The Review of Austrian Economics (2022) 35:39–61
https://doi.org/10.1007/s11138-019-00481-w

Hayek, Hicks, Radner and four equilibrium concepts: Perfect foresight, sequential, temporary, and rational expectations

David Glasner[1]

Published online: 30 January 2020

Abstract
Hayek was among the first to realize that for intertemporal equilibrium to obtain all agents must have correct expectations of future prices. Before comparing four categories of intertemporal, the paper explains Hayek's distinction between correct expectations and perfect foresight. The four equilibrium concepts considered are: (1) Perfect foresight equilibrium of which the Arrow-Debreu-McKenzie (ADM) model of equilibrium with complete markets is an alternative version, (2) Radner's sequential equilibrium with incomplete markets, (3) Hicks's temporary equilibrium, as extended by Bliss; (4) the Muth rational-expectations equilibrium as extended by Lucas into macroeconomics. While Hayek's understanding closely resembles Radner's sequential equilibrium, described by Radner as an equilibrium of plans, prices, and price expectations, Hicks's temporary equilibrium seems to have been the natural extension of Hayek's approach. The now dominant Lucas rational-expectations equilibrium misconceives intertemporal equilibrium, suppressing Hayek's insights thereby retreating to a sterile perfect-foresight equilibrium.

Keywords Intertemporal equilibrium · Temporary equilibrium · Rational expectations · Perfect foresight · Arrow-Debreu-McKenzie model · Hayek · Lindahl · Myrdal · Hicks · Bliss · Radner · Muth · Morgenstern · Lucas · Alchian

JEL classification B2 · B3 · B4 · E0 · E3

The views expressed in this paper do not necessarily reflect the views of the Federal Trade Commission or the individual Commissioners

✉ David Glasner
uneasymoney@hotmail.com

[1] Bureau of Economics, Federal Trade Commission, 600 Pennsylvania Avenue NW, Washington, DC 20580, USA

1 The concept of intertemporal equilibrium

Equilibrium is an essential concept in economics. While also essential in other sciences, and probably imported into economics from physics (Canard 1801), equilibrium has a distinct meaning in economics that cannot be derived from its meaning in physics. The dissonance between the physical and economic meanings of equilibrium occasioned a long process of explication and clarification, before the concept and its essential role in economic theory came into clear focus.

Applying the physical meaning of equilibrium, the classical economists regarded an economic system in equilibrium as analogous to a physical system at rest, movement being either absent or repetitive. But what does it mean for an economic system to be at rest? The classical answer was that quantities and prices of goods produced, exchanged and consumed would not change. If the amount supplied equals the amount demanded in each market, and if no exogenous change (e.g., in population, technology, tastes, etc.) disturbs the system, there would be no reason for prices or quantities to change. But because a large, and causally important, subset of economic activity – saving and investment – is predicated on the assumption that prices and quantities do change, the notion of an economic system at rest seemed unrealistic.

Thus, in the works of classical economists, equilibrium was not an achievable state, but simply an end-state toward which economic processes, if allowed to operate without disturbance, were tending. This, not very satisfactory, equilibrium concept of a system at rest was undermined when the neoclassical pioneers, Jevons, Menger and Walras introduced the idea of optimizing decisions by rational decision-making agents. The notion of optimality, later formalized by Pareto, provided the analytical key to transforming the earlier classical equilibrium concept into a more robust and fruitful concept.

If each economic agent (household or business firm) is viewed as making optimal decisions, based on given preferences, and subject to constraints imposed by capacities, endowments, technologies, and the legal system, the equilibrium of an economy can be understood as a state of affairs in which each agent is deciding optimally, and every optimal decision is both consistent with, and, directly or indirectly, contingent upon those of all other agents; the decisions of all buyers of how much to buy must be consistent with the decisions of all sellers of how much to sell. But, like every piece in a jig-saw puzzle, all decisions must fit in with all other decisions. If one decision is suboptimal, none of the decisions contingent upon that decision can be optimal.[1]

The idea of an equilibrium as a set of independently conceived, mutually consistent, optimal decisions was latent in the earlier notions of equilibrium, but it could not be coherently articulated without a formal concept of optimality.[2] The concept of an optimal plan allowed a uniquely economic idea of equilibrium to be formulated, not in terms of stationarity, but in terms of mutually consistent optimal plans.

[1] Individual agents can optimize their plans conditional on the suboptimal plans of other agents, but plans conditioned on the suboptimal plans of other agents will not be socially optimal. For example, a chess player may choose an optimal strategy based on expected moves of his opponent. If both players are optimizing, the game must end in a draw. Note the analogy to the theory of second-best (Lipsey and Lancaster 1956)

[2] An anonymous referee observes that the idea of optimality was in some sense already implicit in Smith (1776), but perhaps first formalized by Pareto, though Wicksteed (1910) may also have some claim to priority.

But an optimal plan may encompass not just actions at a moment in time, it may encompass a sequence of actions to be taken over an interval of time. Indeed, the idea of an optimal plan at least implies a future different from the present. So, once grasped, the idea of equilibrium as the mutual consistency of optimal plans, it became possible to extend the idea to encompass change and development over time. But an extended process of intellectual reflection was required before change and development could be incorporated into an equilibrium framework, allowing time to gain significance beyond merely assigning the label "time" to one of the axes in n-dimensional vector space.

This paper examines the process by which the concept of equilibrium was transformed from a timeless or static concept into an intertemporal one by focusing on the pathbreaking contribution of F. A. Hayek and its relation to subsequent developments of the idea of intertemporal equilibrium. While the idea of intertemporal equilibrium was articulated more or less contemporaneously with Hayek (1928 [1984]) by Lindahl (1929 [1939]) and Myrdal (1927), all three justly sharing credit for priority, in this paper I am especially interested in Hayek's subsequent 1937 paper, which clarified the key distinction between perfect and correct foresight. Confusion about the meaning and interpretation of foresight led to Morgenstern's (1935 [1976]) attack on the idea of equilibrium. Hayek's 1937 paper, apparently a response to Morgenstern's attack on equilibrium, displayed a deep understanding of what is and what is not entailed by the concept of intertemporal equilibrium as the consistency of optimal plans extending through time.

Beyond explaining Hayek's articulation of intertemporal equilibrium, I examine four noteworthy, derivative versions of intertemporal equilibrium in the light of Hayek's articulation: (1) the modern version of a perfect-foresight intertemporal equilibrium embodied in the canonical complete-markets Arrow-Debreu-Mackenzie (ADM) model, (2) Radner's modern incomplete-markets version of Hayek's intertemporal equilibrium as an equilibrium of plans, prices, and price expectations, (3) Hick's incomplete-markets temporary equilibrium, and (4) Lucas's incomplete-markets rational-expectations equilibrium.

Before discussing these versions of intertemporal equilibrium, I summarize in section two Hayek's 1937 contribution, clarifying the necessary conditions for the existence of intertemporal equilibrium. In section three, I elaborate on Hayek's distinction between perfect foresight and contingently correct foresight in response to Morgenstern's attack on equilibrium and the idea of perfect foresight. In section four, I consider Radner's generalization of the ADM model, which in most respects captures Hayek's understanding of a correct- (though imperfect-) foresight intertemporal equilibrium. But in proving the existence of an equilibrium of plans, prices and price expectations, Radner departed from Hayek's philosophically parsimonious view of rationality and knowledge.

