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Integrating Physical Real Estate and Infrastructure Assets in Enterprise Risk Management

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Actuaries

Risk is Opportunity.[sm]

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Real estate and infrastructure as asset classes have traditionally been an essential part of many diversified institutional portfolios, and legitimate candidates for the type of risk analysis typically required for other assets that are publicly traded. These illiquid asset classes have been labeled diversifiers and inflation hedges, and touted as providing idiosyncratic alpha opportunities and enhanced portfolio yield at moderate risk. Their sheer physicality, unlike other financial products that seem to disintegrate, default or flee to some secretive banking regime in times of crisis, somehow conveys a sense of security to their owners. Unfortunately, this naïve perception has little to do with reality with respect to their actual yield, return-generating capability and risk characteristics. The rigorous quantification of the risk/reward trade-off for real estate and infrastructure has been a problem that has never found a clear answer with either investors or academics. It is the intent of this paper to directly address this problem in a detailed, bottom-up fashion that satisfies both fundamental “brick-and-mortar” traditionalists as well as provide a rigorous quantitative approach that allows private equity real estate’s and infrastructure’s full integration into a best practices multi-asset risk model.

Due to the geographically bounded nature of their underlying business models, real estate and infrastructure are surprisingly similar. The profit-generating mechanism of both types of investments involves owning long-term leasable assets that generate relatively stable revenue streams and have relatively predictable expenditure schedules. Both feature location as an important determinant of economic value, and clear usage that is closely connected to the nature of the leasable assets. As a consequence, it is logical to expect that their payoff characteristics and the types of sensitivities to risk drivers should be very much related. Our discussion to reveal what those risk drivers are will start with the major problems these asset classes have faced traditionally in enterprise risk management (ERM). We will also provide a baseline reference point and modeling approach. Building on those premises, we will then create a theoretical framework describing the unobservable performance of these assets. We will also demonstrate the application of this modeling system for both real estate and infrastructure, as well as detail the model’s risk results. Finally, we will answer the question posed by the paper’s title:

namely, how the chosen approach enables us to integrate these assets into the risk estimation and optimization at the enterprise investment portfolio level.

Historically, there have been two major obstacles before infrastructure and real estate could be included in ERM. The first is an expression of the idiosyncratic nature of those investments, and the second is a general methodology challenge of risk management to expand to an ever-increasing number of asset classes. Unlike equity share certificates and bond contracts that are printed or issued in multiples and whose inherent value is described daily by the trading undertaken by market participants, buildings and toll roads do not have these characteristics. Each of those investments is unique and is defined by its location, size, clients or tenants base, facility condition, etc. Moreover, these investments are not divisible and are only available for outright purchase unlike, e.g., real estate investment trusts (REITs), which can be purchased at the share level. The large capital requirement and indivisibility make these investments accessible only to the largest of investors, and even for them it is not a trade to be taken lightly. Unlike the disposition or purchase of almost any common stock, which can be reversed the next day, a purchase or sale of a commercial building is measured in months if not years. Even if you do not sell your shares of Company X today, the same type of share will change hands in the market within some short period of time, revealing its current market value. That is certainly not the case for Building X. Due to its indivisibility, and therefore large capital requirements, its true market value is exposed only when it goes to market. This is an investment management challenge because we would like to draw inferences (e.g., project mean value and standard deviation of return to gauge respectively expected profitability and risk) based on the market value track record of a building before we decide to engage in an actual trade. This complication has forced real estate and infrastructure analysts to resort to appraised values as their metric of estimated market value.

Since appraised values are derived from qualitative, heuristic-based methodologies rather than market-driven, auction-based pricing, this has created a particular set of problems for risk estimation. Appraised values are determined by one and/or a combination of three techniques: replacement cost, comparable sales and/or income capitalization. Each technique has its advantages and disadvantages, but all of them require a large amount of qualitative judgment; and all of them are done at some low level of periodicity. Other common problems are that during economic downturns, appraisers have difficulties finding usable “comparables” since in the jargon of appraisers there are no “willing buyers and sellers.” Furthermore, the income capitalization approach is difficult to use since there are, again, few reliable transactions from which a consensus discount rate can be formed. Even in normal years, only a small portion of the institutional building stock is sold in any given year. This means that the comparable sales approach tends to use a fairly small sample when determining values and relies more on historic rather than expected market changes.[1] Not surprisingly, the discounted cash flow (rents/revenues minus expenses) model typically uses a discount rate ("cap" rate) that is higher for high-risk investments and low for low-risk investments. Given that the historical volatility of such investments is only available at discontinuous periods, the lags in judgment inherent in the "comparable sales" approach are present in the formation in the cap rate as well. The result is similar—a reported reinforcement of the prior price trend. Finally, the replacement cost approach is doomed to a similar fate as its cousins. During non-equilibrium portions of the construction cycle, both land and construction costs are biased estimators of "true" long-term replacement values, and appraisers find it difficult to find the correct adjustment factors. Therefore, it is rare to find a valuation that heavily relies on the replacement methodology to determine market value.

While this backward-looking bias may represent a relatively small proportion of dollar value at any given point in time and by itself does not negate the purpose of appraisals for determining an approximate value for its own sake, the bias becomes much more pronounced when first differences and historical returns thereof are calculated using appraisal-based value time series. The problem compounds even further when the standard deviations of appraisal-based returns are calculated—the "sameness" or smoothing of the appraisal bias naturally suppresses the volatility of the time series. The inherent positive serial correlation is visible in the following graph of a popular real estate index that is based on appraised valuations.[2]

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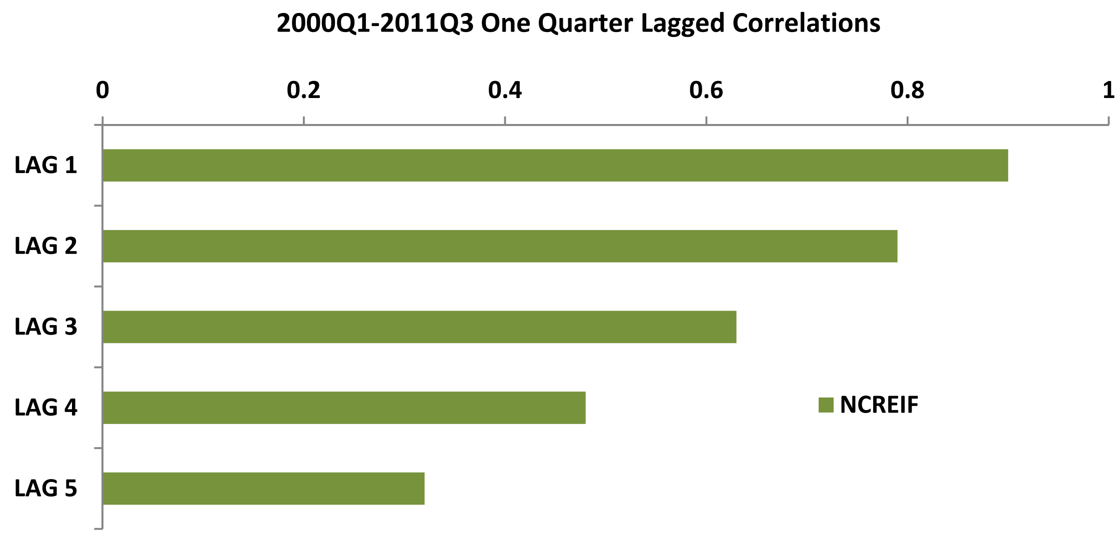
[1] Even though the prices paid by sellers most likely were at least partially based on discounted future cash flow streams, these are often translated in metrics such as cost per square foot. A cost per square foot done six months or a year ago does not translate directly from building to building even adjusting for time and inflation without also adjusting for expected yield curve changes, tenant quality, lease durations, fixed and variable cost, and a host of other differences between buildings.

