

Pay Attention to the Physics Analogies in Richard Wagner's *Mind, Society, and Human Action*

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My supreme effort must consist in this:

not to see myself *in me*, but to be seen *by me*, with my own eyes, but as if they
were those of another: that other that everyone sees and I do not.

--Pirendello

Two physics analogies animate Richard Wagner's book *Mind, Society, and Human Action*. Toward the end of the book Wagner points to the literature on "quantum entanglement" by saying that political economy "denotes an entangled network of enterprises that are constituted under different institutional arrangements that generate a continually evolving admixture of cooperation and conflict" (Wagner 2010, p. 160). Just as two distant particles may be "entangled" in physics such that the properties of one depends instantaneously on the properties of the other, the behavior of "private" and "public" enterprises are "entangled" such that the nature of the one type of enterprise is a function of the nature of the other type of enterprise. In the current American system of crony capitalism, for example, "systemic" enterprises are gambling with other people's money and rationally take on, therefore, more risk than otherwise similar enterprises under a regime that does not invite moral hazard by privatizing profits while socializing losses. In this example, the policy regime shapes the risk tolerance of "private" actors.

Second, Wagner points to Neils Bohr's complementarity principle when he says that "economic theory, like physics, requires two distinct theoretical

frameworks,” a timeless neo-Walrasian framework and a dynamic neo-Mengerian framework. Just as we need a model of light as particle *and* a model of light as wave, we need a model of the economy as set of a super-intelligent maximizing choices in the perfect equipoise of static equilibrium *and* a model of the economy as a pulsing network of imperfect humans, each acting on a few shards of doubtful information.

In physics, Schrödinger coined the term “entanglement” (“Verschränkung”), in 1935 although the phenomenon was also noted by Einstein, Podolsky and Rosen in 1935 (Schrödinger 1935a and Einstein, Podolsky and Rosen 1935 as cited in Horodecki et al. 2009). “This feature implies the existence of global states of composite system[s] which cannot be written as a product of the states of individual subsystems” (Horodecki et al. 2009). For example, if two particles bounce off each other, they will determine one another’s position and momentum. If I measure the position of one then, the position of the other is instantaneously determined. They are “entangled” because an observation about one particle instantly creates information about another, distant particle. Einstein seems to have referred to this property of entangled particles as *spukhafte Fernwirkungen*, or “spooky action at a distance” (Buhrman, Cleve, and Van Dam 2001, p. 1829).

When two subsystems are entangled, you cannot describe the overarching system by stringing together independent descriptions of each subsystem. Schrödinger said,

[T]he best possible knowledge of a whole does not necessarily include the best possible knowledge of all its parts, even though they may be entirely separate and therefore virtually capable of being ‘best possibly known,’ i.e., of possessing, each of them, a representative of its own. The lack of knowledge is by no means due to the interaction being insufficiently known — at least not in the way that it could possibly be known more completely — it is due to the interaction itself (Schrödinger 1935b as quoted in Bub 2010).

Such entanglement is a good analogy for a politico-economic system in which public and private entities are oriented to each other. State entities are not neutral referees existing tranquilly above the fray. They are rent-generating enterprises serving a competitive market of rent seekers. Similarly, private firms are not so many *Candides* each quietly tilling the soil of local demand. Many are rent seekers attempting to wrest special favors from “public” enterprises. All profit-seeking enterprises must take into account the policy regime and its uncertainties. Almost no transaction is a simple trade between

private parties because the hand of the state touches most transactions through prohibitions, taxes, regulations, and licensing restrictions. With interventionism, it takes three to tango.

Wagner's use of the entanglement analogy warns us against viewing market and political entities as separate and independent. They are entangled. His use of the complementarity analogy admonishes us to view neo-Walrasian and neo-Mengerian models as separate and independent. We need them both even though they are incompatible. Thus, Wagner's physics analogies help us to see what is and is not separable in economics. Our models of private and public enterprises should not be separable, but static and dynamic models should be separable.