In section five, I explore how Hicks's concept of temporary equilibrium, inspired by Hayek, though later credited by Hicks (1965) to Lindahl (1929 [1939]), provides a bridge connecting the hypothetical equilibrium of correct expectations and consistency of plans with the messy real world of disappointed expectations and revised and abandoned plans. The advantage of the temporary-equilibrium approach is to provide the conceptual tools for understanding how financial crises occur and can be propagated and amplified into economic depressions, thereby enabling the kind of business-cycle model that Hayek had tried to create. But while Hicks omitted mention of Hayek's insights in articulating the temporary-equilibrium approach, Hayek, for his

part, failed to grasp that temporary equilibrium could serve as a modeling strategy by which the equilibrium method could be adapted to the reality of the expectational inconsistency among agents that characterizes disequilibrium.[3]

Finally, in section six, I discuss rational expectations in macroeconomic models, mainly to argue that it assumes away the problem of expectational convergence and plan consistency with which Hayek, Hicks, Radner and others who developed the idea of intertemporal equilibrium were so profoundly concerned. Rational expectations thereby became the vehicle by which the complete-markets, virtual-perfect-foresight ADM model could be deployed as a macroeconomic model, even though, as I hope becomes clear in what follows, the ADM model is fundamentally unequipped and unsuited for analyzing macroeconomic fluctuations. I conclude in section seven.

2 Hayek and intertemporal equilibrium

Because current goods and services, and otherwise identical, future goods and services can be treated as economically distinct, defining the conditions for an intertemporal equilibrium is formally equivalent to defining the conditions for a static equilibrium. Just as the conditions for a static equilibrium may be stated in terms of equalities between the marginal rates of substitution between goods and their corresponding price ratios, the conditions for an intertemporal equilibrium could be stated in terms of equalities between the marginal rates of intertemporal substitution and corresponding intertemporal price ratios (Bliss 1975).[4]

[3] I refer to "expectational inconsistency" among agents rather than "expectational error" to underscore that inconsistent expectations are a sufficient condition for disequilibrium while "incorrect expectations" held by all agents could potentially be equilibrium expectations in a possible (though not actual) state of the world.

[4] I cite Bliss (1975) for his explicit and remarkably clear and penetrating explanation that the rate of interest is a relationship implicit in the structure of an intertemporal general equilibrium price vector. But the key point was already made by Fisher (1898, 1907). The following passage effectively makes the point that the rate of interest cannot be analyzed as being determined through a partial-equilibrium analysis of the market for loanable funds, but must be analyzed as a general-equilibrium phenomenon:

> If a modern business man is asked what determines the rate of interest, he may. .. answer, "the supply and demand of loanable money." But "supply and demand" is a phrase which has been too often into service to cover up difficult problems. Even economists have been prone to employ it to describe economic causation which they could not unravel.. .. It is true that every ratio of exchange is due to the resultant of causes operating on the buyer and seller, and we may classify these as "demand" and supply." But this fact does not relieve us of the necessity of examining specifically the two sets of causes, including utility in its effect on demand, and cost in its effect on supply. Consequently, when we say that the rate of interest is due to the supply and demand of "capital" or of "money" or of "loans," we are very far from having an adequate explanation. It is true that when merchants seek to discount bills at a bank in large numbers and for large amounts, the rate of interest will tend to be low. But we must inquire for what purposes and from what causes merchants thus apply to a bank for the discount of loans and others supply the bank with the funds to be loaned. The real problem is: What causes make the demand for loans and what causes make the supply? This question is not answered by the summary "supply and demand" theory. The explanation is not simply that those who have little capital demand them. In fact, the contrary is often the case. (Fisher 1907, pp. 6–7)

Where Fisher's formulation falls short of Hayek's is in not explicitly recognizing the role of price expectations and plan consistency in characterizing an intertemporal general equilibrium as an intertemporal equilibrium vector of current and *expected* future prices.

The formal identity between the necessary conditions for a static equilibrium and the necessary conditions for an intertemporal equilibrium is preserved in the ADM model with a complete set of forward markets covering all contingent events. However, that formal identity cannot be maintained without a complete set of markets, because agents can optimize based on their *common knowledge* of actual prices only if they all have immediate access to all current and forward prices. With incomplete forward markets, agents must optimize based on *expected* – not known – future prices.

With complete forward and contingent markets, the resulting intertemporal equilibrium presupposes that all economic decisions are made *before* any production and consumption begins. The passage of time is conceptual, and all decisions are pre-programmed. The unrealism of the ADM paradigm is impressive, rendering money and asset markets superfluous. Though intertemporal in the sense that actual production and consumption are presumed to occur in a sequence of distinct time periods, all decisions are made once and irrevocably.

However, in a minimally realistic intertemporal model, unlike a static model or the quasi-static ADM model, marginal rates of substitution cannot be equated with ratios of known actual prices. Instead, marginal rates of substitution in a true intertemporal model must be equated either with ratios of *unknown expected* prices to known actual prices or with ratios of *unknown expected* prices to other *unknown expected* prices. It follows that unless all economic agents have the same expectations of the future prices in terms of which they formulate their optimal plans, their plans cannot be mutually consistent.

Although Hayek (1937) provided the first English articulation of the concept of intertemporal equilibrium, it was from Hicks (1939) that the concept became widely known. Hicks distinguished between a full dynamic equilibrium in which expectations are correct and a temporary equilibrium in which expectations may be incorrect while current prices adjust to clear current (spot) markets.[5] Despite generally acknowledging Hayek's contribution to the ideas presented, Hicks did not acknowledge Hayek's, or any author's, contribution to the idea of intertemporal equilibrium.[6]

Although the ADM model is now considered the canonical version of an intertemporal equilibrium model, the assumption of complete forward and contingent markets upon which it rests attenuate its status as an intertemporal model. At time zero,

[5] Flow demands and flow supplies need not be equal, but accumulation or decumulation of stocks is voluntary in the sense that, given the future price expectations of stock holders, stock holdings increase or decrease by the amounts desired. See Hicks (1982, 232)

> What makes the difference is that on the flexprice method it is insisted that the producer will only accumulate stocks if he thinks that the price he will be able to get, by selling them in some future period, will be better (in spite of the costs of holding) than what he could get by selling now; so in this sense the accumulation is *voluntary*. If the behaviour of all markets is interpreted in this manner, the system is regarded as being *in equilibrium* all the time.. .. The flexprice method is a *temporary equilibrium* method.

[6] Milgate (1979) drew attention to Hayek's key role in developing the idea of intertemporal equilibrium in terms of the consistency of decentralized optimal plans and to document Hayek's claim to priority in introducing the concept to economists. See Currie and Steedman (1989) for an illuminating and insightful comparison of the evolution of Hayek's and Lindahl's understanding of intertemporal equilibrium between 1928 and 1939.

not only does trading for all future time periods take place, contingent trading also occurs for all future time periods. Just as identical goods traded at distinct prices for delivery at distinct times and places, identical goods can be distinguished under different states of the world (an ice cream cone on July 4, 2020 in Washington DC at 2 pm only if the temperature is above 90 degrees). Given complete state-contingent markets and the known probabilities of the contingent events, an equilibrium price vector for the complete set of markets would result in optimal trades reallocating the risks associated with future contingencies, thereby allowing optimal resource-allocation across space, time, and states of the world.

The assumptions of the ADM model replace what was called a perfect-foresight equilibrium, in which agents can foresee the future, but those assumptions – that agents across all future time periods gather at time zero to trade at an equilibrium price vector covering all time periods and all possible states of the world, for which states they assign accurate probabilities – seemno less extreme than perfect foresight.

The seminal contribution of Radner (1972, 1979, 1982) of relaxing the extreme assumptions of the ADM model, underscores Hayek's earlier contribution. At an informal level, Hayek had addressed the same problem Radner, deploying analytical tools unavailable to Hayek, took up: under what conditions could agents, lacking both perfect foresight and complete markets, reach a state of intertemporal equilibrium? Without complete forward and state-contingent markets, an intertemporal equilibrium is not determined in advance; it must unfold as time passes. Outcomes are not predetermined – only anticipated.

Echoing Hayek, Radner described intertemporal equilibrium under uncertainty as an equilibrium of plans, prices, and price expectations (EPPPE). Even if it exists, the Radner equilibrium differs from an ADM equilibrium, because with incomplete markets, agents are still subject to unavoidable uncertainty. The distinction between ex ante and ex post, absent from the ADM equilibrium, is inherent in the Radner equilibrium.