[2] NCREIF appraisals can be either internal or externally done by professional appraisers. The frequency at which a property is appraised and what type of appraisal it receives depend on a number of factors.

Figure 1. Return Persistence in Appraisal-Based Indexes: National Council of Real Estate Investment Fiduciaries (NCREIF)



Another expression of the "slow-to-trade" and idiosyncratic nature of real estate and infrastructure is the cultural silos in which those mandates operate within most organizations. Due to the dearth of price information associated with both asset classes, financial and risk analytics for both real estate and infrastructure have almost exclusively focused on the first moment of the return and price distributions to gauge the attractiveness of an investment. Publicly traded assets like stocks, bonds and derivatives have a wealth of price data on which to base elaborate statistical projections of future performance, based on quantitative techniques that have evolved to a high degree of sophistication. While within an investment fund the "illiquid" departments talk about "NPV" and "cap rates," the public market departments discuss "market factor," "yield curve twists," "correlations and co-integration," "volatility smiles," etc. Not only does this terminology "gap" pose an obstacle for effective communication between the different mandates, it also creates a barrier for effectively understanding and controlling risk at the enterprise level.

The second major obstacle to integrating real estate and infrastructure in ERM has to do with the mechanics of putting different asset classes together in estimating total enterprise portfolio risk. This problem arises naturally when a risk department is trying to analyze simultaneously many asset classes that are each modeled using a unique set of factors pertinent to that asset class model or geography. The evolution of department risk to enterprise risk, rather than the other way around, predisposed the choice of disparate factor sets across asset class models—normally those that the analysts in the different mandates found most familiar and intuitive, which rarely overlap across department boundaries. Let us assume for simplicity that all such models are estimated using the same number of historical observations—N. Let us also assume that each of those models has somewhere between K1 and K20 for 20 different models. The resulting covariance matrix—the only binding mechanism of the disparate factor structures—among all factors at work at the enterprise level then will have:

$$\sum_{i=1}^{20} K_i$$

overall number of factors. Suddenly, the number of observations N which has been sufficient to reliably estimate the factor covariance within each asset class model, now appears to fall short of the required number of observations to generate the same joint statistical confidence in the covariances of 20 times more factors. The problem can become so severe as to impair the possibility that the matrix of factor covariance estimates to be an actual covariance matrix in that it can stop being positive semi-definite. The positive-semi-definite quality is defined by:

$$\boldsymbol{B}^{'} \cdot \boldsymbol{COV} \cdot \boldsymbol{B} \geq 0$$

In other words, if the covariance matrix COV is multiplied on both sides by a real vector B, the result should be a non-negative number. If we redress this statement in risk terminology, the factor covariance matrix multiplied on both sides by a/(any) vector of factor exposures, then the resulting variance (risk) should be a non-negative number (assuming idiosyncratic risks at the individual asset level to be negligible).

One of the reasons that real-estate- and infrastructure-specific risk models have traditionally been unable to be incorporated into the enterprise covariance matrix has been their status of late adopters of quantitative techniques. Equity and fixed income analysts were better able to find common language in factor expression, long before the first attempts were made to include illiquid assets in the total portfolio risk analysis. This prior expansion of the covariance matrix leaves less room for additional estimation error of covariances due to introduction of yet another silo risk sub-model.

Another reason for the outsider status of real estate is methodological. Once the problems associated with appraisal smoothing were recognized, "de-smoothing" techniques were developed. In some cases those techniques assume that the unobservable real estate returns have to conform to a market efficiency assumption (one cannot predict actual returns from past returns), while in others they do not (Lo, Getmansky, *et al* 2004 as well as Belev and Gold, 2014). [i, ii] In all cases, however, these methods depend on some form of an autoregressive (AR) model, most often constructed from rolling observations of proportional changes in appraisal-based values on their period lag 1 observation:

$$R_{Appraisal\ T} = B \cdot\ R_{Appraisal\ T-1} + \varepsilon_T$$

For our discussion, the market efficiency assumption in these AR models or lack thereof is irrelevant. It only matters that an additional layer of statistical estimation is required to produce the "actual" return of the real estate indexes for proxy purposes. Let us assume that one such procedure produces an estimate for one index (market) with confidence 90 percent. If we have two markets, the joint confidence (embodied by the covariance of the two de-smoothed indexes) would drop to 81 percent. For even minimal level of geographic diversification (e.g., 10 markets) of the overall real estate portfolio, the confidence drops very quickly to levels of 20 percent or 30 percent, which is very unsatisfactory. The confidence in the estimates gets completely dissipated when we incorporate those real estate covariances in the total portfolio covariance matrix. Any enterprise risk inferences based on it are bound to be highly unreliable, if at all possible, due to the positive-semi-definite requirement. Of course, one fact that should not go unnoticed is that by going through all this estimation effort with dubious effect, we are accomplishing nothing more than estimating broad market proxies that may not satisfactorily represent our actual real estate investments.

The inferences that can be made from the prior discussion regarding the challenges of incorporating infrastructure and real estate into the total portfolio risk estimation process reflect the contrast between the desirable characteristics of the process itself and the risk model employed. First, such a model has to feature a factor set that transcends asset classes and geography so as to reduce the estimate requirements of the covariance matrix. Second, it has to have a parsimonious set of factors in its own right for similar reasons. Third, it has to capture the maximum level of descriptive information and granularity of each of the investments to reflect their true nature. Regarding the last point, the particular level of granularity need not be accomplished through encumbering the factor set in order not to contradict the first requirement.

For the sake of conciseness, we will address the first requirement on an intuitive level rather than attempt to explore each and every asset class to demonstrate that a chosen framework of factors applies to it. Notably, we should observe that any investment payoff is eventually sourced into one or both of two types of claims in the economy—a claim that provides income that varies with an underlying economic activity (intuitively exemplified by equity), or a claim that provides income that is fixed over time (intuitively exemplified by an investment in a debt instrument). The first type of claim epitomizes processes that are intrinsically connected with economic growth and profit, and the second type of claim embodies the baseline TVM price that investors expect to receive for parting temporarily with their money. Any claim thereof is in some sense a derivative and mechanized combination of these two types of claims. As one of a few examples, a credit default swap in a simplified way is being short the second type of claim (pay premiums), and long the first type of claim (a payoff if economic performance undergoes a significant change). A variance swap is similarly being short a fixed premium and long a payoff that is a numerical transformation (variance) of the performance of the first type of claim. A barrier stock option is simply a compounded (kick-in and strike level) contingency version of the first type of claim. (The proof that this logic applies also to real estate and infrastructure investments is left for a later part of our discussion.)

