Bars, Models, and Russell's Chicken

The lens of complexity and the
interpretation of empirical evidence.

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"*Since solipsism, and an infinity of related theories, are logically consistent with your perceiving any possible observational evidence, it follows that you can logically deduce nothing about reality from observational evidence.*"

- David Deutsch, *The Fabric of Reality*

Reality, And Models Thereof

When discussing investments, many economists use a time-tested method for highlighting just how complicated financial markets are. The audience in question is shown two graphs. One is the daily price of an instrument or index (e.g. the S&P 500), and the other is a computer generated random walk. One plot is the result of millions of decisions, interactions, transactions, and discrete measurements. The other is pure noise. Whether by design or forgetfulness, the economist is rarely willing to say which is which.

As a variation on this theme, consider the exercise of opening a newspaper to the business section and observing a time series graph of a financial instrument. If left free to do so, the amazing pattern recognition skills of the human mind will almost invariably begin to "connect the dots". Induction will then spring into action, as the observer begins to build a causal story around the marks on the page. Very few people can resist the temptation to extrapolate beyond the right hand border.

This process of observation, induction, and extrapolation is carried out daily by a myriad of people in a wide variety of contexts. Our anticipatory nature does not allow us to be content with the de facto state of the world; we are continuously forming expectations of the future by extrapolating from even the most diminutive historic samples.

A crucial element in this continuous cycle of inductive forays is our adaptative formulation of models. For the purpose of this article, we can think of a model as any abstraction or construct which provides a framework for evaluating and advancing evidence. These can range from simple rules of thumb (e.g., what goes up must come down) to sophisticated mathematical amalgams (e.g., Arrow-Debreu general equilibrium). In fact, we have no option but to consider reality from a subjective vantage point which is delineated by our current model set. To employ an appropriate — if much overused — phrase, at any given time we operate within a particular paradigm; the eye never observes nakedly, but always makes use of some more or less idiosyncratic lens.

More than 40 years go, Bertrand Russell illustrated the scope for error inherent in seeing through an inappropriate lens by telling his story of the chicken. Every day, a farmer brings a chicken a more-or-less constant quantity of food. The chicken considers this growing dataset, but does so with a model that emphasizes humanity's benevolence to fowl. When the farmer arrives with a knife in his hand, the chicken is amazed to discover that it's prediction for the day could be so wrong.

Some of our recent work has produced a prime candidate for paradigm misapplication with ostensibly far reaching consequences. Building on work by Arthur (1994) and Casti (1996), we have extended the renowned

El Farol Problem (EFP), which we explain below. Our findings suggest that an interpretation of market stability in the EFP made through the lens of standard economic theory may be extremely misleading.

Paradigms, Dominance, and Economic Theory

Throughout economics, perfect rationality constitutes a dominant paradigm. Sub-disciplines, such as game theory, neo-classical thought, and new Keynesianism, differ markedly at many levels. Nevertheless, they tend to share at least two fundamental assumptions:

1) Economic actors can perfectly solve problems of arbitrary complexity.

2) The decisions of these actors are coordinated by an often incompletely defined mechanism which allows for the emergence of prices and produces the possibility of exchange.

These tenets have an intricate history, and are virtually impossible to extricate from the history of economic thought. Moreover, the majority of recognized work in economics consists of formal analytical models, which are generally tractable only because of these assumptions. Any significant departure from this status quo exposes the modeler to a host of criticisms. Explicit but imperfect micro-market theorizing generally leads to claims of ad-hocery, while limiting actors' problem solving skills in some bounded rational way invites the question of why any particular limitation was chosen out of the infinite set of alternatives.

With that dominant model in mind, consider Panel A of Figure 1, which shows a series of matched price and quantity observations from an (artificial) market.

In the absence of any other details, how should one interpret the data that Panel A illustrates? A typical economist might use their expertise to explain this market's perceived stability. Viewed through a standard lens, the complete lack of change in price and small variation in quantity suggests some obvious possibilities:

