rudin and Morgan's [2006] marginal PDI analysis based upon the S&P 100 index. Specifically, I randomly draw K countries from the international portfolio pool, which consists of 48 countries, and compute the resulting PDI score, with local investors' home country being always included into the portfolio pool. Then, I repeat the process many times for different international portfolio pool sizes ranging from 2 to 48, and report the average PDI scores. Exhibit 4 shows the evolution of the PDI scores with respect to different portfolio pool sizes.

[Insert Exhibit 4 about here]

Exhibit 4 confirms the limits of diversification in international portfolio investments using the PDI technique, rejecting the view that more is better. Different plots drawn for developed countries' investors are clearly sublinear, which means that the increase in diversification gains are not proportional to the number of countries included into the international portfolio. In general, for pool sizes exceeding 20 countries, the incremental PDI gains are mostly limited and close to zero. For example, for Japanese and UK investors, holding an international portfolio made up by 48 instead of 24 countries (including their own home country), increases the initial PDI scores by only about 7% and 9% respectively. Overall, the results are consistent with those presented by Rudin and Morgan [2006] who also underline the declining value of diversification by means of PDI analysis using data on S&P 100 index members.

6. CONCLUSION

The *Portfolio Diversification Index* provides a practical and parsimonious tool to practitioners willing to understand the diversification potential represented by a particular portfolio pool. It resumes the underlying correlation structure among different portfolio constituents within a single statistic, which is also comparable across various portfolio pools and over time. This study is an attempt to provide an example as to how the PDI technique can also be implemented in the context of international portfolio investments. The analysis suggests that the PDI methodology allows one to efficiently replicate a number of well-known investment patterns related to literature on international portfolio selection and the home bias, such as the opportunity costs of portfolio underdiversification or investors' preference toward geographically closer markets.

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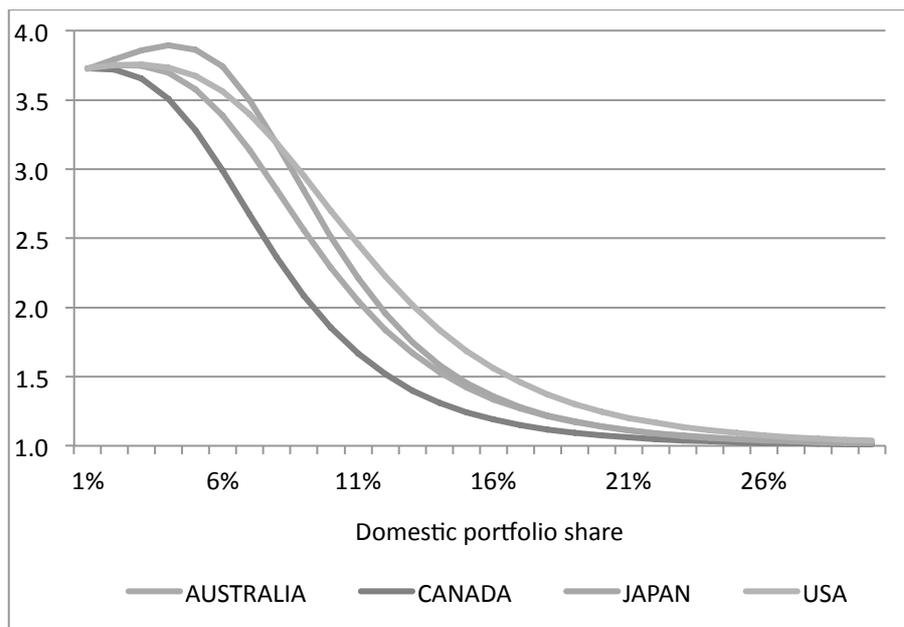
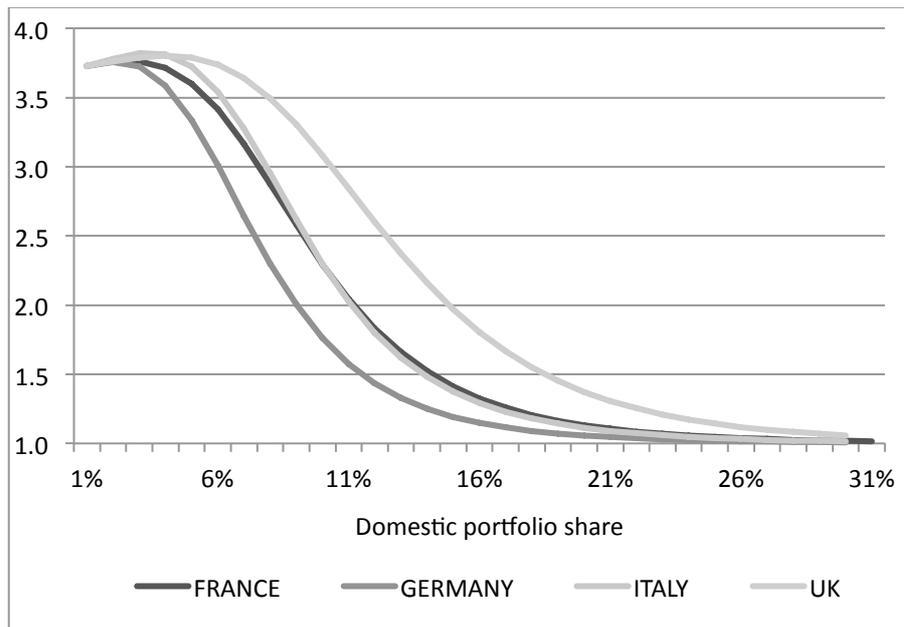
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Exhibit 1. Summary statistics and correlation

