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Executive Summary. *As index-based real estate derivatives are being introduced in the United States, this paper questions the validity of these instruments for hedging risks involved in commercial real estate markets. It first shows that the concept of index-based derivatives may not be appropriate for intrinsically heterogeneous assets such as real estate. Based on an innovative framework drawn from the field of biomedical sciences, it then proposes the establishment of a radically new breed of derivatives market that would enable effective hedging of commercial real estate assets. It concludes by outlining a framework for modeling real estate risk based on genetics that could be used with the proposed derivatives market.*

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by Patrick Lecomte*

"What we need is imagination, but imagination in a terrible strait-jacket."
Robert Feynman, Physics Nobel Prize 1965 in The Character of Physical Laws

"Quod est eius causa?"
(Translation: What is the cause of that?)
Aristotle

There has been much excitement in recent months in Europe and the United States over the introduction of index-based derivatives aimed at investors in private commercial real estate assets. The concept of property derivatives is not new. It has taken many forms over the last twenty years, from swaps to bond-like instruments, and involved OTC markets, as well as standardized exchanges (e.g., the London Fox Property Futures market in the early 1990s).

One might argue that what is really different this time is the apparent commitment of the real estate industry motivated by the claim that these instruments are more than mere diversification tools but effective devices for hedging risks involved in portfolios of properties and even individual buildings (Fisher, 2005).

Although it is still a conundrum in many ways, risk is very much at the core of real estate finance (Graaskamp, 1977a). One anecdotal illustration of that point is the fact that one pioneer in the field, James A. Graaskamp, started his academic career by attending a Ph.D. not only in urban land economics but also in risk management. The search

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for efficient risk management tools applicable to private commercial real estate assets has indeed attracted academics' interest for many years (e.g., Riddiough, 1995), albeit with few concrete results so far.

Real estate is well known for its overwhelmingly idiosyncratic risk structure stemming from heterogeneous assets traded on illiquid markets with asymmetric information. Encapsulating these characteristics within a single product or series of products is a major hurdle that academics and industry participants have found challenging to overcome. While some researchers (e.g., Gordon and Havsy, 1999) argue that designing effective hedges for private commercial real estate assets is basically unfeasible because of a lack of reliable and representative underlying indices, others (e.g., Shiller, 1993a) claim that markets for cash-settled derivatives ought to be established based on alternative indices such as hedonic price indices. Academics' interests with respect to property derivatives have been mostly focused on the choice and design of optimal underlying indices while the basic structure determining the workings of the derivative itself (i.e., the fact that existing or proposed property derivatives are all index-based instruments) has been totally overlooked. Although the crucial question of indices in real estate has been a catalyst for many breakthroughs in other fields of real estate finance (e.g., smoothing in appraisals), such a one-sided approach seems somewhat limitative. A derivative contract is the combination of both an underlying and a product structure. Hedging effectiveness results from the ability of this combination to deal with the phenomenon at work, not from the underlying alone. The index-based model—be it OTC or standardized—is only one among many possible formats a property derivative could potentially take. A certain amount of imagination is obviously required here inasmuch as there is no workable alternative to index-based derivatives as of today. This paper aims at presenting possible alternatives. To do so, it addresses the question of property derivatives by considering conjointly issues involved in the choice of underlying and product structure. It is organized along three sections. In the first section, it reviews the concept of index-based derivatives in the broader context of the history of derivatives and studies the appropriateness of this recent concept with the specificities of real estate risk. In the second section, it applies an analogical framework drawn from the field of biomedical sciences to describe real estate risk and infer an array of possible novel approaches for hedging it. In the third section, it describes two innovative product structures that might allow effective hedging of real estate risk and questions whether the relevance of these proposed instruments with the phenomena at work would be sufficient to lead to the emergence of a new breed of derivatives market. It concludes by presenting a model for analyzing real estate risk that could contribute to the success of the proposed derivative market while defining a new concept of randomness in real estate prices.

Index-based Derivatives

Historical Perspective on the Concept of Derivatives

Going back to the origins of commodity derivatives and index-based derivatives, this section identifies some essential concepts that can be applied to better understand the issues at stake with property derivatives.

Commodity Derivatives. By all accounts, derivatives instruments are not modern inventions. They have been traded for centuries and have taken many forms since their inception: forward, swap, futures, option, and contract for difference.

The usual historiography asserts that derivatives were invented in Chicago in 1848 or in Japan in the seventeenth century. In fact, their creation goes back 2000 BC in ancient Mesopotamia where a highly lucrative trade in grains developed under the umbrella of "grain loans" (Swan, 2000). At the time, contracts could involve private parties, priests, and even the God. Temples played the role of centralized counterparty facilities and provided sites for commodity storage. It is not clear whether the priests or the God profited most of these flourishing activities but one thing is certain: Grain derivatives played a major role in regulating the workings of this mostly agricultural economy. Likewise, commodity futures contracts were actively traded in antique Rome where securing the food supply of a large population was seen as one of the Emperor's main responsibilities. One could actually argue that until the advent of a more sophisticated merchant economy (i.e., late Middle Ages, which witnessed the first financial derivatives) taking uncertainty out of the fulfillment of basic human material requirements was historically the main underpinning to the concept of derivatives. Included in those requirements is obviously the need for a shelter or in modern parlance a dwelling, a need that Graaskamp (1972) linked to a 'Neanderthal developer.' Surprisingly though, real estate has never been the support of derivatives trades. In essence, the closest there was ever to property futures were contracts on bricks and stones, which were traded on the Chicago Board of Trade soon after its establishment in 1848 (Swan, 2000).

On a conceptual level, it is interesting to note that components of manufactured products (e.g., bricks in a building, flour in bread, glass in a mirror) were traditionally the support of derivative trades, whereas manufactured products themselves were rarely considered. There are a few exceptions in the history of derivatives [e.g., futures contracts for wine in Roman Egypt or cheese in the 1930's in the U.S. as mentioned by Carlton (1984)] but the idea that a composite asset can be used as underlying is actually quite unusual. This should come as no surprise insofar as commodity derivatives have customarily been associated with raw products. The commodity derivatives model implies that underlying assets be standardized while being potentially subject to differentiating, though generic, quality variables such as grade and delivery location. More significant is the pattern it reveals. Although very early on, derivatives' modes of physical delivery recognized potential differences in commodities, these instruments were conceived to deal with simple phenomena. For instance, in the case of grain, which is historically the most prevalent underlying used in a derivative, factors that might affect the quality of the commodity are well known and limited in scope. It is ultimately bread (or its equivalent) people are interested in. But bread is a composite asset, which is much trickier to deal with than grain. Bread involves other ingredients than just flour, as well as a process implying cooking, baking, storing, and human labor. While grain is a commodity, bread is a constructed, man-made product that is much more difficult to comprehend and price. In effect, the price of bread is subject to an infinite range of factors foreign to the commodity (e.g., shape, taste). Noticeably, contrary to grain, bread goes through a rapid and complex aging process not straightforwardly encapsulated in a standardized framework. The same reasoning could hold for bricks and buildings. In other words, initial promoters of derivatives traditionally focused on 'mono-dimensional' risks that could be easily captured in derivative contracts involving physical delivery. In theory nonetheless, commodity derivatives could involve more challenging risk structures. Any asset liable to be standardized and physically delivered could potentially be used as underlying.

In this respect, designing property derivatives modeled after commodity futures is an interesting theoretical idea. The prerequisite would be that real estate be somehow turned into a standardized asset, for instance through a reasonably efficient scoring system (the equivalent of 'grading' in the context of commodity derivatives). This process which would make it possible to trade futures contracts in real estate as fungible instruments would entail a number of issues already touched on in the appraisal academic literature (Adair and Hutchison, 2005). Overall, derivatives would lose some of the underlying assets' characteristics but may still enable effective hedging, depending on the calibration and validity of the scores. However, there is one major catch. Physical delivery that ultimately assures futures-cash convergence in a commodity derivatives market (Martell and Salzman, 1981) would be problematic, let alone very costly (e.g., legal fees, stamp duties). Even though futures contracts could possibly involve ex-pit exchange-for-physical (EFP) trades or partial cash settlement as described by Garbade and Silber (1983) (e.g., settlement by offset or settlement by nonpar physical delivery with a cash adjustment), the whole idea seems highly unfeasible in practice.

The Advent of Index-based Derivatives. The year 1982 marks a remarkable breakthrough from the ancient world of commodity derivatives. In that year, cash-settled contracts based on composite financial indices were first introduced. The advent of stock index derivatives is a major milestone in the recent history of finance. These products' innovativeness resides as much in the way the instrument is structured (i.e., cash settlement) as in the use of a novel type of diversified aggregate underlying (Miller, 1986). Over the first months of 1982, trading began at three different exchanges in futures contracts based on stock indices (Figlewski, 1985). The first contract to trade in February 1982 was listed on the Kansas City Board of Trade and based on the Value Line Index Composite Average. The Chicago Mercantile Exchange introduced its own contract based on the Standard and Poor's 500 in April of that same year, followed shortly by the New York Futures Exchange's contract on the NYSE Composite Index. The new market was an immediate success, which is a notable achievement for innovative derivative contracts.

Shiller (1993a) asserts that "accidents of history play a major role in determining the kinds of markets we have. [...] If we understand the role of accidents in developing our markets, we can move to make fundamental new changes in the markets." In the case of stock index futures, there was no accident. The process had been many years in the making before the first contract was launched.[1]

Indeed, researchers who wrote on the topic at the time (e.g., Niederhoffer and Zeckhauser, 1980; and Weiner, 1981) acknowledged that the major trigger for creating futures tied to composite stock indices was the prevalence of the mean-variance Capital Asset Pricing Model in Modern Portfolio Theory (Markowitz, 1959; and Sharpe, 1964). Futures industry professionals (e.g., Martell and Salzman, 1981; and Tosini and Moriarty, 1982) explicitly justified the establishment of index-based futures on the ground of the CAPM. Therefore, one may rightfully wonder whether the establishment of stock index futures was nothing more than yet another consequence of the CAPM. Bernstein's (1995) assessment of the way CAPM came to dominate the investment management industry brings some light to that question. Mean variance, the CAPM, and the Efficient Market Hypothesis, he argues, find their philosophical roots from the optimism of the early post-war years (1950s, 1960s) when people believed in a well-behaved world, functioning within clearly recognized standard deviations and with generally accepted means. Finance practitioners were initially not convinced but their reluctant acceptance of the classical ideas came after the turbulence of 1973 and 1974. Bernstein explains that it reflected a search for order at a "terrifying moment after OPEC had taken process to remind us that we were verging on chaos." This is almost coincidentally the time when futures markets started working on stock index futures contracts (Meier, 2003). It seems fair to say that stock index-based derivatives were actually designed for a perfect world. CAPM explained risk involved in equity portfolios with a reassuring dual framework (systematic/idiosyncratic). Stock index futures made it possible to hedge market risk. Diversification would do the rest. One cannot help wondering what would have happened in derivatives markets if a factor model such as the Arbitrage Pricing Theory (Ross, 1978) instead of the CAPM had come to dominate the world of finance. Would existing index-based instruments be relevant in that case? This is an open question very much at the core of this analysis of property derivatives. The paper will come back to this point later.[2]

The consequence of the CAPM as far as derivatives are concerned is the invention of the cash-settled composite index model, the very model that is currently being used or proposed for property derivatives. Hence, index-based hedging is an almost natural extension of the CAPM. What does it imply conceptually? The CAPM's essentially reductionist approach[3] to equity portfolio risk imposes on derivatives users a simplistic framework of analysis, i.e., there may be dozens of risk factors involved in portfolios but risk has to be dealt with in two categories only (systematic and idiosyncratic). Implied is the assumption that systematic risk accounts for the brunt of the portfolio's variability in returns (Martell and Salzman, 1981). The composite index derivatives template makes it possible to deal in bulk with complex risks but an immediate drawback is the almost unavoidable cross-hedge basis it entails (Figlewski, 1984). In fact, the link between this model of derivatives and the CAPM seems so close that one may question its general applicability. In other words, can this model hold for assets whose returns are not adequately explained by the CAPM? One such example would involve overwhelmingly idiosyncratic assets not easily diversifiable within a portfolio context. In this case, which is incidentally that of commercial real estate, composite index-based derivatives would be of little use to help managers reduce the portfolio's total risk.

Now that some essential concepts underpinning the working of commodity and index-based derivatives have been identified, the paper will focus on real estate assets and see how real estate risk as usually described in the academic literature fits with the above mentioned concepts.

