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Chun-Hung (Hugo) Tang PhD
Oklahoma State University

SooCheong (Shawn) Jang PhD
Purdue University

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Weather Risk Management in Ski Resorts: Exploring the Effect of Geographical Diversification on Financial Hedging

Chun-Hung (Hugo) Tang, Ph.D.
Oklahoma State University
Stillwater, Oklahoma USA

SooCheong (Shawn) Jang, Ph.D.
Purdue University
West Lafayette, Indiana USA

ABSTRACT

In this study, the authors examine the effect of geographical diversification on risk exposure to snowfall risk and the hedging effectiveness of hypothetical snowfall forwards. The graphical simulation of the model based on a hypothetical two-property ski resort suggests that, from a risk reduction point of view, the “best” property to be acquired would be the one whose basis is positively correlated with the existing basis and negatively correlated with the existing snowfall. The “best” property is the property that allows the hedging in place to reach the highest hedging effectiveness.

INTRODUCTION

The Chicago Mercantile Exchange (CME) estimates that nearly 20% of the U.S. economy is directly affected by weather. Industries such as agriculture, energy, retailing, travel, leisure, and entertainment are usually susceptible to weather conditions (Chicago Mercantile Exchange 2005). The impact of weather volatility is especially significant in the nature-based tourism business since the natural setting is the most critical factor in determining the length of the season and the quality of the tourism product (Scott 2003). For ski resorts, snowfall constitutes a major source of business risk because the number of visits, and therefore cash flows, are closely tied to snow depth (Fukushima et al., 2002). Shih, Nicholls, and Holecek (2009) also demonstrate that daily weather variations have significant impact on the demand such as daily ski lift ticket sales in ski resorts. On the supply side, capacity is also influenced by the amount of snowfall. Snow depth has to be at least 30 cm to be skiable (Scott, McBoyle, & Mills, 2003). By managing the influence of weather risks, companies can reduce their cash flow volatility and subsequently increase shareholder value. For example, Allayannis and Weston (2001) show that by reducing cash flow volatility through hedging foreign exchange exposure, companies can increase their firm value by 4.87%.

When facing weather risks, companies usually respond with changing the operations associated with the risk exposure to reduce the risk. For individual ski resorts, snowmaking is a common practice in response to poor snow conditions. On the company level, ski resort companies also can diversify into different geographical regions to reduce the negative impacts of poor snow conditions from certain properties. Operational hedging is generally effective in managing long-term exposure. However, these strategies could require a substantial amount of capital investment and could be difficult to be reversed due to equipments and physical presence (Pantzalis, Simkins, and Laux 2001).

Recent innovations in finance have spurred the creation of financial derivatives based on weather variables such as temperature, rainfall, or snowfall. With weather derivatives, companies could transfer their risks to the market instead of having to engage in operational changes to

reduce risk exposure or the risk directly. These financial products provide alternative ways for nature-based tourism companies to manage their weather related risks without influencing the investments or operations (Kim, Mathur, and Nam 2006).

It is not our intention to argue that financial hedging is superior to operational hedging. In fact, researchers (Allayannis, Ihrig, and Weston 2001; Kim et al., 2006; Petersen and Thiagarajan 2000) have shown that the decisions and outcomes of these two types of strategies could interact. For ski resorts, geographic diversification can directly reduce the firm's exposure to the snowfall risk of individual properties. But if the companies have limited resources to acquire new properties or appropriate properties cannot be identified, financial hedging could be an alternative tool for risk management. Therefore, from a risk management perspective, it is important for the management to consider geographic diversification and financial hedging together.

In the hope to provide a stepping stone towards the integration of financial and operational hedging, the purpose of this study is to examine the interaction between these two hedging approaches in the context of ski resorts. Ski resorts are a good target for our study because ski resorts' major business risk, snowfall risk, can be managed by either geographic diversification or financial hedging at the company level and the outcomes of these two strategies are interrelated due to their correlations with snowfalls. To explore the interactions between these two strategies, our objective is to examine the effect of geographic diversification on the hedging effectiveness of snowfall forwards in a multiple-property ski resort. A snowfall forward is an agreement between two parties to buy or sell a snowfall index at a specified point of time in the future. Although the present study is based on ski resorts and snowfall risk, the methodologies and results can be applied to any nature-based business that is sensitive to weather risks.

