DECAMERON TECHNOLOGIES

White Paper 0: General Principles of Decameron Technologies' Model Construction

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General Principles of Decameron Technologies' Model Construction

This note serves as an introduction to Decameron fixed income models and presents an overview of the intuition that underlies these models. Details of how this intuition translates into the actual practice of constructing models will be taken up in subsequent papers. This piece begins by outlining the purposes of financial models and then spells out several general principles of model construction that are important to keep in mind, given these purposes, in the development and use of models for all manner of application to financial markets. We concentrate on model construction for market practitioners; academic financial modeling can involve issues that will be of lesser concern to the practitioner. The construction of interest rate yield curves gives an example of these general principles in action and is the subject of the next article in this series of Decameron white papers.

Introduction: What is the Purpose of a Financial Model?

Put simply, a financial model is a quantitative representation of the way various forces influence market prices. Implicit in the model's design is an assumption that there exists a paradigm in which certain forces create a certain effect. Therefore, upon ingesting certain required market inputs, a model typically reflects both what is happening and quantifying the extent to which this diverges from what should happen given the model's assumptions.

Assuming the paradigm underlying the model is deemed to correctly capture market dynamics, the model then provides a computed price and a computed 'risk' for the security in question. This computed price, often called the 'fair' price or the model price, would be the actual market price of the security if it behaved exactly as the model would predict. The fair model price serves as a quantitative anchoring point for any further analysis and allows the practitioner to begin his decision making in a quantitative context. The computed 'risk' represents the way the price of the security should change given specified changes in the underlying market environment. Correspondingly, this serves as the quantitative basis for the practitioner to assess his risk position and constitutes the foundation of risk analysis of single securities all the way up to that of large multi-asset portfolios.

When presented with model information on both price and risk, it is then up to the market practitioner to decide whether the model's assumptions accurately reflect the prevailing paradigm. If the practitioner determines that the paradigm remains intact, then the model can be expected to accurately reflect the relationship between the prices of different financial instruments and can therefore be used to predict either the moves of the overall market or of one instrument relative to another. If the practitioner determines that the paradigm under which the market is actually operating diverges from the assumptions in the model, he must decide whether to adjust the underlying assumptions, change the structure of the model itself, or turn the model "off" altogether. Therefore, a good model not only accurately accounts for changes in market prices over long periods of time, but it also makes its assumptions and underlying structure explicit so as to allow the practitioner to quickly and easily determine whether, in certain market environments, it requires recalibration, amendment, or being disregarded altogether.

Consider this process in more detail first from the standpoint of the pricing and valuation aspect of the model. Suppose the market price of an asset is found to differ from the fair model price as determined by a model employed by the decision maker. Assume further that he accepts that the model properly represents the dynamics of the market. The practitioner must then figure out what is causing the difference between the 'fair' model price and the observed market price. He must consider whether this pattern will persist, will get more extreme, or will reverse, and over what timescales any of this might happen.

The model will never tell him very much about this. He must make these assessments based on other considerations, such as his own market intuition, his own guesses as to how market microstructure specific to that asset may evolve, or indeed what the broader macroeconomic situation of relevant markets may be in the future. The model only provides a quantitative measurement of the value of the security given the specified assumptions. It will not specify whether this value will increase or decrease or, more generally, how it will evolve going forward.

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As noted previously, in addition to providing a quantitative anchor to the analysis of the 'right' price, a second important function of a financial model is to help understand the 'risk' embedded in the instrument. There are two types of measures of risk: (i) fundamental measures, and (ii) market implied measures. The first type consists of understanding how the price of an asset should change if one of the underlying inputs into the model changes. In the case of a bond, for example, one could assess how much the net present value of future cash flows should change if the discounting associated with those cash flows were to change, and what would be the resulting change in the model price of the bond. This would be the 'risk' of the bond price to changes in the anticipated interest rate of borrowing. Indeed, the 'risk' of the bond price to any of the underlying inputs could be assessed in the same way. These are 'fundamental' measures of risk because they are the outputs of a deterministic calculation of how model prices change with changes in the underlying inputs as specified by the model being used. It is a model-based approach to risk.

The second form of risk measure, market implied, is a measure of risk that is inferred from recent realized trends in the market. Perhaps the most well-known and common risk measure of this variety is commonly referred to as 'market beta' in the world of equities. This is simply how the price of a particular individual stock changes when the overall market, as specified by some broad index of stocks such as the S&P 500, changes. The market beta is usually computed simply by running an historical regression of the market prices of the stock in question versus a price history of the specified broad market index.