Additionally, because trading in the ADM model occurs before "time" starts, neither the holding of an asset used only as a medium of exchange nor the existence of a liquidity premium can be rationalized.[7] In early writings, Hayek (1927 [1933]) seemed to grasp this point, questioning whether the holding of money could be explained in a model of full equilibrium, observing that the direct connection between aggregate demand and aggregate supply characteristic of a barter economy is broken when money is held and used as a medium of exchange. The shift from a barter to a money economy implies that Say's Law can be violated, and that cumulative deviations from an equilibrium time-path may occur.

Hayek never realized his early hopes that the Walrasian equilibrium method could accommodate the existence of money, uncertainty, and other features of the real world, bringing the analytical rigor of the optimality principle and the equilibrium method to bear on the study of economic fluctuations. Although that research program required resources beyond those at Hayek's, disposal, it would be unfair to fault Hayek for perceiving and framing a problem he could not solve.

But nearly at the end of Hayek's intense engagement with business-cycle theory, Hicks (1939) introduced the concept of temporary equilibrium as an alternative

[7] Patinkin (1965) "solved" the problem of explaining why money is held in general equilibrium with an ad hoc assumption that real money balances are an argument in household utility functions.

approach to studying economic fluctuations. Recognizing the key point that full intertemporal equilibrium requires that agents condition their plans upon correctly foreseen future prices, Hicks suggested restricting the assumption of equilibrium and market-clearing to the current period while allowing agents to base their plans to purchase and sell in the current period on diverging, and therefore incorrect, expectations of future prices. Hayek (1941), however, dismissed the idea of temporary equilibrium.

Moreover, the holding of an asset as a medium of exchange and the provision by financial intermediaries of credit instruments that serve as a medium of exchange can be rationalized in a temporary-equilibrium framework (Bliss 1976). In temporary equilibrium, not only can the private supply of a medium of exchange be modeled, but the systemic breakdowns and financial crises can be explained, along lines sketched by Hawtrey (1913), as the result of the divergent expectations held by agents and financial intermediaries. Sufficient divergences of actual from expected prices may even preclude the existence of a temporary equilibrium. Perfect price flexibility cannot ensure that a non-existing equilibrium will be reached.

In a general-equilibrium framework with incomplete markets, price expectations, like spot prices, are equilibrating variables, in the sense that an equilibrium exists only a subset of potential values of prices and of expected prices; some prices and some expected prices are inconsistent with equilibrium.[8] Although we have a partial-equilibrium theory of how spot prices tend to reach their equilibrium values, we have no comparable theory for expected-price equilibration. The rational-expectations postulate imposes expected-price equilibration as a methodological axiom implied by optimizing behavior rather than a theoretical result deduced from a theory of market interactions. The macroeconomic significance of the methodologically imposed rational-expectations axiom, I shall argue below (section VI), is to reintroduce the assumption of perfect foresight.

3 Correct versus perfect foresight in intertemporal equilibrium

I have suggested that Hayek's key conceptual breakthrough was to view equilibrium not as a stationary state, but as a state in which decentralized plans are both optimal, from the perspective of those formulating them, and mutually consistent, so that the individual plans could, potentially, be executed simultaneously without revision or regret.

In an intertemporal context, optimal plans cannot be formulated on the basis of just those prices at which transactions are being executed at present; the relevant set of prices must also include the future prices at which planned future transactions will be executed. Because even decisions about current transactions depend on the anticipated prices at which future transactions occur, future prices affect both current and future demands and supplies. So the problem posed by the concept of intertemporal equilibrium is to generalize the notion of an equilibrium as a vector of all currently observed

[8] Under certain conditions, there may be expected prices that are self-fulfilling and give rise to sunspot equilibria or rational bubbles (Cass and Shell 1983). Such equilibria require a convergence of individual expectations.

prices of goods and services into a multi-period context in which the equilibrium price vector includes both the prices of goods currently traded and the prices of goods that agents plan to buy or sell in the future.

But without a complete set of forward markets, the future prices on which plans are formulated can only be anticipated, not known. And unless each plan is formulated on the basis of the same vector of anticipated prices, not all those individually optimal plans can be executed without revision, because at least some of those plans, having been based on incorrect price expectations, will turn out to be sub-optimal relative to the actual price vector.

The recognition that the mutual consistency of optimal plans requires individuals to foresee the future prices upon which their optimal choices are conditioned suggests that intertemporal equilibrium cannot be attained unless individual agents are endowed with extraordinary capacities of foresight. This inference led Oskar Morgenstern (1935 [1976]) to launch a strident attack against the concept of equilibrium as dependent on the self-contradictory, assumption of perfect foresight.

> The impossibly high claims . . . attributed to the intellectual efficiency of the economic subject immediately indicate that there are included in this equilibrium system not ordinary men, but rather . . . exactly equal demi-gods, in case the claim of complete foresight is fulfilled. If this is the case, there is, of course, nothing more to be done. If "full" or "perfect" foresight is to provide the basis of the theory of equilibrium in the strictly specified sense, and in the meaning obviously intended by the economic authors, then, a completely meaningless assumption is being considered. If limitations are introduced in such a way that the perfection of foresight is not reached, then these limitations are to be stated very precisely. They would have to be so narrowly drawn that the fundamental aim of producing ostensibly full rationality of the system by means of high, de facto unlimited, foresight, would be lost. For the theoretical economist, there is no way out of this dilemma.

Continuing in this vein, Morgenstern reinforced his argument against perfect foresight by invoking an example that would reappear in the famous work on game theory by von Neumann and Morgenstern (1944).[9]

> Sherlock Holmes, pursued by his opponent, Moriarity, leaves London for Dover. The train stops at a station on the way, and he alights there rather than traveling on to Dover. He has seen Moriarity at the railway station, recognizes that he is very clever and expects that Moriarity will take a faster special train in order to catch him in Dover. Holmes' anticipation turns out to be correct. But what if Moriarity had been still more clever, had estimated Holmes' mental abilities better and had foreseen his actions accordingly? Then, obviously, he would have traveled to the intermediate station. Holmes,

[9] Düppe and Weintraub (2016) have recently documented the importance of the contribution made by Morgenstern's research assistant, Abraham Wald, who was his mathematical mentor, and arguably deserving of co-authorship of *The Theory of Games and Economic Behavior* and thus recognition as a co-founder of game theory.

> again, would have had to calculate that, and he himself would have decided to go on to Dover. Whereupon, Moriarity would again have "reacted" differently. Because of so much thinking they might not have been able to act at all or the intellectually weaker of the two would have surrendered to the other in the Victoria Station, since the whole flight would have become unnecessary. Examples of this kind can be drawn from everywhere. However, chess, strategy, etc. presuppose expert knowledge, which encumbers the example unnecessarily.
>
> One may be easily convinced that here lies an insoluble paradox. And the situation is not improved, but, rather, greatly aggravated if we assume that more than two individuals-as, for example, is the case with exchange-are brought together into a position, which would correspond to the one brought forward here. Always, there is exhibited an endless chain of reciprocally conjectural reactions and counter-reactions. This chain can never be broken by an act of knowledge but always only through an arbitrary act-a resolution. This resolution, again, would have to be foreseen by the two or more persons concerned. The paradox still remains no matter how one attempts to twist or turn things around. Unlimited foresight and economic equilibrium are thus irreconcilable with one another. But can equilibrium really take place with a faulty, heterogeneous foresight, however, it may be disposed? This is the question which arises at once when an answer is sought. One can even say this: has foresight been truly introduced at all into the consideration of equilibrium, or, rather, does not the theorem of equilibrium generally stand in no proven connection with the assumptions about foresight, so that a false assumption is being considered?