HEDGING SNOWFALL RISK

Weather risk is defined as the uncertainty of cash flow or earnings caused by weather volatility (Cogen, 1998). Snowfall risk as one of the weather risk is different from commodity price risk and other financial risks in several aspects. First, weather risk is a 'volume' risk in that it affects the quantity not price. Second, weather risk is a highly localized risk, as micro-climates could vary from one location to another. Third, local weather risk also has a low correlation with other financial risks, such as exchange rate risk, interest rate risk, or even commodity risk. Fourth, there is no physical market in weather. For example, we cannot store the snow from last year to deliver this year. Fifth, weather risk is a pure exogenous risk that is beyond human control. It cannot be forecasted beyond a few days, even with today's technology. Since it is almost impossible to directly "manage" or store weather in order to reduce weather-related cash flow volatility, weather derivatives naturally become one of the most viable tools to manage the weather risk.

Currently, CME offers snowfall index futures and options based on Boston and New York snowfalls only. The index is based on the accumulation of daily snowfall during a calendar month. Each point on the index, representing one inch of snow, corresponds to \$200. The months traded are from October to April. However, a pay-off based on snowfall in Boston or New York is unlikely to exactly compensate for the fluctuation of cash flows at a ski resort located in other locations because weather risk is highly localized. Derivatives based on the local weather index are usually more effective in hedging weather risk. In this study, we use forward contracts based on local snowfall index as the tool for weather risk hedging because they provide higher effectiveness. The analysis is also simplified because there is no price fluctuation and the interest rate need not be considered.

To reduce cash flow volatility, a firm needs to build a position in a hedging instrument that could compensate the effect due to the exposure to the risk factor. Ski resorts have a natural long position in the snowfall index; the cash flow rises and falls with the amount of snowfall. Therefore, it should enter a

short position in a forwards contract based on local snowfall index to offset the possible adverse effect of low levels of snowfall. It should be noted that the goal of entering a hedge position is to minimize the volatility of cash flow, not to maximize the amount of cash flow.

MODEL DEVELOPMENT

The unique challenge in studying the effect of geographic diversification on snowfall risk hedging is the existence of basis risk. In finance, basis is defined as the difference between the spot price of the hedged asset and the price of the futures contract based on the same asset. When the spot price and futures price are not perfectly correlated, the basis will not be constant. Therefore, basis risk exists. In ski resorts, cash flow from operation and the amount of snowfall are not perfectly correlated so basis risk exists when using snowfall based derivatives to hedge cash flow's exposure to snowfall risk. When only one basis risk is considered as in a single-property ski resort, the best estimate for the optimal hedge ratio is the same as the case without the basis risk (Castelino, 1992); the coefficient of the simple regression that regresses cash flow on snowfall index. But in a multiple-property resort, finding the optimal hedge ratio is more complicated. The multiple-property ski resort faces multiple basis risks because each of the property represents one basis risk. Under such situation, the correlations between the basis of different properties, the correlations between snowfall indices, and the cross-correlations between the basis and the snowfall index have to be considered in finding the optimal hedge ratio for each property.

To examine the effect of multiple basis risk on hedging effectiveness, we start by incorporating a single basis into the equation of hedged cash flow. Based on Castelino (1992), the basis is defined as the difference between cash flow and the snowfall index ($B = CF_{op} - F$), where basis B is the difference between cash flow and snowfall forwards. Castelino's (1992) framework for analyzing price risk is also modified for the quantity risk because snowfall risk is a quantity risk, which affects the amount, not the value, of cash flow. The hedged cash flow is expressed as $CF_{hedged} = CF_{op} - h \cdot (F - K)$, where

CF_{hedged}	= hedged cash flow over a quarter
CF_{op}	= operating cash flow produced over a quarter
h	= hedge ratio
F	= actual snowfall index level at the end of a quarter
K	= fair strike, a pre-determined strike level that neither side has a advantage

This quantity-risk version is actually simpler than Castelino's (1992) price risk version because the cash flow and the snowfall index already are the difference over a period. This is equivalent to the scenario when the initial price is zero in the price risk framework.