Although Wagner does not explicitly refer to Neils Bohr's complementarity principle, his allusion to it seems pretty clear. The complementarity principle in physics is sometimes summarized as the view that light "is" both wave and particle simultaneously. This expression of the idea is not really appropriate. Bohr did not say that light "is" both wave and particle simultaneously. To say so would be paradoxical and mysterious. The universe revealed by physics must be spooky and weird if light "is" two incompatible things at the same time. It is probably closer to Bohr's meaning to say that we need both *models* of light according to the problem we are addressing. Importantly, both models are incomplete and in some sense unsatisfactory. Mehra and Rechenberg (2000, p.193) quote notes for a lecture Bohr gave in 1927: "The complementary features of the apparent contradictory claims of individuality and superposition [find their] explanation thereby that such agencies as free material particles and radiation in empty space are abstractions according to quantum theory. They can only be observed through their interactions." The seemingly impossible idea of complementarity reflects our existence in the world. To observe the world, we must interact with it and, therefore, act upon it. If we could describe the world without interacting with it, paradoxes such as that of wave/particle duality might disappear. But we are in the world when we observe it and must therefore get along with incomplete and inadequate abstractions that are, as it were, activated only by our interactions with them. The physicist is a part of the world he wants to observe, and physical theory must respect and reflect this fact. Otherwise he is in the position of the psychologist who observed the mood of his patients by seeing how they reacted to insults and concluded that all his subjects were ill-humored.

Wagner's notion of the complementarity between models that are in time and models that are out of time is similar to Bohr's original notion of complementarity. In both cases we have logically incompatible models capturing differing aspects of a complex world that we can understand only

imperfectly. In both cases we need both models and cannot pick one over the other without loss of valuable information. And in both cases, the infirmities of our models are a consequence of our existence in the world we wish to observe.

In both physics and economics we should put ourselves in the model. It is hard to put yourself in the model. Apparently, Einstein's objections to the Copenhagen interpretation of quantum physics were rooted (in part at least) in his desire to preserve the perspective of the "detached observer" (Bub 2010). Whatever may be true of quantum mechanics (a closed book for me), social science should be restructured to reflect the scientist's existence in the world he examines.

The requirement that we put ourselves in the model has been discussed in the past, of course. Adam Smith warned of the "vanity of the philosopher" as Peart & Levy (2005) have noted. Adam Smith also warned us of the "man of system" who "seems to imagine that he can arrange the different members of a great society with as much ease as the hand arranges the different pieces upon a chess-board" (Smith 1790, pp. 380-381). George Soros has helped to coin the term "reflexivity" for problems created by the fact that participants in the system also think about it. Soros (1994) describes a system in which "both the situation and the participants' views are dependent variables so that an initial change precipitates further changes both in the situation and the participants' views" (p. 42). (Soros 1994 was first published in 1987.) He illustrates with a pair of equations in which y is a function of x in the first equation, and x is a different function of y in the second equation. By substitution, Soros shows that y a function of y and x is a function of x . In "situations that have thinking participants," Soros explains in a more recent book, the ("partial and distorted") views of the participants "can influence the situation to which they relate because false views lead to inappropriate actions" (Soros 2010, p. 10). Soros hastens to point out that his notion of "reflexivity" is "obvious" and "common sense." His claim that reflexivity has been "studiously avoided and even denied by economic theory" (2010, p. 10) seems overstated. But it does seem fair to say that economists have not paid enough attention to the problems of reflexivity broadly conceived. It is high time we take reflexivity more seriously.

At least two things follow from the fact that we are a part of our subject in economics. First, if we are in the system, then our ideas about how things work may be shared by the agents in our model, and we had better know what happens when they are. What happens if we fold the model into itself? Second, if the agents in our models respond to incentives, then we must model ourselves and all experts as agents that respond to incentives. David Levy and

Sandra Peart call this principle of methodological symmetry “analytical egalitarianism.” (See, for example, Levy and Peart 2008.)