Index-based Derivatives and Real Estate

Index-based Derivatives and the Selection of a Risk Model for Real Estate. As stated numerous times in the academic literature (e.g., Weimer, 1966; Miles and Graaskamp, 1984), real estate presents many particularities that distinguish it from financial assets: asymmetric information, high transaction costs, illiquid markets, importance of location to name a few. There is indeed converging evidence that real estate assets significantly differ from the perfect world implied in the classical finance's assumptions used in the CAPM (Clapp, Goldberg, and Myers, 1993). Since the early 1980s, portfolio diversification literature has produced a number of studies on the topic of real estate risk, which quantify the breakdown between systematic and idiosyncratic risks for diversified portfolios of commercial real estate assets. For instance, Miles and McCue (1984) and Hartzell, Hekman, and Miles (1986) indicate that systematic risk as defined by the CAPM rarely exceed 20% of total risk involved in U.S. real estate portfolios. Likewise, looking at U.K. property markets, Brown and Matysiak (2000) explain that the market accounts for less than 10% of total variation in returns of the average monthly valued property as opposed to about 30% for the average stock. In fact, past research indicates that CAPM-related single index models are not efficient at capturing the risk-return relationship of real estate assets (e.g., Brueggeman, Chen, and Thibodeau, 1984; and Titman and Warga, 1986). Young and Graff (1996) sum up the situation by questioning the very applicability of the Modern Portfolio Theory (MPT) and its antecedent the Efficient Market Hypothesis (EMH) in real estate analysis. They write: "MPT and EMH seem to have been introduced into real estate to justify the use of particular statistical techniques and portfolio strategies rather than as a consequence of empirical analysis of investment return and risk characteristics. In science, the situation is generally reversed: theories are developed to explain observations." Consequently, researchers have looked for more appropriate models to explain real estate returns (e.g., Hoag, 1980). Most of these models are based on what Clapp and Myers (1999) describe as "one of the major real estate paradigms," a theory "relevant for understanding the complex commodities that have come to characterize the modern economy," namely the hedonic pricing theory (Lancaster, 1966).

In terms of implied risk structure, hedonic pricing theory is comparable for real estate to what the Arbitrage Pricing Theory is for stocks. While the CAPM assumes that there is only one source of risk that can be embedded in the market portfolio, multi factor models recognize that risks may come from multiple sources. The CAPM with its "one-size-fits-all" approach implicitly validates a mono causal analysis of risk, whereas a factor model acknowledges the plurality of causes and their varying degree of influence on the observed phenomenon. Seen from the viewpoint of derivatives, this "tailor-made" approach supposes that risk is probably more complicated and less amenable than initially envisaged. Therefore, one cannot help wondering why current property derivatives are implicitly based on the CAPM (i.e., composite index template) and not on a multi-factor pricing model. Actually, one obvious explanation is that no existing structures of derivatives can accommodate the myriad factors such a model would entail. As mentioned before, commodity derivatives were designed for standardized simple assets while index-based derivatives impose a dual framework inefficient for highly idiosyncratic risk structure. Hence, notwithstanding evident interest from the academic community and practitioners alike, creative thinking is found lacking in that area.

Index-based Derivatives and the Two Realms of Commercial Real Estate. Due to the obvious limitations of the composite index model of derivatives, instruments which would combine a hedonic underlying and an index-based structure (e.g., a hedonic index-based property futures) are sometimes presented as an alternative. Shiller (1993a) mentions such a combination. What is particularly interesting about this model is what it reveals about the true nature of commercial real estate, namely: is real estate essentially a physical entity or a financial asset? Grissom and Liu's (1993) analysis of the paradigms in real estate provides some useful elements to answer that question. In a nutshell, two models can be applied to set up real estate problems: a 'space time' model as defined by Graaskamp (1976) and a 'money time' model.[4] The ultimate goal of real estate investment is the cash cycle conversion represented by the 'space-time to money-time' equation. Interestingly, property derivatives stand very much at the junction of these two models: they are an operator, or at least a regulator, in the above-mentioned equation. The choice of underlying and product structure for a property derivative does automatically position real estate either in a 'space time' realm or in a 'money time' realm. That is why defining an optimal model for these instruments is challenging. The benefit of hedonic index derivatives is to conciliate these two realms. This study explains how by comparing the effects that the two models of derivatives described before (i.e., commodity and index-based) would have on property derivatives.

A property derivative modeled after commodity derivatives (as briefly mentioned before) focuses on real estate's idiosyncrasies. It integrates risk issues in a 'space x time' realm, by acknowledging the dominance of individual properties' physical characteristics over any other characteristic, especially those related to the investment process. Conversely, a property derivative modeled after stock index futures considers real estate like any other financial investments. It disregards the physical dimension of real estate assets and reduces risk issues to a 'money-time' component. As eloquently explained by Grissom and Liu (1993), "the money-time component represented in the classical literature is only a portion of the total real estate equation. The space-time dimension must be fully comprehended to understand the nature of real estate products, markets, and problems. In a financial context, the failure to grasp the space-time component will result in inappropriate analysis of the risk dimension of real estate." A hedonic index derivative seems like an astute way to combine real estate's two dimensions, i.e., a hedonic underlying to take account of spatial issues on the one hand, an index-based structure to encapsulate the capital component on the other. On paper, hedonic index derivatives manage to reconcile the benefits of index-based hedging with the idiosyncrasies of real estate assets. But, to put it bluntly, can it work? Although very interesting in theory, the hedonic index-based template of property derivatives would be very intricate to implement in practice. First, as a general shortcoming of the hedonic regression theory, difficulties in identifying pertinent factors and pricing them have until now greatly delayed the development of effective hedonic indices that would meet practitioners' wide approval (a condition absolutely essential to the choice of an underlying to a derivatives contract as explained by Lecomte and McIntosh, 2005a). Concretely, there are no underlying hedonic indices readily available for commercial real estate assets (Shiller, 1993a). Secondly, deriving hedonic price indices is comparatively more challenging for commercial real estate than for residential properties due to fewer transactions and more fundamental property alterations between sales (Shiller, 1993a). As a result, it would be tricky to build repeat sales indices for commercial real estate. Shiller (1993b) proposes an alternative, which would use a rental index to establish a market for 'regional commercial real estate perpetual futures contracts.' At first glance, such a model would unfortunately not capture the full space-time component of commercial real estate but instead moves back to a money-time realm. A simpler alternative sometimes considered is to establish derivatives on highly specific composite sub-indices of real estate's appraised prices rather than hedonic prices. Research shows that as appraisal-based indices become more efficient, this is conceptually feasible (Lecomte and McIntosh, 2006). It is indeed one route that promoters of current OTC property derivatives will very probably explore in the near future (Fisher, 2005; and Lecomte and McIntosh, 2005b). These instruments would combine, albeit less effectively than hedonic-based instruments, the two dimensions of real estate but their development might be hindered by a set of issues deeply rooted in the modern history of derivatives: regulation and the risk of manipulation.

Structural Issues Involved in Narrow-based Index Property Derivatives. Derivatives based on hedonic prices or specific composite sub indices share common structural issues. In essence, market authorities have traditionally been very suspicious of derivatives on narrow based indexes, lest they be associated with manipulations in the underlying cash market. Past history of derivatives is full of such cases.[5] For a given cash market, the narrower the index, the more likely manipulations might occur. As an illustration of how serious this question is being considered, U.S. futures exchanges wishing to list derivatives based on narrow equity indices must get, under the 1982 Shad-Johnson Accord, the agreement of both the Securities and Exchange Commission (SEC) and the Commodity Futures Trading Commission (CFTC), whereas broad-based indices are subject to the authority of the CFTC only (U.S. General Accounting Office, 2000). More telling even, until 1999, the SEC deemed the Dow Jones Utilities and Transportation Indices too narrow to meet its requirements. With respect to commercial real estate, one may wonder how market authorities would look at derivatives, say futures, linked to narrow-based indexes.

An interesting recent development in this area is the decision by the Chicago Mercantile Exchange to launch futures and options based on indices depicting single family residential dwellings in ten large U.S. metropolitan statistical areas (Labuszewski, 2005). Proponents of narrow-based index derivatives would argue that similar instruments might be established for commercial real estate. Actually, such a claim is questionable. With respect to repeated sales indices' feasibility and the proper use of narrow-based indices, residential and commercial markets greatly differ. Shiller (1993a) acknowledges that "manipulation of the futures market via sales in the cash market" is a major factor to consider when analyzing potential property derivatives for commercial real estate. The risk of manipulation on a narrow-based index is fairly unlikely in derivatives based on large MSA residential indexes: atomization of ownership would make it difficult to massively corner the market. It might be different in the case of commercial real estate where individual stakes (i.e., lot sizes) are much higher and involve fewer players. Obviously, not all sub-markets would be unfit to narrow-based index futures. The largest, most liquid ones might be natural candidates. However, they would require a constant monitoring by market authorities to ensure that no manipulation is possible. This painstaking process would involve a careful review of underlying cash markets (e.g., by property type x region) to assess their suitability with derivatives. Striking the right balance between faithfulness to real estate' physical characteristics and acceptable narrowness of the underlying index seems quite a challenge to take up. In all probabilities, narrow-based index property derivatives, be they using a hedonic or composite underlying, would be confined to OTC instruments and would never make it to the standardized exchange-traded stage. Lecomte and McIntosh (2005b) explain that the expected outcome would be a cluster of niche markets for highly customized OTC vehicles. In case of particularly concentrated or illiquid real estate sub-markets, it is not even sure that OTC structures would be advisable. The paradox is as follows: property derivatives need to reflect as much as possible real estate's space-time component but the more they do so, the less likely they are to make it in the world of finance.

Summary. Considering the various derivatives templates reviewed so far (summarized in Exhibit 1), it seems quite clear that no existing model of derivatives can satisfactorily address real estate investors' hedging needs. In theory, property derivatives should be based on multi-factor models cognizant of real estate's fundamental risk structure. In practice, no existing derivatives template knows how to accommodate multi-factors. What is currently available are derivatives meant for hedging at the aggregate level, whereas real estate might demand for a more molecular approach. Hedonic index-based derivatives or highly-specific composite sub index derivatives would represent an improvement to current derivatives modeled after financial derivatives. However, they would have to face a number of structural issues that could ultimately hinder their establishment. The analysis is therefore faced with a conceptual deadlock and has to ask whether it is possible to imagine a totally different template for hedging real estate risk. If so, where can clues be found? In fact, as surprising

Exhibit 1
Models of Derivatives and Real Estate

Model of Derivatives	Ways to Deal With an Asset's Physical Characteristics	Implicit Risk Structure	Relevance for Hedging Real Estate Risk
Commodity Derivatives	Focus on standardized physical assets. Classification by grades and delivery locations.	Derivative template per se does not limit potential complexity of risk. Hedged risks tend to be simple because of standardized underlying.	The model fully acknowledges the 'space-time' dimension of real estate. However, to do so, it imposes standardization and physical delivery, which makes it inapplicable to real estate in practice.
Composite Index-Based Derivatives	Ignored. The model was designed for financial assets.	Dual risk framework. Only concerned with market risk in accordance with the CAPM.	This model proposes a 'one-size-fits-all' approach, which is over-simplistic for heterogeneous assets. Cash settlement template enables overall efficiency but ignores asset's idiosyncrasies. Basis risk is potentially high.
Hedonic Index-Based Derivatives	Embedded in the index.	The model combines a multi-factor approach embedded in the underlying index with a dual risk framework.	The model accommodates both the 'space-time' and the 'money-time' dimensions of real estate. In essence, it is a 'tailor-made' approach. However, deriving hedonic price indices for commercial real estate will be challenging. Corresponding instruments might never be traded on standardized exchanges due to market authorities' misgivings with narrow based indices.
Narrow-Based Composite Index Derivatives	Approximated by index (e.g., sector specific property sub index).	The model attempts to capture risks by defining sub markets but the overall risk framework is dual.	The model proposes a workable alternative to a hedonic index. However, it only allows for imperfect hedging and carries substantial basis risk. Corresponding derivatives are unlikely to be traded on standardized exchanges due to market authorities' misgivings with narrow based indices.

as it might seem, the field of biomedical sciences may provide a useful analogy.

Biomedical Sciences and Real Estate Risk: Dealing with Complex Phenomena

Because of its complex character, real estate has long been known for triggering innovation in the financial realm, e.g., securitization, use of real options in corporate finance, or index building techniques. It is not by chance that Weimer, Hoyt, and Bloom (1972) mention "creative thinking" as a necessary quality for real estate researchers and practitioners. They write: "The study of the real estate field provides an unusual form of 'laboratory work'. [...] One of the most important abilities [one] should acquire through [the] study of this topic is that of producing ideas." Reflecting over the lives of pioneers in the real estate area (including Homer Hoyt), Weimer et al. adds: "These men were not limited by traditional approaches to problems nor traditional solutions. When established methods and procedures failed, they invented new methods and procedures. They all had imagination and in varying degrees had creative ability." This section will try to put their words in action by developing an analogy between biomedical sciences (i.e., medicine and pharmacology) and real estate in the context of risk management. The objective is to uncover ideas applicable to the design of new hedging products for commercial real estate. Before getting into the nuts and bolts of the analysis, a fundamental point has to be addressed: What is the link between biomedical sciences and real estate? Actually, as the following section will demonstrate, biomedical sciences as well as real estate risk management have to deal with complex phenomena. As such, they contain models and methods that can be applied to finance, especially when real assets are concerned.

This section has three parts. It first presents the methodology in light of past academic economics/real estate literature. It then exposes details of the selected analogical framework and, finally, summarizes the findings by proposing nine possible generic models of real estate derivatives.

Methodology

The Value of Analogy. Analogy has traditionally been associated with discovery in social sciences. It can serve many purposes, such as justifying novel theory or explaining abstruse concepts. Cohen (1994) explains that "analogies arise from the recognition that an idea, concept, law, theory, system or equations [...] or any other element of one subject is similar to some element in another or has properties that enable it to be introduced usefully into that other subject."