As such, the value of beta is determined entirely by the realized price histories of the stock and the broad index. These calculations do not require the use of any underlying financial model. This series of risk measures is derived by looking at historically realized correlations or behaviors of various markets and instruments, as opposed to calculations of underlying factors, as would be the case if fundamental valuation models were to be used.

Regardless of whether measures of risk are derived fundamentally from a model or implied by market movements, they are useful for hedging, risk management more generally, and for scenario analysis. For example, suppose someone who holds a particular bond does not want to be exposed to whatever interest rate sensitivity exists in the bond. In the most general case, the dependence of the fair model price of a bond could arise from a diversity of sources, all of which require consideration. For example, the cash flows of the bond itself could depend upon the future cash flow environment, as would be the case for callable or putable bonds and US mortgage securities. The bond holder may elect to use his model computation of risk to understand what this exposure is and then execute a series of trades across other interest rate instruments and derivatives (such as US Government bonds or swap options) in order to hedge this exposure in the bond he is holding. Alternatively, he could use the market implied sensitivity to interest rates to tell him what hedge to execute against his bond position. Either way, this is an example where the risk measure is used to hedge an unwanted exposure.

Additionally, he could elect to simply bear the risk arising from interest rates in his bond portfolio, knowing full well that it is there. However, in this case, the risk measure provides him a quantitative assessment as to the extent of his exposure, so he knows exactly what he is dealing with. Quantitative knowledge of the extent of this risk and the decision as to accept it or hedge it is the process of risk management generally.

Whether to use fundamental or market implied risk measures depends on the specific purpose and the timeframe over which the measures are to be used. The choices are often not black or white but are questions of considered judgement with many moving parts. For example, if a dealer is trading actively and simply wants to hedge his portfolio for a short period of time before he trades out of it, he may elect to use market implied values since this is the way the market is behaving at that moment. This would likely be a better hedge given his purposes and timeframe. On the other hand, a portfolio manager who intends to hold on to his portfolio for the long term can expect to go through several unpredictable market cycles where market conditions and behavior can reasonably be expected to change considerably. In this case, it may be better to use fundamental risk measures since these are not predicated on the specific manner in which markets behave at any given moment in time, which is anticipated to potentially vary widely, but in the way they should behave on a long term 'equilibrium' basis.

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So, to summarize, investment related questions are the same for any type of asset, be it equities, fixed income, a hybrid of the two (e.g., a convertible bond), or anything else. Is it cheap or expensive? What risks does it have exposure to and how big are these risks? Model valuations and risk measures derived from fixed income models allows the fixed income practitioner to do this set of things in his particular space.

A fair 'model' price for a fixed income asset provides a definitive quantitative baseline or anchoring point from which to proceed in terms of the valuation and portfolio management decision making process. The absence of this starting point again limits the decision-making process to less accurate qualitative considerations and makes things more difficult and unwieldy. The set of computed fundamental risks, perhaps alongside complementary market implied risks, provides the quantitative inputs into the general hedging, risk management, or scenario analysis process for fixed income portfolios.

An important feature of fixed income markets that is perhaps less of an issue in other markets is the considerable diversity of instruments that are actively traded as well as the significant complexity of some of these instruments. Therefore, an important purpose of model valuation is to provide a quantitative baseline or anchoring point not just for a single asset in isolation, but across different types of assets in such a way that everything can be compared on a like for like basis. A manager or analyst who is simultaneously responsible for a variety of different types of fixed income instruments across different markets can be assured that assessments of richness or cheapness can be inclusive of all the different types of assets in an entirely consistent manner. For example, he would be able to compare a Danish mortgage asset to a GBP interest rate swap to an option on a US Treasury futures contract, all within the same framework. In a sense, this is the true culmination of the reasons for addressing fixed income markets in a model-based fashion, that all different types of assets can be simultaneously valued and analyzed consistently and within the same framework.