Zappia (1999) suggests that Morgenstern's attack on intertemporal equilibrium and perfect foresight prompted Hayek's (1937) articulation of the idea. Hayek's insight was that an intertemporal equilibrium is not the causal result of correct foresight. Rather, correct foresight is a defining property of "intertemporal equilibrium." Morgenstern's error was to mistake a tautological statement about what must be true if intertemporal equilibrium obtains for a statement about what causes a state of intertemporal equilibrium to be reached. As Hayek (pp. 41–42) put it,

> Correct foresight is then not, as it has sometimes been misunderstood, a precondition which must exist in order that equilibrium may be arrived at. It is rather the defining characteristic of a state of equilibrium. Nor need foresight for this purpose be perfect in the sense that it need extend into the indefinite future, or that everybody must foresee everything correctly. We should rather say that equilibrium will last so long as the anticipations prove correct, and that they need to be correct only on those points which are relevant for the decisions of the individuals.

It is worth noting that, under a probabilistic interpretation of the interaction between Holmes and Moriarity, there could be equilibrium mixed strategies in a repeated Holmes-Moriarity game. But if the interaction is a unique non-repeatable event, the

correct interpretation of the interaction is not that correct foresight is impossible, but that the game has no equilibrium solution.[10] It is therefore precisely the non-existence of an equilibrium that renders correct foresight logically impossible. It is the existence of an equilibrium that makes correct foresight possible, not perfect foresight that makes equilibrium possible.

4 Radner on the equilibrium of plans, prices, and price expectations

In this section, I discuss Radner's treatment of an equilibrium of plans, prices, and price expectations (EPPPE) and its relationship to Hayek's conception of intertemporal equilibrium. Although I have seen no evidence that Radner was influenced by Hayek, Radner's conception of EPPPE can be viewed as a technically sophisticated version of Hayek's conception of intertemporal equilibrium as a state in which agents, independently formulating their optimal plans based on observed current prices and conditional on expected future prices, execute their plans as intended. While currently observed prices are treated as common knowledge, expected future prices are conjectures, based partly on common knowledge and partly on private knowledge along with the subjective methods used to form expectations of future prices.

The mutual consistency of the optimal plans of agents follows from the assumption that all agents observe the same current prices – their common knowledge – and make the same forecasts of the future prices upon which their optimal plans are conditioned. Even if their forecasts of future prices are disappointed, their plans remain mutually consistent and, relative to the information on which those plans were chosen, optimal. The failure of equilibrium to be realized is attributable to new information rendering formerly optimal plans sub-optimal. But until new information becomes available, the mutual consistency of optimal plans signifies, at least momentarily, an equilibrium state.

The EPPPE, being an equilibrium characterized by a vector of observed current and expected future prices, differs fundamentally from the ADM equilibrium in which equilibrium prices over all future time periods become common knowledge before trading starts. Furthermore, under the assumptions of the ADM model, the equilibrium is Pareto-optimal, and any Pareto-optimum allocation, by a suitable redistribution of initial endowments, could be achieved as a general equilibrium (two welfare theorems). These results do not generally hold for EPPPE, because, in contrast to the ADM model, agents in EPPPE can acquire additional information over time, not only passively, but by devoting resources to produce or acquire information.

Devoting resources to obtaining information can cause inefficiency in two ways: first, by creating non-convexities (owing to start-up costs in information-gathering activities) inconsistent with the uniform prices characteristic of the ADM equilibrium; second, by creating incentives to devote resources to acquire information whose value derives from trading with those lacking the information (Hirshleifer 1971).

[10] Alternatively, as Koppl and Rosser (2002) argued, even if there is a mixed (probabilistic) strategy that could be considered an equilibrium solution of a non-repeated game, the equilibrium mixed probabilistic could not necessarily be found in a finite number of iterations owing to the reflexive nature of the problem.

But the salient macroeconomic distinction between the EPPPE and the ADM equilibrium is the fragility of EPPPE. Unlike the ADM equilibrium, established once and forever at time zero, the EPPPE, even if achieved, is momentary and subject to revision or disequilibrium as new information induces changes in current or expected future prices, requiring agents to revise or replace formerly optimal plans.

In the EPPPE, time is not, as it is in the ADM model, a mere appendage (Bliss 1976, 187). EPPPE therefore accounts for phenomena, practices, and institutions excluded from the ADM model, e.g., stock markets in which ownership shares of firms, capitalizing the expected future income streams generated by those firms, are traded, and a medium of exchange supplied by banks. Each agent in the ADM model faces, at time zero, an intertemporal budget constraint over periods from 1 to n. Given that constraint, Walras's Law holds across all time periods, all agents transacting at the same n-period price vector. The solvency and the integrity of all parties to all transactions being assured through the trading process at time zero, a loan default is impossible, and all agents can trade income between time periods at the same intertemporal price ratios. All transactions being costlessly and irrevocably executed at time zero, holding or supplying a medium of exchange cannot be rationalized.

Moreover, an equilibrium vector of all future prices having been announced at time zero, each agent knows that optimal plans conditioned on those prices will be executed exactly as formulated. The future income streams from each firm being known in advance, a market for trading shares of firms would be redundant.

The ADM equilibrium describes a process different from Radner's EPPPE, because, in EPPPE, agents cannot assume that their current plans will remain so, even if those plans are at any time both optimal and mutually consistent with those of all other agents. Unlike the ADM equilibrium, EPPPE does not exclude the possibility that the prevailing equilibrium will be upset by new information, rendering formerly optimal plans incompatible.

The possibility that optimal plans may need to be revised compells agents to consider the solvency of counterparties. The potential for insolvency allows financial intermediaries (aka banks) to offer their debt, generally more acceptable than that of other agents, in exchange for the debt of non-banks seeking to finance purchases of consumption or investment goods. Many agents therefore exchange their own debt for generally accepted bank debt with fixed face value. Moreover, as new information becomes available, agents may undertake speculative trades of commodities or assets. Such assets include shares of firms, and agents may revise their valuations of shares as they revise their expectations of future prices.[11]

I discuss the special role of banks at greater length in the following section on temporary equilibrium. But one point merits immediate attention: in the EPPPE, if agents hold differing expectations of future prices, Walras's Law may be violated. The standard proof of Walras's Law assumes that the market price for any commodity (defined by location and time period) is the same price in all transactions. But in the EPPPE, in which only current, not future, prices are observed, plans are formulated based on expected future prices. If agents hold different price expectations for the same commodity, then some of those expectations must be disappointed. Agents, whose

[11] As noted above in fn. 8, the possibility of an equilibrium bubble cannot be ruled out, though defining a "speculative bubble" may be tricky.

plans were conditioned on overly optimistic price expectations, may find themselves unable to discharge commitments to buy (or future commitments to repay debts financing present purchase) leading to the violation of Walras's Law.

Finally, a word about Radner's terminology. Radner (1987, 312) writes:

> A trader's expectations concern both future environmental events and future prices. Regarding expectations about future environmental events, there is no conceptual problem. According to the Expected Utility Hypothesis, each trader is characterized by a subjective probability measure on the set of complete histories of the environment. Since, by definition, the evolution of the environment is exogenous, a trader's conditional probability of a future event, given the information to date, is well defined.
>
> It is not so obvious how to proceed with regard to trader's expectations about future prices. I shall contrast two possible approaches. In the first, which I shall call the perfect foresight approach, let us assume that the behaviour of traders is such as to determine, for each complete history of the environment, a unique corresponding sequence of price system[s]. . .
>
> Thus, the perfect foresight approach implies that, in equilibrium, traders have common price expectation functions. These price expectation functions indicate, for each date-event pair, what the equilibrium price system would be in the corresponding market at that date-event pair. . . . [I]t follows that, in equilibrium the traders would have strategies (plans) such that if these strategies were carried out, the markets would be cleared at each date-event pair. Call such plans *consistent*. A set of common price expectations and corresponding consistent plans is called an *equilibrium of plans, prices, and price expectations*.

My only reservation about Radner's formulation concerns the definition of equilibrium in terms of the capacity of traders to predict prices rather than in terms of the correctness of their expectations. Why traders can predict future prices correctly is irrelevant for the definition of EPPPE. When agents' price expectations are momentarily in accord, it is irrelevant whether expectations are in accord because agents share the correct model of the economy, or because they randomly formed matching expectations of future prices.