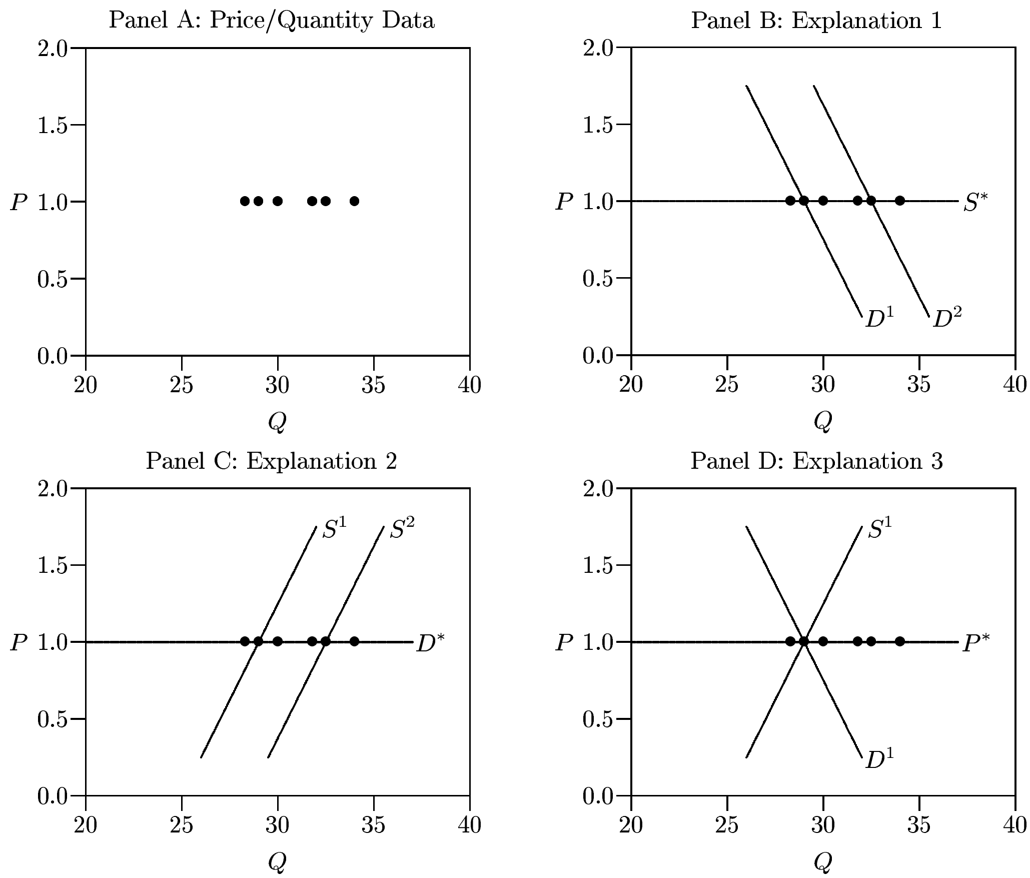
1) The good's supply curve is essentially flat and only small variations in demand can be observed. A possible candidate explanation would be that we are tracking a competitive market for a commodity-like good (Figure 1, Panel B).

2) Demand is completely flat, but there are small supply variations. A market for power supply might be a likely example (Figure 1, Panel C).

3) The price is set in a non-market manner (government fiat, cultural convention, etc.) and variations on the short side of the market (whether demand or supply) are responsible for quantity changes (Figure 1, Panel D).

In fact, in the (artificial) world from which these data are drawn, both supply and demand are constant, yet there is a great deal of unsatisfied demand. The price, at least in the sense of a displayed fee for consumption, is not fixed in any way. The prevalent economic paradigm, which includes the "laws" of supply and demand, is simply inappropriate for describing these kinds of observations. Moreover, if we force ourselves to interpret the data through the lens of standard theory, we can be easily led to erroneous conclusions about the nature of this market, the forces that affect it, and what policies we might prescribe to regulate it.