Consequently, the factor DNA of a global multi-asset-class model should be one that contains no more and no less than the risk drivers for both of these types of claims. If we put colloquial names for the first and second type of claims—respectively, equity and fixed income—then we should look for the applicable risk drivers for these instruments, which are quite familiar from the expertise of the public market investment mandates. Naturally, equities will be driven by factors that influence economic growth and profitability as measured by general, geographical, industrial, and other types of (factor) indexes, investor risk aversion level, borrowing costs and production costs. Fixed income, on the other hand, will be driven entirely by the discount rate that consists of the time value of money (TVM) and some premium required for the probability and severity of default of the debtor. The probability of default in itself is influenced by the same factors that affect the equity claims (a defaulted firm is one whose equity goes to zero). That is why the following factor set is considered very relevant (but by no means claimed to be unique in that respect, apart from the importance of the factor themes it embodies):

- Six broad industrial sector indexes
- Five broad global regional indexes
- Energy costs
- Global bond index
- Investor risk aversion measures—Indexes for size, market development and value/growth
- A small number of statistical factors, used to capture transient effects and correlations in the investable universe
- Global currencies introduced to reflect the change of numeraire of investors across borders
- Global yield curves reduced to a single global yield curve construct, represented by factor for change of level (shift), change of slope (twist), and change of curvature (butterfly).

As this represents a very limited set of factors (in this case the currency factors included are of denominational nature only, and do not introduce estimation error from, e.g., a regression analysis), we can be assured that this model structure also satisfies the second condition—parsimony. This very broad factor structure can actually be harnessed to describe the volatility of real estate and infrastructure investments, and surprisingly, also provides the means to capture the granularity and idiosyncrasy that are defining traits of these investments.

A convenient starting point in this endeavor is to create an admittedly simplistic but revealing expression of the value of an investment that brings rent-related revenue far into the future. This is essentially the present value of a perpetuity, which is calculated as:

$$PV = \frac{ANNUAL\ INCOME}{ANNUAL\ DISCOUNT\ RATE}$$

What is immediately appealing about this expression is that it gives us a way to think about the value of these investments in terms of our two original types of claim—the profitability claim and the TVM claim, as embodied respectively in the numerator and denominator of this ratio. In other words, if the numerator does not change, while only the denominator can change, then the investment has all the features of a bond. If the numerators were allowed to change, so much as to offset changes in the discount rate, and in excess of that, then the present value will be dependent entirely on the profitability dimension.

If, for illustration purposes, we make the reasonable assumption that the annual net operating income (NOI) follows a geometric Brownian motion, then the following will hold true for NOI at some future point in time t:

$$NOI_T = NOI_0 e^{[\left(\mu - \frac{\sigma^2}{2}\right)t - \sigma B_t]}$$

and recognizing that the fair value V of the investment is equal to the sum of the expected present values of NOI terms over the useful life of the investment:

$$V = \sum_{t=1}^{T} \frac{NOI_0 e^{[\left(\mu - \frac{\sigma^2}{2}\right)t - \sigma B_t]}}{(1+k)^t} = NOI_0 \sum_{t=1}^{T} \frac{e^{[\left(\mu - \frac{\sigma^2}{2}\right)t - \sigma B_t]}}{(1+k)^t}$$

In a similar fashion, the above argument can be adapted to any diffusion process of NOI where future values are a proportional to the current value of NOI. The set of such processes is very broad, but probably the most common and intuitive is where these proportional changes follow a normal distribution, which has the added advantage to allow temporary negative values of NOI.

Consequently, we recognize that a proportional shock of size X in NOI_0 will result in a commensurate proportional shock in the fair value of the investment. Therefore, to model volatility of investment return associated by the profitability claim component, we should look for a relationship between the proportional changes in NOI and the chosen explanatory model factors.

The essence of the model is that it isolates the effects of changes in the discount rate and changes in income. This is effectively done by observing the following distinct components within the investment payoff structure. First, we capture the discount rate effect by forecasting the time series of a property's cash flow in a deterministic fashion, without considering rent volatility. Using the framework of fixed income securities markets, we consider tenant leases as similar to long positions in bonds. These pseudo-bonds are subject to credit risk, and have other bond-like characteristics such as fixed expiration dates and embedded options (a tenant renewal option). The only source of volatility for this component will be changes in the discount rate—consisting of TVM premium and a credit spread. The second component of risk is the expected change in market rents, which introduces effectively the property market's long-term exposure to local economic demand. Via the geometric Brownian motion/NOI proportional change argument, we have already asserted the linkage of this component to the risk model factors in the same fashion as a stock would be related to those factors. Finally, real estate investments normally have a certain degree of leverage. This is not more complicated than thinking of the mortgage cash flows as another fixed income instrument, this time as a short position, which has all the features of traditional mortgages like amortization, adjustment of coupon rates, prepayment, etc.

Modeling Physical Real Estate Investments

Our private equity real estate risk methodology transforms a property's traditional cash flow profile into a series of factor-based risk exposures thereby eliminating the need to rely on traditional appraisal-based indexes for risk- or value-based metrics. Because the risk and return characteristics of a property, and by extension a property portfolio, can now be viewed as a collection of factor exposures, they can be then fully integrated into a multi-asset-class risk model.

Even if the model uses similar inputs, our model's structure is fundamentally orthogonal to traditional techniques used by real estate professionals when assessing property and portfolio risk. One key difference is that it focuses directly on the second moment (concerned with scatter parameters of forecasted investment performance), rather than the first moment (concerned with central tendency parameters of forecasted performance). Furthermore, it eliminates the need for appraisal-based return and risk metrics altogether, solving the issues with serial correlation and the extremely limited nature of the market representative index factor set

Model Structure

As previously mentioned, our private equity real estate model decomposes a property's cash flow into three basic components, the first of which is a deterministic/steady-state cash flow module for existing and expected leases over a building's useful life. This cash flow stream is adjusted for the property's physical characteristics (e.g., number of leasable units), the credit rating of its tenants, and other lease characteristics such as the downtime between leases, probability of lease renewal, lease length, etc. Rents in the steady-state module are assumed to grow at the rate of customizable inflation rate. The steady-state cash flow's volatility can be viewed as largely bond-like cash flow annuity with credit characteristics that are initially dependent on the quality of existing tenants, and as the building's leases turn, the probability that the existing tenants will not renew their lease, the change in the credit profile as the building as tenants are replaced. It is assumed that "known" tenants are replaced with increasing probability by "unknown" generic tenants over the life of a building. The credit quality (as expressed by risk factor exposures) of the "generic" tenant is the average credit quality for a firm in the local market based on the specific local market's industry mix.

Over the useful life of the building, a decision tree is built for each lease where user-defined expected renewal rates are used to determine the probability of renewal at each decision node. Assuming there is no credit event, a decision point is reached at the end of the lease term as to whether or not the lease is re-signed. If it is renewed, the existing tenant stays in place and there is no downtime. If the tenant chooses to leave there is downtime, the amount and cost of which are estimated in advance for each market until eventually a new lease is signed. Assuming an average lease of 10 years, a useful life of 50 years, and a lease renewal probability of 65 percent, there is a 13 percent probability (assuming no credit event), that an original tenant would renew its lease for the entire useful life of the building.

In addition to rental growth, operating margins also depend on occupancy levels since revenues depend on vacancy and vacant space is generally costlier to landlords than occupied space. Consequently, incoming cash flows in the model take into consideration expected vacancy levels. A building's long-term vacancy is assumed to move from its current level to a long-term equilibrium structural vacancy over time, unless there are convincing property-specific factors to assume otherwise. Lease renewal rates for existing tenants are also modeled in a manner that makes them inversely related to vacancy.