Nevertheless, by pursuing the idea that agents have their own models of how the economy works, Radner modified the perfect-foresight approach in which all relevant information is held in common. In such cases, by observing that prices differ from what had been expected, agents may be able to draw corresponding inferences about their environment.

> The situation in which traders enter the market with different non-price information presents an opportunity for agents to learn about the environment from prices, since current prices reflect, in a possibly complicated manner, the non-price information signals received by the various agents. To take an extreme example, the "inside information" of a trader in a securities market may lead him to bid up the price to a level higher than it otherwise would have been. . . . [A]n

> astute market observer might be able to infer that an insider has obtained some favourable information, just by careful observation of the price movement. (p. 313)

The ability to infer non-price information from otherwise inexplicable movements in prices suggested to Radner a particular concept of rational-expectations equilibrium.

> [E]conomic agents have the opportunity to revise their individual models in the light of observations and published data. Hence, there is a feedback from the true relationship to the individual models. An equilibrium of this system, in which the individual models are identical with the true model, is called a rational expectations equilibrium. This concept of equilibrium is more subtle, of course, than the ordinary concept of equilibrium of supply and demand. In a rational-expectations equilibrium, not only are prices determined so as to equate supply and demand, but individual economic agents correctly perceive the true relationship between the non-price information received by the market participants and the resulting equilibrium market prices. (p. 313)

While proposing an interesting line of theoretical inquiry, Radner departs from Hayek's (1937) distinction between the necessary conditions for an intertemporal equilibrium to obtain and the assumptions that entail satisfaction of those conditions. If all agents formulate their optimal plans based on the same vector of current and expected future prices, those optimal plans are potentially consistent and will be successfully executed without revision if the underlying common knowledge upon which their plans were conditioned proves to have been correct. How it happened that they arrived at identical expectations – by luck, chance or supernatural powers of foresight – is irrelevant to the definition of equilibrium.

At any rate, Radner properly recognized that, to be a useful tool of positive analysis, equilibrium theory had to be revised in a way that relaxed the necessary conditions for equilibrium to obtain. And although EPPPE accommodates a richer set of activities and institutions than the ADM (virtual perfect-foresight) equilibrium, Radner argued for a further relaxation of the assumptions to allow incorrect future price expectations to be accommodated within an equilibrium analytical framework.

> Although it is capable of describing a richer set of institutions and behavior than is the Arrow-Debreu model, the perfect-foresight approach is contrary to the spirit of much of competitive market theory in that it postulates that individual traders must be able to forecast . . . the equilibrium prices that will prevail in the future under all alternative states of the environment. . . .[T]his approach . . . seems to require of the traders a capacity for imagination and computation far beyond what is realistic. . . .
>
> These last considerations lead us in a different direction, which I shall call the bounded rationality approach. This approach . . . expresses itself in terms of various retreats from the hypothesis of "fully rational" behavior by traders. . . . An

> example of the bounded-rationality approach is the theory of temporary equilibrium. (pp. 313-14)

Irrespective of the "rationality" or computational powers of agents, the key issue is whether agents share identical expectations of future prices. If expectations are in accord, a momentary equilibrium of plans, prices and price expectations, though not guaranteed, is possible. When expectations diverge, a temporary equilibrium may not even exist, and what kind of dynamic path(s) is (are) associated with diverging expectations is unclear. In the next section, I discuss the characteristics and implications of a temporary-equilibrium approach for macroeconomics.

5 Hayek, Hicks, and temporary equilibrium

What defines an intertemporal equilibrium is that agents share the same – correct – expectations of future prices over their planning horizons. In such an equilibrium, the optimizing plans of the agents are at least momentarily consistent, because, given those expectations, none of the agents would change its optimal plan provided that price expectations do not change, or are not disappointed.

A natural generalization of the intertemporal equilibrium concept is for agents to hold different price expectations reflecting differences in information or the processing of information. But given informational differences, agents' subjectively optimal plans will be inconsistent and incapable of simultaneous implementation without revision. Unfortunately, this generalization seems incompatible with the sequential equilibrium of optimal plans, prices and price expectations conceived by Hayek and elaborated by Radner. As Radner recognized in the passage quoted at the end of the previous section, relaxing the assumption that agents have correct expectations about future prices means a retreat from the assumption of full rationality, full rationality requiring that each agent optimize subject to the optimal plans of all other agents.

The question arises how the absence of an equilibrium in which agents are executing optimal plans can be reconciled with the intuitive notion of market clearing, routinely applied to markets for assets, for current delivery, and for services. If those markets are in equilibrium, in the sense that prices adjust to equate the quantities demanded and supplied, how can the inconsistency of the optimizing plans of agents be reconciled with market-clearing equilibrium?

Hicks (1939) was the first to analyze this intermediate situation, which in one sense is, and in another is not, an equilibrium. Agents' divergent price expectations on the basis of which they formulate optimal plans makes it inevitable that at least some of those expectations will be disappointed, so that at least some agents will be unable to execute their originally formulated plans.

Hayek, in his early writings, suggested analyzing business cycles as deviations from an equilibrium path. The problem Hayek struggled with was that equilibrium analysis can characterize the equilibrium path of an economy, but not a non-equilibrium path, corresponding to attempts by agents to implement incompatible plans that must be revised or replaced. When the optimality (aka rationality) postulate is inapplicable, standard equilibrium methods are analytically suspect.

Hayek ([1927] 1933, 1931) attributed cumulative cyclical deviations from an equilibrium path to the lagged effects of monetary expansion, which cause an unsustainable, investment-driven increase of output and employment followed by a disappointment of expectations leading to a cumulative decrease in output and employment. But Hayek's use of equilibrium analysis to explain business-cycle fluctuations was largely unsuccessful, and his monetary theory of the cycle remained inconsistent with standard equilibrium analysis.

In temporary equilibrium, all spot prices adjust to clear markets for assets and current delivery. If future prices deviate from current expectations, agents will revise or replace plans based on incorrect expectations. At the end of his efforts to fashion a coherent business-cycle theory in a Walrasian general-equilibrium framework, Hayek (1941, 44-45) briefly considered temporary equilibrium as an alternative to the Walrasian intertemporal- equilibrium framework, only to dismiss it. Yet, Hicksian temporary equilibrium would have provided Hayek with an alernative framework within which to analyze the divergent expectations that lead first to an expansion and then, as expectations adjust, trigger a downturn and, with a variable lag, a recovery.[12]

How could a temporary-equilibrium method have enabled Hayek to describe the conditions for a cumulative monetary disequilibrium? I make no attempt to outline a specifically Hayekian theory of monetary disequilibrium, though others may find such an endeavor worthwhile. My focus is on monetary effects without attending to the capital-theoretic analysis on which Hayek laid, in my view undue, stress.

As noted above, agents are aware that their price expectations may not be implemented as planned, recognizing that their plans may require revision or replacement, and that, given such uncertainty, not all debt instruments are equally reliable. The general understanding that debt instruments – promises to make future payments – must be assessed makes specializing in debt assessment by financial intermediaries profitable.

A particular kind of financial intermediary – banks – is of special interest. After assessing the debt instruments offered by non-banks, the bank selects those instruments that it considers sufficiently reliable to be accepted in exchange for the bank's instruments. Non-banks do not generally accept the instruments of non-banks on terms as favorable as those offered by banks. In return for non-bank instruments, the bank issues borrowers a corresponding amount of its own instruments, which, because the bank promises to redeem those instruments for the numeraire commodity on demand at a fixed prespecified rate, are generally accepted at face value. Banks' debt instruments therefore serve as a medium of exchange, enabling non-banks to make expenditures they might not otherwise have made.

In assessing a prospective borrower's creditworthiness, a bank makes two judgments. First, is the income-earning capacity of the borrower sufficient to make the repayments to which the borrower commits himself? Second, if the borrower is unable

[12] Keynes (1936) also sought to provide a vehicle whereby equilibrium analysis could be made applicable to a disequilibrium phenomenon. But instead of pursuing an intertemporal equilibrium approach, Keynes fell back on a single-period multiplier analysis with appendages like the explicitly forward-looking marginal efficiency of capital that remained in the background of his one-period equilibrium model. See Laidler (1998) for insightful discussion of these issues.

to meet its repayment obligations, does the borrower post sufficient collateral to allow the debt to be recovered? In making those judgments, the bank must assess both the future income of the borrower and the future value of the collateral.