Rational expectations models fold the model into itself by giving the representative agent the model and the ability to use it. As Peter Boettke has pointed out in a blog comment, this “methodological stricture” is almost the opposite of the more Hayekian requirement of “not assuming that the economist has greater knowledge of the details than the actors” (Boettke 2011). At about the time of the rational expectations revolution Oskar Morgenstern (1972) gave us a different, and perhaps deeper, understanding of what happens when we fold the model into itself. Morgenstern (1972) imagines an economy of naïve agents who then “absorb” the economic theory of such an economy. This “theory absorption” may change their behavior, which might imply the need for a second-level theory. If the second-order theory is absorbed the economist may require a third-order theory, and so on. Does the series converge? Is there a fixed point? The theory of rational expectations simply assumes convergence at some infinite level.

Koppl and Luther (n.d.) provide a quick look at the scant literature on theory absorption. They say, “Morgenstern and Schwödiauer (1976) point out that convergence to the core in game theory requires a certain naivety of the agents. Agents familiar with the theory may be able to achieve outcomes they prefer to the core by engaging in collusive bargaining, which, ironically, makes the core unstable.” Thus, “The theory of convergence to the core is not robust to theory absorption.” Unfortunately, the idea of theory absorption does not seem to have been examined by more than a few economists. Beninghaus et al. (2003) show that a rationality assumption may not close the model if agent models have multiple equilibria. Canning (1992) reaches a related result in the context of computability, though he does not cite Morgenstern (1972) or Beninghaus et al. (2003). Dacey (1976, 1981) and Sandri (2009) also discuss theory absorption.

Morgenstern’s idea of theory absorption does not imply that the model should remain unchanged when folded into itself. Indeed, such a requirement may come to seem like an evasion of reflexivity. To take reflexivity seriously, we must put ourselves in our models. But putting oneself in the model compromises the posture of the “detached observer.” We should try to be disinterested and objective in our analyses, but we are attached to our object of inquiry and a part of it.

Morgenstern imagines a recursive series of systems obtained by folding the system into itself repeatedly. Wolpert (2001) generates important results (in the context of physics and mathematics) by considering simultaneously all “computers” within a system. He generates a series of noncomputability results that do not depend on any particular model of computing. He defines

“computer” broadly enough to include supercomputers, ordinary laptops, and human beings. Wolpert’s results follow from his decision to put all possible “computers” into the system together. He puts all the computers into one model, and does not allow one or more computers to be somehow above the world and independent of it. This move lets him show that for any pair of computers it is impossible for each to reliably predict the output of the other. We may infer that if at least one private actor uses a computer (be it an abacus, a Cray supercomputer, or a human brain) as powerful as that of the policymaker, then the policymaker will make mistakes.

Wolpert’s noncomputability results are unusual and powerful in part because they do not depend on any particular model of computing. Usually, noncomputability results refer to Turing computability. The mathematician constructs a kind of ideal type of a digital computer, which is called a “universal Turing machine” after its originator, Alan Turing (1937). The machine is fed a tape containing a program that embodies some mathematical problem such as computing the largest perfect number less than 12 or computing a best-reply strategy in matching pennies. (In matching pennies, each of us has a penny and picks heads or tails. If we pick the same, I get the two pennies and you get nothing. If we pick differently, you get the two pennies and I get nothing.) If the function is “computable,” then the Turing machine will eventually halt and spool out the answer. A Turing machine can be programmed to compute the largest perfect number less than 12, which is 10; the function is computable. No Turing machine can be programmed to compute a best reply strategy in matching pennies; the function is *not* computable (Koppl and Rosser 2002 pp. 341-348, Prasad 2009). If we feed such a problem to a universal Turing machine, it will buzz, whir, and calculate endlessly, never stopping to spool out an answer. When a universal Turing machine fails to halt, the function is “noncomputable.” (Kleene 1967 is a standard introduction to Turing computability.)

I note in passing that it is surprising that best-reply strategies are not computable in matching pennies. The Nash equilibrium is easily computed, which seems to imply that best replies are computable. It turns out, however, that there is a difference between a participant computing a best-reply strategy and an observer, who is outside of the game, computing a Nash equilibrium. I discuss the point more carefully in Koppl (2008, pp. 838-839) and Koppl (2010, p. 861).