In the implementation of the model, we are using a contingent claims analysis (CCA) of tenant credit risk, whereas default by tenants on their obligations is a put option at the hands of the tenant entity. The CCA approach to defaults was originally developed by Merton. [iii] We have modified the approach to produce risk factor exposures in line with the inputs available by the model. [iv] In essence, the procedure, using arguments from option pricing theory and non-arbitrage arguments, distills the risk factor exposures of the tenant entities to risk factor exposures of their debt obligations. Leases are viewed as subordinate debt obligations of the tenant entities and, accordingly, adopt the same risk factor exposures.

The second of the three components of real estate and infrastructure risk is the rent change module that econometrically links changes in local market rents to changes in factors defined by Northfield's six standard industry sectors. The inclusion of the latter as an explanatory variable is further adjusted by the structural profile of the local economy in an employment-share-weighted average of sector performance. Since the rent change equation is driven by an employment-weighted equity factor return change, effectively, it is an expression for the underlying demand for space. In periods of sustained growth in Northfield's six equity sectors, demand for space generally outstrips the increase in new supply. In turn, vacancy rates decline and upward pressure is put on rents. As each market has its own unique employment profile, its exposure to each sector risk factor will be shaped by the local employment signature. Houston, with its greater dependency on oil, would have a greater exposure to energy than New York, which has a higher concentration of finance employment. Other global factors from the Northfield EE model are also considered as explanatory variables, if the intuition of their inclusion exists, and there is statistical evidence that they are in fact correlated with rent changes. As office, industrial and retail buildings are encumbered with long-term leases, it generally takes a period of sustained factor return growth to impact rent changes in the econometric analysis. In the case of apartments and hotels with much shorter lease durations, a proportional shorter growth period is observed in the estimation procedure.

As one practical challenge, a history of "asking" rent data is occasionally not available or reliable for certain markets (notably emerging markets). In those cases, macro proxies are used as independent variables such as per capita retail sales (retail market), changes in personal income (residential), hiring (office), and industrial output (warehouse market).

An important part of the model process is the calculation of rent sensitivity. It is synonymous with the proportion of the investment payoff that exhibits "equity-like" rather than "bond-like" properties as described earlier. In general terms, this variable defines the window of opportunity for the impact on investment values of future lease changes as determined by vacancy, frequency of lease renewals, and frequency of rent renegotiation. The bond-like nature of property's cash flow stream is also highly dependent on how often the building's leases come to market. A building with a 30 year single high quality tenant would behave much more like a bond than a hotel or an apartment building with much shorter leases which are exposed to the uncertainties of the market on an on-going basis, making them more volatile and more equity-like. The same is valid for a property or facility that exhibits a high vacancy rate (low capacity utilization), increasing the proportion of expected future revenues open to rent market volatility.

The final high-level risk component is leverage. If present, it is represented as a short position on the building's cash flows. Just like the deterministic lease cash flow module is subject to a renewal option at the hands of the tenants, the mortgage bond is subject to a prepayment (call) option at the hands of the investor. To inscribe all the varieties of mortgage property debt, the model has been adapted to handle features such as , but not limited to, cross-collateralization, portfolio-level vs. property-level leverage, fixed rate and/or floating rate debt, etc.

Data Inputs

At its most granular level, the model requires approximately 40 data inputs. While at first glance the number of data fields may seem large, nearly all the model's inputs can be downloaded from standard real estate software packages such as Argus™ or Yardi. For those investors who do not use these software products, the data can be sourced from core data points from a typical investment package used in the offering process.

Figure 2. Property-Level Data Inputs

1. Property Profile
    a. Property Name
    b. Location
    c. Property Type
2. Physical Characteristics
    a. Property Class (A, B, C, D)
    b. Leasable Units
    c. Construction Year/Last Major Rehab
    d. Total Useful Life

    e. Square Footage

3. Occupancy Profile
    a. Current Vacancy Rate
    b. Anchor Tenants
    c. Anchor Tenants' Credit Ratings
    d. Anchor Tenant Maturity(ies)
4. Market Information
    a. Long-Term Structural Vacancy (MSA or Submarket)
    b. Years before Market Reaches Long-Term Vacancy
5. Operating Income and Expenses
    a. Net Operating Income
    b. Annual Expenses for Occupied Lease Space (Per Occupied Square Foot)
    c. Annual Expenses for Vacant Space (Per Square Foot)
    d. Current Renewal Rate (Percentage)
    e. Rent Sensitivity Scale Factor
    f. Standard Lease Term—Years
    g. Pay Periods within Lease
    h. Downtime between Leases (in Months)
6. Building Cost
    a. Balance Sheet Value
    b. Acquisition Price
    c. Total Capital
    d. Own Equity
    e. Partner Equity
    f. Current Capitalization Rate
7. Debt
    a. Total Debt
    b. Interest Rate(s) on Fixed Rate Mortgages
    c. Interest Rate Premium(s) of Floating Rate Mortgages
    d. Face Amount(s) on Fixed Rate Mortgages
    e. Face Amount(s) on Floating Rate Mortgages

f. Maturity(ies) on Fixed Rate Mortgages
g. Maturity(ies) on Floating Rate Mortgages
h. Years of Amortization Fixed
i. Start Year of Amortization Fixed
j. Years of Amortization Floating
k. Start Year of Amortization Floating
l. Loan-to-Price Proportion
m. Cross-Collateralized Asset Name

There are seven general categories of model inputs starting with a building's profile that identifies its geospatial location and major land use(s). This in turn determines which rent time series are relevant. The property's physical characteristics, occupancy profile, market information, and operating income and expenses determine the building's steady-state cash flow. A series of inputs are also needed to model any gearing that might be present.

Several of the individual inputs require further delineation. For example, a market's structural vacancy rate is defined as the vacancy rate at which neither an asset owner nor the tenant has an advantage in negotiating lease terms. This number is typically property owner supplied. However, if the prior is not available, typically a long-term vacancy rate average (seven to 10 years) is used as a proxy. For buildings whose current vacancy is significantly below the market's structural rates, there will be downward pressure on NOI growth as current vacancy reverts to the market's structural rate since tenants whose leases expire will face an opportunity cost to renew their existing leases in the face of multiple, less expensive but equally utilitarian, opportunities from competing building owners.

In the case of a mixed-use building, the model effectively breaks down the asset into its elemental sub-uses, as necessary, for the purposes of the steady-state cash flow and rent change calculations. Eventually, the elements are recombined to achieve their overall risk characteristics, including the effect of debt.

For investors who cannot (or choose not to) assemble granular-level, property-level information, a "generic" approach can be implemented. This often is the case for fund-level investors who only have access to limited property-level information from the fund manager. In these cases, the model can be adapted to operate with a limited number of property-specific data points such as property type, location, value as a percent of total fund value, and property/fund debt information. Given sufficient and widely available generic data for various markets, in conjunction with maintenance of proprietary experience-based databases of typical property characteristics, it is possible for the remainder of the inputs in the model to be proxied with a set of generic values.

Econometric Treatment of Rent Changes

While rent levels are normally used in most deterministic cash flow models, this model employs the change in rent as the dependent variable in an econometric regression. The typical rent change equation regresses the year-over-year change in quarterly rents for a particular market and property type combination (New York office or Sydney retail) against an employment-weighted sector factor return variable wherever detailed sector-level employment data is available (United States, Canada, Australia, and selected markets in Asia and Europe). Similar to real estate return indexes (but for an entirely different reason—overlap of return periods), the real estate rent time series have some degree of return persistence that is accounted for as part of the estimation process, using a Box-Jenkins AR procedure. For this reason, the equation's non-AR betas are important, and AR regression betas are not. The regression's residual variance is used directly in the model, but the intercept term is not, as it has no bearing on the second moment of the return distribution.