Country	Mean	Standard deviation	Average correlation with		
			all countries	developed countries	emerging countries
Australia	1.30	5.11	51.9	57.8	46.8
Canada	1.17	5.95	53.5	61.7	47.8
France	0.95	5.24	52.0	68.6	37.3
Germany	0.84	6.60	51.9	66.1	39.5
Italy	0.89	5.58	45.1	58.6	33.2
Japan	0.38	5.31	36.2	40.4	32.6
U.K.	0.60	3.88	51.8	65.4	39.8
U.S.A.	0.47	4.30	51.9	62.1	42.9

Notes: The first two columns show the sample mean and standard deviation of monthly returns over the period January 1998 – December 2007. The last three columns show the average correlation of the country returns with the remaining 47 countries in the international portfolio pool, as well as with developed and emerging countries. All numbers are expressed as percentage values

Exhibit 2. Home bias: PDI by domestic investment share



Notes: The plots show the dependence of the PDI scores for local investors in G7 countries and Australia as a function of the domestic portfolio share. For a given level of domestic investment share, say $d\%$ (horizontal axis), it is assumed that local investors follow an equally-weighted portfolio strategy for their foreign holdings allocated into remaining countries in the international portfolio pool (i.e. $(100 - d\%)/47$), and the resulting PDI score is reported (vertical axis).

