From Physics to Finance

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PHYS20181F Professional Development Essay

> Essentially, all models are wrong, but some are useful. However, the approximate nature of the model must always be borne in mind.
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> *George E. P. Box*
> *British statistician*

Over the last few decades, the financial services industry has experienced an increase in demand for highly technical professionals. This is due to a variety of reasons, which we shall explain in due time, but the essence is that the sector has experienced a quantitative revolution. Companies are presented with a large amount of available data, lowered latency trading algorithms, complex financial instruments and mathematical risk management models (as opposed to traditional fundamental analysis), and, as such, they require graduates who can help make sense of all the information and analyse and optimize processes within the firm. This essay will discuss how the skills learnt in a physics degree can be extrapolated to the financial industry, by focusing on both the taught concepts but also the shared methodology that is followed to reach conclusions.

On the one hand, we shall cover the relevant content for the sector. It's worth mentioning, however, that the mathematical knowledge possessed by a physics graduate will most likely exceed the requirements for a standard financial analyst role, with the exception of highly numerical positions such as quantitative researcher or quantitative trader. Basics of university-level maths such as linear algebra, multivariate calculus and differential equations will prove to be useful in virtually all scenarios. The former has extensive applications in programming, serving as the basics of sophisticated fields like machine learning and is applied by Markowitz in his modern portfolio theory (MPT), employing the covariance matrix. Calculus and differential equations are utilised at the modelling stage.

For instance, in order to determine what the price of a European option (financial instrument) should be, economists Fischer Black and Myron Scholes published in 1973 a formula to determine it, which stems from a solution to the Black-Scholes partial differential equation, namely

$$\frac{\partial \mathrm{C}}{\partial \mathrm{t}} + \frac{1}{2}\sigma^2 \mathrm{S}^2 \frac{\partial^2 \mathrm{C}}{\partial \mathrm{C}^2} + \mathrm{rS}\frac{\partial \mathrm{C}}{\partial \mathrm{S}} = \mathrm{rC}. \tag{1}$$

Topics specifically taught in physics are also useful, and have to do with the probabilistic areas of the field, such as statistical mechanics and brownian motion. Brownian motion, first described in 1827 by Robert Brown and explained by Albert Einstein in 1905, is a model that illustrates the aleatory motion of particles. Coincidentally, the Black-Scholes equation presented above, is geometric brownian motion used as an option pricing strategy.

The field characterised by the utilisation of physical concepts to solve problems in economics is called econophysics and, within it, we find quantum finance, a subfield that was made notorious in 2018, when Rebentrost developed an algorithm run by a quantum computer for pricing derivatives in a more efficient manner than by applying classical models (Rebentrost et al, 2018). More specifically, they used Monte Carlo methods, a very common yet useful approach in both physics and finance, consisting in repeated random sampling to obtain numerical results. It's useful for solving integrals and optimization problems.

Other examples of physical applications to finance include the fact that "by analogy with energy, the equilibrium probability distribution of money must follow the exponential Boltzmann-Gibbs law characterized by an effective temperature equal to the average amount of money per economic agent; and the distribution of income is described for the great majority of population by an exponential distribution, whereas the high-end tail follows a power law" (Dragulescu, 2002).

On the other hand, physics and finance are not only related by the skill set required to develop them, but also by the methodology employed to do so. In essence, both fields of study attempt to explain a series of processes using a mathematical formalism in accordance with a fixed number of fundamental assumptions. Thus, physical modelling implies a simplification of the system to disregard largely insignificant nuance and focus on the bigger picture. This is precisely what George Box meant by "all models are wrong but some are useful" and the financial discipline works in a broadly equivalent manner. The development of models starts with the identification of the problem or process that we will be attempting to explain, we set an equation in which the variable we want to solve for is subject to the constraints of the system, we solve the equation, and finally, we check that it predicts real world outcomes in a relatively accurate manner, that is, within an acceptable error range.

To conclude, I would like to reiterate the main points described formerly. Finance has transitioned into becoming a greatly quantitative field, and its hiring needs are starting to reflect this shift in perspective. Physics graduates are ideally suited for roles in said industry due to their critical thinking skills, their mathematical expertise, their rigour in uncertainty quantification and their problem solving abilities. Furthermore, in the sub-field of quantitative finance, prior physicists are likely to re-encounter topics covered throughout their degree, such as differential equations, statistics, stochastic calculus and brownian motion.

References

[1] Rebentrost, P., Gupt, B. and Bromley, T.R., 2018. Quantum computational finance: Monte Carlo pricing of financial derivatives. Physical Review A, 98(2), p.022321.

[2] Dragulescu, A.A., 2002. Applications of physics to economics and finance: Money, income, wealth, and the stock market (Doctoral dissertation, University of Maryland, College Park).