Figure 3. Rent Change Equation: Atlanta Office

Atlanta Office			
Variable	Coeff	T-Stat	Comment
AR{1}	1.17	8.50	
AR{2}	-0.26	-1.85	
Employment-Weighted Factor Returns	0.21	4.39	10 quarter moving average
R-Bar^2	0.94		

In that rent data is not always available for every market or in certain markets rent reflects asking/headline, not effective rents, it is sometimes necessary to use proxy variables for the dependent variable. For example, since retail rents are not collected in a typical emerging market in South America, appropriate substitutes such as the change in per capita retail sales or gross domestic product (GDP) would typically be used instead. The assumption is that the long-term patterns of these instrumental variables represent the rental opportunity cost facing tenants in these markets. There are also cases where rent series in developed markets show little variance over time because they reflect headline/asking, not effective rents, and therefore do not reveal the market's true dynamics. This varies by market, property type, and to some extent data provider. When these situations are encountered, proxy variables are once again employed.

Model Results

Since by definition the model is meant to operate in the vacuum of observable and reliable track record of investment performance, it would be practically impossible to try to "back-test" its results against time series of investment market values, as we could have done for publicly traded instruments. Therefore, we propose the following comparative tests as a means to judge the reasonableness of the model's results:

1. Compare the model's output with other asset classes and see if the ranking across individual investments as well as across asset classes corresponds to our intuition.
2. De-smooth real estate appraisal-based indexes using a time horizon of a typical property holding period and compare standard deviations.
3. Use real estate expert qualitative risk rankings and compare to model predicted risk rankings.

Property-Level Risk

As a test of the model, we have taken a small, high-quality core portfolio consisting of 14 European properties, across eight countries, four property types (office, industrial, retail and apartment), with less than 15 percent leverage, and generated 12-month *ex ante* estimates of risk for each individual property and by extension the entire portfolio. We first examined the results property by property and then compared the portfolio results to well-known equity and bond benchmarks to test whether the model's output appeared reasonable and consistent with our priors.

Figure 4. Portfolio Profile

PORTFOLIO PROFILE				
Metro	Apartment	Office	Industrial	Retail
Berlin	1			
Budapest				1
Frankfurt		1		
Rome			2	
London	1	2	1	
Marseilles				1
Amsterdam			1	
Paris		1		
Bucharest	1			
Stockholm				1

The de-levered average country-level results showed expected one year *ex ante* value-weighted risk ranging from approximately 16 percent to 21 percent after removing leverage from the portfolio. This property-level variation can be attributed to a host of factors including, but not limited to, interest rate risk, lease duration, and exposure to various model-defined economic/regional risk factors such as "Continental Europe" and "English-Speaking Countries."

In Figure 5 the risk decomposition report shows that interest rate risk arising from the three treasury curve factors is the single largest risk factor contribution. This is neither surprising nor the whole story, as can be seen in the example for an unlevered Bucharest apartment building. First, the treasury curve factor contributions appear disproportionately large because they are in variance (squared return units), not standard deviation space (return units). Second, while it is certainly the case that interest rate risk represents a significant portion of expected risk (13.7 percent), this should come as no surprise given the bond-like nature of a real property's cash flows.

Figure 5. Risk Decomposition Report: Bucharest Apartments (Leverage Removed)

Factor	PortExp	BenchExp	ActiveExp	FactorVar	VarContr
ENERGY MINERAL SECTOR	0.00	0	0.00	235.60	0.00
INDUSTRIAL SECTOR	0.00	0	0.00	247.12	0.01
TECHNOLOGY&HEALTH SECTOR	0.00	0	0.00	161.43	0.05
INTEREST RATE SENSITIVE SECTR	0.00	0	0.00	204.85	0.06
NON-ENERGY MINERALS	0.00	0	0.00	423.90	0.06
DEVELOPING MARKET	0.01	0	0.01	115.72	0.13
VALUE/GROWTH	-0.02	0	-0.02	6.47	0.13
CONSUMER SECTOR	0.00	0	0.00	134.21	0.29
CONTINENTAL EUROPE	0.28	0	0.28	208.25	25.97
TREASURY CURVE FACTOR1	-17.88	0	-17.88	0.30	121.76
TREASURY CURVE FACTOR2	-221.58	0	-221.58	0.00	145.07
TREASURY CURVE FACTOR3	-1590.87	0	-1590.87	0.00	-79.82
Factor Tracking Variance					212.94
Stock Specific Tracking Variance					39.97
Total Tracking Variance					252.92
Tracking Error					15.90
Total Risk of Portfolio					15.90
Total Risk of Benchmark					0.00
R-Squared					0.00

Broken down into economic components, apart from interest rate risk, the model risk composition looks as follows: rent risk: 6.9 percent; credit risk: 1.2 percent; idiosyncratic risk: 6.3 percent.[3] As this decomposition of risk is done in absolute terms, the final two table rows may be ignored.

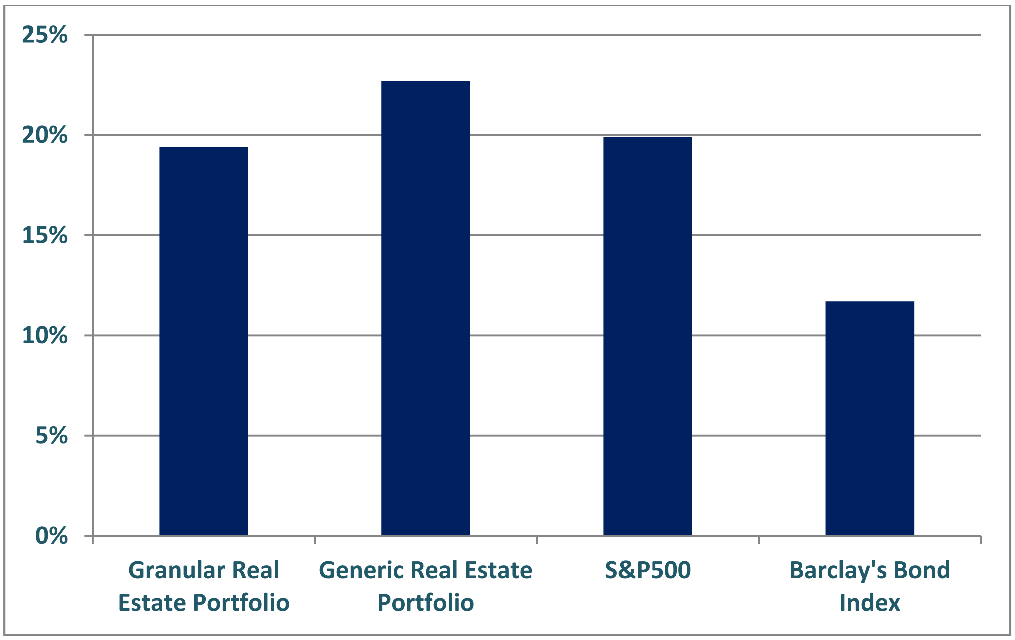
Portfolio-Level Risk

When rolled up to the portfolio level and reintroducing leverage (less than 15 percent on average across the entire portfolio), the total 12-month *ex ante* risk as of November 2013 was found to be 19.4 percent. Again interest rate risk was found to be the dominant contributor, but given our argumentation so far,

[3] Since standard deviations are not additive, it is necessary to first square the individual risk components, then sum, and finally take their square root to arrive at the bottom-line 15.9 percent risk figure.

finding otherwise would be a surprise. Idiosyncratic falls to 2 percent, indicating that diversification was taking place as the number of assets grew. While it is unlikely that complete diversification would ever occur, the rapid decline in asset-specific risk after only 14 assets was encouraging.

