Consilience and Economics:

How the Natural Sciences can improve Economics and Finance

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Introduction: Consilience and Economics

"He who understands baboon would do more towards metaphysics than Locke."

—Charles Darwin, 1838: Notebook M

Economists should pay more attention to baboons and less to mathematics. The target paper (Danielsson and Shin, 2009) for these comments explores "anomalous" behavior in financial markets. Human behavior that differs from that predicted by standard neoclassical theory is labeled as anomalous. Economic efforts to reconcile theory with anomalies involve relaxing one of more of the standard assumptions and showing that some stylized features of actual behaviorare consistent with the modified assumptions. This approach is now common in many behavioral papers on topics such as other-regarding preferences (Bolton, 1991) and intertemporal decisions (Laibson, 1997).

E.O. Wilson advocates a radically different approach in his book *Consilience* (Wilson, 1998). Wilson has long advocated that social scientists ground their work in the natural sciences (Wilson, 1978). Consilience is the jumping together of fields. In practice, Wilson's advice suggests that social scientists ought leave their hermeneutic departments and work with biologists, primatologists, archeologists, neurologists, and a host of other fields.

The eventual result of a consilient approach to economic behavior will, Wilson argues, be a richer and more accurate field. The result need not be inconsistent with mathematical models, but mathematical models without natural science knowledge will be limited.

The rest of this note describes the economic and a consilient approaches to understanding behavioral anomalies. It then describes some pioneering work using natural science approaches to understanding risk, the anomalous behavior in focus for the target paper. The paper ends with concluding comments.

Two approaches to Anomalies

Economic approach

The anomalies literature has documented a wide-variety of divergences between actual human behavior and that predicted by standard economic theory. The behavioral school has become so well-known that citations are not required; most practitioners know to look at the work of Kahneman & Tversky, and Richard Thaler.

The early phase of the behavioral approach focused on documenting failures of the standard model. These are labeled “anomalies” in the lexicon taken from Thomas Kuhn’s *The Structure of Scientific Revolutions*.

A second phase of the behavioral approach attempts to build models of the anomalous behavior. These models tend to relax a small number of assumptions in the standard framework and end up with a model that mimics the most significant stylized facts in actual human behavior.

For example, game offers (Guth et al., 1982). Dozens of papers have postulated ultimatum game rejections as the product of rational maximization of the other-regarding preferences. These other-regarding preference structures, when made sufficiently complex, can be made consistent with some significant percentage of the experimental results. It is not clear that any of these other-regarding preference structures extends our understanding of the phenomena beyond the evidence.

The target paper on risk follows exactly this formula. The anomaly, discovered again in the financial crises of 2008, is that people’s willingness to bear risk goes down as asset markets decline. The produces the paradoxical result that investors loved owning equities when the Dow Jones Industrial Average was at 14,000, they become scared when the Dow hit 10,000, and sold in a panic at Dow 6,500. The paper describes the puzzle as, “as financial conditions worsen, the willingness of market participants to bear risk seemingly evaporates even in the absence of any further hard news.”

Using the standard view that people are rational maximizers, how can we make sense of buying stocks at 14,000, and selling them at the half price? The paper relaxes a few assumptions, and is able to build a model that has some of the features of reality. In particular the paper relaxes the standard setup by allowing some traders to be forced to curtail risk because of VaR (value-at-risk) rules. The paper then applies standard tools of rational expectations and fixed point equilibrium.

Does the model work? It is consistent with some of stylized facts that we knew before the model was written. Specifically, the authors write, “As well as the omnipresent implied volatility skew at any given moment in time, our model also predicts that implied volatilities move together in a crisis, which has indeed occurred, across securities as well as across asset classes.”

Consilience approach

E.O. Wilson suggests we look to natural science to understand human attitudes towards risk. Nobel Laureate Nikolaas Tinbergen (his brother Jan won the Noble Prize in Economics) provides a framework for examining behavior (Mayr, 1961, Tinbergen, 1963, 1968).