Exhibit 3. Marginal PDI analysis of the preference for geographic proximity

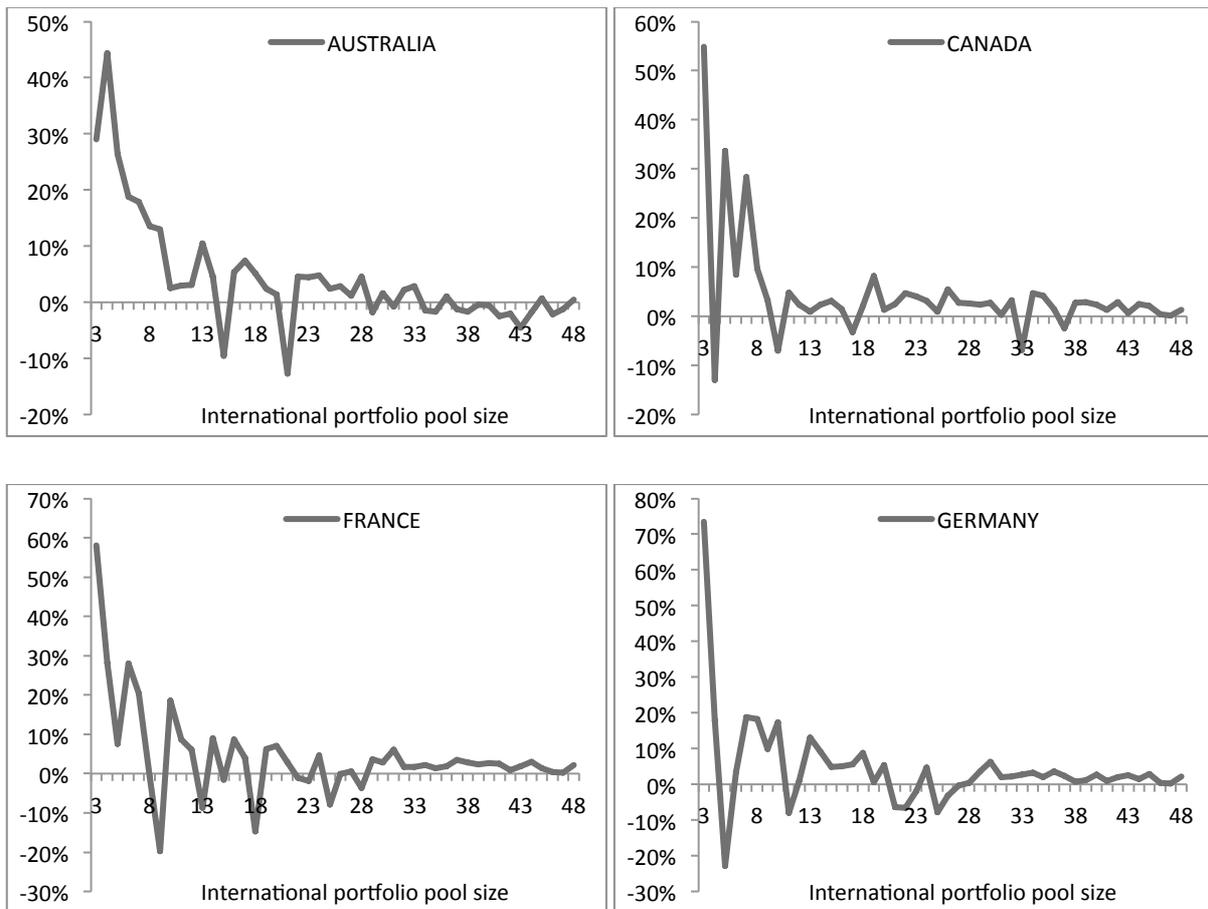
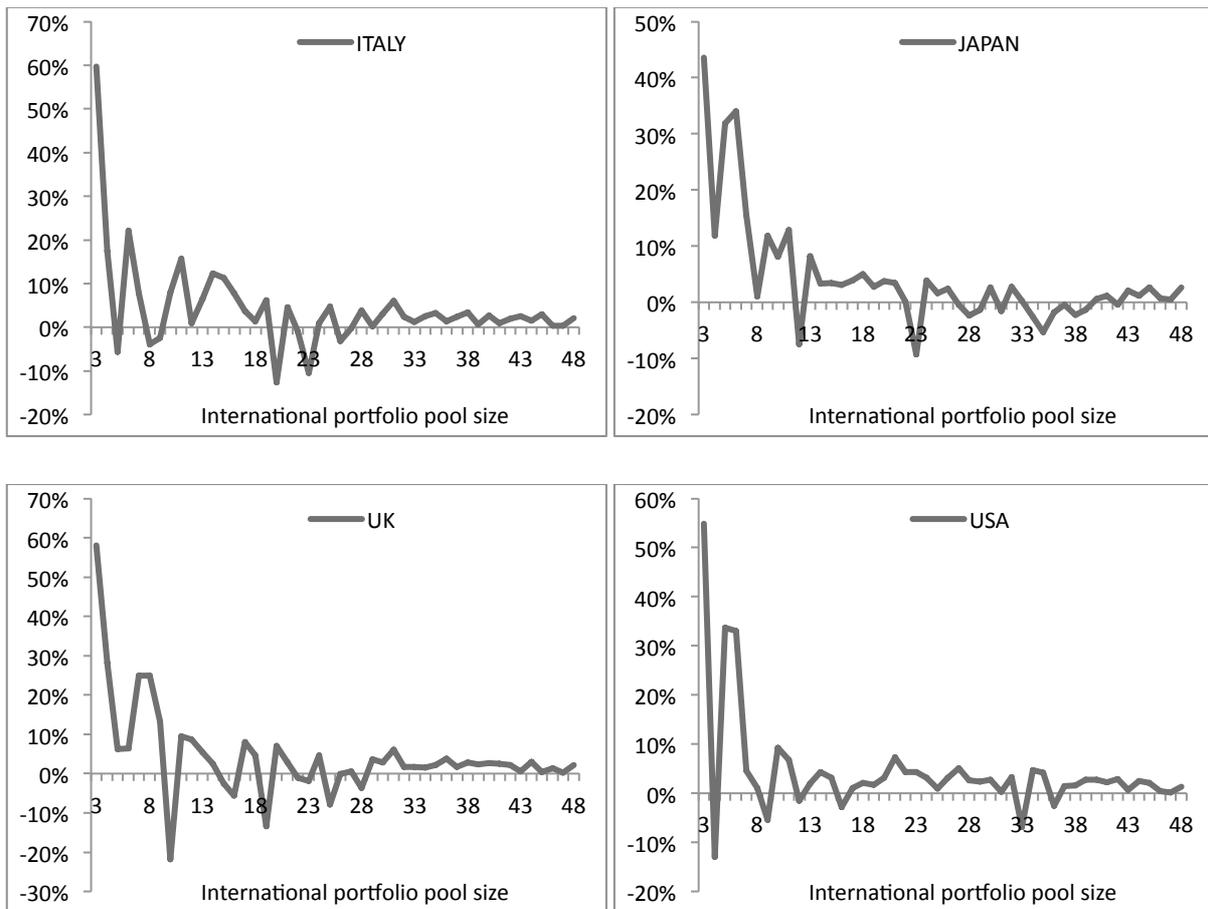