The literature on Turing computability does not address the possibility that an analog computer might be able to solve problems that a digital computer cannot solve. In particular, an analog “hypercomputer” could theoretically compute functions that are not Turing computable (da Costa and Doria 2009 p. 80). Bartholo et al. (2009) say, “It is plausible to believe that an

economic system might act as a hypercomputer” (p. 8). Cockshott et al. (2008) deny that hypercomputers are even theoretically possible. But da Costa and Doria (2009, p. 79) “have always believed that someday someone will build a hypercomputer.”

In contrast to the standard literature on computability, Wolpert’s analysis does not depend on any particular model of a computer. His definition of a computer (2001, p. 016128-18) is somewhat dense. In substance, however, it comes close to saying that a computer is any physically realizable system having something we can reasonably construe as input asking a question and something we can reasonably construe as output answering the question, whether correctly or incorrectly. His definition thus covers hypercomputers if they are physically realizable as believed by da Costa and Doria (2009). It also covers humans. His results hold for people, therefore, “even if Penrose’s musing on quantum gravity and intelligence turns out to be valid—even if human computational powers are not subject to the restrictions that apply to any of the members of the Chomsky hierarchy,” including Turing machines (p. 016128-2).

Wolpert shows that “the universe cannot contain a computer to which one can pose any arbitrary computational task” (2001, p. 016128-1). Any computer that exists in the world will sometimes be mistaken about the world. Wolpert builds on this basic result to show that no computer in the world can predict everything about the world ahead of time. Even if the computer could answer every question about moment $t + x$ given input available at time t , for at least some questions the computer would not be able to spool out its “prediction” until *after* $t + x$. In this sense, no computer can “process information faster than the universe.” Wolpert is thinking about physics. Citing Wolpert (1997), Koppl and Rosser (2002, pp. 354-358) show that his result about the limits of prediction apply to social science as well. Wolpert (2002, pp. 016128-3 and 016128-14) notes that his results are robust to the interpretation of the universe in his analysis; they require only that the computers considered exist within the system in question.

The model of the universe that Wolpert uses to get his unpredictability result is so broad that it “does not rely on temporal orderings of events.” Thus, his unpredictability results also shows that “no computer can infallibly predict the *past*” either (Wolpert 2001, p. 016128-1, emphasis in original). This limit, in turn, implies that memory is fallible. Nor can there be “an infallible general purpose observation device” or “an infallible general purpose control device” (p. 016128-2).

Wolpert’s concept of “god computer” helps to reveal limits to error correction. He defines a god computer as “any physical computer in a set of computers such that all other physical computers in that set are predictable to

the god computer.” Any set of (“pairwise-distinguishable”) computers can have at most one god computer. A god computer is omniscient if it can predict not merely any other individual computer in the set, but all of them simultaneously (Wolpert 2001, p. 016128-10). One might expect that a cooperative combination of fallible computers might be able to achieve perfection through error correction. This does not seem to be the case, however. Consider the case of three (“pairwise-distinguishable”) computers, C^1 , C^2 , and C^3 , where C^2 corrects the prediction C^3 makes about C^1 . “Then it turns out that . . . if C^1 is omniscient, it is not possible that C^2 always correctly inputs a bit saying whether C^3 ’s answer is the correct response to C^3 ’s question.” This result is “a restriction on the efficacy of any error correction scheme in the presence of a distinguishable omniscient computer” (p. 016128-10). (The theological implications of Wolpert’s analysis are intriguing, but well beyond the scope of this comment.)

Wolpert’s impossibility results “are all derived through what is essentially a physical version of a Cretan liar paradox . . . involving two instances of the putative computer rather than self-referential computers” (2001, p. 016128-2). In other words, Wolpert gets his results by putting all computers in the model and thus avoiding the errors created by trying to adopt the perspective of Einstein’s “detached observer.” When you put all computers into the model, self-reference creates computability limits.