In a temporary equilibrium, agents hold differing price expectations, so that they are vulnerable if they incur obligations conditioned on overly optimistic price expectations. If they hold assets of sufficient value, they may still be able to meet their obligations by selling assets. Besides selling assets, they may have to reduce expenditures, thereby reducing the incomes of other agents below their expectations. Many agents will prefer to finance current obligations by borrowing and repaying on a fixed schedule to distress liquidation of assets, but only prospective borrowers able to show creditworthiness, which, in turn, depends on prices and expected prices, will be able to borrow.

Agents whose price expectations have been disappointed, whether they can borrow or must liquidate assets, will revise previous plans, primarily by reducing expenditures. The disappointment of some agents' expectations becomes cumulative when the disappointment of their optimistic expectations is not offset by the better-than-expected results of other agents (Hawtrey 1913).

If the disappointment of optimistic price expectations is of sufficient magnitude, or if the disappointment is systematic, for example, prices falling generally below what they had been expected to be, a systemic contractionary process may start (Fisher 1933). If so, instead of revising their plans, some agents may choose, or may be forced, to abandon them entirely. In general, beyond some threshold level of disappointment, previously optimal plans will be abandoned, rather than revised, by firms that stop producing and by households that stop working.

When agents whose price expectations have been disappointed respond with marginal revisions of existing plans rather than scrapping them or replacing them with new ones, a temporary equilibrium with disappointed expectations may still exist, and price adjustments in the markets for current delivery may achieve a temporary equilibrium with markets for current delivery clearing, notwithstanding that agents hold divergent expectations of future prices. A sub-optimal temporary equilibrium is inferior to the allocation that would have resulted had all agents correctly anticipated future prices, but given a history of incorrect price expectations and misallocations of capital assets, labor, and other factors of production, the sub-optimal temporary equilibrium may be the best currently feasible outcome.[13]

But the existence of a temporary equilibrium cannot be taken for granted. If actual prices differ from what they were expected to be, sufficiently large deviations of actual from expected prices in markets for current delivery may imply discontinuous changes in the excess demands of agents (Bliss 1976, pp. 199–201). When the price of a product falls below some threshold, one or more firms producing that product will cease producing it, either shutting down or switching to the production of another. Moreover, below some threshold price for a product, firms producing the product may be forced into bankruptcy, and households with ownership shares in the firm may also face bankruptcy, especially if households anticipating high prices borrowed on that expectation and cannot repay their loans at the current price. The implied discontinuities in

[13] Of course, even if a price vector consistent with temporary equilibrium exists, there is no assurance that the temporary-equilibrium price vector will be arrived at.

excess-demand functions make it difficult to apply the standard fixed-point theorems normally used to demonstrate the existence of an equilibrium.[14]

If ownership shares in a firm forced to cease production are held by households that have predicated their consumption plans on prior borrowing and current repayment obligations, those households may be unable to fulfill their obligations once those firms stop paying dividends and share prices plummet. The net worth of banks holding debts incurred by firms or households that borrowers cannot service may be reduced sufficiently to impair the creditworthiness of the banks, potentially leading to a systemic breakdown of the payment system and a sudden contraction in the privately supplied medium of exchange. Such systemic crises and breakdowns are not excluded by a temporary-equilibrium model if realized prices diverge sufficiently from the prices agents had expected and whose consumption and production plans had been conditioned on those expectations.

From the perspective of macroeconomic and business-cycle theory, the introduction of banks that supply a medium of exchange while intermediating between ultimate borrowers and ultimate lenders seems a promising way to think about how an economy may, in some circumstance, operate at or near a temporary equilibrium, but, under other circumstances, may break down. This approach captures the potential for monetary disruptions caused by the lending and money-creating activities of private banks – a central concern of Hayek – while providing a rationale for the money-creating operations of private banks, which, in Hayek's business-cycle writings, seemed, on balance, destabilizing.

In the real world, economies sometimes appear to function, from a high-level macroeconomic perspective, reasonably well with low unemployment, increasing per capita output, and stable prices. At other times, economies do not function well, with high unemployment, negative growth, and with high rates of inflation or deflation. Sometimes, economies are beset with financial crises in which there is contagious insolvency, affecting many formerly solvent firms, with credit becoming unavailable. A macroeconomic model should be able to account in some way for the diversity of observed macroeconomic experience, and specify, if only in general terms, the conditions that lead to stability or instability.

The temporary-equilibrium paradigm offers such a theoretical account: the degree of congruence between actual prices and the prices that had been expected by agents. When price expectations are reasonably accurate, the economy is able to function at or near a temporary equilibrium. When expectations diverge greatly, or are disappointed by unexpected changes, a temporary equilibrium may not exist, and even if it does, the equilibrium may not reached. Price adjustments in current markets may be incapable of restoring equilibrium inasmuch as expectations of future prices must also adjust to

[14] Depending on what assumptions are made about limited liability and bankruptcy, the fluctuations in wealth resulting from unexpected price changes will be reflected entirely in the potentially negative wealth of shareholders if there is no limited liability or in creditors holding non-performing debit if there is limited liability. "[I]t seems plain that the history of the economy may make it impossible to guarantee the continuity properties of the various functions and correspondences and this is bad for existence proofs." (Arrow and Hahn 1971, p. 354). Also see (Ravagnani 1989) for a discussion of the problem of reconciling the expectational differences of households owning shares in firms with the investment and production plans chosen by the firms. See text below at p. 21.

equilibrate the economy, there being no market mechanism whereby price expectations are adjusted to be consistent with equilibrium.

This insight is consistent with and elucidates Leijonhufvud's (1973) idea of a corridor within which an economy normally tends to stay close to an equilibrium path. However, if the economy drifts, or is shocked, away from its equilibrium time path, the stabilizing forces keeping it within the corridor may be weak or ineffectual.

6 Hayek, Radner and rational expectations

In this section, I discuss a particular kind of intertemporal equilibrium: rational-expectations equilibrium. It is noteworthy that in his discussions of intertemporal equilibrium, Radner assigns a meaning to the term "rational-expectations equilibrium" different from that normally associated with the term, defining it as the equilibrium that results when agents can draw inferences about the beliefs of other agents if observed prices differ from what they had expected. Attributing the differences between observed and expected prices to the information of better-informed agents, they revise their own expectations to correspond to the implied information justifying observed prices.[15]

Radner also showed that if less-informed agents can infer from the deviation of observed from expected prices the information used by more-informed agents to cause actual prices to deviate from their expectations, those inferences do not necessarily cause a convergence on correct price expectations. The interaction between expectational revisions and price changes need not lead to correct expectations even in the absence of the arrival or discovery of new information.[16] Radner's result actually supports Hayek's insight that, although expectations are equilibrating variables, there is no economic mechanism that leads price expectations toward equilibrium values. Unlike the mechanism whereby current prices rise (fall) in response to excess demands (supplies), no corresponding feedback mechanism operates on price expectations inconsistent with equilibrium. If price expectations are brought into correspondence with what the future holds, it comes about through their own more or less well-informed conjectures, not by automatic responses to market signals.

Although Radner's conception of rational expectations differs from the more commonly used meaning of the term, his conception clarifies the limited role that the "rational expectations" assumption has in macroeconomics, which is that if the expectations of agents in a macroeconomic model correspond to the prices predicted by the model, those expectations will be realized. In this narrow sense, rational expectations is a necessary property of *any* model. If one assumes that agents expect the equilibrium solution of the model, then, under those expectations, the model must generate the

[15] At least one historical episode in which unknown – indeed secret – information was inferred from publicly available price data has been documented. In 1954, Armen Alchian inferred the chemicals used to make the just-developed hydrogen bomb by identifying companies whose stock prices had risen too much to be otherwise explained. Then consulting at the Rand Corporation, Alchian wrote a paper for Rand listing the chemicals used to make the hydrogen bomb. When word of the paper reached the Pentagon, the paper was confiscated, at the behest of the Defense Department, was confiscated from Alchian and destroyed. Newhard (2014) recounts the incident and reconstructs Alchian's event study.