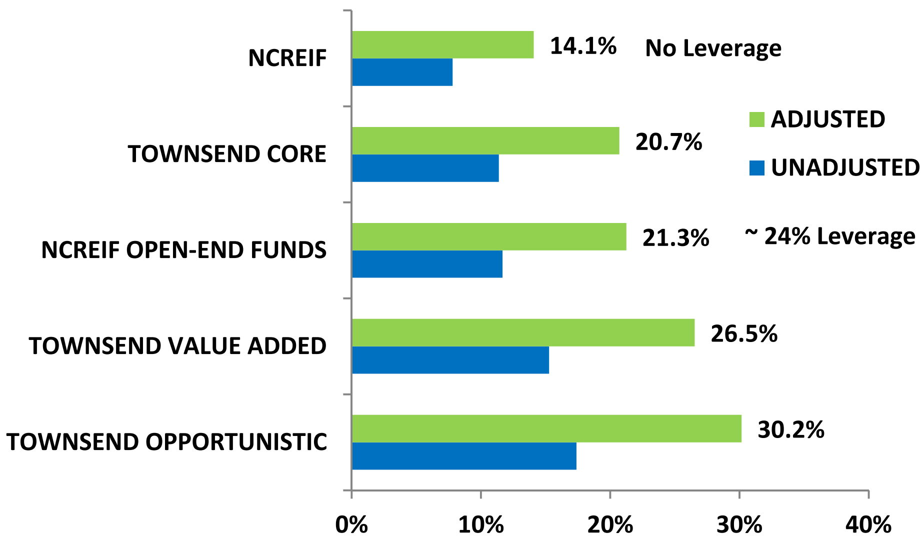
Figure 6. Expected 12-Month *Ex Ante* Risk by Asset Class—November 2013



Reasonableness Tests

Since, as previously mentioned, there are no unbiased benchmarks against which to test the results, we decided to use "reasonableness" hurdles instead. The first is to compare the *ex ante* portfolio results against other asset classes for the 12 months starting in November 2013. Figure 6 shows the expected risks for the "Granular" inputs test portfolio, the test portfolio using the "Generic" model inputs, the S&P500, and a Barclay's Bond Index. The results are consistent with our priors. The "Granular" portfolio with an expected risk of 19.4 percent had risk above bonds, but below equity, keeping in mind that it had 15 percent leverage. The "Generic" portfolio had slightly higher expected risk (22.7 percent) but given its lower-quality tenant roster and, generally, shorter lease durations, this higher risk profile is expected.

Figure 7. NCREIF De-Smoothed Historic Standard Deviations—20 Quarters Ending September 2013



The second test is a comparison of the granular portfolio's results with the historic risk of the appraisal-based indexes after they are de-smoothed using an AR smoothing technique similar to that proposed by Lo and Getmansky. (Specifically, a similar technique developed by Anish Shah, from Northfield Information Services, was employed to correct the data; see reference section for a complete description of the methodology.[v]) This was done for the 20 quarters ending September 2013. The results are revealing. For example, the reported total NCREIF Index with over 6,000 properties across the United States, without leverage, and not de-smoothed, had an annualized standard deviation of 3.9 percent. However, when de-smoothed, the series' implied annualized risk turns into 14.1 percent. For NCREIF's core open-end fund index, which had approximately 24 percent leverage, the de-smoothed implied annualized volatility was over 21 percent. These numbers, while U.S.- and not European-based, are in with the approximate range of the model's results.

The third test was to compare the model's quantitative results with the opinions of market experts at a major North American pension fund with a large diversified global real estate portfolio.[4] The risk

[4] Due to compliance considerations the fund opted to remain anonymous in this work, but they are willing to provide confirmation on an individual basis if a request is sent to the authors of this paper. The portfolio consists of hundreds of properties in North and South America, Asia, Australia, Europe and Africa. It has investments in all the major land uses as well as several secondary property types. Leverage tends to be conservative and loan duration under 10 years. Properties tend to be of higher quality, as do the properties' tenants.

rankings produced by this approach were compared to a blind study that tapped into the expertise of internal experts within the fund. The results of this study showed a high correlation between the model's quantitative risk ranking and the experts' qualitative rankings. Since it was the intent of the model to use similar logic as fundamental real estate analysis while adding a quantification rigor layer, it is not a surprising result. Yet it is reassuring that the model delivered on its objective. The results also build the confidence that the model can become the de facto expert, where human expertise in certain markets is not available within the organization.

Modeling Infrastructure Investments

In the introductory section we stated that there is a remarkable similarity between physical real estate assets and infrastructure, which is based on a relatively well predicable business model of collecting rents for the use of some form of long-term assets. Therefore, the type of payoff risk for infrastructure inscribes completely within the previously described model framework for real estate. Throughout the rest of this section we will focus on some of the distinctive features of infrastructure that differentiate it from real estate and warrant a slightly more tailored approach.

One of the ways in which infrastructure is different from physical real estate is that it often consists of several different types of rentable facilities that should be treated as distinct lines of business. For example, an airport offers airlines the possibility to rent gates and rights on take-off and landing strips, but also offers retail companies to rent retail store and restaurant space adjacent to the airport gates. Parking garages and lots attached to the airport are additional types of revenue. All of these sources of income conform to the previously described model framework, but each will have a distinct set of parameters—lease term, renewals, tenant quality, downtime, etc.—that requires separate, albeit similar, rounds of application of the model. Similarly, an electric utility company usually features different types of deliveries and grid connections on its "trunk" and retail branches. Likewise, a cargo port collects revenue from a range of different types of cargo, each having different tariffs and fee structures, and loading/unloading as well as transportation facilities.

All of these examples demonstrate that the approach to modeling such investments should entail identifying the comprising revenue lines, modeling each one separately, and then assembling into a composite asset that is a collective representation of the risk characteristics of the entire investment.

Another (practical) difference of infrastructure model methodology is related to data availability for estimating the “rent volatility” component of the investment. For real estate there is an abundance of commercial vendors providing such data, sometimes specializing in certain geographical markets, and other times having global coverage. For infrastructure, on the other hand, due to the much more pronounced idiosyncrasy of a particular investment within a particular geography (i.e., one or two electric utilities within a certain Canadian province, vs. dozens of office buildings within a city of that province), such data is not available unless those infrastructure providers collect and maintain themselves databases of historical revenues and operating cash flows. While this is often the case in practice, sometimes institutional investors in such ventures depend on managers and general partners to provide this data, which makes the interactive access a challenge.

Just like in cases when rent/revenue series data is not available for real estate markets, a practical model that aims at broad application needs to provide the tool set to handle limited data. And just as proxy variables can be used for real estate instead of the actual times series of revenue as measure of demand expressed in relation to the risk model factors, the same can be done for infrastructure. Examples of such proxy metrics applicable to different infrastructure investments include:

- Passengers transported from international airports
- Number of flights from international airports
- Price per cargo container
- Cubic meters of natural gas delivered
- Electricity consumption.