Tinbergen argues that behavior should be examined from four perspectives.

1) Ultimate cause – how does the behavior lead to increased evolutionary success? This is the domain of maximizing models in evolutionary biology.

2) Proximate cause – what machinery in the brain and body produces the behavior. Some of the proximate cause will include hormonal influence, neuroscience work

on brain function, and cognitive studies of how the brain stores and uses information

3) Ontogeny – how does the behavior develop over the lifetime of an organism? When do children develop these traits and what influences their manifestations
4) Phylogeny – looking across species, what can we learn about how and why the trait developed over evolutionary time?

These are early days in consilient economics, but the number of studies is expanding rapidly. There is quite a significant field on neuroeconomics, some significant work on hormones and economic behavior, a handful of studies on non-human primates and economic behavior, and a few twin studies.

The next section describes four studies on risk that I label as “consilient”. These are new approaches and they should not be expected to as well-developed as areas that have been under persistent study for decades.

Consilience and Risk: Pioneering natural science work on risk

Dopamine Receptor Structure and Risk Taking

Dopamine is a central reward pathway in human brains. The dopamine receptor D_4 (DRD4) gene is hypothesized to be involved in modulation of a variety of behaviors. Individuals vary in the genetic structure of the DRD4. One variant, 7R+, has been shown to be associated with a “blunted” response to dopamine. Some studies argue that people with the 7R+ allele are more risk seeking because higher levels of risk are needed to generate a dopamine-based positive feeling.

One study reports that the 7R+ allele is correlated with risk-seeking behavior in an economic experiment (Dreber et al., 2009). Subjects had their DRD4 alleles genotyped, and, for this analysis, were divided into those with 7R+ allele and those with other alleles (7R-). The subjects were asked to allocate $250 between a safe and risky investment. The safe investment returned 100% of the money invested with certainty. The risky investment had two outcomes -- $0 and 250% of the money invested.

The study correlated the amount invested in the risky investment with the dopamine allele. It reports that subjects with the 7R+ allele took more risks than 7R- subjects. Specifically, the 7R+ subjects invested an average of $175 in the risky asset vs. $136 for the 7R- subjects (p-value = 0.023).

Genes and Portfolio Choice

A study used twins to study risky behavior in laboratory games, and concludes that risk attitudes are partly caused by genes (Cesarini et al., 2009). The partial privatization of Swedish pensions allowed examination of the genetic role in portfolio choice.

In 2001, Sweden altered in pension system to allow individuals to choose their portfolio allocation with part of the forced retirement savings (Cronqvist and Thaler, 2004). The participants could choose to remain in a default allocation, or choose to allocate among approximately 500 different funds. Each of the funds was ranked for level of risk (based on the prior 36 months of monthly return). The risk level was assigned to one of 5 categories ranging from very safe (low standard deviation of historical monthly returns) to very risky.

Twin studies separate the effects of gene and environment by comparing behavioral correlations between identical or Monozygotic twins (MZ) vs. fraternal or dizygotic twins (DZ). MZ twins start with identical genetic material while DZ twins are as closely related as siblings born in separate pregnancies. Traits that are highly heritable will be more similar in MZ twins than in DZ twins. At an extreme, a trait like eye color will be the same in almost all monozygotic twins (not 100% as mutations can occur during cell division). Non-heritable traits, such as color of one's car will be no more correlated between MZ twins than between DZ twins.

The study of the genetic influence on portfolio choice uses the Swedish pension reform in a classic twin study (Cesarini et al., forthcoming). The study uses only twins, and examines the overall risk level of the portfolio. The methodology allows an estimate of the genetic contribution to portfolio choice. The direction of the analysis is the greater the genetic contribution, the higher the relative correlation of risk between MZ twins as compared to DZ twins.