James A. Graaskamp was a fervent proponent of analogy in real estate analysis. In his *Guide to Feasibility Analysis* (1970), he stresses the potential benefits of analogy, which enables to make "the strange familiar and the familiar strange to gain simplification and perspective." He adds: "the ability to associate a real estate problem with some analogous natural or mechanical process and to extend the metaphor may well lead to creative perception and construction. [This kind of thinking] is the basic tool of the good writer, the creative artist, or the intelligent analyst." Clapp and Myers (1999) emphasize this dimension of Graaskamp's empirical methodology: analogies are part of the process of rigorous research as defined by its logical relevance to a real world problem. Researchers should "select methods that are most appropriate for making progress on the problem. These methods might be drawn from other disciplines."

However, all analogies are not equally helpful. Some may be inappropriate and generate even more confusion about the issues. For example, Cohen (1994) notes that "despite the hopes of many social scientists, Newton's physics [...] has never provided a useful analogy for economics, political science, or sociology." One other caveat playfully noted by Feynman (1998) is the risk "of making a fool of oneself" in an age of extreme scientific specialization.

Choice of a Biomedical Analogy. Biological analogies have already been applied in real estate analysis in the context of systems thinking. In essence, urban economic systems are highly complex evolving organisms. This supposes that all parts be described pretty much as medical science describes the human body. Descriptive studies as practiced in biology provide clues for dealing with problems of complexity and change over time (Clapp, Goldberg, and Myers, 1993). Similarly, biological analogies are sometimes mentioned in risk analysis. For instance, Fishkin (2005) suggests the visualization of risk structure based on biological metaphors.

In fact, the linkage of biomedical sciences with social sciences, and economics in particular, is not new. In the late nineteenth century, physics and biology were considered as offering equally valid paradigms by social scientists (Cohen, 1994). Although neo-classical economics eventually chose physics as the science to emulate, some marginalists preferred a biological to a mathematico-physical model.[6] Chief among them was Marshall, the famous Cambridge academic. Marshall was very impressed by the extraordinary successes of biology in the nineteenth century and argued that discoveries in biology could provide useful analogies in economics. Interestingly, what was true over a century ago seems even more relevant today. Biomedical sciences have witnessed incredible breakthroughs over the last fifty years with the advent of numerous new concepts and methods. This paper will explore some of these breakthroughs in the context of risk management.

Analogical Framework

Generally speaking, there are two classes of analogy: "substantive" analogies in which a theory or system is patterned on the model of another system, which contains known basis, and "formal" analogies, which are based on a structure of abstract relationships (Nagel, 1961). The analogy presented thereafter is formal. As such, it is limited in reach. Many interesting related questions such as the potential impact of a biological model on a behavioral approach to real estate analysis (e.g., Diaz, 1999) or the merits of an inductive approach versus a deductive model in the analysis of heterogeneous assets are beyond the scope of this paper. Likewise, the presentation of biomedical concepts will be at best sketchy. The history of medicine is vast and complicated, involving many different paradigms that will not be described here (Bynum and Porter, 1993; and Porter, 1997). All assertions concerning biomedical sciences are made with the current modern consensus in mind.

Real Estate Risk as Multifactorial Disease. The premise of the methodology is to recognize that biomedical sciences and real estate risk management share common conceptual issues. As stated before, both biomedical sciences and real estate risk management have to deal with complex phenomena.

Biomedical sciences (i.e., medicine, pharmacology) are concerned with human health. Their ultimate role is to treat diseases or in other words to counter-act the adverse impacts of outside factors that may alter a patient's health. A disease is, as its etymological root suggests, an abnormal state causing discomfort as opposed to health, which is the normal state. Diseases are complex phenomena involving dozen of parameters. King (1981) explains that "each disease is a congeries of factors, and no single factor, by itself, identifies the disease." Although diseases have features in common, each disease is highly idiosyncratic.[7] Diseases are not tangible entities but rather represent immaterial patterns of events or relationships whose significance comes from their recurrence. The more complex the disease is, the less decipherable the patterns are. Disease analysis hinges on the assumption that the individual and his surroundings form an integrated system, a total environment, divided into two parts: the external component including factors such as light, heat, oxygen and the internal component (e.g., anatomical structures). Medical science studies the internal component and its relations with the external component. As mentioned by Thagard (1999), a disease is multifactorial whenever environmental factors interacting with the patient and her genes play a substantial role in producing the disease. Modern medicine recognizes that most common human diseases are multifactorial.

Risk interferes with properties' income producing abilities. It creates conditions such that cash flows (i.e., income, capital appreciation) stemming from a property or portfolio of properties become unpredictable. In that sense, risk disrupts the normal desirable state. Real estate risk is highly idiosyncratic. It hinges on many immaterial and difficult to define factors. Quantifying their individual disruptive effect is a challenge. Their specific combination, however, defines a particular asset's risk profile or pattern of reaction to risk. In this respect, the real estate portfolio literature (e.g., Eichholz, Hoesli, MacGregor, and Nanthakumaran, 1995) is essentially interested in finding out the most relevant classification of those patterns. Risk management, through hedging, aims at offsetting the adverse effects of risk on the predictability of a property/portfolio of properties' cash flows. These adverse effects stem from the relations of a given property with its environment. Graaskamp (1970b) states that "the prolonged payback of capital [involved in the real estate process] means long-term exposure to the dynamics of a changing society to which real estate cannot readily adapt due to its immobility, inflexibility, durability, and complexity. Constant adaptation to changing outside circumstances requires ever-constant management attention, and the ability of real estate investment to glide through economic adversity can be likened to the helicopter which in the absence of power and pilot control has the natural glide angle of a falling brick." Thus, real estate risk depends on the interactions between a property's internal component and its rapidly changing external component. In essence, real estate risk is very similar to a multifactorial disease.

Hedge as Treatment. If real estate risk shares common features with multifactorial diseases, then medicine's approaches to these diseases might contain information relevant to the analysis.

The paper pointed out in its introduction that a hedge product is the combination of both an underlying and a product structure. The same is true for a medical treatment, which combines a drug (or drugs) with a mode of delivering it.

Hence,

$$\text{Underlying} \times \text{Structure} = \text{Hedge}$$
$$\text{Drug(s)} \times \text{Mode of delivery} = \text{Treatment}$$

In other words, in the analogical framework, real estate risk management is very similar to treating a multifactorial disease: hedge underlying relates to drug(s) in a treatment; hedge structure relates to mode of delivery of the drug(s.)

Likewise, hedging implies concepts such as hedging effectiveness, hedge ratio, and basis. The paper briefly referred before to shortcomings entailed by an imperfect hedge, namely poor hedging effectiveness and cross-hedge basis. Very similar concepts apply to gauge drug therapies: efficacy, dosage and side effects. Hence, treatment efficacy relates to hedging effectiveness; dosage relates to hedge ratio; and side effects relate to cross-hedge basis.

Hedging follows the principle of negative replication stemming from the basic medical concept 'like cures like.' The problem is that nobody knows what the 'likes' are or should be. Real estate risk is not properly understood and the appropriate underlying to this replication process, as well as the optimal way to deliver it, is not clear either. Thus, a biomedical analogy can help in two dimensions: (1) mode of action: choice of underlying or component of the hedge and (2) mode of approaching the phenomenon or structure of the hedge.

A variety of potential underlying to property derivatives has already been mentioned: physical properties (akin to commodity derivatives), composite indices, specific sub-indices, and hedonic indices. The main difference among all those underlyings is their closeness with actual properties whose risks have to be hedged. Biomedical sciences provide some interesting concepts in that respect. The history of pharmacology describes scientists' incessant search for always more efficient drugs. Most of the time, increased efficiency was achieved thanks to progress made in designing purer drugs. The notion that pure drugs are not only more efficient but also more reliable than non-purified preparations from plants is linked to the discovery of active principles (e.g., pure alkaloids like morphine, quinine, caffeine) in the early nineteenth century. Bynum and Porter (1993) explain that isolation of active principles from a therapeutically active material became an established procedure, which paved the way for the age of industrialized drugs known today. Since the 1950s, drugs are basically compounds aimed at generic categories of diseases and marketed as 'blockbuster' products by pharmaceutical companies. In recent years, the trend toward always purer drugs has gained substantial momentum with progresses in the sciences of chemistry and pharmacology (e.g., pharmacogenetics) that make it possible to envision novel agents engineered to target specific dimensions of multifactorial diseases for targeted and genetically identifiable subgroups of the population (Evans and Relling, 1999). Interestingly, purity of therapeutic compounds has been conducive to both enhanced efficacy and lower toxicity. In the analogical framework, this would be equivalent to improved hedging effectiveness and reduced basis.

Physicians can either treat a disease with one drug (monotherapy) or a combination of drugs (Grahame-Smith and Aronson, 2002). Combination therapies are used for increased efficacy, especially in case of very complex diseases. They can be either sequential or consequential. In the latter case, physicians are concerned with the interactions between drugs and their positive or adverse effects on patients' health. In some instances, because of a lack of appropriate remedies or poor understanding of the disease, medicine cannot cure and only aims to contain the phenomenon (e.g., Highly Active AntiRetroviral Therapy also known as HAART applied in the treatment of infectious viral diseases). The development of purer drugs has been accompanied with a search for more effective modes of delivery culminating in concepts such as targeted therapies and individualized medicines.

In a nutshell, modern scientists' major concern is about delivering the correct amount of the most effective therapeutic agents at the proper place in the body with as few side effects as possible. Recent breakthroughs are making this goal more reachable while opening the way to a radically new age of treatments and therapies. In effect, targeted therapies and individualized medicines embody what is potentially a new paradigm in medicine and a true holy grail: optimal efficacy for each patient with no side effects at all. It is important to keep in mind the two conditions that underpin these revolutionary concepts. First, a thorough understanding of causal networks involved in multifactorial diseases is an absolute prerequisite. As noted by Thagard (1999), "understanding the mechanism that produces a disease can lead to new ideas about how the disease can be treated." Second, these novel therapeutic approaches to complex diseases are holistic in nature insofar as they make use of advances in many different fields: biology, chemistry, pharmacology, medicine, genetics, biotechnology, nanotechnology, and other related fields. Hence, an interdisciplinary approach has been instrumental in establishing new paradigms in biomedical sciences.

- **Targeted Therapies**: In its simplest form, targeted therapy implies a therapy with a specific molecular target (Sledge, 2005). Targeted therapies are commonly considered in oncology. They can involve one or more drugs, usually novel therapeutic agents (Craddock and Hochhauser, 2002). A very interesting kind of targeted therapy is the smart bomb, a concept that is experimentally developed in cancer therapy to selectively kill tumor cells without adversely affecting normal ones. Smart bombs that can be seen as the ultimate form of combination therapy usually involve highly specific therapeutic agents released in a patient's system according to a pre-arranged procedure and schedule to ensure maximum efficacy (e.g., anti-cancer smart bomb). A remarkable feature of smart bombs, as far as this analysis is concerned, is their cutting-edge approach to complex phenomena that combines a variety of 'pure' drugs with selective modes of delivery.
- **Individualized Medicines**: Developed by FitzGerald (2005), the concept of individualized medicine goes even further than targeted therapies in the search for optimal efficacy. Individualized medicines would in effect be treatments individually targeted and exclusively formulated. In sharp contrast with the mass market model aggressively pursued by the pharmaceutical industry, this approach represents a radical shift from the 'one-size-fits-all' model of drug therapy. Instead of selling compound 'blockbuster' drugs, pharmaceutical companies would manufacture highly specific therapeutic agents liable to be specifically combined for each patient on criteria such as genetics.

What is interesting in these cutting-edge concepts is the drastic move they epitomize from a standardized vision of drug therapy to sophisticated processes of customization, which rely on: (1) highly specific drugs that are no longer compounds but 'pure' therapeutic agents purposely designed to act on one particular molecular target (i.e., one dimension of the phenomenon); and (2) conjointly a targeted approach using innovative delivery structures (e.g., smart bombs) or asking for a tectonic shift in the way drugs are manufactured and sold (e.g., individualized therapies).

Tensions between standardization and customization are not new in medicine. As mentioned in Endnote 7, they can be traced back to the scientific view of medicine developed in the nineteenth century (Bynum, 1994). Faced with intricate and idiosyncratic phenomena, modern medicine is developing tools and resources, drawn from a wide range of fields, to conciliate these two dimensions. While practical and economic constraints plead for a standardized template, the quest for maximum efficacy and minimum harm suggests customized therapeutics. Customization is a challenging and demanding process that supposes an in-depth analysis of diseases' causes, as well as a complex study of individual differences in drug response (FitzGerald, 2005). As mentioned by Lecomte and McIntosh (2005b), promoters of property derivtives are confronted with a very similar set of issues.

Summary and Synthesis

The concept of disease provides a useful framework for analyzing a complex phenomenon involving patterns immersed into the confusion of a total environment (Exhibit 2). The mechanism of the analogy starts with identifying similarities between real estate risk and a multifactorial disease. In essence:

1. Real estate risk is like a multi-factorial disease.
2. Multifactorial diseases are best treated by using targeted therapies with highly specific therapeutic agents, or individualized medicines.
3. Real estate risk may be best treated by using targeted or individualized hedges.

Exhibit 2
Analogical Framework

Real Estate Risk Explanation Schema

Explanation target: How can we best hedge real estate risk?

Explanation pattern:
1. Real estate risk is like a multi-factorial disease.
2. Multifactorial diseases are best treated by using targeted therapies with highly specific therapeutic agents, or individualized medicines.
3. Real estate risk may be best treated by using targeted or individualized hedges with specific underlying.