All this data is widely available from government and international NGO databases like the national statistical bureaus, the World Bank, IMF, etc.

For infrastructure, an alternative approach to the regression methodology typically applied to real estate rent time series and the risk model factors involves forming a representative portfolio of stocks of companies that are the current or potential clients of the infrastructure facility. That portfolio is then rebalanced in a numerical optimization so that the resulting solution minimizes the Euclidean distance between the portfolio volatility and the volatility of several benchmarks of demand like the previously mentioned usage metrics. The rationale of this process is that an improved or worsened outlook for the main clients of the infrastructure facility corresponds to a commensurate change in the utilization of the facility. The outlook of profitability, however, is a result of operational and financing leverage. The solution procedure effectively “de-levers” the reference portfolio, so that the volatility is brought to a level that corresponds to changes in demand, but preserves the factor exposure “signature” that is inherent to the line of business of the clients of the infrastructure facility.

The third aspect in which infrastructure distinguishes itself from real estate concerns the specifics of the “lease” contracts with the users of the facility. Real estate properties predominantly have long-term leases that have a fixed level of rent within each contract period. On the other hand, infrastructure has either longer-term contracts that allow for frequent rent-level negotiations (e.g., airlines renting gates, normally each year), or have very short-term usage spans (e.g., a day for toll roads). This reset feature, whenever it exists, has a marked impact on the risk profile of an infrastructure investment in comparison with real estate. The long period of “fixed” cash flows within leases of real estate increases their durations and suppresses the effect of the “equity-type” claim in the investment—i.e., volatility from rents. Infrastructure, on the other hand, will adjust more frequently in response to changes in market rent rates, which will allow it to compensate for changes in the discount rate, reducing the duration of the cash flows, and exhibiting a more “equity-like” pattern of factor exposures. The effect of frequency of lease resets can be most clearly seen with the formula that is used to calculate the rent sensitivity, which, while not an explicit factor exposure, represents the proportion of investment payoff that exhibits “equity-like” quality vs. “bond-like” qualities and risk profile.

$$RS = V + \{(1-V)[\left(1-\frac{1}{M}\right)\left(\frac{1}{M1}\right)+\left(\frac{1}{M}\right)R+\left(\frac{D}{M}\right)(1-R)]\}$$

V – Vacancy Rate

M – Contract Term

R – Renewal Rate

D – Downtime

M1 – Time Between Contractual Lease Rate Resets (Other Than at Lease Expiration)

Note that the above formula is entirely in agreement with the popular industry belief that infrastructure investment is a combination of a stock and a bond. The formula has the advantage to ascertain how much of infrastructure is a “bond” vs. “stock,” which the anecdotal belief cannot help determine.

To illustrate how all of the above points integrate with infrastructure risk, we provide the following two example reports for an actual airport in Australia (with slightly stylized composition). The first point to note is that, just like with real estate, all of the constituents of risk are represented as marketable securities, which allows the attribution of risk both in terms of economic sources as well as client entities associated with the particular “securities.” In the “***Holdings***” report, the relatively low composition of rent volatility synthetic securities “RENT_” corresponds exactly to the “rent sensitivity” defined previously, and indicates a comparatively lower percentage of the investment is an “equity-type” claim and higher percentage is a “bond-type” claim. The same inference can be drawn from the ***“Risk Report,”*** given the high percentage of total risk explained by “Interest Rates Curve” factors.

Figure 8. Percent of Holdings Breakdown—Airport Example

Symbol	Composite Assets	Portfolio Weight
	Total	**100.00**
A_1_0_1	Gate Lease 1	12.87
A_1_1_1	Gate Lease 2	13.63
A_1_2_1	Gate Lease 3	13.51
A_1_3_1	Gate Lease 4	4.75
A_1_4_1	Gate Lease 5	9.00
A_1_5_1	Gate Lease 6	2.61
A_1_6_1	Gate Lease 7	2.61
A_1_7_1	Gate Lease 8	2.61
RNT_AIRPORTGATES	Rent volatility synthetic security (Gate)	12.16
RNT_AIRPORTRETAIL	Rent volatility synthetic security (Retail)	8.30
A_0_0_1	Retail Lease 1	5.68
A_0_1_1	Retail Lease 2	9.42
A_0_2_1	Retail Lease 3	6.03

A_0_3_1	Retail Lease 4	4.80
A_0_4_1	Retail Lease 5	1.93
A_0_5_1	Retail Lease 6	3.42
A_0_6_1	Retail Lease 7	2.38
A_0_7_1	Retail Lease 8	2.38
A_0_8_1	Retail Lease 9	2.38

Figure 9. Percent of Holdings Breakdown—Airport Example

	Factor Contribution (Std Dev)	Percent Contribution
Total Risk (Std Dev)	13.53	
Stock Specific Risk	0.86	4%
Factor Risk	13.50	
Factor Contribution (Std Dev)		
Region	1.63	8%
Sectors	2.35	12%
Energy	0.79	4%
Investor Confidence	1.10	6%
Statistical Factors	--	
Currency	--	
Interest Rate Curve	13.12	66%

Incorporating Real Estate and Infrastructure Investments in Enterprise Risk Management

The essence of assimilating these types of assets in ERM has been mentioned repeatedly in our discussion so far, but for the sake of clarity we shall summarize here. This will also serve as a convenient reference point for illustrating the ERM benefits of the methodology.

The integration approach rests on the fact that the risk characteristics of the illiquid and liquid assets are described via exposures to the same general factor set plus idiosyncratic risks, which combine linearly in a value-weighted average to produce portfolio-level risk factor exposures, and combine linearly (in variance space) via a quadratic-value-weight average over the idiosyncratic risk components to produce an overall idiosyncratic proportion of portfolio risk. This approach is well familiar in risk management for securities within traded asset classes, but it is the common risk factor structure that allows it to be applied across silos and at the total portfolio level. The resulting factor covariance matrix is one that is parsimonious and not prone to the statistical problems described earlier.

As a matter of fact, the methodology, natively based on the global model factor set used for illustration, can be "generic"-ized to any risk model that is *complete*. A complete model is defined as one that has all residual (component of return unexplained by model factors) uncorrelated across investments. A formal proof exists that one complete model is a linear transformation of another as long as they span the same probability space.