Figure 1



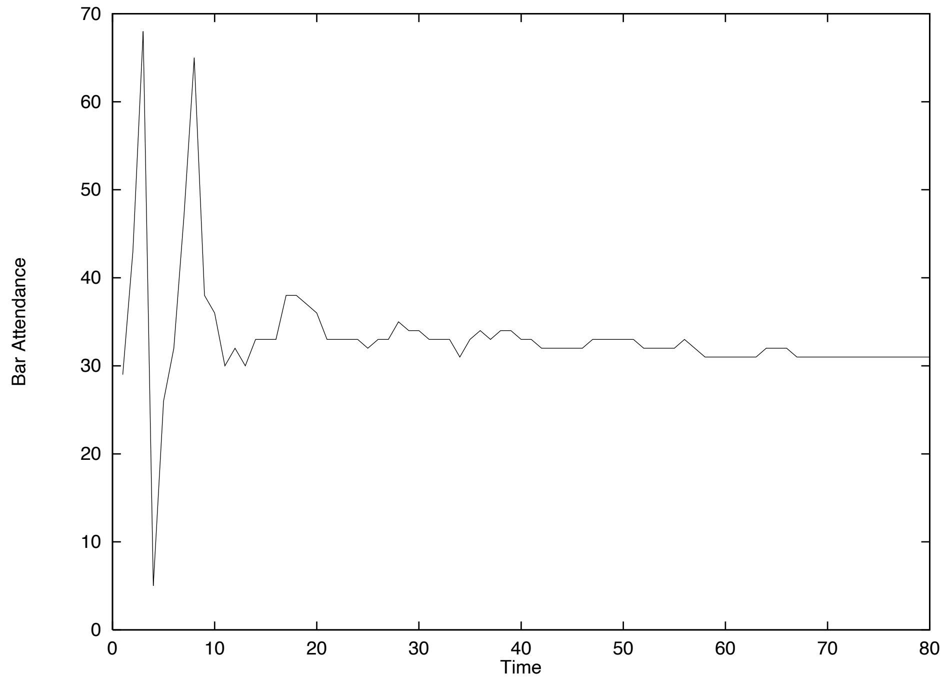
Barstool Economics

In 1994, a relatively short paper by Brian Arthur entitled "Inductive Reasoning and Bounded Rationality" appeared in the American Economic Review. It argued that the dominant model of human decision making embedded in virtually all of economic theory — perfect rationality — was not necessarily an appropriate modeling assumption. Moreover, a significant shortcoming of the perfect rationality approach was highlighted by way of the EFP.

This puzzle takes it name from a bar in Santa Fe, and the story runs as follows. Suppose 100 people have to decide each day whether or not to go to a bar. Their preferences are such that they will want to go if the total number of bar goers will total 30 or less. Any more, and the bar will be too crowded for anyone to enjoy themselves. The interesting thing about the problem is that there is no straightforward way to solve it using perfect rationality. The reason, of course, is that everyone's decision is contingent on what everyone else will do. In a fury of confounding self-reference that is reminiscent of the Liar's Paradox, if all believe none will go, then all will go. Similarly, if all believe all will go, the bar will be empty.

Arthur argued that a sensible way to explore this problem would be to play out the repeated attempts of individuals to create a useful decision process inside a computer. But he knew that if the 100 agents in this artificial world all used the same perfectly rational analytical decision process, the system would simply oscillate between minimum and maximum crowd levels of 0 and 100. Instead, Arthur thought up about

Figure 2 - Arthur's El Farol Problem



20 inductive procedures the agents could use, and then fed every agent the crowd size at the end of each day. These algorithms included things like moving averages, mirrors around 30, and so on. Each agent was endowed with a smaller subset of the possible mappings between past data and a prediction. At every time period they would calculate the output of each of their predictors, but actually make their decision by using the method that had been most accurate in the recent past.

Remarkably, this inductive reasoning model proved to be incredibly powerful. The system would always settle in on an attendance level of roughly 30, although the composition of the crowd would change over time. The system was also very robust to changes in the optimal bar size, the number of total predictors, the amount of predictors each agent had access to, and so on. A sample run of the problem is shown here in Figure 2.

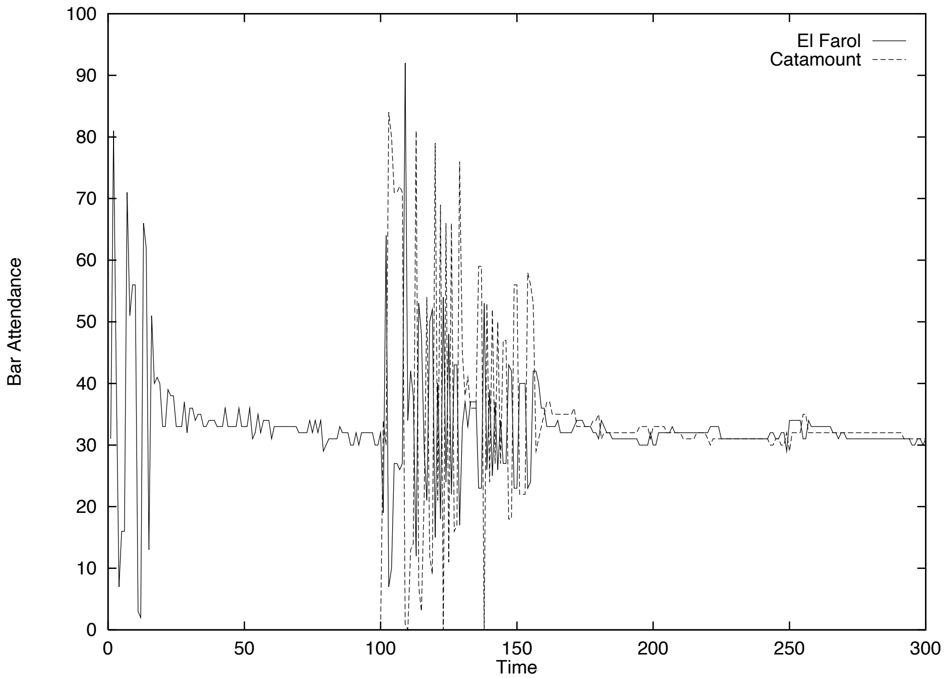
This convergence result is surprising because there is no simple set of factors that explains where it comes from. Rather, it is an emergent property of what can be considered a complex system. The interdependent decisions of 100 autonomous actors have been coordinated not by any explicit price adjustment, but by the interconnectedness of many inductive processes. Moreover, the large majority of the population does not go to the bar, although the optimal bar size has been achieved. Because of the almost ecological form of the forces shaping the result, we refer to the convergence in Arthur's setup as an "organic" equilibrium.