When basis is incorporated into equation 3.1, the single hedged cash flow then becomes $CF_{hedged} = B + (1 - h) \cdot (F - K)$. Extending the above equation to the multiple-cash-flow case, the

aggregated hedged cash flows will be $\sum_i CF_{hedged,i} = \sum_i B_i + \sum_i [(1 - h_i) \cdot (F_i - K_i)]$ and the

variance of the aggregated hedged cash flows becomes

$$\begin{aligned} Var(\sum_i CF_{hedged,i}) &= \sum_i Var(B_i) + \sum_i \sum_{j \neq i} Cov(B_i, B_j) + \sum_i (1 - h_i)^2 \cdot Var(F_i) \\ &+ \sum_i \sum_{j \neq i} (1 - h_i) \cdot (1 - h_j) \cdot Cov(F_i, F_j) + 2 \cdot \sum_i \sum_j (1 - h_j) Cov(B_i, F_j) \end{aligned}$$

To find the optimal hedge ratios, the above equation is differentiated with respect to h_i 's and set to zero. The optimal hedge ratios would be obtained by solving i equations simultaneously. For example, in a simplified case of a two-property ski resort ($i = 2$, two cash flows and two snowfall indices), the optimal hedge ratio for snowfall index 1 is

$$h_1 = 1 + \frac{Cov(F_1, F_2)[Cov(B_1, F_2) + Cov(B_2, F_2)] - Var(F_2)[Cov(B_1, F_1) + Cov(B_2, F_1)]}{[Cov(F_1, F_2)]^2 - Var(F_1) \cdot Var(F_2)} \quad \text{Eq. 1}$$

Finally, hedging effectiveness is measured as in Ederington (1979).

$$HE = 1 - (\sigma_{hedgedCF}^2 / \sigma_{unhedgedCF}^2) \quad \text{Eq. 2}$$

The variance of the un-hedged aggregated cash flow is

$$\begin{aligned} Var(CF_{op}) = & \sum_i Var(B_i) + \sum_i \sum_{j \neq i} Cov(B_i, B_j) + \sum_i Var(F_i) + \sum_i \sum_{j \neq i} Cov(F_i, F_j) \\ & + \sum_i Cov(B_i, F_i) + \sum_i \sum_{j \neq i} Cov(B_i, F_j) \end{aligned}$$

In the finance domain, many researchers have studied the effect of basis risk on the hedging effectiveness of futures (Netz, 1996). However, most of the studies (i.e., Castelino et al., 1991; Figlewski, 1984; Netz, 1996) are based on price risks, such as stock index futures and commodity futures, and consider only one basis risk at a time. Golden, Wang, and Yang (2007) extended the literature by studying the interaction between credit risk and basis risk in weather derivatives. But the researchers still considered only the weather derivatives of a single location. This study extends the literature on basis risk by examining the effect of multiple basis risks on hedging effectiveness.

GRAPHICAL SIMULATION

In order to provide a straightforward and intuitive interpretation for the relationships embodied in the complex non-linear equations derived above, we demonstrate the hedging effectiveness in graphs based on a hypothetical two-property ski resort. The hedging effectiveness in a two-property resort is a function of the 10 variances and covariances between and within index and basis as listed below.

Var(F1), Var(F2)	variances of indices 1 and 2
Cov(F1, F2)	covariance between indices 1 and 2
Cov(B1, F1), Cov(B2, F2)	covariance between the index and basis
Cov(B1, F2), Cov(B2, F1)	covariance between basis and the other index
Var(B1), Var(B2)	variances of basis between the index and corresponding cash flow
Cov(B1, B2)	covariance between bases 1 and 2

The demonstration is based on standardized variables, which means all variables have variances of 1 and the covariances are between -1 and 1. To demonstrate graphically, we start by setting all variables to constants and relax only one or two correlations at a time to allow them to move between -0.9 and 0.9. The range is not set to be between -1 and 1 in order to avoid the denominator in the optimal hedge ratio equation (equation 1) becoming zero. Finally, the values of hedging effectiveness are plotted on a 3-dimensional graph to form a response surface.