To an Austrian economist, Wolpert’s analysis is reminiscent of Hayek’s “diagonal argument” that the human mind cannot fully explain itself. (See Koppl 2010.) I wonder if it might also help to identify what Hayek was talking about when he contrasted “what we can say ‘within a system’ and what we can say ‘about a system.’” (The passage comes from a 1952 letter to Karl Popper as quoted in Kresge 1994, p. 25.) Birner (2009) shows that this distinction is related to the problem of communication and the higher functions of language. I cannot help wondering, however, whether Hayek might have had an even larger issue in mind. Hayek’s letter to Popper continues, “I am convinced that this is a most important problem, since ever since I began to see it clearly I meet it constantly in all sorts of different connections, but though I have made some little headway it is one of the most difficult and elusive problems I have ever tackled” (Kresge 1994, p. 25). If the problem arises “constantly in all sorts of different connections,” then it exceeds (while still including) problems of the communicative and argumentative functions of language. The part that goes beyond these issues of language may be the logical issues of what can be known by an agent from *within a system* and what can be known *about a system* by an imaginary agent existing outside and above it. Perhaps we can imagine someone existing outside a system who has complete and flawless knowledge

about the system. Presumably, it might be possible if the observer is, in some sense, more complex than the system being observed. Whatever may be true for outside observers, Wolpert shows that no one existing *within* the system can have complete and flawless knowledge *about* the system.

We are like the Pirandello's Vitangelo, who attempts in vain to see himself in the mirror as others see him, not as he sees himself. He tries in vain to adopt the perspective of the detached observer. We can probably roughly divide modern economists into those who are attempting to adopt the Einsteinian perspective of the "detached observer," gathering knowledge about the system from above, and those who humbly recognize that our knowledge of the system must be limited and fallible because we are a part of the system.

It is probably fair to say that Keynes was in the first group, attempting to view the system from above and to control it with adroit interventions based in judgment and discretion. Hayek was clearly in the second group, attempting to warn his fellow economists against the pretense of knowledge implied by the perspective of the detached observer. It matters whether we attempt to manage complexity from within the system or from beyond the system. We have some limited ability to manage the system from within. It makes no sense to attempt to manage complexity from beyond the system, however, because we are inevitably *in* the system.

This stuff matters. We can see the importance of such distinctions in the policy response to the financial crisis of 2008. The Dodd-Frank Act chooses the path of discretion and judgment by creating the "Financial Stability Oversight Council," which has broad powers to identify "systemic" financial institutions and apply to them special regulatory restrictions. The list of specified criteria the council shall use to decide whether an institution is "systemic" includes "any other risk-related factors that the Council deems appropriate." In other words, you are a systemic institution if and only if we say so. This top-down approach to financial regulation neglects the fact that regulators are *in the system* and *entangled* with the "private" institutions they regulate. The "private" and "public" actors in the system created by Dodd-Frank model each other and respond to each other. Regulated firms model the regulator and respond to the Financial Stability Oversight Council. Regulated firms will attempt to "capture" the regulators who will surely continue to practice too-big-to-fail. Even if the regulators were motivated only by the common good, the results of Wolpert (2001) should make us doubt that they will be able to predict or control the system reliably enough to do more good than harm. Recall that Wolpert showed that the system cannot include "an infallible general purpose observation device" or "an infallible general purpose control device" (2001, p. 016128-2). Regulators cannot always know what they are doing, and their actions cannot always have the intended effects.

If regulators are in the system, then perhaps we should regulate the regulators in the same way that “private” firms are regulated by markets, namely, through competition. Romano (1998) and Stoll (1998) have outlined plans for competitive regulation of financial institutions. This sort of proposal would be more common if economists would take reflexivity seriously. And it would be more common if economists would take Wagner’s physics analogies more seriously.

Wagner is in the group of economists who humbly recognize our existence in the system and do not imagine themselves to somehow float godlike above the system. Wagner’s physics analogies warn us that “private” and “public” entities are *entangled* and that, because we are in the system we model, because we are entangled too, our models are fallible and incomplete. Theorists of emergent order should study and imitate Wagner’s example of how to theorize from within a system.

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