Exhibit 3 (continued).



Notes: The plots show the incremental PDI scores for local investors from G7 countries and Australia. Starting with local investors' home country, I gradually enlarge the international portfolio pool by including the first geographically close foreign country and compute the resulting PDI score. The process is then repeated till the most distance foreign country is included, which ultimately consists of 47 foreign countries plus investors' home country (horizontal axis). First differences of the PDI scores as a function of the portfolio pool size are provided on the vertical axis.

Exhibit 4. Incremental gains from international diversification: Simulation results

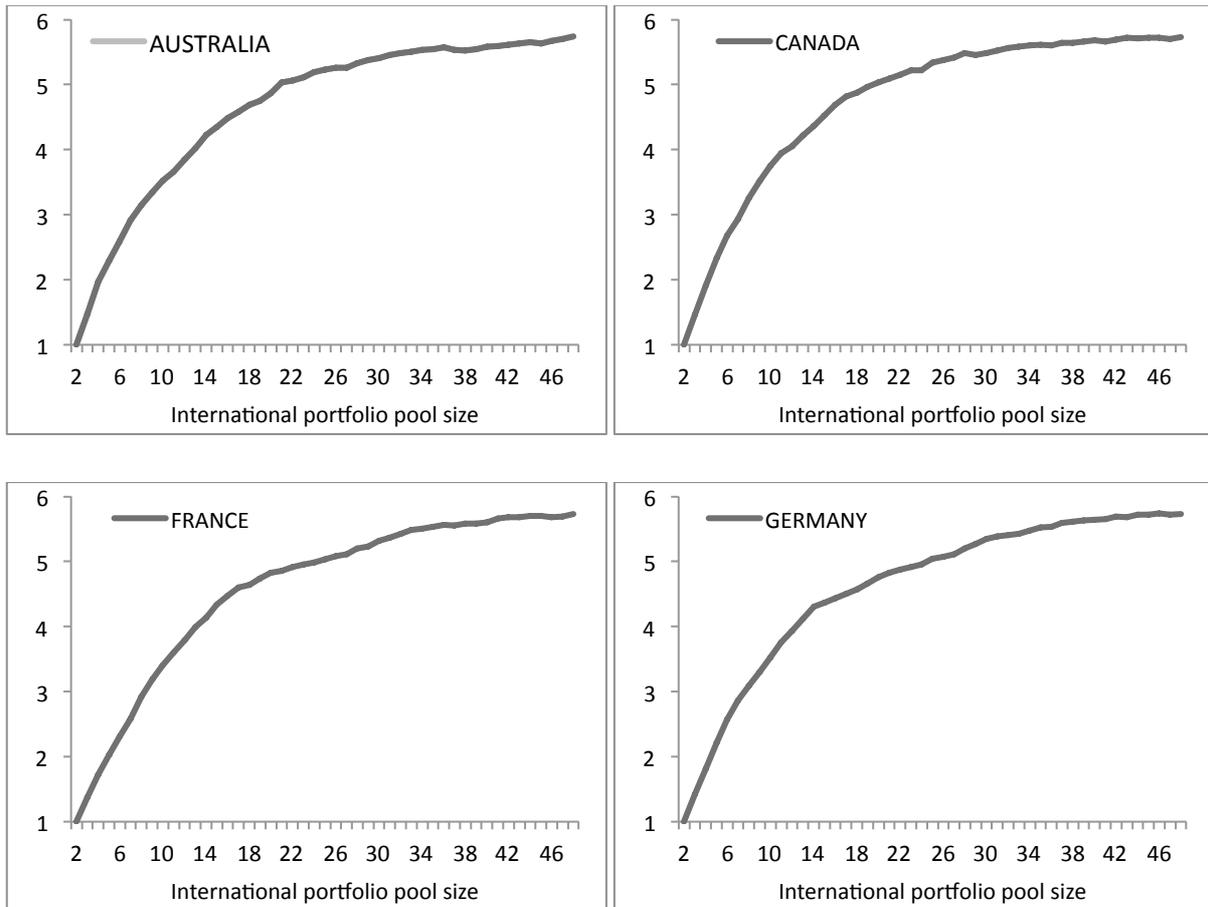
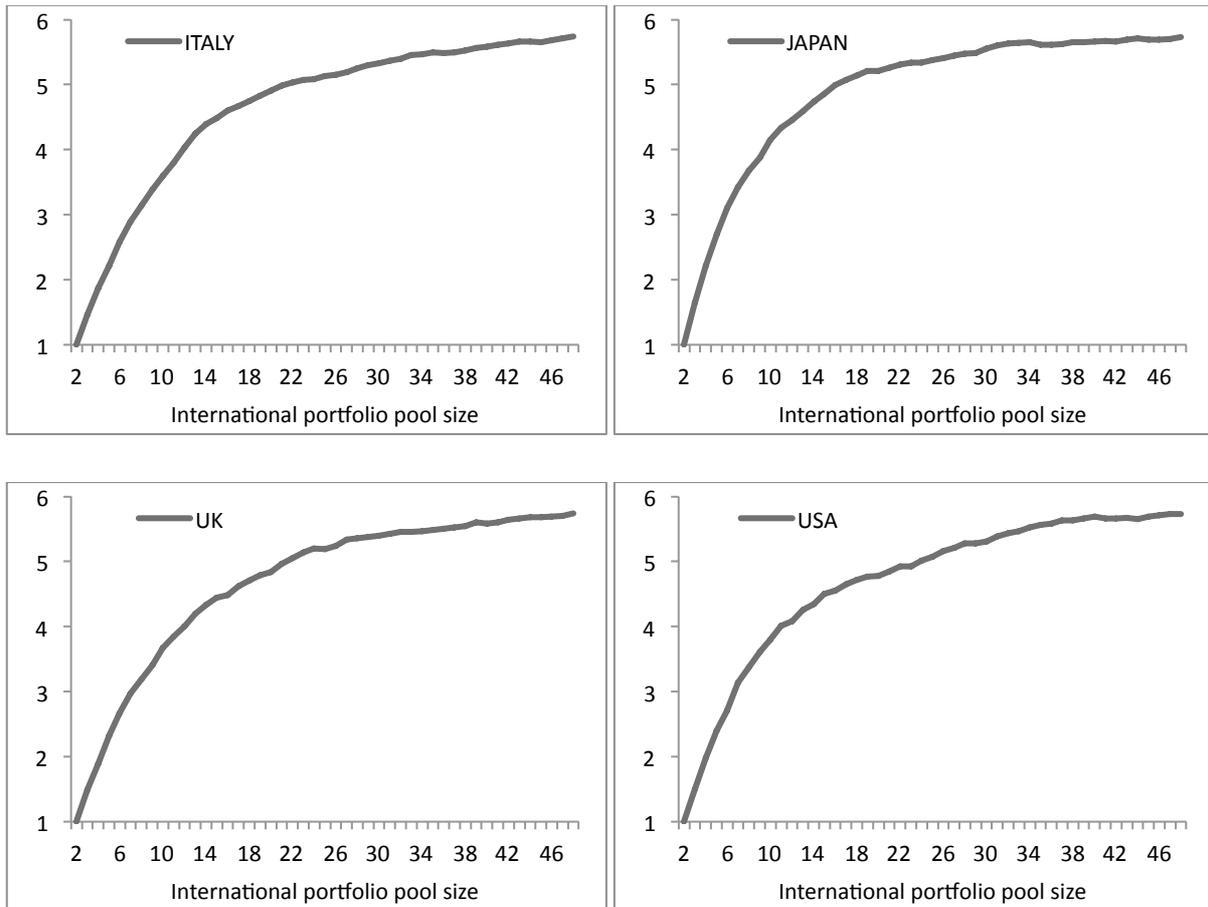


Exhibit 4 (continued).



Notes: This exhibit shows the marginal declining value of international diversification using PDI technique. To obtain the graphs for each country, I randomly choose an international portfolio consisting of K countries and compute the PDI score. Then, I repeat the process many times for different international portfolio pool sizes of $K = 2, \dots, 48$ countries (horizontal axis), and report the average PDI scores (vertical axis).