Real Estate Risk

Real Estate Risk → Multifactorial Disease
Risk affects properties' income producing ability → Disease affects the normal functioning of human bodies
Each building is different → Each patient is different
Buildings are subject to obsolescence → Patients suffer from aging

Hedging

Hedge → Treatment (drug therapy)
Underlying → Drug
Composite index → Generic, mass market drug
Narrow-based index → Specific, niche market drug
Pure factor → Engineered therapeutic agent, pure drug
Product Structure → Mode of delivery
Underlying × Product Structure → Drug × mode of delivery
Hedging Effectiveness → Therapeutic efficacy
Basis → Side effects
Hedge Ratio → Dosage

Product Design

Index-Based Instrument → Monotherapy
Combinative Instrument → Combination therapy
Factor Hedge → Individualized medicine

Moreover, recent advances in drug therapies provide hints as to possible underlying and structures of hedge instruments:

- Drugs can be composite (aimed at broadly defined generic diseases), specific (aimed at narrowly defined diseases) or pure (as therapeutic agents aimed at one molecular target involved in the disease process).
- Mode of delivery can involve monotherapy, combination therapy either indiscriminately targeted or individualized.
- Optimal treatment efficacy is achieved by combining purified drugs with selective modes of delivery.

Hence, translating these concepts in terms of hedge instruments, it appears that:

- Underlying can be composite (e.g., NPI indices), specific (e.g., hedonic or narrow-based indices) or 'pure factor' covering one particular dimension of total risk (Exhibit 3). The meaning of 'pure factor' in this context has still to be defined.
- Product structure can involve one underlying (e.g., any single index-based derivatives), several underlyings either indiscriminately, targeted (i.e., combinative structure) or individualized depending on the asset's internal and external components (i.e., factor-based structure).

Exhibit 3
Possible Underlying to Real Estate Hedge Instruments

Proposed Underlying	Analogy (Drug)
Composite Index	Generic, mass-produced drug. Blockbuster, "one-size-fits-all" model with potentially important troublesome side-effects.
Specific Index (e.g., hedonic)	Disease-specific, niche market drug.
Pure Factor	Engineered therapeutic agent individually selected and combined.

Exhibit 4
Possible Structures of Real Estate Hedge Instruments

Proposed Structure	Analogy (Mode of Delivery)
Index-Based Derivative	Monotherapy.
Combinative Instrument	Combination therapies: targeted therapeutics, smart bombs.
Factor-Based Instrument	Individualized medicine aiming for optimal efficacy and minimum side effects.

- Efficient instruments will combine specific underlying with innovative product structures.

Exhibits 3 and 4 summarize the analysis.

As can be seen in Exhibit 5, crossing the three possible underlying (numbered from 1 to 3) with the three possible mode of delivery (referenced from A to C), the analysis defines nine possible models for property derivatives (from 1A to 3).

Current property derivatives are composite index-based instruments (1A) that emulate a "one-size-fits-all" monotherapy. Shiller (1993b) mentions hedonic index-based derivatives (2A). Lecomte and McIntosh (2006) describe narrow-based index derivatives (2A). Three generic models are conceptually unfeasible (grey cells in Exhibit 5: 3A, 1C, 2C) because of obvious incompatibility between underlying and product structure. To be relevant, innovations in mode of delivery have to be accompanied by simultaneous advances in the purity of underlying. Thus, the biomedical analogy has enabled identification of two potentially revolutionary models of derivative: combinative structures (1B, 2B, 3B) and the factor model (3C).

Beyond Index-based Hedging

A comparison of current real estate hedge products with modern drug therapeutics shows finance's abyssal lack of sophistication compared with biomedical sciences when dealing with complex phenomena. Index-based derivatives are primitive in their approach to real estate risk, and basis can be seen as a consequence of this primitivism. As explained by Shiller (1993b), psychological barriers and the custom of habit play a central role in refraining innovations in derivative design even though "the functioning of the market economy awaits new invention." Indeed, composite index-based hedging might become to real estate what blood-letting was to medicine: a misconstrued habit based on a wrong framework of analysis and poor understanding of the phenomena at work. Hedging risks involved in heterogeneous assets such as real estate requires 'radical financial innovations' (Shiller, 2004). The next section reviews prerequisites to such innovations and then presents two innovative models of derivatives before assessing their capability to chart a new way forward for real estate risk management.

Exhibit 5
Three Possible Underlying

Structure/Underlying	Index-Based Instrument	Combinative Structure	Factor-Based Hedge
Composite Index	Current property derivatives (e.g., NPI-based swaps) *1A*	Model reviewed in this paper *1B*	*1C*
Specific Index	Narrow-based index (e.g., Lecomte and McIntosh, 2006) or hedonic index-based derivatives (e.g., Shiller, 1993) *2A*	Model reviewed in this paper *2B*	*2C*
Pure Factor	*3A*	Model reviewed in this paper *3B*	Model reviewed in this paper *3C*

Note: LetterNumbers in italics (*1A, 2A . . .*) refer to underlying/structures presented in Exhibits 3 and 4.

Thinking Real Estate: The Process to Optimal Hedging Instruments

Causality in Real Estate Analysis. Real estate as the epitome of heterogeneous assets is probably the most challenging asset class of the whole investment spectrum. In their 'total environment,' buildings meet Simon's (1996) definition of complex systems. They are made up of a 'large number of parts that have many interactions and for which the whole is clearly more than the sum of the parts." Buildings are about national macroeconomic trends and local geographic factors. Buildings are ultimately about people: the way they live, shop, work, travel, and vacation. Buildings themselves are like living organisms. They age (both materially and in relation to their environment), can be maintained or even rejuvenated through frequent alterations. In that sense, real estate is a 'physically alive' asset class where finance meets economics, sociology, psychology, engineering, and architecture among other fields. As defined by Graaskamp (1977b), it is very much an 'applied social science.'

A major hurdle to effective hedging of real estate risk lies in an inherently flawed conception of the hedging process. For the most part, hedging has essentially been about replicating the phenomenon as faithfully as possible (what was called earlier a process of 'negative replication'), whereas a proper analysis should hinge on thoroughly understanding variables or pure factors whose interactions with the internal and external components of real estate generate risk. This analysis is all the more crucial as means available to deal with a phenomenon tend to influence the representation of the phenomenon and thus significantly impair the ability to come up with novel approaches. This has been repeatedly noted in medicine (Temkin, 1981).

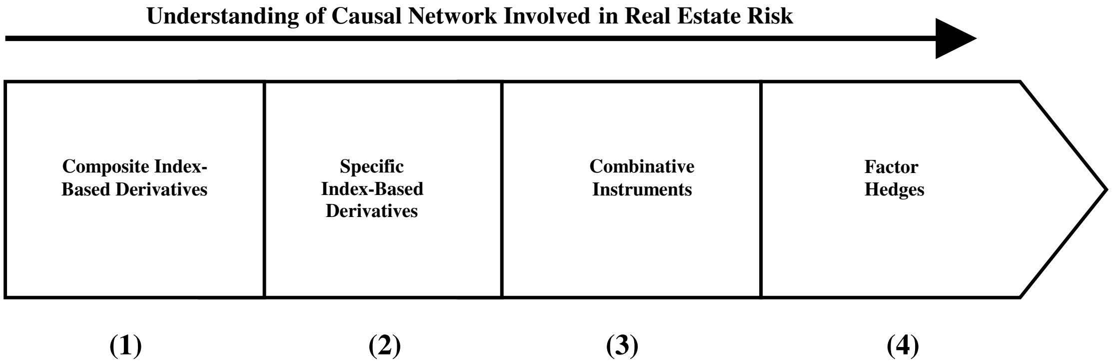
Thinking real estate risk as a complex system involving an intricate causal network is a prerequisite to designing property derivatives. Simon (1996) notes that social sciences should aim "to show that complexity, correctly viewed, is only a mask for simplicity, to find pattern hidden in apparent chaos." This search for patterns should look for innovative methodologies reaching much further than traditional statistical analysis centered on correlation (Cheng, 1997). Indeed, statistics should not be "the resort of an incomplete and faulty science that had failed to produce a simple one-to-one relation between cause and effect," (Cohen, 1994). Devising risk explanation schemes in pretty much the same way as medicine identified and classified in well-known hierarchies, diseases and their symptoms[8] would provide patterns of causal relations responsible for adverse effects on real estate's income producing abilities. Lecomte and McIntosh (2006) propose the establishment of quarterly risk tables that would be a first step in that direction.

Moving away from a correlation model to a fully fledged causal analysis of real estate risk could trigger a drastic shift in risk management from a commodity or price hedging approach to a truly innovative template focused on risk hedging. In fact, it seems the only way forward to effective hedging of risks involved in real estate investment, and in any heterogeneous assets for that matter, is to separate the asset defined as a bundle of characteristics from individual factors impacting these characteristics. The ultimate aim is to design fully individualized hedge products traded on a new kind of standardized markets. These instruments called 'factor-based hedges' will no longer be derivatives inasmuch as their value will not derive from that of the underlying asset but from risk variables or 'pure' risk factors impacting the cash market. Exhibit 6 illustrates the corresponding customization process.

Issues with the Design of 'Pure' Underlying. The process described here is not simply theoretical. As a testimony of its validity, it is substantiated by recent innovations in derivatives markets. The concept of risk hedging is well exemplified by weather derivatives, which are based on a risk factor and not on a commodity or index representative of an asset, be it physical or financial. Likewise, nuclear financial economics (Sharpe, 1995) and economic derivatives (Lange and Economides, 2001) go in a direction that might ultimately lead to the advent of combinative instruments and factor hedges. However, much work needs to be done.

New product structures would comparatively be easier to implement than deriving appropriate underlying to combine with those structures. The

Exhibit 6
From Index-Based Derivatives to Factor Hedges



Necessary Conditions: At all stages, market readiness, as well as market authorities' involvement is a prerequisite.

From (1) to (2): Availability of relevant indices.
Minor product innovations (e.g., settlement).
From (2) to (3): Classification of relevant variables impacting risk/return,
Major product innovations.
From (3) to (4): Identification and quantification of pure factors,
Shift in theory of hedging: from commodity (price) hedging to risk factor hedging.
Structure of derivatives markets: Can existing channels be used? Is there a need to set up new markets?

advent of causal risk analysis advocated before should lead to the design of a new type of underlying or 'pure factors' whose values are not derived from some cash market's underlying price but from their contribution to the asset's total risk. These factors will be of a dual nature: internal (micro factors) for interactions caused by a building's characteristics with its outside environment and external (macro factors) for interactions stemming from outside variables with the building. This is conceptually consistent with the Hoag (1980) model, which encompasses both the micromarket for property specific characteristics and the macromarket climate captured by regional and national variables. Identifying and classifying factors will give rise to myriad methodological issues. First, defining the scope of the phenomenon to be hedged (i.e., the appropriate definition of risk) is crucial. Indeed, how far reaching and inclusive should the choice of risk sources be? How can the analysis differentiate between real estate's internal and external components? How to deal with multicollinearity? Likewise, quantifying and pricing the 'pure' impact of single risk factors will be a major challenge: When does a variable become a significant risk factor? How should each factor's sensitivity and its contribution to total risk be priced? These questions are common to most multifactor models, be it the APT for stocks or the hedonic regression theory for real assets (Shiller, 1993a). This is where innovative thinking is most required to overcome seemingly insurmountable issues, which in the past have hindered the applicability of multifactor models in real estate (e.g., Draper and Findlay, 1982). In this respect, concepts such as Riddiough's replicating portfolios (1995) are very interesting in their non-restrictive use of a wide range of factors. The analysis advocated here should follow similar paths but would focus on factors identified in the causal analysis of real estate risk. The starting point of any such endeavor should be a thorough analysis of what real estate stands for. Thinking real estate in a new innovative way is essential. Econometricians will then have to take over and demonstrate their creative skills. The biomedical analogy may provide some useful methodological tools. Hierarchy, for instance, has been shown to be of great help in revealing sense out of complexity, by separating high-frequency dynamics from low-frequency dynamics in a complex system (Simon, 1996). Moreover, chaos theory (Cohen and Stewart, 1994), as well as reductionism in biomedical sciences (Dupre, 1993) shows that turning complicated systems into simpler constituents can considerably ease the process of discovering simplicity, a process widely applied in modern molecular biology (Webster, 2003). Sharpe (1995) applies very similar views in his 'nuclear financial economics' but he attributes them to nuclear physics. This paper presents in its last section a framework for analyzing real estate risk that could help in the identification of patterns and associated factors. Issues pertaining to the design of 'pure' underlying are absolutely crucial in determining the overall feasibility of the proposed models of derivatives.

Combinative Instruments

Combination therapy is an interesting concept that shows that complex phenomena may be better addressed from various angles (either simultaneously or sequentially) rather than frontally. A combinative approach allows for greater efficiency and/or flexibility. One drug for the brunt of a phenomenon and a combination or succession of other drugs are considered an effective manner to tackle various components of the same disease. When definite cures are missing, it can serve to contain the phenomenon. Why can't finance do the same? To answer these questions, the paper describes three possible combinative structures tied to respectively composite indices (1B), specific indices (2B), and factors (3B), as shown in Exhibit 5.