The un-relaxed correlations have to be set to realistic values because the hedge ratio and hedging effectiveness are functions of these correlations and the chosen values will affect the

direction and magnitude of the hedge ratio and hedging effectiveness. Therefore, we employ annual data from two real skiing locations, Vail and Breckenridge, to calculate the value needed for setting the un-relaxed correlations. The number of visitors is used for the calculation of basis because of the lack of property-level cash flow data. This should be less problematic since we are interested only in correlations, and operating cash flow is a function of the number of visitors. The number of visitors and snowfall of both locations are standardized, and the basis of each location is the standardized number of visitors minus the standardized snowfall. The correlations within and between snowfalls and basis are presented in Table 1, in which Vail is location 1 and Breckenridge is location 2. When the variances and correlations in Table 1 are plugged into equations 1 and 2, the hedging effectiveness is 56.76%, which can serve as the benchmark in the later discussions of the graphical demonstration results.

Table 1. Correlations within and between the Index and Basis.

	F1	F2	B1	B2
F1	1	0.888***	-0.497*	-0.653**
F2		1	-0.555**	-0.747***
B1			1	0.359
B2				1

Note: Vail = 1, Breckenridge = 2; F = snowfall index, B = basis

FINDINGS

Figure 1 presents the relationships between hedging effectiveness and various correlations. It is important to note that these relationships are specific to the correlations presented in Table 1. The correlations within snowfalls or bases are positive, but the correlations between snowfalls and basis are negative. Under such a situation, the hedging effectiveness has a negative, but non-linear, relationship with the correlations between the index and basis. The highest hedging effectiveness occurs when these correlations are negative. In the case of the correlation between two bases, hedging effectiveness increases as the correlation increases, but in a concave relationship.

Much of the hedging effectiveness exceeds the lower bond of zero. This happens because all variables are standardized and the un-relaxed variances are fixed at 1 and the correlations are fixed at the values presented in Table 1. When the relaxed correlations are assigned very large negative values and detour from the real relationships presented in Table 1, the sum of the covariances could be negative and makes the cash flow variance very small or even negative in calculating the variances of un-hedged cash flow. This is also the reason that Figure 2 shows negative hedging effectiveness as well.