Opening the Catamount

Our point of departure on the original EFP was to extend and explore the notion of inductive decision making. If actors in the real world make decisions in analogous ways, then the paradigm inherent in Arthur's proposal may be appropriate to a wide range of phenomena. Our recent paper (1999) set this problem in the context of a policy decision.

Imagine that a fictitious official responsible for issuing bar licenses in the artificial Santa Fe receives an application to open a second establishment. Suppose, moreover, that this individual is equipped with only

Figure 3 - The Extended El Farol Problem



recent data on attendance levels at the current bar and a considerable grasp of standard economic theory. This is an example of the paradigm problem posed earlier in this paper, and the data presented in Figure 1 are actually extracted from a run of our implementation of the EFP.

The official could well refuse to grant a second license, on the grounds that the current demand for space on bar stools is well met. After all, there are no lineups at the El Farol, and the crowd size is remarkably stable. In an act of extrapolation reminiscent of Russell's chicken, one might be tempted to presume that a second bar would do nothing but split the existing demand, possibly leaving neither establishment with enough revenue to continue operating.

As the omniscient modelers, however, we know that every evening some 70 dipsomaniacal agents are sitting at home but would rather be in a bar. Since no explicit price mechanism is in play, individuals cannot readily signal these desires. The attendance levels do not reflect rationing on the basis of willingness to pay, but, rather, on the basis of inductive (in-)accuracy. If this situation is representative of at least some real world phenomenon, then apparently stable markets may be the result of a much more complicated set of interdependent decisions than orthodox theory suggests. To begin exploring these issues, we extended the original EFP to a two bar problem. We named our construct the Extended El Farol Problem (EEFP).

Most fundamentally, we were curious to see if EFP-like agents could operate in a more complicated decision space. To this end, we replicated the original EFP, but gave every agent two sets of predictors to draw from. The second set came into play only after time period 100, when the second bar opened. In the spirit of Arthur, we labeled this establishment The Catamount, after our favorite watering hole in Santa Fe.

As shown in Figure 3, our findings suggest that the basic EFP framework is amenable to this extended problem domain. Indeed, after a sufficiently long period of time, the system settles into an organic equilibrium where each bar supports a crowd of approximately 30 people. Although the complexity of the problem has at least doubled, the emergent property of stable attendance levels and inter-connected self-selection on the basis of idiosyncratic induction persists. Our hypothesized license issuer would clearly have made the wrong decision.

Strawman Heal Thyself

So what do the EFP and EEFP tell us? At the risk of another dubious extrapolation, they hint that in many aspects of economic behavior, the dominant mode of thinking about the world may be wrong-headed. Assumptions of perfect rationality and omniscient price adjustments may not always be the appropriate way to characterize economic activity. Awareness of the possibility of complex interdependence amounts, in effect, to a new sort of identification problem.

To be fair, we may have simply illustrated a strawman argument that has little importance for the real world. It is hardly surprising that the standard model is inappropriate for interpreting artificial data that were produced in a simulation that is so patently non-standard. We have yet to display any data from a genuine process of scientific observation, and shown that it is better explained through the lens of complexity.

A deeper potential criticism is that we are guilty of a category error. In mixing thoughts about reality and models, it could be argued that we are not recognizing that — by deliberate design — a model must be an abstraction; no sensible economist has ever claimed that real consumers spend their time perfectly solving optimization functions. It is precisely because the real world is so complex and interdependent that models are required. This is a valid consideration. Nevertheless, our extended El Farol model is hardly a one-to-one map of the world. Because it is based around a numerical simulation, we would argue that it is, in fact, more straightforward than most standard (i.e., analytical, closed-form) economic constructs.

Implications about the process of modeling, the merits of explanatory and predictive power, and so on, are not, however, the most compelling aspects of this research. What is truly fascinating is how the perspective that this sort of approach provides can be so infectious. It is difficult to think about a problem in this way and then erase that perspective when returning to the real world. Economic phenomena such as fad participation, real estate markets, highway use, and even where to work look much different through the lens of complexity.

To take a topical example, a currency crises, to us, now looks like a failure of heterogeneity. Liquidity disappears not as a result of a shock that all agents perfectly optimize over, but as a complicated set of events that produce a uniformity in inductive predictions; if all believe none will buy, none buy. Mutual interaction and organic webs of interdependence seem suddenly to be everywhere.

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