Choice of Underlying. As drug interaction is a major issue with multi drug regimen, index or factor interactions expressed by multicollinearity could represent a massive shortcoming of combination hedges. To mitigate that risk, it seems that combinative structures should optimally be based either on an assortment of specific indices and factors (2B), or factors only (3B). For instance, a combinative hedging instrument akin to a smart bomb could mix several individual hedges selected by their users to best cover corresponding constituents of a given risk. This new derivative could take the shape of a futures contract based on a broadly defined sub-index with add-on factor-based features (e.g., options), resulting in a customizable hybrid hedging vehicle made up of standardized (and hence tradable) derivatives products (Figure c in Exhibit 7). This template implicitly conveys a hierarchy of causes. In effect, there would be a main 'efficient' cause (i.e., captured with the futures) and additional causes (encapsulated in the choice of factor underlying). Interestingly, there is extensive academic literature to support this analysis. For instance, Eichholz et al. (1995) note that one dominant factor and several less important ones can be expected in multifactor models of real estate in accordance with the empirical APT literature. Specifically, research on diversification benefits explains that property type is the most important dimension in determining different real estate market behavior [e.g., Miles and McCue (1982) or for the U.K., Hamelink, Hoesli, Lizieri, and MacGregor (2000)] while a geographic factor plays a secondary role only. Economic diversification literature after Hartzell, Shulman, and Wurtzebach (1987) also suggests that incorporating location into a combinative instrument might be optimally achieved by considering economic variables rather than purely geographic criteria. Mueller and Ziering (1992) and Mueller (1993) propose interesting economic base categories (EBC) that stress the importance of local economics and might provide a first approach to selecting relevant economic indicators (e.g., Gordon, Mosbaugh, and Canter's analysis of the office market, 1996).

Hence, in its simplest form, a smart bomb's main component (e.g., futures) could be based on some specifically defined property type sub-index while add-on features (e.g., options) could be tied to economic variables representative of the location component of a real estate asset. This template is not strictly causal since the brunt of the risk is still expressed in terms of an asset's generic physical dimension. Nonetheless, it would epitomize a major step in that direction. Its originality stems from its ability to combine standardization and customization within a single aggregate instrument that encompasses, albeit imperfectly, real estate risk's polymorphic dimension. It is a multifaceted approach whose main objective is to contain the phenomenon.

Practical Implementation. So, how might a real estate combinative instrument be practically marketed and traded? Actually, the smart bomb template does not require the establishment of a new type of derivatives market. Providing further advances in the nascent field of economic derivatives (Gadanecz, Moessner, and Upper, 2007), it could rely on existing models of derivatives.

Exhibit 7
Real Estate Risk Structure and the Choice of Optimal Hedges

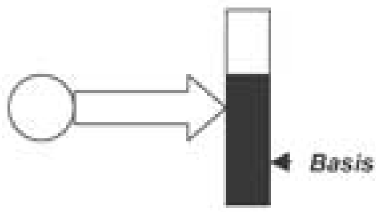


Figure A: Composite Index-Based Derivatives
This unifactorial template is the basic financial derivatives approach to risk. Because of minimal causal analysis, cross-hedged basis is potentially large, all the more so as assets are heterogeneous.

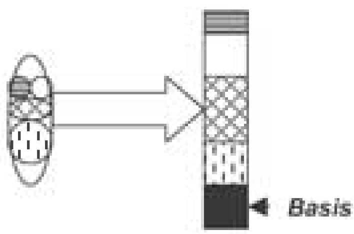


Figure B: Narrow-Based Index or Hedonic Index Derivatives
Risk structure is multifactorial but interactions between factors are poorly understood. Index design aims to mimic underlying cash market's characteristics. To do so, it uses aggregate underlying and an index-based template, which generates basis. Basis is substantially lower than in the case of composite index based (Figure A).

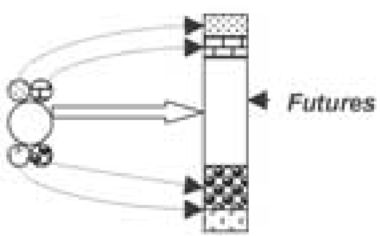


Figure C: Combinative Derivatives
In its simplest form, a combinative instrument is made up of a futures contract tied to a property type sub-index and add-on features linked to selected economic indicators. Components of this aggregate hedge are individually tradable. It is a multifaceted approach to real estate risk that combines standardization and customization (see Exhibit 8 for an example of combinative derivative applied to commercial real estate).

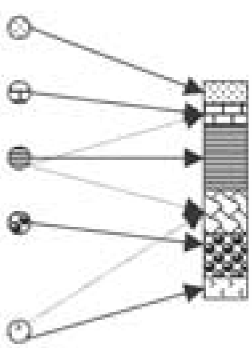


Figure D: Factor-Based Hedging Instruments
It is the ultimate step in the process of customization. Factor hedges materialize into sophisticated combinative instruments where all underlying are 'pure' factors. One factor may impact several risk components, which will make it very difficult to implement in practice. Therefore, this template is combined with a new type of derivatives market centred on the concept of hedging effectiveness.

To allow for standardization necessary to create a liquid market, all features in a combinative hedge could be bundled together at purchase but under some restrictive conditions, market participants should be able to trade them separately. Cost could be an issue, although it might be mitigated by the intrinsically low volatility of the cash markets. Exhibit 8 illustrates what a pro format combination hedge for commercial real estate could look like in practice.

In terms of product design, the smart bomb template has many advantages. First, the ability to separate the two dimensions (i.e., property type and location) might considerably ease its practical implementation. Likewise, the fact that its main

Exhibit 8
Combinative Derivatives Proformat Input Form

Main Component: Futures Contract (e.g., based on property type specific sub-index)

1.-Return

- Total ☐
- Income ☐
- Capital Appreciation ☐

2.-Type of Hedge

- Portfolio (Aggregate) ☐
- Individual Property ☐

3. Hedge Horizon

Anticipated Expiration Date ▭

4. Number of Contracts

Face Value $1,000,000 ▭

5. Property Type

- Apartment:
  - Garden ☐
  - High Rise ☐
- Industrial:
  - Warehouse ☐
  - R&D ☐
  - Flex ☐
- Office:
  - CBD ☐
  - Suburban ☐
- Retail:
  - Neighborhood ☐
  - Community ☐
  - Regional ☐
  - Super Regional ☐
- Hotel: ☐

Depending on selected property type

6. Additional Information

- Assessed Market Value (in M$) ▭
- Year of Completion ▭
- Total Square Feet Area ▭

Any other relevant criteria here

Add-On Features (e.g., options based on Region and Location factors). This is optional.

7. First, select the dominant Economic Base Category (EBC)

Diversified ☐ Finance/Insurance ☐ Manufacturing ☐ Military ☐ Mineral Extraction ☐ Transportation ☐ Government ☐ Services ☐

8. Then, enter MSA Size (in '000) ▭

9. Select underlying characteristics (you may choose any number of economic factors). Total number of options depends on total number of futures contracts selected above.

Economic Indicator #1	**Economic Indicator #2**	**Economic Indictor #3**	**Economic Indicator #4**	**Economic Indicator #5**	**Economic Indicator #6**
(e.g., Growth Rate)	(e.g., Unemployment Rate)	(e.g., Consumer Price Index)			
Call ☐	Call ☐	Call ☐	Call ☐	Call ☐	Call ☐
Put ☐	Put ☐	Put ☐	Put ☐	Put ☐	Put ☐
Strike in % ☐	Strike in % ☐	Strike in % ☐	Strike in % ☐	Strike in % ☐	Strike in % ☐

For each selected factor, right click to enter your expectation and standard deviation. You will then access a table of real time prices for currently trading options.

Explanations

Sections 1 to 5 are based on Lecomte and McIntosh (2006). Futures Contract will be either annual or pluri-annual. Choice of factors in section 6 will depend on selected property type in light of relevant studies. Selections in sections 5, 7, and 8 will determine economic factors (choices and pricing) in section 9. For instance, if users select Property type = Office, EBC = Manufacturing and MSA = 1 million, option on economic indicator #1 (e.g., growth rate) will be based on estimated growth rate for this particular location profile (manufacturing and MSA of 1 million inhabitants). Economic indicators, which are artificially limited to six in the example above, may cover a wide range of criteria.

component is based on a generic property type (or possibly a crossover property x region but not at the MSA level) should mitigate market authorities' reservations with respect to narrow-based indices while the use of economic factors instead of geographic factors significantly reduces risks of cash market manipulation.

Factor Hedges

Concepts. A factor-based instrument would take customization one step further by emulating the concept of individualized medicines described before. Factor hedges could logically materialize into sophisticated combinative instruments where all underlying are 'pure' risk factors (Exhibit 7, Figure d). These instruments that would use existing channels for trading would be limited by their reliance on 'pure' factors. How 'pure' will those risk factors ever be? Can they be freed of multicollinearity, especially in the context of multiple factors being aggregated in a single hedge? As long as there are no satisfying answers to these questions, the establishment of truly multivariate hedges will be stalled. A factor template that would bypass this process by dealing structurally with econometrics' shortcomings would represent a major breakthrough. How can it be done? Actually, this paper argues that a radically new form of derivatives market based on factor hedges is conceptually feasible provided some creative thinking and technological innovations.

For starters, a radical new vision of hedging is needed. As hinted before, factor hedges might lead to a true market for risk in sharp contrast with current derivatives markets, which are intrinsically tied to a commodity or price hedging approach. One way to do so is to reverse the way the concept of hedging effectiveness is being used. In the classical framework, hedging effectiveness results from an optimal combination of underlying and product structure given the cash market's characteristics. The contract has to be designed in a way that provides maximum correlation with the risk to be hedged (Ederington, 1979).[9] The market proposed here would inverse the proposition and consider hedging effectiveness not as a consequence but as the central criterion in the hedging process. In essence, a market where optimal correlation between the underlying instrument and the asset is not a consequence of the hedge but a condition defined by users when initiating the hedge. This concept of market for basis embodies the notion that in incomplete markets, hedging is by definition imperfect. What this paper advocates is inherently a market for hedgers although trading opportunities built in a multi-factor structure should allow speculators to intervene as well.

To achieve its goals, the new market would make massive use of modern technologies. Current derivatives were designed in an age when information technology had not reached its contemporary achievements. Indeed, the 1970s when the index-based model of derivatives was designed seems ages ago. As biomedical sciences resort to state-of-the-art methodologies from a wide range of related fields, risk management should make use of processing and analytical resources offered by computers. Today's computing resources give access to unprecedented potential in equity trading (e.g., Leinweber and Beinart, 1996). Why has this fact so far eschewed radical innovations in risk management? Shiller (2004) asks the same question. In effect, the advent of factor hedges might trigger a new approach to hedging, eventually resulting in organized markets taking account of the potential offered by modern IT.

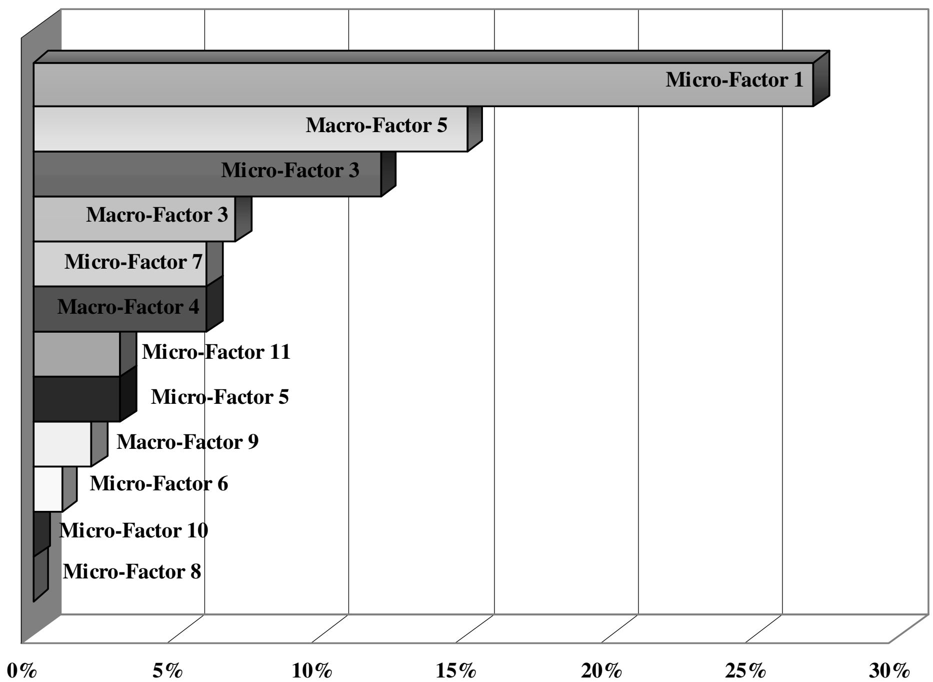
A Market for Hedging Effectiveness. Once again, identifying all factors pertaining to commercial real estate risk is a prerequisite to this new type of market. These factors would then be fed into a platform (called system thereafter) that would constantly match assets to be hedged (either single properties or portfolios of properties) with possible combinations of factors to achieve maximum hedging effectiveness. How would it work?