The paper reports significantly higher correlations for MZ twins than for DZ twins, "In women the correlations are 0.27 and 0.16. In men, they are 0.29 and 0.13." The authors state that 30% of the variation of portfolio risk is explained by shared genes and environment. The exact proportion that is genetic is not identifiable as it is possible that MZ twins have a more common environment than DZ twins. Parents may treat MZ twins more similarly than DZ twins, and they may be part of the reason that MZ twins' portfolios are more correlated. That said, it is also possible that parents treat MZ twins more similarly because MZ twins are more alike genetically.

Testosterone and Risk Taking

Testosterone is associated with a variety of behaviors in men and males of a wide-variety of species (Wingfield et al., 1990). In men, high testosterone is correlated with dominance seeking behavior (Mazur and Booth, 1998). When dominance is mediated by aggression, testosterone also appears to facilitate this process. A meta-analysis, summarizing the results of 45 human studies, found a consistent, positive relationship between aggression and testosterone (Book et al., 2001). Testosterone is hypothesized to mediate status and hierarchy in an adaptive manner (Kemper, 1990, Mazur, 1985,, 1973,, 1983). Testosterone modulates a variety of behaviors that are risky.

Subjects in the study of testosterone and risk taking (Apicella et al., 2008) had their testosterone levels assayed using saliva samples. They participated in the same experimental assessment of risk as the study of D4DR allele. Specifically, they allocated $250 between a safe asset and a risky asset. The study reports that a one standard deviation increase in testosterone is associated with 12% higher contribution ($30) to the risky asset.

Non-human Apes and Risk Taking

Chimpanzees (*Pan troglodytes*) and bonobos (*Pan paniscus*) are the closest living relatives to humans. In the wild, chimpanzees depend on riskier food sources than do bonobos. The authors of a study of the phylogeny of risk-attitudes hypothesize that if risk preferences are shaped by the environment, over evolutionary time periods, that chimpanzee should exhibit riskier behavior than bonobos (Heilbronner et al., 2008).

Chimpanzees and bonobos made a risky choice in a laboratory setting. The animals selected one of two upside down bowls. The safe bowl always contained four grape pieces. The risky bowl contained either one grape piece or seven with equal chance. (Note that the risky option has the same expected value as the safe option.) Chimpanzees selected the risky option 64% versus 28% for the bonobos (p=0.003). Thus the hypothesis that chimpanzees are built to be more risk seeking than bonobos is consistent with the findings.

Concluding comments

The target paper begins with a puzzle about human nature. When asset markets decline, people seek safety and sell their risky assets. What have we learned about risk from the four studies described above?

In summary, the studies suggest that biology and evolution play a role in our risky behaviors. Chimpanzees and bonobos in the wild live in different environments, and these environments are hypothesized to connect to their risk attitudes in experiments. If the “natural” environment that shaped bonobo and chimpanzee risk preferences, then we might learn a lot about human risk preferences by learning more about humans “in the wild”. Some important scholars argue that the wild environment for humans ended 10,000 years ago with the invention of agriculture (Cosmides and Tooby, 1994, Tooby and Cosmides, 1990). If we are, as these scholars argue, “Pleistocene hunter-gatherers”, then economists will have to learn from archeologists and anthropologists.

Our shared human environment might explain average levels of risk-taking but what about variation between people? The early twin studies suggest that different genes in different people influence behavior. Our genes may have profound influences on our choices ranging from laboratory gambles to asset allocation. If this is true, economists have much to learn from geneticists and evolutionary biologists.

How do genes alter risky choices? We have two studies that suggest roles for dopamine and testosterone. Those with particular brain structures, particularly the 7R+ allele of dopamine, may be more risk seeking. In addition, those with high testosterone may be more likely to take risky economic decisions. If these are important for a wide-range of economic behaviors, again the lesson is that economists ought learn from the related natural science fields.

The consilient approach to economic behavior is a growing part of the literature. For it to become more fully integrated, scholars in both social and natural sciences will have to spend more time together, and learn from each other.