This is likewise an important consideration with respect to risk. The ability to compute risks in an entirely consistent fashion across asset types and different markets here as well constitutes the true culmination of model-based risk calculation. The approach assures the decision maker, for example, that the risks computed for the Danish mortgage asset are within the same framework and can be directly compared to the risk computed for the GBP interest rate swap, and by extension also directly comparable to the option on the USD Treasury future. The calculation of total portfolio risk then reduces to simply adding up the various types of risk contributed by each asset in a portfolio, since they are all computed in a consistent manner. The power and flexibility of this approach are borne out by its inherent transparency and the effortless scalability of model-based risk assessments to portfolios of any size.

General Principles:

The purpose of a financial model drives decisions around how such a model should actually be constructed. Given the stated purposes above, the process of model building can be distilled down to a small set of general principles that are substantially helpful and should be followed when creating models:

I. **Model structure should be parsimonious.** As noted above, model results are used as guidance when making portfolio decisions. It is therefore important for the user to have an intuitive understanding of how the model is working and why the results are turning out the way they are. As such, a model should not be very complicated or else it will defy this simple understanding. A model that has too many levers is subject to the deficiency that the user cannot identify which factor, or factors, are responsible for a particular aspect of market dynamics, rendering decision making based on such a model basically impossible. It may also be imagined that since financial markets are very complex that models need to be correspondingly complex in order to capture enough of the information that affects the dynamics of markets so that the models are in fact useful. This is not necessarily so. There is a maxim coming from the physical sciences that, 'three parameters are sufficient to fit an elephant,' suggesting this same idea that even a small number of truly independent factors offers sufficient flexibility to model a rich collection of disparate forces and phenomena at the same time. The optimal trade-off between complexity and completeness versus parsimony and intuitive accessibility is a key aspect of the art of model building that is best understood only after extensive experience with models in trading, portfolio management, and risk management.

II. **Models should be structured so as to capture the underlying dynamics and economics of relevant markets.** It was noted that market dynamics can sometimes change significantly, especially when there are regime shifts in the underlying economic environment of a given market. Financial models that are designed so as to explicitly capture this underlying economics generally have the highest potential of being able to accommodate these inevitable changes without requiring adjustment or alteration. This is because what happens in the market usually falls within the framework of the model. Only those situations that generally constitute the most significant regime changes may require corresponding model changes. For example, significant regulatory or tax reforms could be instances where the resulting structural shifts are so significant that actual model changes cannot be avoided. Stable models have several very important advantages: First, since the same model is used over a long period of time, model valuations and risk can be compared in a like-for-like fashion over this extended period. This provides valuable long-term insights that would not be possible if the time series of valuations and risks were to be chopped up into smaller inconsistent pieces because the model was being changed all the time. Second, since a long-term history likely includes periods of regime shift as well as elevated market volatility resulting from significant market events (e.g. Financial Crisis, Global Pandemic, etc.), the dynamics of these periods will be captured in a consistent manner to other periods and can be analyzed accordingly and in a consistent

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manner. Market dynamics during these high volatility and uncertain periods can then also be ascribed to specific factors of the model. Indeed, models constructed to be consistent with economics are also generally superior, for example, to heuristic models (i.e., linear interpolation, splines, regression, etc.) since market moves can be ascribed to specific economically meaningful factors in general, whether markets are volatile or not.

III. **Proper selection of parameter values.** The use cases of financial models usually involve the present or future path of markets; seldom is the past a consideration. For example, when cash flows or discounting rates are computed in order to value a security, these values are computed in the future. When the risk of a portfolio is assessed, it is done so in order to again understand what might happen to the portfolio in the future. Therefore, parameters should be set to reflect the anticipated future state of the market. Historical trends can be used to provide guidance, but this is useful only to the extent the future bears similarities to the past. In this context, historical regression is a frequently used method to derive historically driven values for parameters. However, the utility of this approach is again limited to the extent the historical window over which the regression was done resembles the relevant future period. The alternative is to use arguments based on market and economic structure, such as the balance of supply and demand for risk, or extent of investment capital, etc. As in II. above, parameters once properly chosen should only require infrequent adjustment since they are reflective of the prevailing structure of the market and of the macroeconomic environment. Appropriately choosing such parameter values is again an aspect of the art of proper financial model construction.

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Concluding Comments:

This paper described the purposes of financial models, and a set of corresponding general principles that should be adhered to in order to best achieve these purposes. While this current paper focused on generalities and the intuitive basis of financial model building, these principles and practices will become more specific in subsequent papers. In particular, we will focus on the construction of interest rate models, upon which all other models rely, in the next set of papers.

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