Let us assume that we start with a matrix of model factor vectors (return realizations) $\boldsymbol{F_{Start}}$. Using Eigenvalue Decomposition, $\boldsymbol{F_{Start}}$ can be transformed into a set of orthogonal principal components $\boldsymbol{B_{Start}}$. $\boldsymbol{B_{Start}}$ will have the same number of dimensions or less as the dimensions of $\boldsymbol{F_{Start}}$. The transformation from $\boldsymbol{B_{Start}}$ to $\boldsymbol{F_{Start}}$ is linear (multiplying by the transpose/inverse of the eigenvector matrix $\boldsymbol{E_{Start}}$).

$$\boldsymbol{F_{Start}} = \boldsymbol{B_{Start}} \cdot \boldsymbol{E'_{Start}}$$

Another, also complete, factor set $\boldsymbol{F_{New}}$ can similarly be decomposed into a set of orthogonal principal components $\boldsymbol{B_{New}}$. $\boldsymbol{B_{New}}$ will have the same number of dimensions or less than the dimensions of $\boldsymbol{F_{New}}$. The transformation from $\boldsymbol{F_{New}}$ to $\boldsymbol{B_{New}}$ is linear (using the eigenvector matrix).

$$\boldsymbol{B_{New}} = \boldsymbol{F_{New}} \cdot \boldsymbol{E_{New}}$$

Given that the two sets of principal components span completely the same probability space and the fact that each of these PC sets has orthogonal dimensions (probabilities of realizations on different dimensions are independent), $\boldsymbol{B}_{\boldsymbol{New}}$ and $\boldsymbol{B}_{\boldsymbol{Start}}$ must have the same order of orthogonal dimensions. This is only possible if one is simply a rotation of the other (denoted by a rotation matrix $\boldsymbol{M}_{\boldsymbol{Rotation}}$).

$$\boldsymbol{B}_{\boldsymbol{Start}} = \boldsymbol{B}_{\boldsymbol{New}} \cdot \boldsymbol{M}_{\boldsymbol{Rotation}}^{\boldsymbol{T}}$$

Eventually we have a sequence of linear transformations from $\boldsymbol{F}_{\boldsymbol{New}}$ to $\boldsymbol{F}_{\boldsymbol{Start}}$.

$$\boldsymbol{F}_{\boldsymbol{Start}} = \boldsymbol{F}_{\boldsymbol{New}} \cdot \boldsymbol{E}_{\boldsymbol{New}} \cdot \boldsymbol{M}_{\boldsymbol{Rotation}}^{\boldsymbol{T}} \cdot \boldsymbol{E}_{\boldsymbol{Start}}^{'}$$

Or

$$\boldsymbol{F}_{\boldsymbol{New}} = \boldsymbol{F}_{\boldsymbol{Start}} \cdot \boldsymbol{T}_{\boldsymbol{Start\ to\ New}}^{'}$$

Where:

$$\boldsymbol{T}_{\boldsymbol{Start\ to\ New}} = \boldsymbol{E}_{\boldsymbol{New}} \cdot \boldsymbol{M}_{\boldsymbol{Rotation}}^{\boldsymbol{T}} \cdot \boldsymbol{E}_{\boldsymbol{Start}}^{'}$$

And $\boldsymbol{T}_{\boldsymbol{Start\ to\ New}}^{'}$is the linear transformation matrix from the starting factor set to the new factor set. Using the same transformation matrix, the factor exposures we have calculated for all asset classes using our model methodology can be translated into factor exposures to factors of another complete model:

$$\boldsymbol{\beta}_{\boldsymbol{New}} = \boldsymbol{\beta}_{\boldsymbol{Start}} \cdot \boldsymbol{T}_{\boldsymbol{Start\ to\ New}}^{'}$$

The transformation has a broad application in the practice of risk management. From the discussion so far it becomes immediately obviously that it applies to cases where we are using an analytic approach to portfolio risk, where factor exposures are a formulaic input. However, given that such analytic approaches often involve parametric assumptions, which may or may not appeal to ERM practitioners, especially in stress testing, they may prefer to use a numerical technique like Monte Carlo simulation or boot-strap simulation whereas the effect of a range of economic scenarios is observed across the portfolio, with or without a full distribution of such realizations and summary distributional statistics thereof be calculated. The factor exposure transformation approach is entirely applicable in those cases as well, provided that economic scenarios (i.e., the bankruptcy of Lehman Brothers, the Long-Term

Capital Management crisis, a hyperinflation bout, a conflict in the Middle East) can be represented by vectors of factor realizations themselves. Once that representation is done, the factor distributional assumptions can be relaxed, and a full-blown analysis of total portfolio performance can be performed under a stressed distribution (skewed, fat-tailed, etc.).

The most attractive benefits of a broad factor-based model approach, however, emerge in total portfolio rebalancing and enterprise-level hedging. Given that both real estate and infrastructure are highly illiquid investments, the broad risk drivers generated by a global risk model provide two very important dimensions of flexibility.

First, the fundamentally oriented set of inputs of the model gives us unique insights applicable to risk management. Each of the inputs provides a particular impact to investment and overall risk, and such sensitivities can be captured and utilized in fine-tuning the risk profile. For example, a building can be sold at high transaction cost and large incremental impact (all-or-nothing), which will be a costly and crude risk management approach. Alternatively, the investor can explore how changing property variables that are in the investor's control—lease term and provisions, tenant composition, vacancy, and leverage—impacts the risk profile of the property and hence overall risk. We might not be able to sell a building that contributes a lot of interest rate risk to the portfolio, but we can reduce the standard lease contract or decrease leverage to bring that effect to a tolerable level. With the same intent, we might decide to temporarily increase the vacancy in the building to ward off the negative impact of a large pending interest rate swing, as vacancy is one of the main formulaic determinants of the "rent sensitivity" that transforms the investment from a bond-like claim to an equity-like claim. It should also be noted that the granular, property- and project-specific inputs to the model allow for an unprecedented level of detail and distinction in the risk/return analysis of impact of new deals that come in the investment pipeline, or that are considered for disposition. This level of detail is beyond the reach of de-smoothed and other index-based approaches.

A key benefit from the approach, however, is the ability to hedge risks sourced in the illiquid part of the overall portfolio, with instruments from the public markets. This is a direct consequence from the common dimensions of risk measurement across the private and public mandates.[vi] For example, if we are overly exposed to high-rise development deals in Dubai, which has high exposure to energy costs, and want to mitigate that risk, we can do this using a commodity futures strategy or tapering some of the oil stock exposure in the public portfolio. If we have very high interest rate exposure from a long fixed guarantee contract with the government for operation of a toll road, we can effectively hedge it using interest rate derivative contracts, or adjusting the durations of our bond portfolio. If we own an office building in Palo Alto, California, we might consider the potential impact of underperformance of the technology sector and reduce such exposure in the public securities composition. Given that the low cost hedge in the public markets can take a practically infinite number of configurations to match corresponding factor exposures on the illiquid side, we are practically free to fine-tune our overall risk profile to any level and along any dimension. The only practical limitation to this approach is that the size of our public investments matches or surpasses the size of our illiquid investments, a condition which is almost always satisfied in practice. The consequence of this newly found freedom is that the investor does not bear the full brunt of forgoing the “option to rebalance” inherent in the purchase of illiquid investments,[vii] which in itself simultaneously improves dramatically the attractiveness of illiquid investments and hence the ability to diversify, and with that the effectiveness of ERM to achieve a risk/return trade-off featuring maximal attainable utility.

Summary

We will conclude by summarizing the methodology and its results. First, we defined the challenges of real estate and infrastructure and created a road map to a risk model factor structure that will overcome those challenges. Then we disassembled the illiquid investments into their intuitive economic payoff pieces to be analyzed separately with the proposed factor set. Finally, we reassembled the pieces into a coherent unit that naturally integrates with risk analysis across all mandates of the organization. While the approach is thorough in regard to required inputs, in practice, the data requirements are manageable and easily serviced through standard software data systems for illiquid investments. The payoff of being thorough is that the results do not cut corners with respect to the granularity, locality and idiosyncrasy of the investments, which are unattainable with index proxy approaches. The generalized factor DNA of the model allows for identification and management of risks at low cost and high precision, which takes total portfolio risk management to a categorically higher level.

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