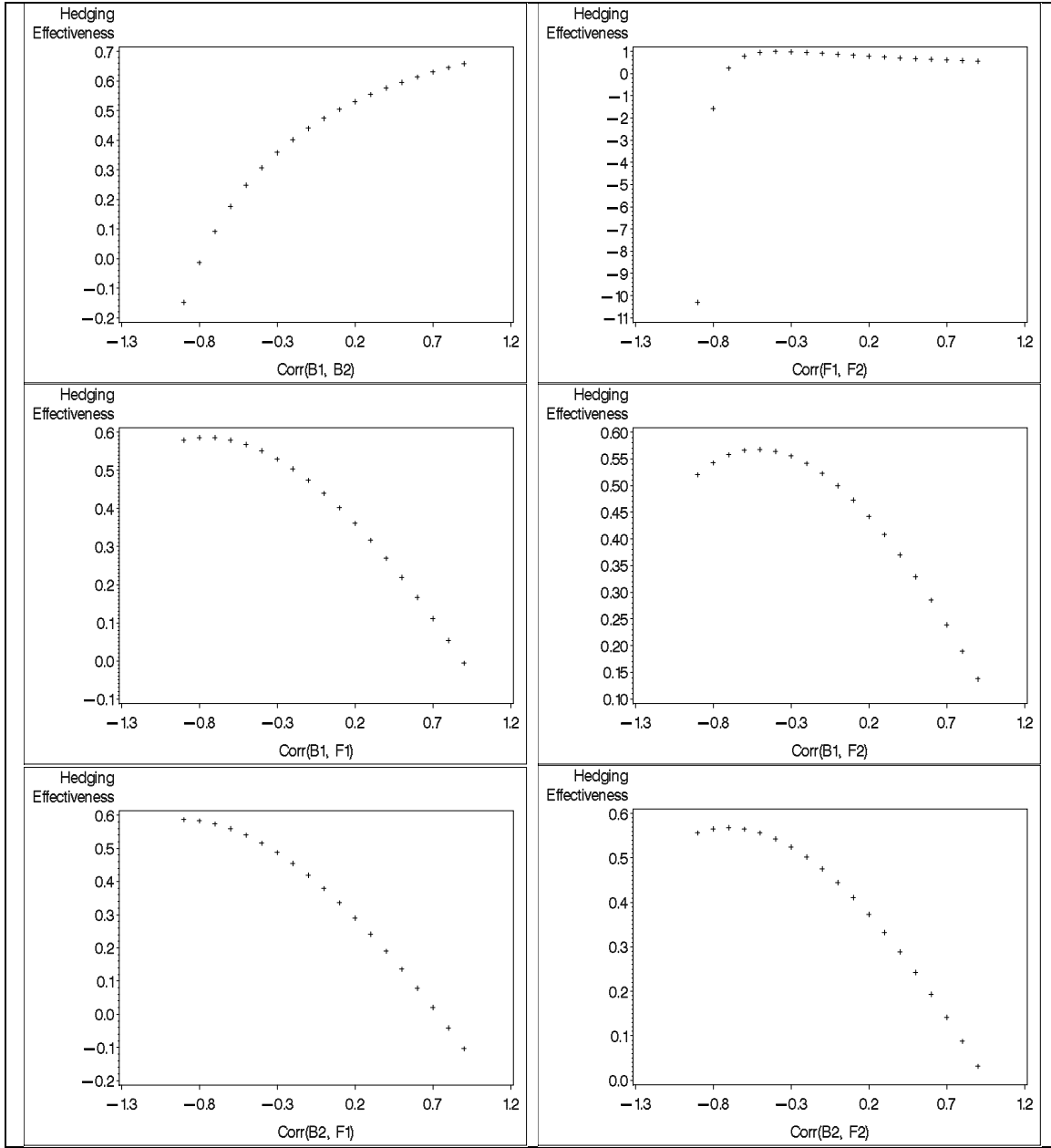


Figure 1. The Relationship between Hedging Effectiveness and Correlations.

Next, we relax two correlations at the same time to demonstrate the effect of two different correlations on hedging effectiveness. Figure 2.A represents the hedging effectiveness under different levels of Corr(F1, F2) and Corr(B1, F1). The pattern of the response surface remains very similar when Corr(B1, F1) is replaced by other correlations between snowfall and the index. This suggests that the correlation between two snowfalls is more influential on hedging effectiveness than the correlations between snowfall and basis. The correlation in Figure 2.A is restricted to larger than -0.7 because the rapid decline in hedging effectiveness after about -0.4 would dramatically distort the scale of the vertical axis and make the surface appear to be horizontal. Figure 2.A suggests that theoretically it is possible to reach 100% hedging

effectiveness when two snowfall indices are negatively correlated (i.e., $\text{Cov}(F1, F2) = -0.35$, $\text{Cov}(B1, F1) = -0.65$ in this case). However, in a real situation, the two snowfall indices within the vicinity are more likely to positively correlated, which makes 100% hedging effectiveness impossible in this case. For example, the hedging effectiveness of our hypothetical two-property resort (56.76%) locates on the intercept of the Z-axis and the response surface.

Figure 2.B shows that financial hedging is most efficient when the two indices are not correlated but the two bases have a strong positive correlation. These two correlations are restricted to positive values in order to avoid the variance of the original cash flow becoming negative. Restricting $\text{Corr}(F1, F2)$ and $\text{Corr}(B1, B2)$ to positive is also a realistic scenario because fundamental weather variables tend to correlate across close locations (Jewson & Brix, 2005).

Figure 2.C represents the hedging effectiveness under the combinations of $\text{Corr}(B1, B2)$ and $\text{Corr}(B1, F1)$. The response surface remains very similar when $\text{Corr}(B1, F1)$ is replaced by other correlations between basis and the index. This also suggests that the correlation between bases is more influential than the correlation between basis and the index. It also shows that hedging effectiveness increases as the correlation between bases increases.

Figure 2.D indicates that hedging effectiveness increases as the cross-correlations between basis and the index become more negative.