[16] Such interactions give rise to the indeterminacy exemplified by the Holmes-Moriarity interaction discussed above. See Koppl and Rosser (2002).

equilibrium of the model. If equilibrium price expectations are not self-fulfilling, the model is internally inconsistent and invalid.

But there is a difference between saying (a) that a model should have the property that correct expectations are self-fulfilling and saying (b) that agents in the model understand how the model works, and, using their knowledge of the model, form expectations of the equilibrium predicted by the model.

Rational expectations in the first sense is a minimal consistency property of an economic model; in the latter sense it is an empirical hypothesis. One can assert such a hypothesis, but it remains an empirical statement that may, or may not, be true, not an axiomatic truism or a methodological imperative. The nearly sacrosanct status of the rational-expectations postulate in modern macroeconomics is supported not by empirical evidence, but by methodological tyrannizing and a reductive insistence on microfoundations.

Hayek (1937) explained that correct expectations are logically implied by the concept of an equilibrium of mutually consistent plans extending through time. But he also understood that correct expectations are not normally descriptive of reality and that we have no theoretical explanation of any mechanism whereby correct expectations become commonly shared, merely alluding to the empirical observation – perhaps not the most realistic description of reality in 1937 – of a tendency for markets to move toward equilibrium, so that there is a tendency toward expectational accuracy over time.

It is noteworthy that when Muth (1961) introduced the idea of rational expectations it was in the context of a partial-equilibrium model in which the rational expectation in the model is the equilibrium price of that model. Muth used rational expectation of the equilibrium price as an empirical hypothesis with which to challenge the cobweb-cycle model in which producers decide how much to produce in the next period before learning the future price of what they produce. With a one-period lag between production decisions and realized output, basing production decisions on the currently observed price of output implies an alternating sequence of high and low prices, high prices in one period inducing increased output in the next period, driving prices down, then leading to low output and high prices in the third period, and so on.

Muth argued that rational producers would not respond to price signals in such a way that their expectations were consistently mistaken period after period as suggested by the cobweb model. Muth asserted that the rational-expectations assumption predicted observed prices more accurately than the adaptive-expectations assumption of the cobweb model. Rational expectations, in Muth's hands, was thus an empirically testable hypothesis about how producers form expectations.[17]

Although originally proposed as a testable theoretical innovation, rational expectations, when applied in macroeconomics, has been largely insulated from serious empirical testing. When subjected to serious testing, rational-expectations models have consistently failed to generate better predictions than macro-models using other expectational assumptions (Carlaw and Lipsey 2012). For the most part, rational expectations

[17] While Muth found empirical support for rational expectations in microeconomic applications, as the lag between production decisions and realized output lengthens, the volatility of the price and output cycles seems to increase. See Rosen et al. (1994)

has been treated as an axiom supposedly required by a spurious methodological precept that macroeconomic models be "micro-founded."

The precept stems from a reductionist impulse that is no more than a question-begging exercise. The reduction of a macro-theory (e.g., chemistry or psychology) to a more basic theory (physics or neuroscience) cannot be accomplished by methodological fiat; it must be demonstrated in detail, accounting for previously unknown or unrecognized relationships and interactions, not by radical simplifications and hand-waving assumptions that abstract from, or elide, those relationships (Popper and Eccles 1977, 14–21).

In an autobiographical account of his development as an economist, Lucas (2009) credited the first four chapters of Samuelson (1947), covering the basic ideas of optimization, equilibrium and comparative statics, for teaching him the "standards for when an economic question had been properly posed and when it had been answered." Samuelson's explication of the method of comparative-statics thus became Lucas's ideal of rigorous theorizing based on equilibrium and optimization.

But Lucas and other advocates of rational-expectations methodology have misunderstood the role of the comparative-statics method. The comparative-statics method isolates the pure theoretical effect of a parameter change under a *ceteris-paribus* assumption. Such an effect can be derived by comparing two equilibria (before and after the parameter change) under the assumption of a unique and locally stable equilibrium.

The refutable theorems of microeconomics derived from rigorously applying the comparative-statics method depend on the assumption that all markets but the one under analysis are in equilibrium.[18] It has become an axiom of modern macroeconmoics that macroeconomic analysis that does not rest on microfoundations – equilibrium and optimization – is unworthy of serious attention. But the refutable theorems constituting the empirical content of microeconomics could not be derived without macrofoundations, i.e., a locally stable general equilibrium. While appropriate for partial-equilibrium microeconomic, comparative-statics analysis is inappropriate for most macroeconomic problems, which are concerned with a failure to achieve, or even to approximate, the locally stable equilibrium state presumed by the comparative-statics method.

Modern macroeconomics now offers an array of models simplified sufficiently so that they are solvable using dynamic-optimization techniques. Dynamic optimization by individual agents — the microfoundations of modern macro — makes sense only in the context of a full intertemporal equilibrium with correct expectations. But it is just the possibility that intertemporal equilibrium may not obtain that makes macroeconomics interesting and relevant. As Lavington (1922) observed, "the inactivity of all is the cause of the inactivity of each."

But the confusion besetting the macroeconomic application of rational expectations runs deeper. The original empirical application of the rational-expectations hypothesis by Muth (1961) was to a single market populated by well-informed specialists

[18] An anonymous referee argues that comparative statics does not assume that all markets but the one under analysis are in equilibrium, just that total income, input prices, and the prices of other products don't change. While I suppose it is possible to imagine a situation in which the absence of equilibrium in markets other than one under analysis is compatible with no violation of the ceteris paribus assumption, the assumption seems implausible if not almost certain to be violated.

presumed to have well-founded expectations, implicitly conditioned on a stable macroeconomic environment, of future prices. Under unstable macroeconomic conditions, the accumulated knowledge and experience of market participants would not necessarily enable specialists and traders to form accurate expectations of future prices even in those markets about which they are knowledgeable.

Thus, the plausibility of rational expectations as an assumption about the formation of price expectations is highly sensitive to the context in which expectations are being formed: expectations about a single market in isolation or expectations about the evolution of a vector of relative prices and their overall level. It is one thing to assume that some agents have expert knowledge about future prices in one or a few particular markets; it is quite another to assume that they have knowledge sufficient to forecast the course of all future prices and in particular to understand the subtle interactions between prices in one market and the apparently unrelated prices in another market. Partial-equilibrium analysis abstracts from those interactions, but generalequilibrium analysis and macroeconomics cannot make such abstractions.

It is often subtle interactions that allow the kinds of informational inferences made by Alchian to be drawn from differences between expected and observed prices. Expert traders are likely to be able to predict future prices when the assumptions of partial-equilibrium analysis are satisfied and the effects of interactions with other markets can be safely disregarded.[19] But the comprehensive knowledge required to anticipate a broad range of prices in unrelated markets is knowledge that would only be possessed by an omniscient central planner.

The key error of the rational-expectations methodology is that rational expectations somehow cause or bring about an intertemporal equilibrium. It is certainly true that people strive to use all available information to anticipate what may happen in the future, and any bit of new information will be rapidly assessed and assimilated, and may occasion the revision of previously held expectations of the future. But that does not mean that this continuous process of information gathering, processing and evaluation leads to a convergence on correct expectations of future prices. Indeed, Radner proved that, even under strong assumptions, the process of information revision based on the observed differences between expected and actual prices need not lead to an equilibrium.

There is therefore no causal relationship between rational expectations and equilibrium. Rather, rational expectations are a property of equilibrium. The term "rational-expectations equilibrium" is a truism. Expectations can be rational in macroeconomics only in an equilibrium state. Outside of equilibrium, expectations cannot be "rational." Failing to grasp that point, Morgenstern mistakenly argued that the Holmes-Moriarty interaction shows that equilibrium is a nonsensical concept; all he showed was that in the single game played by Holmes and Moriarty for which no equilibrium solution exists, the outcome of the game cannot be foreseen.