Through an iterative process, the system would map the risk profile of the asset(s) to be hedged and determine a 'risk scan' (Exhibit 9). This would be done at inception of the hedge and on a continuous basis throughout the life of the hedge in order to capture subtle variations in the asset's risk profile. From this risk scan, the system would come up with an initial optimal hedge that best matches

Exhibit 9
Factor Hedges and Market for Hedging Effectiveness

Model of Risk Scan Report for Hedging Effectiveness

Hedging Effectiveness: Target = 80% **Time Horizon = 18 months**



Total Factor-Based Hedging Effectiveness: 82%
Standard Deviation: 6%
Confidence Interval: 5%–10%
Quoted Price of Hedge (in $ for each $1 M of hedged underlying asset): $5,000

Risk Scan
Macro-Factors: 30% in 8 Factors
Micro-Factors: 52% in 4 Factors

Explanations
At inception, users enter their desired level of hedging effectiveness and time horizon. The asset's risk profile is then determined to define the best optimal combination of risk factors from a pool of identified, classified, and priced risk sources. Factors are both macro-factors (tied to macroeconomic criteria) and micro-factors (linked to a particular asset class or asset type). On a periodical (e.g., daily) basis, the optimal combination of factors enabling maximum hedging effectiveness is rebalanced by applying genetic algorithms to capture variations in risk factors and asset's risk profile. The difference between two periodical optimal combinations may generate a 'basis call.' For a given asset, the higher the expected hedging effectiveness, the higher the price of the hedge. The price of the hedge will also depend on underlying factors, each factor having a different price. Numbers in the example above are only illustrative. Other indicators pertaining to the quality of the hedge may be added on the Risk Scan Report.

each asset's or portfolio of assets risk profile given a set of criteria selected by users including, but not restricted to, desired level of hedging effectiveness (r-square) and time horizon. If users' expectations are not achievable, the system would then indicate the best possible attainable combination that maximizes hedging effectiveness and level of confidence given time constraints. This process would determine the optimal initial combination of factors. This combination would be rebalanced daily to achieve an optimal level of hedging effectiveness. Daily rebalancing would entail a process called 'marked to basis' in which, depending on the level of hedging effectiveness achieved between two consecutive daily combinations of factors, users may be required to deposit additional funds into a 'basis' account. These deposits would be known as 'basis calls.' The optimization as well as the rebalancing process leading to successive optimal combinations of factors would be done using genetic algorithms.[10] Thus, a factor hedge would adapt itself to the changing structure of real estate risk and variations in underlying factors. In effect, hedgers would not have to worry about hedge ratios. The system will do it for them, thereby automatically generating dynamic hedging strategies. A market for hedging effectiveness would be a market for hedge without hedge ratios. Likewise, a market for hedging effectiveness would circumvent the question of multicollinearity. What matters is the aggregate effect of the hedge and its match with the cash assets. The price of a hedge would depend on the risk factor combination, as well as time horizon.

In parallel to this market intended for hedgers, there should be another market aimed at hedgers and non-hedgers alike, enabling trading in a wide range of single factors. Hence, in case the market for hedging effectiveness is extended to other asset classes than commercial real estate, inter-asset class counterparty of risk factors, as well as trading of single risk factors among completely different asset classes could be envisioned, at least for those factors that are common to several asset classes.

Factors would realistically be of two origins: (1) *Macro-factors* that could easily be interchangeable and traded (e.g., economic indicators). Real estate literature provides useful hints with respect to the nature of these factors (e.g., Chen, Hsieh, and Jordan, 1997; Kling and McCue, 1987; Ling and Naranjo, 1996; and Liang and McIntosh, 1998). (2) *Micro-factors* that would be asset class specific. They would probably be more difficult to trade than macro-factors, although if the underlying cash market is large enough, there might also be a liquid market for single micro-factors.

What is proposed here is in many ways a high tech, advanced version of Riddiough's (1995) approach to hedging real estate risk. The analysis addresses the author's concern for dynamic hedging strategy by setting up a model with constantly rebalanced hedges fine-tuned to reflect variations in both underlying factors and assets' risk profile.

In sum, a market for hedging effectiveness would represent the ultimate stage in the customization process. Tailor-made factor hedges would create a market with no cross-hedge basis risk, no mismatch of maturity, and no risk of manipulation in the underlying cash market. Trading in pure risk factors would probably be OTC at first and take place on an organized private market akin to that of economic indicators. One key to success will be the ability of this new market's promoters to identify, classify, and price single risk factors in a way that meets a general consensus. Factor standardization will be crucial in establishing a fully-fledged risk market that may ultimately enable exchange of risk factors among different asset classes. A necessary, though probably not sufficient, condition to achieve standardization is to first agree on a model for analyzing real estate risk. The following section presents an innovative framework for a model of real estate risk that could pave the way to the identification and standardization of relevant underlying to be used in factor hedging.

Framework for a Model of Real Estate Risk

Coming up with a new approach to real estate risk that will solidly underpin the proposed derivatives market supposes that the analysis focuses on how real estate assets might be envisioned as conceptual entities within a network of causal inferences and environmental relations. Fundamentally, what does real estate stand for? How does it position itself within the big order of things, the Cosmos as the ancient Greeks called it? And to paraphrase Feynman (1998): Are bricks "essential objects"?[11] The framework for modeling real estate risk presented in this paper addresses these questions.

The Choice of Genetic Epidemiology. The model is an extension of the previous analysis, which characterizes real estate risk as a multi-factorial disease. The focus is on understanding the variations in risk defined as a complex phenomenon affecting a population of living organisms (i.e., buildings). The analysis should center on uncovering which underlying factors present in the population of assets, or combination of factor(s) and the environment, trigger the disease. In other words, it is aiming at identifying networks of risk factors that modulate the variability of returns (i.e., risk) in diverse environments. The whole population can be affected by real estate risk. Thus, the disease being potentially widespread, the analysis presented here is interested in epidemiology. Furthermore, by definition, the studied population is heterogeneous. Although buildings share a common nature, they are all different, if only due to each building's unique location. Interestingly, genetics provides concepts and tools that can be used to capture the impact of organisms' fundamental similarities and differences on an observable qualitative or quantitative phenomenon. Analyzing intrinsic differences within a common pot of characteristics and the extent to which those differences interacting among themselves and the environment influence organisms' reaction to outside stimuli is central in genetics. Likewise, it will be key in understanding risk factors affecting heterogeneous assets such as real estate.

What this model is aiming to achieve is in fact very similar to a branch of genetics called genetic epidemiology whose goal is to understand the role of specific genes, specific environmental factors and interactions between genes and the environment in determining a particular trait of interest. The trait of interest here is the ability of properties' to generate returns. It is a continuous quantitative trait. The fact that the analysis brings us back to biomedical sciences and in particular genetics should come as no surprise. For conceptual and historic reasons, genetics has long been at the forefront of scientific innovations for coping with heterogeneity in entities immersed in a complex environment.

The issue of multiple and unobservable factors has already been widely covered in the real estate literature with research using statistical tools such as multiple indicator-multiple cause models (e.g., DYMIMIC in Guntermann and Norrbinn, 1991) and latent-variable methods (e.g., LISREL in Lockwood and Rutheford, 1996; and Ling, Naranjo, and Nimalendran, 2000). A little known fact is that these methods actually derive from path analysis pioneered in the 1920s by famous geneticist Sewall Wright (Tunali, 1990; and Crow, 1992). Wright used path analysis for researching myriad genetic-related topics including inbreeding and assertive mating in livestock or the relative importance of heredity and environment in determining IQ. Similarly, cluster analysis and principal component analysis, which are applied in urban economics and real estate (e.g., Cano-Guervos, Chica-Olmo, and Hermoso-Gutierrez, 2003), originated and/or are widely used in biostatistics (Sokal and Sneath, 1963) and genetics (e.g., Yeung and Ruzzo, 2001).

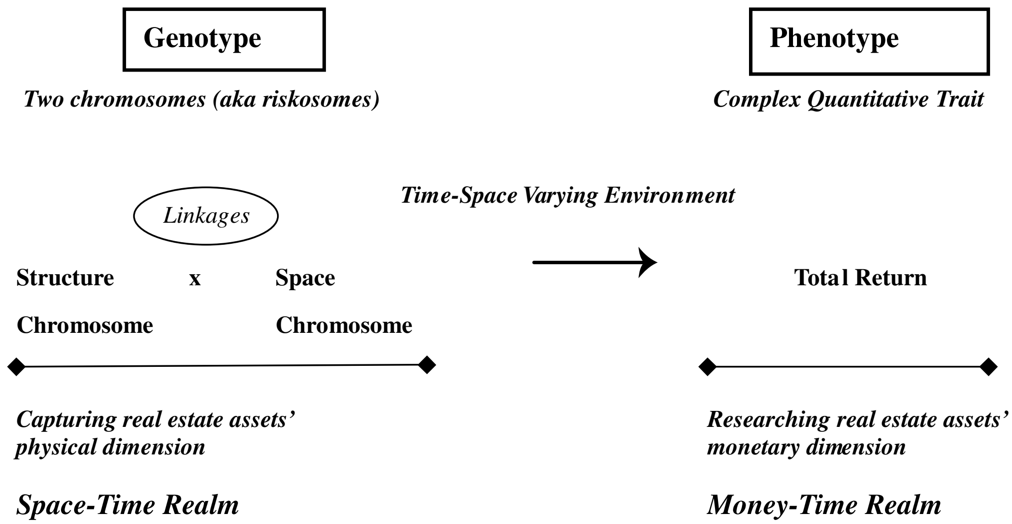
By the same token, risk scans introduced before in this paper are very similar to genome scans employed by geneticists (Peng, Tang, and Siegmund, 2005). They embody the practice of mapping unobservable latent variables. Mapping is an interesting concept that should be applied in the context of real estate risk analysis. An important aspect of genetics and more generally biomedical sciences for the methodology lies in these sciences' intrinsically qualitative dimension. As explained by Dobzhansky (1971): "In biology, it is only rarely practicable to deduce or to predict the patterns from a description of the components. [...] The strategy of biological research is to discover the patterns first, then the components down to the molecular ones, and finally the functional and adaptive meaning." Modeling real estate assets in light of concepts and tools customarily used by geneticists goes back to the origin of statistics. The analysis chooses to initially focus on patterns leading to the observed phenomenon (i.e., the roots of risk) rather than individual isolated factors. By doing so, the proposed risk model acknowledges the very essence of real estate risk as a complex multivariate phenomenon, and ultimately aims to uncover and define pure factors, or in more ambitious terms, what could turn out to be real estate assets' genetic material.

The Model: Real Estate Assets as Living Organisms in a Global Time-Space Varying Environment. The analysis starts by defining the concept of risk in real estate investment. Indeed, what is real estate risk? This seemingly simple question is a Pandora's Box. In addition to the variability of returns, which classically epitomizes risk for investors, how can real estate risk be comprehended so that the model is positioned in a space-time realm while enabling effective hedging of phenomena that are intrinsically linked to a money-time realm? The paper touched upon this issue before when covering the concept of 'pure underlying.' A solid definition of risk supposes a clear understanding of the essence of real estate. On a conceptual level, real estate assets are characterized as entities immersed in both space and time. The logical way to implement this definition is to stick with real estate's essentially physical dimension. A property delineates two different though complementary spaces: the inside, which encompasses the structure and location of the property (i.e., static component), and the outside (i.e., the environment). Under normal circumstances, risk does not lie within a property. Risk stems from the interactions between the inside and the outside. As such, real estate risk is a dynamic process implying complex causal relationships involving an asset's static component and its environment. Time is not part of the essence of real estate. A property's static component is not affected by time, like a living organism's DNA is not affected by time. Obsolescence is to property what aging is to humans. It does not change living organisms' static components but rather modifies their ability to respond to their environments. In the model presented in this paper, time is a catalyst in the risk process by interacting with space to define a time-space varying environment. As eloquently explained by Graaskamp (1970b), "a reason for misleading images of real estate is the physical nature of real estate, which tends to obscure the fact that real estate is essentially a very dynamic abstract process. We see the brick and mortar when we look, rather than perceiving these static elements as a manifestation of a very dynamic process underlying the tangible property." Because of its essentially dynamic nature, real estate risk cannot be properly captured by static variables such as those usually used in hedonic regression models. In fact, the concept of hedonic regression seems poorly adapted to model real estate risk in a comprehensive manner. It is sometimes suggested that hedonic models should include variables pertaining to the time-space varying environment of the assets they are trying to describe [Shiller (1993a) who suggests that time and market conditions be added as hedonic variables]. Although attractive on a practical level, such a suggestion does not make much sense conceptually insofar as risk does not lie in time or space variables but rather as pointed out before in the interactions between an asset's static component and its time-space varying environment. The time-space environment (which is global) triggers an intricate network of apparently incoherent phenomena between the inside and the outside, which ultimately affects the asset's ability to generate predictable returns. In short, real estate risk can only be understood in a dynamic framework encompassing both real estate assets' essential physical and spatial dimensions.