Literature Cited

Apicella, C. L., et al. "Testosterone and Financial Risk Preferences." *Evolution and Human Behavior*, 2008, *29*, pp. 384-90.

Bolton, G. "A Comparative Model of Bargaining: Theory and Evidence." *American Economic Review*, 1991, *81(5)*(December), pp. 1096-136.

Book, A. S., Starzyk, K. B. and Quinsey, V. L. "The Relationship between Testosterone and Aggression: A Meta-Analysis." *Aggression & Violent Behavior*, 2001, *6*(6), pp. 579-99.

Cesarini, D., et al. "Genetic Variation in Preferences for Giving and Risk-Taking." *Quarterly Journal of Economics*, 2009, *124*, pp. 809-42.

____. "Genetic Variation in Attitudes toward Financial Risk." *Journal of Finance*, forthcoming.

Cosmides, L. and Tooby, J. "Better Than Rational: Evolutionary Psychology and the Invisible Hand." *American Economic Review*, 1994, *84*(2), pp. 327-33.

Cronqvist, H. and Thaler, R. H. "Design Choices in Privatized Social-Security Systems: Learning from the Swedish Experience." *American Economic Review*, 2004, *94*(2), pp. 424-28.

Danielsson, J. and Shin, H. S. "Risk Appetite and Endogenous Risk." *manuscript*, 2009.

Dreber, A., et al. "The 7r Polymorphism in the Dopamine Receptor D4 Gene (Drd4) Is Associated with Financial Risk Taking in Men." *Evolution and Human Behavior*, 2009, *30*(2), pp. 85-92.

Guth, W., Schmittberger, R. and Schwarze, B. "An Experimental Analysis of Ultimatum Bargaining." *Journal of Economic Behavior and Organization*, 1982, *3(4)*(December), pp. 367-88.

Heilbronner, S. R., et al. "A Fruit in the Hand or Two in the Bush? Divergent Risk Preferences in Chimpanzees and Bonobos." *Biology Letters*, 2008, *4*(3), pp. 246-49.

Kemper, T. D. *Social Structure and Testosterone: Explorations of the Socio-Bio-Social Chain*. New Brunswick: Rutgers University Press, 1990.

Laibson, D. "Golden Eggs and Hyperbolic Discounting." *The Quarterly Journal of Economics*, 1997, *112*(2), pp. 443-77.

Mayr, E. "Cause and Effect in Biology." *Science*, 1961, *134*, pp. 1501-06.

Mazur, A. "A Biosocial Model of Status in Face-to-Face Primate Groups." *Social Forces*, 1985, *64(2)*, pp. 377-402.

____. "A Cross-Species Comparison of Status in Small Established Groups." *American Sociological Review*, 1973, *38*, pp. 513-30.

____. "Hormones, Aggression and Dominance in Humans.," B. Suare, *Hormones and Aggressive Behavior*. New York: Plenum, 1983,

Mazur, A. and Booth, A. "Testosterone and Dominance in Men." *Behavioral and Brain Sciences*, 1998, *21*, pp. 353-97.

Tinbergen, N. "On Aims and Methods in Ethology." *Zeitschrift fur Tierpsychologie*, 1963, *20*, pp. 410-33.

____. "On War and Peace in Animals and Man. An Ethologist's Approach to the Biology of Aggression." *Science*, 1968, *160*, pp. 1411-18.

Tooby, J. and Cosmides, L. "The Past Explains the Present: Emotional Adaptations and the Structure of Ancestral Environments." *Ethology & Sociobiology*, 1990, *11*, pp. 375-424.

Wilson, E. O. *Consilience*. New York: Knopf, 1998.

____. *On Human Nature*. Cambridge: Harvard University Press, 1978.

Wingfield, J. C., et al. "The 'Challenge Hypothesis' Theoretical Implications for Patterns of Testosterone Secretion, Mating Systems, and Breeding Strategies." *American Naturalist*, 1990, *136*, pp. 829-46.