To think that rational expectations is what leads to equilibrium is a category error, akin to thinking that a triangle is caused by its angles adding up to 180 degrees. That

[19] This is somewhat of an overstatement. Clearly markets for close substitutes and complements will figure into the expectations of expert traders. However, as more distant markets and broader macroeconomic forces begin to impinge on specific markets, the ability of expert traders to forecast future prices is impaired.

the angles of a triangle add up to 180 degrees is not the cause of the triangle; it is a property of being a triangle.

Modern macroeconomic models are typically so highly aggregated that the extreme nature of the rational-expectations assumption is concealed. To treat all output as a single good (which involves treating the single output as both a consumption good and a productive asset generating a flow of productive services) imposes the assumption that the only relative price that can change is the real wage, so that only one future relative price is unknown. That assumption dispenses with the problem of incorrect expectations except for two variables: the future price level and the future productivity of labor.

Having eliminated complexity from their models, modern macroeconomists, purporting to solve micro-founded macromodels, assume that there are just two variables about which agents must form their rational expectations. The simplified expectational assumptions adopted in deriving a micro-founded rational-expectations equilibrium belie the claim to have achieved a truly micro-founded macroeconomic theory.

7 Conclusion

Four score and three years after Hayek explained the subtleties of the notion of intertemporal equilibrium and the elusiveness of any theoretical account of an empirical tendency toward intertemporal equilibrium, modern macroeconomics has built a formidable theoretical apparatus founded on a methodological principle that rejects in principle all the concerns that Hayek found so vexing. Many macroeconomists feel proud of what modern macroeconomics has achieved, but there is reason to think that the path trod by Hayek, Hicks and Radner could have led macroeconomics in a more fruitful direction than the one on which it has been led by Lucas and his associates.

References

Arrow, K. J. and F. H. Hahn. (1971). *General competitive analysis*. San Francisco: Holden-Day.

Bliss, C. J. (1975). *Capital theory and the distribution of income*. Amsterdam: North Holland.

Bliss, C. J. (1976). Capital theory in the short run. In M. Brown, K. Sato, & P. Zarembka (Eds.), *Essays in modern capital theory* (pp. 187–201). Amsterdam: North-Holland.

Canard, N.-F. (1801). *Principes d'économique politique*. Paris: F. Buisson.

Carlaw, & Lipsey, R. G. (2012). Does history matter? Empirical analysis of the evolutionary versus the stationary equilibrium views of the economy. *Journal of Evolutionary Economics, 22*(4), 735–766.

Cass, D. and K. Shell. (1983). "Do sunspots matter?" *Journal of Political Economy 91*(2):193–227.

Currie, M., & Steedman, I. (1989). Agonising over equilibrium: Hayek and Lindahl. *Quaderni di storia dell'economia politica, 7*(1), 75–99.

Düppe, T., & Weintraub, E. R. (2016). Losing equilibrium: On the existence of Abraham Wald's fixed-point proof of 1935. *History of Political Economy, 48*(4), 635–655.

Fisher, I. (1898). *Appreciation and interest*. New York: Macmillan.

Fisher, I. (1907). *The rate of interest*. New York: Macmillan.

Fisher, I. (1933). "The debt-deflation theory of great depressions." *Econometrica 1*(4):337–57.

Hawtrey, R. G. (1913). *Good and bad trade*. London: Constable.

Hayek, F. A. (1927 [1933]). *Monetary theory and the trade cycle*. London: Jonathan Cape.

Hayek, F. A. (1928 [1984]). Intertemporal Price equilibrium and movements in the value of money. In R. McCloughry (Ed.), *Money, capital and fluctuations: Early essays*. London: Routledge.
Hayek, F. A. (1937). Economics and knowledge. *Economica* New Series 4(13):33–54.
Hayek, F. A. (1941). *The pure theory of capital*. Chicago: University of Chicago Press.
Hicks, J. R. (1939). *Value and capital*. Oxford: Oxford University Press.
Hicks, J. R. (1965). *Capital and growth*. Oxford: Oxford University Press.
Hicks, J. R. (1982). "Methods of dynamic analysis." Chap.18 in *Money, Interest, and Wages*, vol. 2 of *Collected Essays on Economic Theory*. Cambridge: Harvard University Press.
Hirshleifer, J. (1971). The private and social value of information and the incentive to reward to inventive activity. *American Economic Review, 61*(4), 561–574.
Keynes, J. M. (1936). *The general theory of employment, interest, and money*. London: Macmillan.
Koppl, R., & Rosser, B. (2002). All that I have to say has already crossed your mind. *Metroeconomica, 53*(4), 339–360.
Laidler, D. (1998). *Fabricating the Keynesian revolution*. Cambridge: Cambridge University Press.
Lavington, F. (1922). *The trade cycle*. London: P. S. King.
Leijonhufvud, A. (1973). Effective demand failures. *Swedish Journal of Economics, 75*(1), 27–48.
Lindahl, E. (1929 [1939). The place of Capital in the Theory of Price. In *Studies in the theory of money and capital*. London: George, Allen & Unwin.
Lipsey, R. G., & Lancaster, K. (1956). The general theory of second best. *Review of Economic Studies, 24*(1), 11–32.
Lucas, R. E. (2009). Chapter 16. In *Lives of the laureates*. Edited by W. Breit and B. T. Hirsch. Cambridge: MIT Press.
Milgate, M. (1979). On the origin of the notion of intertemporal equilibrium. *Economica* New Series 46(181): 1–10.
Morgenstern, O. (1935 [1976). Perfect foresight and economic equilibrium. In A. Schotter (Ed.), *Selected writings of Oskar Morgenstern* (pp. 169–183). Princeton: Princeton University Press.
Muth, J. (1961). Rational expectations and the theory of Price movements. *Econometrica, 29*(3), 315–335.
Myrdal, G. (1927). *Prisbildningsproblemet och Foranderligheten* (Price formation and the change factor). Stockholm: Almqvist & Wicksell.
Neumann, J. v., & Morgenstern, O. (1944). *The theory of games and economic behavior*. Princeton: Princeton University Press.
Newhard, J. (2014). The stock market speaks: How Dr. Alchian learned to build the bomb. *Journal of Corporate Finance, 27*, 116–132.
Patinkin, D. (1965). *Money, interest, and prices: An integration of monetary and value theory* (2nd ed.). New York: Harper and Row.
Popper, K. R., & Eccles, J. C. (1977). *The self and its brain*. Berlin: Springer International.
Radner, R. (1972). Existence of equilibrium of plans, prices, and price expectations. *Econometrica, 40*(2), 289–303.
Radner, R. (1979). Rational expectations equilibrium: Generic existence and the information revealed by prices. *Econometrica, 47*, 655–678.
Radner, R. (1982). Equilibrium under uncertainty. In Handbook of Mathematical Economics edited by K. J. Arrow and M. Intriligator, pp. 923-1006. Amsterdam: North-Holland. 923–1006.
Radner, R. (1987). Uncertainty and equilibrium. *New Palgrave Dictionary of Economics*. London: Macmillan.
Ravagnani, F. (1989). On conflicting expectations in temporary equilibrium models. Political economy. *Political Economy: Studies in the Surplus Approach, 5*(1), 13–36.
Rosen, S., Murphy, K. M., & Scheinkman, J. (1994). Cattle cycles. *Journal of Political Economy, 102*(3), 468–492.
Samuelson, P. J. (1947). *The foundations of economic analysis*. Cambridge: Harvard University Press.
Smith, A. (1776). *An inquiry into the nature and causes of the wealth of nations*. London: Strahan and Cadell.
Wicksteed, P. H. (1910). *The common sense of political economy*. London: Macmillan.
Zappia, C. (1999). The assumption of perfect foresight in Hayek's theory of knowledge. *Revue d'Economique Politique, 109*(6), 833–846.