One fundamental concept in genetics is the differentiation between the specific constitution of an organism (its genotype) and the observed traits (its phenotype). The genotype is not observed directly but rather inferred through the phenotype. The genotype constitutes a living organism's genetic make-up. Geneticists' goal is to figure out the link between components of the genotype (i.e., chromosomes and genes) with identified phenotypes. Genotype and phenotype are two extremely useful concepts in the characterization of complex organisms insofar as they make it possible to differentiate between what is essentially intrinsic and what is only phenomenological (Hartl and Jones, 2001). In this respect, genetics can truly add value to the model. Confusion between essence and phenomenon in real estate risk blurs the analysis and leads to the use of methodologies ill-suited to capture the true essence of real estate. Incidentally, it is worth noting that physics' laws applied to finance tend to catch the phenomenological dimension of complexity but cannot explain it (Cartwright, 1980). In particular, they do not say anything about the essential characteristics underlying complex phenomena. In the model presented here, the use of genetics enables separation of the essence from phenomenon. The phenotype the model is interested in is an asset's risk measured by the variability of its total return while the genotype encompasses the constitution of a real estate asset or its static component. Phenotype and genotype capture the two realms of real estate in a single model: phenotype pertains to the

Exhibit 10

Real Estate Asset's Genetic Framework and the Two Realms of Real Estate



money-time realm while genotype positions real estate assets in the space-time realm (Exhibit 10).

The next level of analysis requires that real estate assets' static components be further modelized. In the genetic framework, a property's static component corresponds to its genetic material. It is akin to an organism's genetic makeup. Without getting too specific, a gene can be defined as a region of DNA that controls a hereditary characteristic (Griffiths, Gelbart, Lewontin, and 2002). Considering real estate assets as living organisms implies that the model looks for their genetic material. To design a model that practically reflects the nature of real estate, the framework sticks to properties' physical nature. A property is basically a structure delineating an inside space. The structure is built on a piece of land, which defines a property's location and its environment (Exhibit 11). Hence, as a simplistic first approach, a property's genome contains two chromosomes: a structure chromosome and a space chromosome. Should there be a third chromosome that captures the fact that all properties share a common nature (i.e., they are all real estate)? The analysis presented here opts for a two-chromosome model only. However, should this model be extended to other heterogeneous asset classes, it might be necessary to add a chromosome characterizing the asset types. Exhibit 12 summarizes the analysis. The term 'riskosome' is an invention of the author. It designates an asset's 'chromosome.'

The model positions real estate assets as polygenic organisms (i.e., multiple genes) with complex quantitative traits (i.e., multi-factorial phenotype expressed in continuous quantitative terms). In genetics, complex traits are typically influenced not only by two or more genes but also by the environment. The phenotype of an organism is therefore potentially influenced by: (1) genetic factors in the form of alternative genotypes of one or more genes; and (2) environmental factors in the form of conditions that are favorable or unfavorable for the development of the trait.

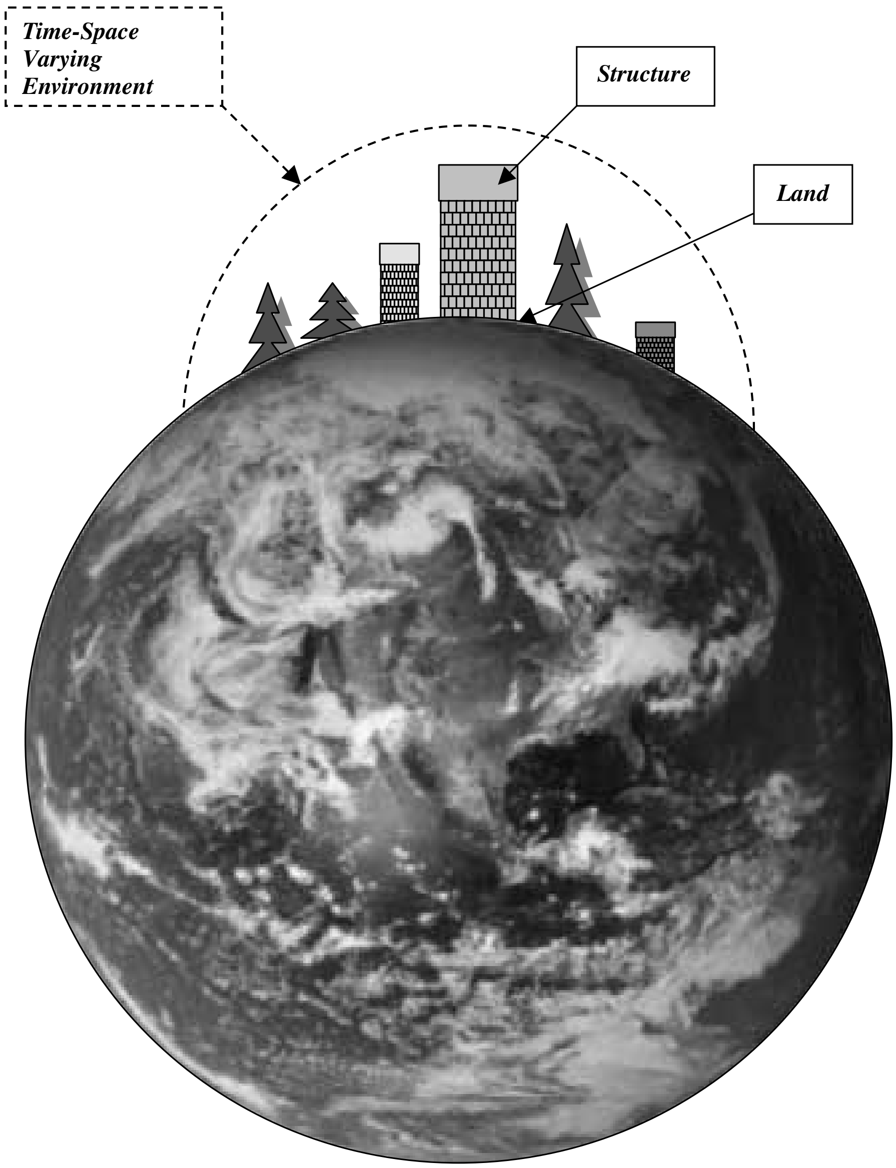
Noticeably, the model does not a priori assume that the more 'genes' shared by two different properties, the more similar their risk profiles. Indeed, risk does not stem from static factors but depends from interactions or dynamic linkages between structure genes and space genes in a given time-space varying environment.[12]

In a static model (e.g., hedonic regression), spatial proximity as well as common structural characteristics are enough to link real estate assets. The closer the entities in terms of structure and space, the more factors they are supposed to share. In a dynamic model, this is no longer the case unless

Exhibit 11
Framework for a Model of Real Estate Risk

The Essence of Real Estate: A 'Google Earth' (Cosmic) View

Real Estate Assets as Living Organisms in a Global Time-Space Varying Environment



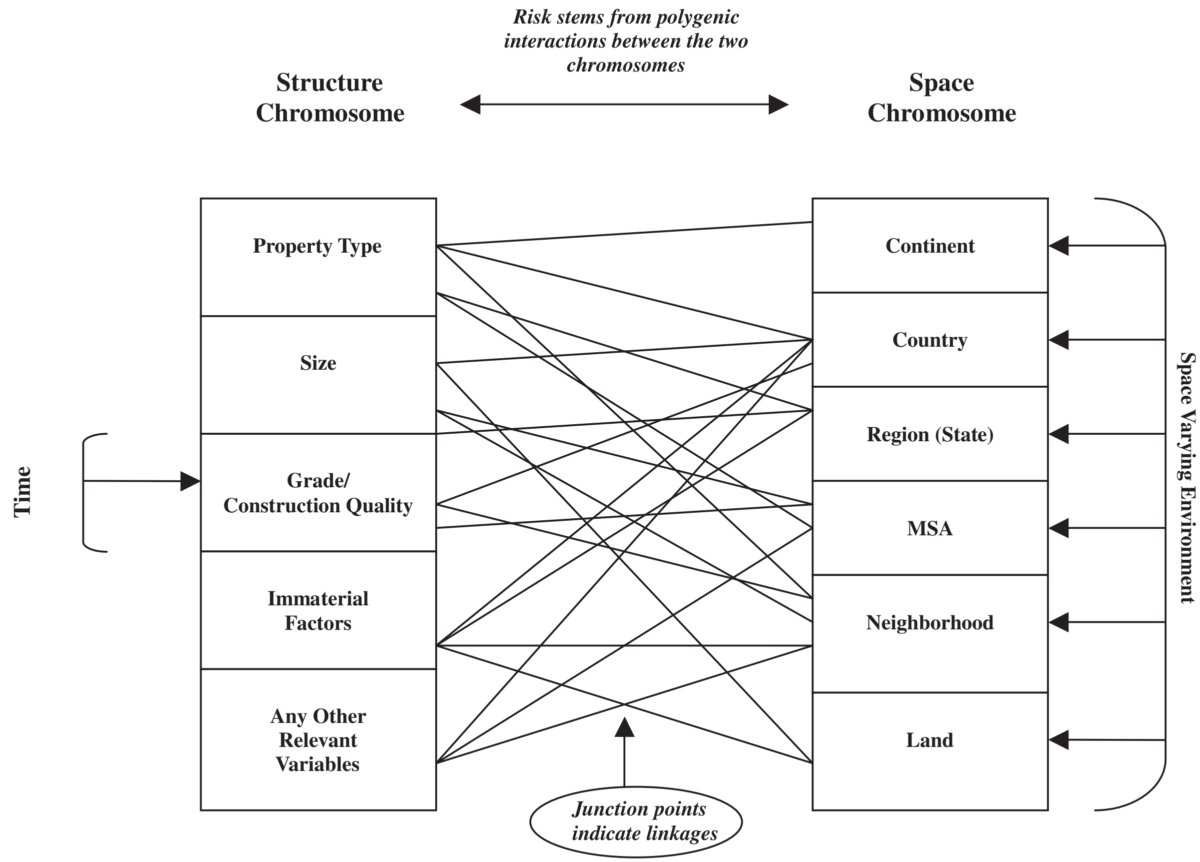
Source: The earth picture–NASA.

the environment is neutral in affecting gene linkages. It is difficult to imagine it could ever be the case in reality, let alone because the asset's structure gene would have to be unrealistically insulated from any adverse effects of time.

Environment, in the broad acceptance of the term, is paramount in the model. As shown in Exhibit 12, a real estate asset's "DNA" includes not only genes linked to the asset's physical nature (e.g., property type, grade) but also genes linked to

Exhibit 12
Real Estate Assets' Genotype

A Two-Chromosome Model:
Real Estate as a Polygenic Organism with Complex Quantitative Traits



Examples of Space-Varying Factors Impacting Interactions between Chromosomes

Continent/Country
Interest rates
Inflation rate
Unemployment growth
Industrial production
Productivity
Financial markets
Foreign direct investments
Institutional investing
Demographics
Legal environment: property rights
Transparency, taxes

Region (State)
Regional economic indicators
Regional real estate market Indicators
Demographics

MSA/Neighborhood
Local economic indicators
Local real estate market indicators
Demographics
Socio-economic factors
Infrastructures: schools, universities, sport facilities, hospital, retail outlets, entertainments, proximity to highways, airports
Environmental contamination

Land
Quality of land
Zoning, entitlement
Contamination
Immediate surrounding

Notes:

- Immaterial factors include a property's historical background as well as its aesthetic and architectural attributes. It is a subjective gene altered by changes in taste. The concept of grade already captures some of its impact. That is why we simplistically consider that time only impacts grade and not immaterial factors. Because of real estate's essentially physical nature, subjectivity is an integral component of pricing. Non physical assets that can be fully explained by mathematical models are supposedly less subject to immaterial factors.
- The specific number and positions of genes on the chromosomes have to be determined. They are specific for each generic type of property. Likewise, sizes of bars on the above figure are not representative of individual genes' relative dominance on each chromosome.
- The position of each junction point indicates the relative dominance/recessiveness of genes involved in linkages.
- Both chromosomes are potentially subjected to Acts of God.

variables having no immediate physical link with the asset's material entity (e.g., region, country, continent). By definition, the structure chromosome is endogenous (i.e., changes in genes are under the owner's control) whereas the space chromosome is subject to myriad exogenous influences. As a result, by anchoring a property in a specific environment, the space chromosome is the vector for most of the risk. It is the catalyst for the model's dynamism. The model metaphorically takes a Google Earth view of what a space chromosome is supposed to be. Starting from a single piece of land, it moves all the way up to the continent on which the property is built. Likewise, age is neither a gene on the structure chromosome nor on the space chromosome. Time intervenes in the model as an external variable impacting the structure chromosome through the grade gene. Physical deterioration and obsolescence show up in the interactions between genes on both chromosomes. They disturb the causal relationships between the structure chromosome and the space chromosome either by modifying their impact on the phenotype or by creating new relationships, which might be age-dependent. In this respect, maintenance, renovations and upgrades correspond to changes in genes on the structure chromosome undertaken to get the desired phenotype. These changes can also impact the space chromosome through externalities altering the neighborhood gene. In the dynamic linkages between genes from the same chromosome (structure on structure, space on space) or between genes on different chromosomes (structure on space, space on structure), some genes may be dominant over others. Dominated genes are known as recessive. For instance, as mentioned before, research shows that property type is more important than region for explaining returns in U.S. commercial real estate. Hence, for U.S. commercial real estate, the property type gene is dominant over the region gene (structure over space). Interestingly, genetics makes it possible to qualify this dominance.