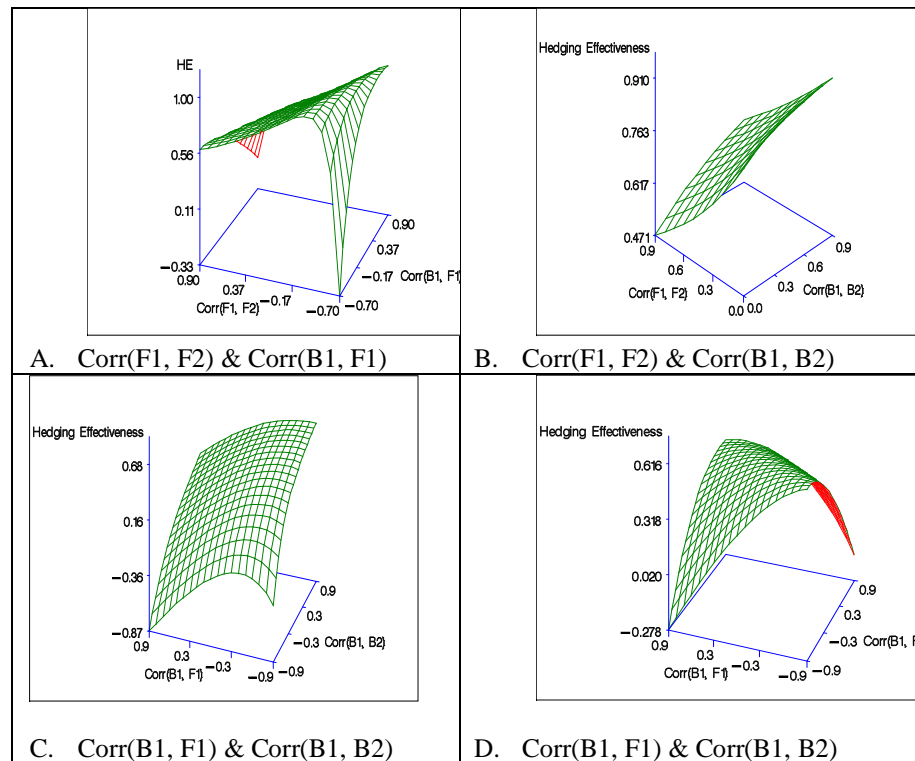


Figure 2. Hedging Effectiveness under Two Correlations

CONCLUSIONS AND APPLICATIONS

The results indicate that the correlations between two snowfalls or two bases are more influential on hedging effectiveness than the cross-correlations between snowfall and basis. The

simulation also shows that hedging effectiveness increases as snowfalls become more negatively correlated, bases become more positively correlated, or the cross-correlation between snowfall and basis become more negatively correlated. Because snowfalls are more likely to be positively correlated in the real world, if a ski resort is planning to add a new property, from a risk reduction point of view, the best candidate would be the one whose basis is positively correlated with the existing basis and negatively correlated with the existing snowfall. We want to point out that other aspects of geographic diversification, such as growth potential offered, operating efficiency, and synergy, should also play an important role in choosing acquisition targets.

Although based on ski resorts, the results apply to any business that is sensitive to weather risk and also seek geographical diversification. Considering that most of the leisure and tourism businesses need to expand geographically for future growth, the results have broad implications. Specifically, for a company that is planning to add a new property, the results could function as a guideline in choosing the location that could provide the highest effectiveness of financial hedging. For example, a beach resort looking to add a new property could choose a location whose basis is positively correlated with the existing basis but negatively correlated with the sunny days in existing resorts. Because most existing basis risk studies are based on price risk and single basis risk, such as stock index futures, this study also extends the methodological aspect of basis risk study by examining the effect of quantity risk and multiple basis risks on hedging effectiveness.

One major limitation of this study is the lacking of property-level cash flow data. Although operating cash flow is a function of the number of visitors; a more direct measure on the correlations between snowfall and cash flow improve the validity of the analysis. Another limitation is that graphical demonstration is limited to three dimensions, which allows only two correlations to be relaxed at a time. Acknowledging the importance of other aspects of geographic diversification, such as operating efficiency and return on investment, in this study we focus on the effect of geographic diversification on financial hedging. The next logical step for this study would be examining financial hedging as a component of the corporate risk management program. The relationship of financial hedging with other financing, investing, and operating decisions could be considered together to provide a more complete picture.

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