WHO NEEDS A NEWTONIAN FINANCE?

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Until recently, mathematics and physics have been intimately related subjects. Particularly between the 17th and 20th centuries, much of mathematics was developed to satisfy the demands of physics, and much of physics was molded after mathematical ideas. One example of mathematics custom-made for physics is calculus. At the end of the 17th century, Newton and Leibniz worked the mathematics needed to model the dynamics involved in classical mechanics. The marriage between mathematics and physics was such that Sir Issac Newton considered Geometry (at the time the main branch of mathematics) to be a part of mechanics (Atiyah et al., 2010). Conversely, an example of physics inspired by mathematics is superstring theory.

NEWTONIAN ECONOMICS

At the beginning of the 20th century, economists wanted to add rigor to their studies. Physics was the most rigorous of sciences, and physics relied on calculus, therefore it was reasonable to express economic problems in calculus terms. Marx's "class struggle" became Arrow's "hill climbing" struggle, with a notion of equilibrium inspired by the celestial bodies of Newtonian physics. In other words, calculus was not chosen because it *solved* economic problems, but rather Calculus *defined* economic problems, just as mathematics made superstring theory. Calculus was the hammer that made a nail out of every economic question. This phenomenon is often referred to as "physics envy."

One explanation for economists' lust for calculus is that it is convenient to represent humans as optimization machines, trying to maximize their utility subject to constraints and scarce resources. Of course, no one has ever seen those proverbial utility functions, and any optimization problem you can write on a piece of paper is too simplistic to characterize the complexity of modern societies. Another explanation is the desire to replace experimentation with a strong *a priori*, purely mathematical structure (Focardi and Fabozzi [2016]), like the one used by superstring theory in physics, even if economic reality disagrees. The role of economic theory is not to explain the world; its role is to legitimize a political subject under the false cover of scientific knowledge (Focardi and Fabozzi [2012]).

ECONOMICS IS A PROFESSION, NOT A SCIENCE

Calculus served its purpose well, and today its use is ubiquitous in physics, engineering and, more surprisingly, economics/finance. But why would economics need a mathematical tool developed for describing the movement of astral bodies? After all, physics and economics could not be further apart as academic subjects: Physics applies experimentation to derive the immutable laws of nature, while economics relies on historical simulations to derive the past state of ever-changing patterns by which humans exchange goods and services. Physics is a science, while economics is a study, like history or sociology (all exciting disciplines). Historians, sociologists and economists all use a growing amount of math, but using math does not qualify a discipline as scientific. From an epistemological standpoint, there are two widely accepted definitions of science: The Popperian and the Lakatosian.

According to the Popperian school, a discipline cannot be a science unless it is endowed with a mechanism to objectively reject false discoveries. The natural sciences have such mechanism: After Einstein proposed his famous Relativity theory, a number of experiments were designed to reject it. So far every experiment has failed to falsify this theory, hence it is "not rejected" for the time being. It is important to understand that according to Popper, science is not a collection of truths but rather a set of statements that have not been rejected yet. So is economics a science in Popper's sense? No. We cannot go back to May 6, 2010 to repeat the events of the flash crash over and over again, while controlling for various environmental variables, in order to derive the cause-effect mechanism that triggered the liquidity event. Economists can perform a statistical analysis of the historical series, but a simulation is not an experiment.

For the Lakatosian school, a discipline is a science if it can produce accurate predictions. Well, this one won't take long, will it? If weather forecasts had the accuracy of economic forecasts, half the population would die of pneumonia or sunstroke within 12 months. Economists have failed to predict every crisis, every bubble, and in many cases they were the force behind them (Focardi and Fabozzi, 2015). Consider the celebrated portfolio theory, which applies convex optimization to asset allocation. Studies have shown that optimal portfolios *in-sample* underperform the naïve 1/N portfolio *out-of-sample* (de Miguel et al. [2009], López de Prado [2016a]). In other words, portfolio optimization is *detrimental* in real-life applications, because the signal-to-noise ratio in economic series is so low that inverting any covariance matrix generates errors that more than offset the benefits of diversification! And where else do economists invert covariance matrices? They do so everywhere in the econometrics toolkit. The famous equation at its core, $\hat{\beta} = (X^T X)^{-1} X^T y$, is the solution to yet another optimization problem. Econometric models fail out-of-sample for the same mathematical reason that portfolio optimization fails. This flaw casts a shadow on popular investment theories, such as CAPM, APT, or factor investing (Calkin et al. [2014]).

THE ETHICS OF TEACHING SOMETHING YOU KNOW IS WRONG

A number of professors have voiced ethical concerns about the overwhelming number of patently false theories still being taught in financial academia (see Bailey et al. [2014], Bookstaber [2017], Fernandez [2017], Harvey et al. [2016]). Of course, the best proof that these theories are wrong is to look at the evidence: Decades after their publication, neither their authors nor their followers have achieved the promised wealth (excluding management fees). So why do economists still teach and use these demonstrably flawed models? First, unlike in physics, economics' tenure-applicants can get away with any false discovery. For every example of failure they'll bring a counter-example, with no way to derive a precise and invariant distribution of outcomes. There are no laboratories to disproof their claims, and unlike in physics, economics papers are virtually *never* retracted. Second, some professors feel that, even though these theories are wrong, it is the best we have got. What this argument misses is that millions of students will pay tuition, work hard and waste precious years for the benefit of a collective delusion. Students deserve to be told that they are joining a field that cannot deliver what it promises.