Hartl and Jones (2001) suggest that for human beings, 99.9% of the DNA sequences in any two individuals are the same. Geneticists have interest in the 0.1% of the DNA sequence that differs from one genome to the next. What is the situation for commercial real estate assets? How differentiated are commercial real estate assets' genomes? Do their genes fundamentally differ or are the intrinsic differences only marginal but masked by extremely dominant genes? In other words, are some of commercial real estate assets' genes so dominant that they obscure other potentially significant influences (e.g., property type for U.S. commercial real estate)? It seems very likely that dominance/recessiveness patterns could depend in part from fundamental macro-factors. For instance, what is the relative magnitude of structure genes in a booming market (e.g., China)? And what do dominance patterns tell us about the state of the market (in terms of speculation among other elements)? By the same token, does global investing impact assets' genotypes, in particular as far as properties with different continent and/or country genes are concerned? As exemplified by these few questions, the genetic framework can accommodate many fundamental research topics in real estate.

Genetic epidemiology (which is the model's frame of reference) searches to uncover the position on chromosomes of each gene involved in a quantitative trait. This position is called a quantitative trait locus or QTL (Falconer and Mackay, 1996). The characterization of QTLs is carried out at both the individual and population level by analyzing: (1) the magnitude of potential genetic influence and (2) specific genes involved in determining underlying quantitative trait.

Real estate risk analysis aims to achieve very similar objectives. Understanding risk supposes that the QTLs of real estate risk be identified. Genetics has developed methods and statistical tools (e.g., linkage mapping and variance analysis) that can be applied to do so (e.g., Eisen, Spellman, Brown, and Botstein, 1998; and Lathrop and Weeks, 2000). It is beyond the scope of this paper to describe in detail these techniques. The goal here is to briefly introduce concepts that might be useful for further research.

Linkage is a method used to locate regions of chromosomes likely to contain a risk gene in an observed phenotype. Linkage can also rule out areas where there is a low chance of finding a risk gene. A linkage or genetic map is a chromosome map of a species or experimental population that shows the position of its known genes relative to each other. Various methods such as model-free (non-parametric) linkage analysis, association studies, and ad hoc algorithms (e.g., Lander and Green, 1987) are employed to construct genetic maps (Hodge, 2001; Rice, Saccone, and Suarez, 2000; and Tang and Siegmund, 2002). Software programs are customarily used by geneticists to perform linkage analysis.[13] Pugh, Mandal, and Wilson (1995) describe an interesting graphical approach for presenting linkage results that could be applied to real estate assets' genomes.

Studying variance for segregation analysis of complex traits is fundamental in genetic epidemiology and quantitative genetics (Falconer and Mackay, 1996). It allows the breakdown of variance in terms of different causes, quantifies their impact on total variance, takes account of interactions among factors, and qualifies the interactions (additive, non-additive). In essence, variance analysis embodies Aristotle's vision of causation by qualifying the origin of causal relationships (see Endnote 8). This approach can be summarized by the following formulas:

$$\begin{aligned} \textit{Phenotype} &= \textit{Variance (Genetic)} \\ &+ \textit{Variance (Environment)} \\ &+ \textit{Variance (Genotype} \times \textit{Environment)} \end{aligned}$$

with

$$\begin{aligned} &\textit{Variance (Genetic)} = \textit{Additive Genetic Variance} \\ &\quad + \textit{Dominant Genetic Variance} \\ &\quad + \textit{Non-Additive Genetic Variance} \end{aligned}$$

and

$$\begin{aligned} &\textit{Variance (Environment)} = \\ &\quad \textit{All Variations of Non-Genetic Origin.} \end{aligned}$$

Note: *Non Additive Genetic Variance* occurs when a gene masks or prevents the expression of another gene, or otherwise affects its expression in a non-additive manner. It is also called epistatic variance.

Applying variance analysis to real estate assets modeled after the genetic framework described in this paper would be a first step in the identification, ranking, and standardization of factors involved in complex risk patterns.

Summary and Synthesis

The genetic framework offers a comprehensive picture of real estate assets that goes all the way from the continent to the specificities of the land on which the researched property is built. This approach labeled 'molecular micro-hedging' (after 'molecular financial economics') is part of a field of finance applied to real assets that the author of this paper has named 'Bio Real Finance.' Bio real finance finds inspiration in concepts and tools developed and applied in the field of biomedical sciences for modeling real assets.[14]

Risk factors are not individual variables but dynamic linkages between genes as triggered by a global time-space varying environment. Conceptually, the model questions the notion of random walk in real estate (see Ling, 2005). Real estate assets' genome implies that pricing is somehow deterministic. Prices depend on assets' genes, some of which cannot be easily altered or modified (e.g., land, which is at the core of real estate's physical dimension). Hence, what is the randomness of assets whose returns are defined with what is essentially a deterministic model? If the model has any relevance at all, the concept of unqualified random walk in real estate is an aberration. Genetics defines randomness in a way that is not fortuitous but causal since linkages have known impact on traits. Therefore, because of their essentially physical nature, real estate assets, and more generally all real assets, suppose a specific definition of randomness. In essence, genetics has the potential to be to real assets what the Brownian motion is to financial assets, by defining and modeling randomness in prices. Random walk is a money-time concept that is not applicable as such to assets physically rooted in a space-time environment. For any given environment, variability in returns is deterministic, dependent on complex, though identifiable, patterns. Real estate follows a multifactorial causal random walk. In other words, the end destination is not clear but the stops in-between are well-known and more or less compulsory.

On another level, the framework has potentially significant implications in the field of urban economics. It creates a link between real estate finance and models of urban development. Considering real estate risk as a disease implies that buildings might be lethally affected by it and be replaced by fitter elements. As old buildings die, developers invest in properties supposed to present the best genetic make-up given the current/expected time-space environment (at least at the time of sale). Developers and associated professionals (e.g., architects) are involved in what is essentially genetic engineering with extremely complex covariate patterns to take into account. Real estate development is by definition eugenic. At equilibrium, the population of properties is made up of the fittest elements.[15] The random walk is therefore influenced by patterns of new developments and deaths, which in effect become Darwinian. The main difference between mammals and buildings is the speed at which their phenotypes react to a changing environment. While it may take years if not centuries for humans, real estate assets' phenotype tends to be extremely reactive, hence the risk for investors. This feature of real estate risk has undoubtedly worsened the confusion surrounding the choice of a relevant framework. The model introduced here might hopefully assist in making sense of this apparent complexity.

Conclusion

This paper has shown that finance can learn from sciences other than mathematics and physics. One field overlooked by modern finance is biomedical sciences that propose alternative approaches to complex phenomena. Finance has indeed to develop more subtle approaches for dealing with risk. Real estate may provide the trigger to do so. A polymorphous risk structure (as is the case of heterogeneous assets) requires a multi-faceted approach to risk management comparable to how biomedical sciences deal with diseases. Models of index-based derivatives were designed for financial assets and, as a result, are not appropriate for heterogeneous asset classes. The proposed design for property derivatives takes account of new technologies that can be applied to conceive efficient hedging instruments and radically novel ways of trading them. A market for hedging effectiveness might entail a paradigm shift in derivatives markets. It will be a collective endeavor that involves academics, practitioners, and market authorities—akin to the way decisive progresses were achieved in medicine.

Before factor hedges become a reality, lots of work needs to be done on a wide range of topics central in real estate finance. In particular, the development of efficient property derivatives will depend on the ability to define the appropriate risk structure and pricing model of real estate assets. Risk is a dynamic process that cannot be properly captured by static models. Genetics provides interesting concepts and tools for analyzing heterogeneous assets such as real estate. Thinking of real estate as a complex system akin to a living organism made it possible to bridge a link between real estate's space-time and money-time realms. The genetic framework gives a big picture of real estate that has many possible applications. Convincing derivatives markets that a new breed of hedging instruments is needed to deal with this risk structure will be the next step. It will be all the more easy as the underlying analysis of real estate risk is solid.

The theoretical frameworks developed in this paper should be applied to actual real estate assets. Research analyzing basis risk reduction using different hedges for a given portfolio and/or individual buildings should be conducted. Full linkage and variance analyses of real estate assets should be carried out, by experimentally applying a variety of methodologies used in biostatistics and genetics.

Endnotes

1. As early as 1959, Bakken discussed the feasibility of financial settlement for futures contracts based on an index. He assessed that such a delivery system could be effective as long as there were 'objective prices.'

2. Instruments available for dealing with risks ultimately depend on the underlying models used to analyze these risks. Hence, it is legitimate to wonder whether efficient hedging instruments can possibly be designed when there is no coherent and agreed upon model of risk (pricing model) for a given asset, irrespectively of the intrinsic validity of this model. Any derivative conceived without a convincing risk model or with the idea that it can impose its own partial interpretation of the asset's risk structure is suspicious of over-simplification or reductionism, which will inevitably jeopardize the instrument's hedging effectiveness.
3. Dupre (1993) defines reductionism as "the commitment to any unifactorial explanation of a range of phenomena."
4. Graaskamp (1970b) proposed an interesting link between the two models. He explained that "real estate is a space-time product, and time becomes the common denominator for the financial dimension. Space time is not sterile, but rather contains a variety of qualitative attributes."
5. The South Sea Company stock bubble that took place in eighteenth century England is one of the most memorable events of market manipulation associated with a narrow-based index (Swan, 2000). It left an enduring mark on the derivatives industry by being responsible for the barring of futures contracts in single stocks (Sir John Barnard's Act). Adam Smith who disagreed with that ban wrote in favor of futures contracts in 1784, stressing instead the need for all parties in the trade "to keep their credit, else no body will deal with them." This would be achieved in 1865 when the CBOT started requiring buyers and sellers in its grain markets to post 'performance bonds' called margin.
6. The choice of biomedical sciences over physics has traditionally been justified by the necessary focus on human behavior that social sciences require. Auguste Comte explained that sciences dealing with human behaviors must be somehow akin to biology (Cohen, 1994). As noted by Bouchard and Potters (2003), finance through economics has taken another route, looking at physics for explanatory models of complex phenomena. Cartwright (1980) provides enlightening explanations about the limits of the mathematico-physical model, which puts in perspective Cambridge physicist, Lord Rutherford's famous, albeit questionable, remark: "All science is either physics or stamp collecting."
7. The conflict between idiosyncrasy as opposed to a reductionist—schematic and generalizing—tendency is central to medicine's history (Rosenberg, 1998). In the nineteenth century, the American School of medicine was famous for analyzing all diseases as patient- and location-specific in sharp contrast with the then prevalent French model, which was centered on deriving universal medical laws (Warner, 1997). The 'principle of specificity,' which asserts that treatment has to be matched to the idiosyncratic characteristics of individual patients and their environments underpins many of medicine's most recent breakthroughs. The progress of genetics applied in the field of pharmacology (i.e., pharmacogenetics, which deals with idiosyncratic drug responses due to hereditary factors) has been paramount in this respect (Nebert and Weber, 1990).
8. The process of classifying diseases is called nosology. Defining the causes of disease in a scientific (i.e., exact and comprehensive) manner was central to medicine's advances over the centuries [see King (1982) who insists on seventeenth century English physician Thomas Sydenham's instrumental contribution in this area]. Following Aristotle's analysis of the 'efficient cause,' scientists understood very early on that the concept of cause had no validity without specification. By 1600s, physicians applied various terms to discriminate a wide diversity of causal relationships using such varied headings as "principal, adjuvant, remote, proximal, external, internal, necessary, contingent, antecedent, conjoint, occasional, continued."
9. The mean variance model described by Ederington (1979) is the conventional method for measuring hedging effectiveness. A hedge is effective if the R-squared of the OLS regression explaining the data is high (i.e., between .80 and .99). Concretely, hedging effectiveness is defined as the reduction in the variance of the value of a position hedged with futures. The objective of a hedge is to minimize the risk of a given position.
10. Genetic programming is an optimization technique based on the principles of natural evolution. It was invented by John Holland in 1960s at the University of Michigan (Mitchell, 1996). Nowadays, genetic algorithms are commonly used in finance (e.g., for trading in S&P 500 futures) (Allen and Karjalainen, 1999).
11. While studying for his PhD in physics at Princeton, Richard Feynman, Nobel Prize winner in physics and a well-known eccentric, wanted to do something useful during his lunch hours. Instead of hanging out with other physicists, he decided to attend courses on totally different topics. He figured that philosophy would do the trick. At the first lecture, he was asked by the professor about the nature of essential objects. Not being totally sure what to answer, he replied by asking a simple question: "Is a brick an essential object?", which triggered a much heated debate. Puzzled by the inability of philosophy to decisively reach any conclusions, he decided to attend a course in biology instead. Presented with a problem concerning felines, he candidly asked: "Do we have a map of the cat?", a question which stirred much amusement. This paper shows that in the course of his lunch hours, Pr. Feynman asked two questions of potentially great interest for real estate researchers.
12. In genetics, linkage refers to the association of genes located on the same chromosome. In the model presented in this paper, linkages represent interactions among genes irrespective of their chromosomes of origin.
13. Identified QTLs are compiled into "bibles" available to all researchers (e.g., www.complextrait.org), which is conceptually similar to factor standardization advocated in this paper.
14. Modeling real estate assets as living organisms entails several methodological issues. Methods applied in genetics often suppose the physical existence of a reference genotype for comparative purposes. Engineered pro-format synthetic assets might be useful in that respect. Likewise, as a first step, the genetic framework might be applied in conjunction with hedonic regression models. An improved version of hedonic regression partly based on pure risk factors would price risk rather than assets' attributes.
15. A building's ability to survive (i.e., to generate consistent returns) defines its fitness. The model that focuses on risk (i.e., variability in returns) could easily accommodate return optimization by setting threshold effects to the observed phenotype (i.e., not only consistent but also high levels of returns).

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