ECONOMICS WITHOUT PHYSICS ENVY

Economists' obsession with calculus is an accident of history. Let us entertain for a moment an alternative history. What would economics look like today if "physics envy" had not taken root? Economists would look at the world with healthy, unenvious eyes, and would realize that economics is the science of relations, not the science of utility-maximization. Not all relations involve optimization, for instance the provision of public services to protected classes. And yes, some agents face maximization problems, but the reason they optimize is because of trade. Optimization does not define the problem, it is only one aspect of it. A more relevant problem is to understand the web of connections in a morass of unstructured data: Why they occur, how they occur, what is the hierarchical structure, what causes them to implode during crises, etc. Even if there is not a theoretical answer to these questions, the description and measurement of these structures is in itself useful. Historians do not attempt to develop a general theory of history, some sort of explanation for everything that has happened and will happen. Why would such theory exist in economics? Economists would still be needed if they acknowledged that economics is a profession rather than a science, like the practice of law, or investing.

Various areas of science and technology study networks and pattern recognition. If we could burn the entire edifice of economic literature to the ground and start again on a clean slate, calculus would play a minor role in that alternative high-GDP world. The mathematics used by economists would have much more to do with Google's machine learning or graph theory than with Newton's calculus.

FIXING THE MATH SYLLABUS FOR ECONOMICS

Gilbert Strang, a world-renowned math professor, teaches calculus among other subjects at MIT. He is the author of several major calculus textbooks. A few years ago he wrote an essay titled "Too much calculus", in which he explained (Strang, 2010):

> *"Calculus I, Calculus II, Calculus III –what an imbalance in our teaching! All the rest of mathematics is overwhelmed by calculus. The next course might be differential equations (more derivatives), and the previous course is probably pre-calculus. I really think it is our job to adjust this balance, we cannot expect other to do it […] The reform of Calculus I, Calculus II, Calculus III must go beyond the presentation of those particular topics. They are important but not all-important. We need to present the mathematics that is most useful to the most students."*

Math is more relevant than ever for finance practitioners (López de Prado, 2016b). That is, modern math, not the 17th century techniques developed for modelling the universe as a clock. Some useful subjects rarely taught in economics programs include: combinatorics, graph theory/networks, kernel theory, information theory, machine learning, experimental math, algorithms, complexity theory, data structures, and data visualization. Today, computer scientists are better trained to deal with economic problems than economics students. That is one reason why banks and hedge funds are filling with data scientists positions previously reserved for economics graduates.

REFERENCES

Atiyah, M., R. Dijkgraaf, and N. Hitchin. "Geometry and Physics." *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*. Vol. 368 (2010), pp. 913–926. Available at http://rsta.royalsocietypublishing.org/content/roypta/368/1914/913.full.pdf

Bailey, D., J. Borwein, M. López de Prado, and J. Zhu. "Pseudo-Mathematics and Financial Charlatanism: Backtest Overfitting and Out-of-Sample Performance." *Notices of the American Mathematical Society* Vol. 61, No. 5 (2014), pp. 458-471.

Bookstaber, R. *The End of Theory: Financial Crises, the Failure of Economics, and the Sweep of Human Interaction*, Princeton, NJ: Princeton University Press, 2017.

Calkin, N. and M. Lopez de Prado. “Stochastic Flow Diagrams.” *Algorithmic Finance*, Vol. 3, No. 2 (2014), pp. 21-42.

De Miguel, V., L. Garlappi, and R. Uppal, R. “Optimal versus Naive Diversification: How Inefficient is the 1/N Portfolio Strategy?” *Review of Financial Studies*, Vol. 22 (2009), pp. 1915–1953.

Fernandez, P. “Is It Ethical to Teach That Beta and CAPM Explain Something?” Working paper, SSRN (2017). Available at SSRN: https://ssrn.com/abstract=2980847

Focardi, S. and F. Fabozzi, “What’s Wrong with Today’s Economics?” Journal of Portfolio Management Vol. 38, No. 3 (2012), pp. 104-119

Focardi, S. and F. Fabozzi, “Economics: An Empirical Science Capable of Forecasting Economic Events?” *The Journal of Portfolio Management*, Vol. 41, No. 4 (2015), pp. 145–151.

Focardi, S., and F. Fabozzi, “Mathematics and Economics: Saving a Marriage on the Brink of Divorce?”, *The Journal of Portfolio Management*, Vol. 42, No. 4 (2016), pp. 1-3.

Harvey, C., L. Yan and H. Zhu. “…and the Cross-Section of Expected Returns.” *Review of Financial Studies,*Vol. 29, No. 1 (2016), pp. 5-68.

López de Prado, M. “Building Portfolios that Outperform Out-of-Sample.” *The Journal of Portfolio Management*, Vol. 42, No. 4 (2016a), pp. 59-69.

López de Prado, M. “Mathematics and Economics: A Reality Check.” *The Journal of Portfolio Management*, Vol. 43, No. 1 (2016b), pp. 5-8.

Sala-i-Martin, X. “I Just Ran Two Million Regressions.” *American Economic Review*, Vol. 87, No. 2 (1997), pp. 178-183.

Strang, G. “Too much calculus”. Working paper, MIT (2010). Available at http://www-math.mit.edu/~gs/papers/essay.pdf